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PJ14-W2 I-CNSS

INTEGRATED COMMUNICATION, NAVIGATION AND SURVEILLANCE SYSTEM

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Abstract

Communication, Navigation and Surveillance (CNS) systems provide the infrastructure and performance which are essential for Air Traffic Management (ATM). CNS mainly enables efficient navigation and safe separation in all phases of flight. Although current CNS systems are mature and globally satisfactory, they are still relying on a system-based approach and all facing technological transition phases to reach the objectives of the SESAR Concept of Operations in terms of performance, cost effectiveness and environmental impact. All the ATM elements will require an underlying supporting infrastructure including communication, navigation and surveillance capabilities that are adapted to support the concept elements in an efficient way.

PJ14-W2 I-CNSS is dealing with these infrastructures. PJ.14-W2-76 D2.1.100 CNS Service assessment will provide a global view of the future Communications, Navigation and Surveillance in the context of service provision. The solution will identify the logic supporting each domain, contributing to CNS performance-based approach. The solution aims to providing efficient services tailored to each domain.

The definition of CNS services and CNS service provision will provide a global framework for services which are different in nature and in their relationship with the CNS data services. The governance of the CNS services is not addressed in this deliverable, which does not allow this document to provide a full set of criteria for concluding on the potential for transitioning to a service-based approach.

Some examples of transition from the system-based approach to the service-based approach will be provided.

Aligned with the 2016-2030 Global Air Navigation Plan, the CNS services assessment will contribute to the update of the European Air Traffic Management Master Plan by providing a phased vision of CNS evolution.

Executive summary

In the context of PJ.14-W2 I-CNSS, the evolution of CNS towards a service-based approach is considered as essential to achieve the technical and non-technical objectives described in the Future Airspace Architecture Study and in the Strategic Research and Innovation Agenda. This evolution of CNS must also be consistent with the performance-based approach and the CNS roadmap also developed in the SESAR Wave 2 PJ14 Solution 76 Integrated CNS and Spectrum. A large part of the deliverable is dedicated to the study of the reference documents relevant to the CNS service-based approach.

Since the governance of the CNS services is addressed in different I, this deliverable aims at identifying a technical set of criteria. These technical criteria will then have to be used along with the other criteria coming from the governance side. Therefore, this deliverable is not providing a full set of criteria: it is a step on concluding on the potential for transitioning to a service-based approach.

Nonetheless, some examples of transition from the system-based approach to the service-based approach will be provided based solely on the technical criteria.

Aligned with the 2016-2030 Global Air Navigation Plan, the CNS services assessment will contribute to the update of the European Air Traffic Management Master Plan by providing a phased vision of CNS evolution.

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1 The context for the CNS services

This document will outline the necessary and dynamic changes offered by the technological evolution and the current constraints/challenges identified. Furthermore, it will describe how it is intended to drive a progressive change from a technology-based approach to a performance-based approach, presenting the idea of monitored service and its quality whence delivered to the client and the user.

In order to provide this information, this document will start with the current or legacy scenario, which may or may not be known to the readers in the often compartmentalized CNS domains, whilst building (evolving) upon it by integrating all the relative actions which lead to the future vision as expressed in the Airspace Architecture Study (AAS), published in March 2019. This study "sets out a proposal for a future Single European Airspace System underpinned by optimized airspace organisation, progressively higher levels of automation and the establishment of common EU-wide ATM data services, enabling on-demand cross-border use of air traffic services[1]". Finally, the objective is within the limits possible, to assess how this transition affects the provision of CNS services from the current model into future conditions, opportunities, and circumstances.

1.1 Current situation

The current ATM architecture is the result of historical operational and technical evolutions primarily conducted on a national basis and leading to an overall fragmented system, where aircraft operations are often restricted by non-operational airspace boundaries, leading to sub-optimal flight trajectories.

This highly vertical approach leads to several constraints in the different layers:

- The airspace layer is limited in capacity and scalability.
- The air traffic service layer with vertical integration of applications and information (such as weather or surveillance information) leads to limited automation and low level of information sharing.
- The physical layer organisation (i.e., sensors and infrastructure) can lead to fragmentation and unwanted duplication of ATM infrastructure.

Each ANSP controls its airspace that is basically bounded by national borders. These, in turn, is fragmented in different ACCs, wherein each one operates its own local physical layer that includes CNS sensors, and ground-ground communications for connectivity with neighbouring ACCs, the network manager and airports. As result of how the current ATM-CNS environment is structured, there are strict limitations in terms of flexibility, integration and automation as mentioned above.

[1] Legal, economic, and regulatory aspects of ATM data services provision and capacity on demand as part of the future European air space architecture - Executive Summary (2020)

Historically, the European ATM system architecture is a collection of bespoke systems, operated by ANSPs and supplied by different industry manufacturers, with different operational concepts and procedures. The level of interoperability between these systems is inherently low, and therefore the capability for data sharing, with most interactions based on legacy exchanges although there has been progress in terms of standardisation (e.g., use of OLDI, ARTAS or ASTERIX). The level of automation support available to controllers is low in general terms. And higher levels of automation and data sharing will progressively enable increased controller productivity and hence airspace capacity.

Further information about factors limiting current airspace capacity can be found in detail in [5].

1.1.1 Different nature of C, N and S

The CNS services have each a different nature. This nature along with their interdependencies must be considered when addressing the integration of these services and their provision in the current and future airspace architectures.

The CNS concept comes from the early days of aviation and remains an important safety principle. Developed during the days of single systems, the logic is that while one part of CNS can have a complete failure, the other two parts enable, as a minimum, safe landing of aircraft. This has led to functions such as the designation of one specific SSR transponder code to indicate loss of communication.

Most CNS services use line of sight radio signals, meaning that aircraft need to be in the range and visibility volume of the infrastructure elements that transmit these signals. These elements can be ground-based or space-based, and if they move their locations, the coverage volume will change.

Nevertheless, although the nature of the CNS domains is different, their purpose is complementary, to enable the ATSP in delivering the required level of service in the defined airspace fulfilling the operational requirements.

With increasing levels of traffic, a significant failure of one of the CNS elements is no longer an option. Therefore, each CNS element has increased its level of reliability and safety by adding redundant and diverse systems or multiple system layers. Both the safety philosophy and the increasing complexity of CNS have led to Communication, Navigation and Surveillance domains developing their systems independently, without much consideration for a coherent CNS development integrated framework.

Therefore, each separate C, N and S domain has evolved according to their specifics needs and having a direct impact on the infrastructure and facilities that form it. This evolution has led to a technology/system-based framework with the three CNS domains poorly integrated, with a non-optimised network, using conventional technologies and resulting in a costly and inefficient scenario, with low interoperability (e.g., civil/military), and, as a result with a saturated spectrum with sub-optimal spectrum utilisation. All these could be seen in the following picture where the C, N and S domains are depicted in different colours showing the variety of technologies per domain and the widespread use of spectrum:

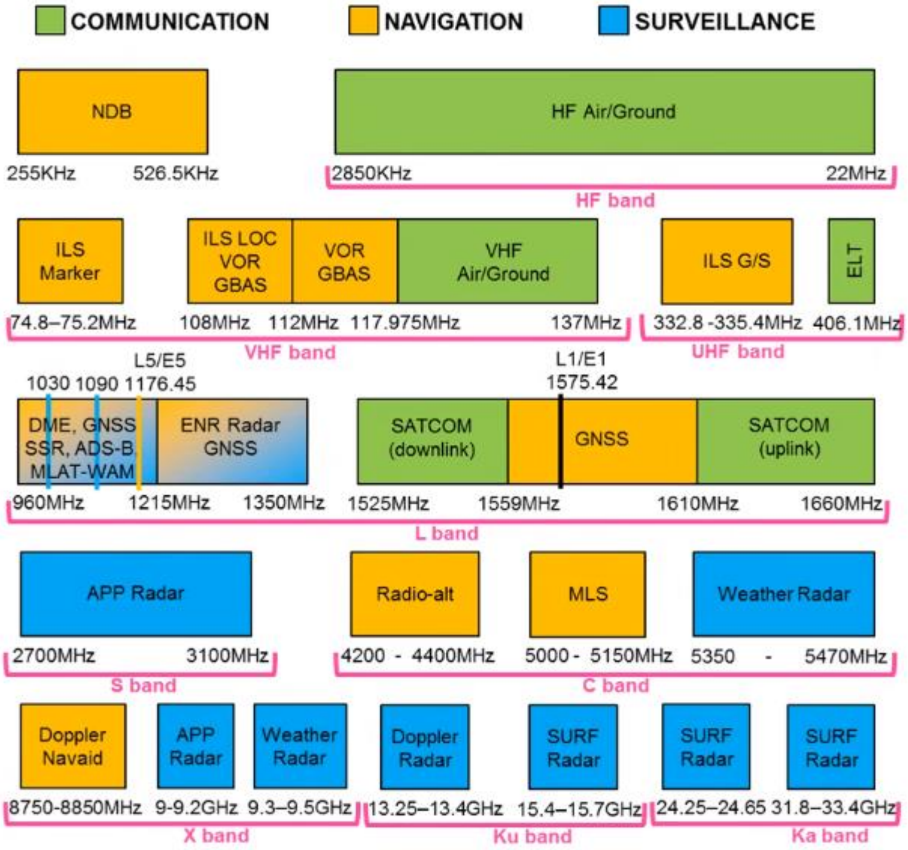

Figure 1: C, N and S domains technologies and spectrum allocation

Currently the nature of each domain lies in its technology, which is totally different between domains and even within each domain depending on its application. This situation leads to a distinction also in the way each domain is defined, using not only different technologies and networks, but also designating different actors, roles, and interfaces for each domain. For example, each of the domains may have a different end user, hence a different perspective:

- For COM, the need is common to the airspace user aircraft and ATS: both aircraft are end users.
- For NAV, the need comes from the airspace user, but in the context of NAV capabilities available in the airspace: the end user is the airspace user.
- For SUR, in continental, the need comes from the ATS: the end user is ATS.

Considering the different perspective for each domain, it seems complex to combine C, N and S in a single CNS domain if the same technology/system-based approach is applied. Another hampering reason is the difference in standards that exists in each domain, which may not cover the rest (e.g., SPI Implementing Rule for SUR, (EU), 1285/2013 for GNSS).

Nevertheless, although the nature of the three domains is different, their purpose is complementary, to enable the provision of the required level of CNS services in support of a defined operational airspace. Exploiting the similarities of each domain rather than their differences seems to be a good way forward. Therefore, the trend is to shift from a technology/system-based approach (differences in technology between domains) to a service-based approach (exploiting similarity in technologies between domains in the need to satisfy customer requirements in the provision of services).

1.1.2 CNS Service provision today

1.1.2.1 Objective and purpose of the CNS service provision today

Currently, Air Traffic Services are mainly provided by national ANSPs who are each responsible for producing/collecting part of the data required for ATS, processing and combining these data to make them available to their ATS units (i.e., air traffic controllers) and using these data to support ATS for airspace users. Most of these data are currently not fully shared between ANSPs for various reasons (historic, technical, regulatory...). Creating a more resilient ATM system at European level could be achieved evolving this organisation; the collaborative management of the airspace, through remote provision of air traffic services, will only be possible if all relevant ATM data is available to all users across the network. This is why the provision of CNS is undergoing a transition towards common ATM data service provision in support of several ATS providers simultaneously. This also requires ATSPs to evolve their thinking to treating CNS provision as a series of packaged data services rather than bespoke individually deployed technologies. Common ATM data services mainly require computational resources, are less dependent on human actors, and therefore are easily scalable. However, the regulatory framework for responsibility sharing among member states is still missing aside from national interests.

Additionally, the European ATM system architecture is a collection of bespoke systems, operated by ANSPs and supplied by different industry manufacturers, with different operational concepts and procedures. The level of interoperability between these systems is low with most interactions based on legacy exchange.

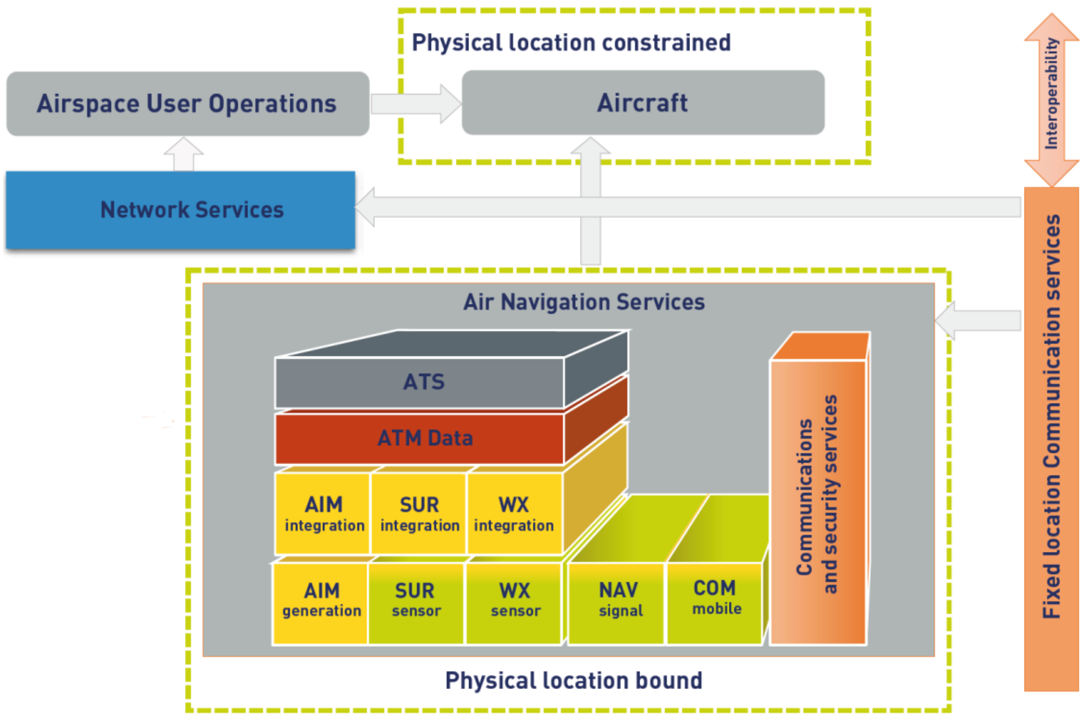

Figure 2: Current 'monolithic' European ATM system architecture[2]

According to the European Commission [4], the CNS services are defined as:

- *"communication services means aeronautical fixed and mobile services to enable ground-to-ground, air-to-ground and air-to-air communications for ATC purposes"*; therefore, exchange of information involving ATCO and aircraft, for the purpose of ATC.

- *"navigation services means those facilities and services that provide aircraft with positioning and timing information"*; therefore, employ various systems and aids to render a navigation solution for a particular aircraft.

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- *"surveillance services means those facilities and services used to determine the respective positions of aircraft to allow safe separation*"; therefore, having a sensor (or a network of sensors) that detects aircraft, providing their position to ATCO, including in many cases other information such as identification, flight level, velocity, among others.

The CNS services are peculiar services in the sense that the well-defined relationship between the customer and the provider in a service-based environment is more complex.

For example, the navigation services are directly and only used by the airspace users (as earlier described). The ATS towers and units do not use these services but need to know the operational status of navigation services essential for approach, landing and take-off. More precisely, the ATS defines/designs and operates the airspace based on the supporting Navigation services. Timing and synchronisation services are also provided to the AU as part of the Navigation services.

It must be noted that the Air Navigation Service Providers are only responsible for ATS communications[3], while other types of communications like AOC, AAC, APC[4] are directly provided by the Communication Service Providers to its users.

Ensuring performance of the current CNS services

CNS service providers are certified by their NSA or may have a Pan-European service certificate [5] by EASA (such is for example for the Network Manager, AIREON(S) or the ESSP(N)). The main difference between a certified and not certified service provider is the following:

[2] *"A proposal for the future architecture of the European airspace"* page 30 (SESAR JU)

[3] Some ANSP also provide this service upstream

[4] Cf section 1.1.2.1 of this document

[5] 'pan-European service' means an activity which is designed and established for users within most or all Member States and which may also extend beyond the airspace of the territory to which the Treaty applies (EASA EAC for ATM/ANS – Reg. EU 2017/373)

- a certified service provider has to comply with regulation (e.g., EASA EAC for ATM/ANS – Reg. EU 2017/373) and is subject to audit and oversight by the certifying body. Thus, is accountable directly to the NSA/EASA, and so an ATSP making use of a service provided by such an entity is not obliged to provide any additional evidence of compliance for that contracted service.
- A non-certified service provider can only deliver its service through a **certified entity**[6] (to which it will provide its services through a contract/SLA) which in turn must comply with regulation. In this case SLAs/Contracts will be signed and in a certain way Performance requirements[7] (such as those found in ANNEX VIII of EASA EAC for ATM/ANS – Reg. EU 2017/373) will be put across to the uncertified provider. Therefore, the non-certified providers will only be bound by the negotiated SLA/Contract and not subject to the supervision required by the NSA/EASA. In addition, an ATSP must include the evidence for use of these contracted services as part of their own regulatory supervision scheme.

In the Communication domain both examples can be found:

- NATS is a certified ATSP/ANSP and provider of CNS services[8] that rely on the contracted communication service provided by Collins and SITA with whom it has SLAs/Contracts.
- ENAV on the other hand, also a certified ATSP/ANSP and CNS provider, relies on its own system to provide the communication service.

In Europe the current scenario is mainly made by ATM/ANS service providers offering both ATM and CNS services and increasingly availing themselves of Pan-European (or globa)l services provided by other service providers.

The airborne perspective for CNS services

On the airborne side, it is worth noting that CNS system are multiple and provide some sensitive data which contribute to ensure safe flight operation and regularity of flights. Too often, different services

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[6] Article 8 of Regulation (EC) nº. 550/2004 requires all ANSPs to have a certificate requires Member States to designate an ATSP to provide ATS in their airspace they are responsible for. The certificate identifies the ANSP is authorised to provide a service (or a bundle of them). Alternatively (article 10), auxiliary services may be provided as sub-contract to the ATSP under the ATSPs' certificate: (e.g. underscored in EC29/2009) ATSPs may choose to rely upon other organisations for the provision of air-ground data link communications services. To ensure appropriate safety, security and efficiency of these services, service level agreements should in this case be established between the parties concerned.

[7] CNS.OR.100 Technical and operational competence and capability (a) A communication, navigation or surveillance services provider shall ensure the availability, continuity, accuracy and integrity of their services. (b A communication, navigation or surveillance services provider shall confirm the quality level of the services they are providing, and shall demonstrate that their equipment is regularly maintained and, where required, calibrated.)

[8] A communication, navigation or surveillance services provider shall confirm the quality level of the services they are providing, and shall demonstrate that their equipment is regularly maintained and, where required, calibrated.

reuiqres a different piece of avionics. Data are either directly available for the pilot of the aircraft and/or communicated through available CNS networks.

Currently, each system is categorised as Communication, Navigation or Surveillance system and all of them are able to generate a huge amount of data. For each functions, several systems are available.

To ensure the Communication function the following systems could be available:

- High Frequency (HF) and Very High Frequency (VHF) Communication systems provide voice and data communication over long between airplanes or between ground stations and airplanes. Multiple HF or VHF systems could be available. Both type of systems operate in identified aeronautical frequency bands.
- Satellite communication systems are able to transmit and receive data and voice messages through Inmarsat and Iridium networks. System operates in the L-band where some frequency ranges are allocated to the aeronautical satellite services.
- Two other ground networks could also contribute to communication purpose:
  o Aeronautical Mobile Airport Communication System (AeroMACS) is a wireless broadband technology that supports data communications and information sharing on the airport surface for both fixed and mobile applications;
  o L-band Digital Aeronautical Communication System (LDACS) is an air-to-ground communications system. Specifications are currently in development.
- Any other validated system that is meeting the performance requirements.

It is important to note that the airborne configuration, in terms of communication system, depends on what route is being flown and which long range communication systems are onboard (e.g., number HF / VHF Comm and/or Satcom availability).

To serve the Navigation function, the following systems are installed on the Aircraft:

- Instrument Landing System (ILS) (Localizer/Glideslope) which provides lateral (localizer) and vertical (glideslope) guidance to the runway on approach. 2 or 3 ILS could be installed on airplane;
- VHF Omni-directional Range (VOR) is a navigation aid that provides magnetic bearing data to a VOR ground station. The VOR system receives the ground station signal from the tuned VOR station and calculates magnetic bearing data. 1 or 2 VOR systems may be installed on the airplane;
- Marker Beacon system provides visual and aural indications when the airplane flies over ground-based marker beacon transmitters. It is used to determine the airplane's position along an established route to a destination (e.g., a runway)
- Low Range Radio Altimeter system measures the distance from the airplane to the ground and outputs radio altitude data. This system is used during approach and landing. 2 or sometimes 3 LRRA systems are installed on the Aircraft.
- Global Navigation Satellite System (GNSS) receives navigation satellites' signals to calculate accurate airplane position, altitude, velocity, and time data which can be used by several airplane systems (e.g., FMS, TAWS, ADS-B, etc.).
- Distance Measuring Equipment (DME) provides distance from an airplane to a selected DME ground station.

To serve the Surveillance function, the following systems are installed on the Aircraft:

- The Air Traffic Control Transponder function replies to 1030 MHz interrogations from ground-based Secondary Surveillance Radars (SSRs) and from airborne TCAS. ATC transponder is able to provide various aircraft data, including flight identification, heading, track, ground speed, TCAS status, and other data. There are two ATC Transponders installed, but only one is active at any given time (the other is a hot spare).
- Automatic Dependent Surveillance Broadcast (ADS-B) out automatically transmits position, velocity, altitude, aircraft identification, and other pertinent aircraft systems data which can be received and used by ground-based ATC receivers (for separation services) and by other aircraft that have ADS-B In receivers (for use by ADS-B In applications). ADS-B IN receives 1090 MHz ADS-B signals from other aircraft.
- Traffic-Alert Collision Avoidance System (TCAS) helps the flight crew maintain safe separation from other ATC transponder equipped airplanes. TCAS is an airborne system that operates independently of the ground-based ATC system. TCAS sends 1030 MHz interrogation signals to nearby ATC transponder equipped airplanes which respond to these interrogations via 1090 MHz replies. TCAS provides a traffic display to the flight crew as well as Traffic Advisories (Tas) to alert the crew of closing aircraft.

The design and installation of CNS systems on board aircraft are highly regulated and constrained by design, installation and operational requirements which are included in the dedicated standards.

1.1.2.2 Examples of Business Models of current CNS services

With the objective to better represent the current situation in CNS service provision, several business models for technologies covering at least one of the three domains, Communication, Navigation and Surveillance, are provided. These business models are presented in canvas format using the Business Model Canvas tool.

The Business Model Canvas is a tool which helps to understand a business model in a straightforward, structured way. By using the canvas different models can be described in the same way whilst giving interesting insights about: the customers served (clients, customers, final users); what value propositions are offered and through which channels; and how the organisation/company makes a revenue.

The following questions (but not limited to) are used as guidelines to construct the core of the Canvas:

- Customer Segments. The customer segments block, describes the most important customers and for whom value is created. The customer segment is the niche of the market selected to serve, solving their specific problem or satisfying their specific needs. Different segments can be considered if different value propositions are required.
- Value Proposition. The value propositions block, describes the group of products and services that create value for the Customer Segment.
- Channels. This block describes how the company communicates with customer segments. How does the company reach its customers, deliver a value proposition, receive customer feedback …etc.
- Customer Relationships. The customer relationships block describes the strategies and tactics used to get, keep, and grow customers.
- Revenue Streams. The revenue streams block, will describe (to the limit allowed) the main origin of revenue generated from the customer segment.

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- Key Resources. The key resources block describes the most important assets required to make a business model work. These resources can be physical, financial, intellectual, or human. Also, the resources can be owned or leased by the company, or they may be acquired.
- Key Activities. Key activities block describes the main activities required to make the business model work.
- Key Partnerships. The key partnerships block describes the network of suppliers and partners that support the organisation in running the rest of your business model blocks.
- Cost Structure. The cost structure block describes all costs incurred to operate the business model, such as the basic operating costs of the business, the cost to build and make the product, the costs of using different channels, the cost to get, keep, and grow customers …etc.

Two examples of business models in Communications and Navigation are described in the following sections.

1.1.2.2.1 Communications: the SITA/CA Business model

SITA and Collins Aerospace (SITA/CA) provide global worldwide aeronautical air/ground and ground/ground telecommunication services. Although this is done with other companies in certain other regions of the world, we focus on the European situation and only address SITA/CA in the framework of air/ground data link (DL) communications.

SITA/CA have deployed telecommunication services in support of these applications, with some infrastructure (e.g., VDL2) shared across them between ACARS and ATN. SITA and CA provide a datalink communication service to aviation in Europe by ensuring their networks are interconnected.

SITA/CA should also provide ATN communications to so-called non-AOC aircraft. Indeed, aircraft typically access ACARS and also ATN data link via their “AOC contract”, which is admittedly the initial commercial driver for installation of the system on board prior to their usage for ATS communications. Aircraft operators which do not have such an AOC contract must however be provided access to the ATN communication service in respect of the above mandate. This causes some practical difficulties which are still not yet finally solved at the time of writing.

There are 5 “families” of Datalink (DL) application services[9], the first 3 of which being considered part of the “Safety Critical” applications:

- **Airline Operational Communications (<u>AOC</u>)**

  AOC is dedicated to airline business communications and many applications have been developed over the years since their introduction in the 1950s with the “Out-Off-On-In” to today’s massive engine information download, in flight but mostly at the gate. Some of these applications are recognized as “safety-related” and share the official Aviation spectrum, for instance in the VHF band. As mentioned above, the AAC service is part of the AOC and uses the same means of communication, but we consider AOC to be the part of the airline’s communications related to safety, although the distinction AOC/AAC is blurred.

[9] ATS regroups two of these families

- **Air Traffic Services (ATS)**
  - ATS (Industry Standard): ARINC 623 and "FANS"
  - ATS (ICAO Standard): Aeronautical Telecommunications Network (ATN)

ATS are the Air Traffic Service Communications, in two categories as above: those standardised by ICAO as part of the Aeronautical Telecommunication Network and those standardised by industry as part of ACARS. In Europe, the European Commission regulation 2015/301 mandates the former.

- **Airline Administrative Communications (AAC)**

AAC services such as passenger lists, connecting gate information etc., are de facto merged with AOC traffic when exchanging the information between aircraft and the ground, and are not discussed in any further detail.

- **Airline Passenger Communications (APC)**

APC communications services typically use a separate airborne infrastructure than the other services for security reasons. Although not in scope of this report, SITA and CA respectively propose SITA FOR AIRCRAFT[10] and CabinConnect™ [11]products for In Flight Passenger Connectivity.

The business model of this case is presented in the diagram below:

Key partners/interfaces	Key activity	Customer relationship	Customer segment
ANSP´s customers Other Communication Service Provider (CSP) connection (SITA-Collins), ENAV and ENAIRE. Airline shareholders SATCOM services for ACARS (Inmarsat)	Maintenance, operation and monitoring of the ACARS and ATN networks. Provision of the ATN Data Link VDL2 services in Europe Provision of ACARS AOC and ATS services in Europe and the world Performance Monitoring and reporting	Service provision Contract with ANSP/Aus Partnership contract with ANSPs who own ATN infrastructure (NOT for Collins Aerospace) CSP Contract to Airlines for ACARS service Free of charge ATN Service Provision to non-AOC Airspace users	Aviation (airspace users) Aviation (ground ANSP)

[10] https://www.sitaonair.aero/solutions-cabin-connectivity-services

[11] https://www.arincdirect.com/what-we-do/cabin-communications/

	Provision of the European current ATN backbone (SITA)		

Value Proposition	Distribution Channels
CSPs deliver the following services: AOC for airline communications ATS safety data link communications over ATN ATS safety data link communications over ACARS	Service is distributed over: Telecommunication service provided by VHF Digital Mode 2 ground antennas for ACARS and ATN SiS via Inmarsat, Iridium Satellites for ACARS ATS and AOC SiS via analog VHF ground antennas for ACARS AOC and ATS SiS over HF Data Link for Collins Aerospace Ground interconnections to ground users (ANSP, Airline Operations Centers)
Cost Structures	Revenue Streams
Costs linked to the operation of the ACARS and ATN networks	The main revenue comes from the Service Provision and/or partnership contracts with the customers.

Table 1: SITA/CA business model

1.1.2.2.2 Navigation: the EGNOS Business model

EGNOS provides corrections and integrity information to GPS signals over a broad area centred over Europe and it is fully interoperable with other existing SBAS systems. EGNOS provides three services **Error! Reference source not found.**:

- **EGNOS Safety of Life (SoL) Service.**

  The EGNOS SoL Service consists of signals for timing and positioning intended for most transport applications in different domains. Nevertheless, navigation operations based on the EGNOS SoL Service may require a specific authorisation, issued by the relevant authority, unless the authority, or applicable regulation, establishes that no such authorisation is required. This SoL service is based on corrections and integrity data provided through the EGNOS satellite signals. The main objective of the EGNOS SoL service is to support civil aviation operations down to Localiser Performance with Vertical Guidance minima. At this stage, a detailed performance characterisation has been conducted only against the requirements expressed by civil aviation, but the EGNOS SoL service might also be used in a wide range of other application domains (e.g., maritime, rail, road…) in the future. To provide the SoL Service, the EGNOS system has been designed so that the EGNOS Signal-In-Space (SIS) is compliant to the ICAO SARPs for SBAS.

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- **Open Service (OS).**

The aim of the EGNOS OS is to improve the achievable positioning accuracy by correcting several error sources affecting the GPS signals. The corrections transmitted by EGNOS contribute to mitigate the ranging error sources related to satellite clocks, satellite position and ionospheric effects. The other error sources (tropospheric effects, multipath and user receiver contributions) are local effects that cannot be corrected by a wide area augmentation system. Finally, EGNOS can also detect distortions affecting the signals transmitted by GPS and prevent users from tracking unhealthy or misleading signals. The EGNOS OS is accessible in Europe to any user equipped with an appropriate GPS/SBAS compatible receiver for Ih no specific receiver certification is required.

- **EGNOS Data Access Service (EDAS).**

EDAS is the EGNOS terrestrial data service which offers ground-based access to EGNOS data in real time and also in a historical File Transfer Protocol archive to authorised users (e.g. added-value application providers). EDAS is the single point of access for the data collected and generated by the EGNOS ground infrastructure mainly distributed over Europe and North Africa.

Application Providers will be able to connect to the EGNOS Data Server, and exploit the EGNOS products, offering high-precision services to final customers.

Key partners/interfaces	Key activity	Customer relationship	Customer segment
EU[12]/EUSPA ESA[13] EASA [14] Thales[15]Alenia Space (France) ESSP shareholders: Skyguide, DFS, DSNA, ENAIRE, NATS, ENAV, NAV-PT	Maintenance, operation and monitoring of the EGNOS system. Provision of the EGNOS positioning[16] services in Europe Support to EUSPA in the field of EGNOS adoption initiatives	EGNOS Service Provision contract with the EC/EUSPA EGNOS Working Agreement[17] (aka. Service Level Agreement) with ANSPs, Rotorcraft and Aerodrome operators. Free of charge EGNOS Service Provision to	Aviation (SoL) and drones Multimodal transport (only Open Service and EDAS) including: Maritime Road Rail Agriculture Location Based Services (LBS) Mapping and Surveying

[12] The European Commission is the owner of the EGNOS system, whilst delegating the EUSPA with the management of the service provision contract with the ESSP

[13] The European space Agency is the design, development and procurement agent of EGNOS

[14] European Union Aviation Safety Agency – responsible for the oversight of the ESSP ANSP certificate

[15] Leader of the industrial consortium tasked by ESA with the development and evolution of the current EGNOS V2 system

[16] Pan-European certified EGNOS SoL service including pre-NOTAM elaboration and notification to the EWA underwriters.

[17] Organisations implementing EGNOS based procedures responsible for the operational use of the respective procedure.

		Airspace users (both CIV/MIL)	
Value Proposition		Distribution Channels	
The ESSP delivers three core Navigation services: Open Service (OS) Safety-of-Life Service (SoL)[18] https://egnos-user-support.essp-sas.eu/new_egnos_ops/services/about-edas		The ESSP distributes its services through two main channels: Signal in Space provided by three Geostationary satellites And internet (only EDAS)	
Cost Structures		Revenue Streams	
Costs linked to the operation of the EGNOS system and the Provision of the Services		The main revenue comes from the Service Provision contract funded by the EU and monitored/managed by the EUSPA.	

Table 2: EGNOS business model

1.1.2.2.3 Surveillance – Aireon Business Model

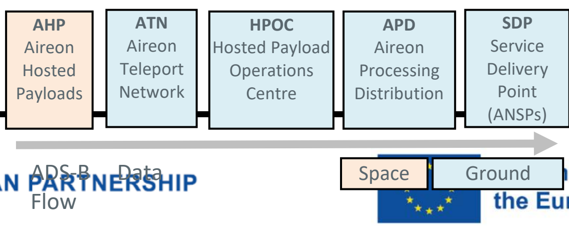
Aireon Services Definition

- **Global Air Traffic Surveillance**. The Aireon payload is hosted on the new Iridium Next Low Earth Orbit satellite constellation (66 satellites in 6 LEO orbits, interlaced communications, with significant overlap and redundancy) its high-performance payloads, providing the first global air traffic surveillance system using a space-based ADS-B network that meets the strict, high level of precision and security, real-time ATS surveillance requirements around the globe [e.g. DO-260B/ED-102A]. Space-based ADS-B provides full, continuous, global air traffic surveillance, whereas before, 70 percent of the world had no access to ATS surveillance information (the oceans, polar regions, remote regions such as mountainous, jungles, deserts). By providing surveillance in remote regions, new routes and a multitude of benefits can be provided to all aviation stakeholders.
- **Aireon Alert**. Aireon ALERT utilizes Aireon's space-based ADS-B data and is operated by the Irish Aviation Authority (IAA). The users of the service simply need to register for the free emergency service. ANSPs, airlines, regulators, and SAR organizations in need of crucial aircraft location data, can rely on this free public service.
- **Global Beacon**. With GlobalBeacon (by combining FlightAware's data processing platform and web-interface, with Aireon's space-based ADS-B network), airlines and aircraft operators are able to exceed GADSS standards and recommended practices for flight tracking for ADS-B out equipped aircrafts (mandated throughout the world). According to ICAO's Global Aeronautical

[18] This is recognised as a European critical service and is specific for the **aviation** sector.

Distress Safety System regulation (GADSS), by 2023, aircrafts operators and airlines will need to automatically receive positions at least once every 15 minutes and once-per-minute for aircraft in distress.

- **Aireon STREAM**: provides a stream of high-fidelity ATS surveillance data combined with flight and airspace contextual information to enhance tracking, situational and analytical tools.
- **Aireon INSIGHTS**: provides a stream of events and alerts for flights, including airport and airspace events, ongoing flight data, safety events, and location alerts to provide key performance indicators related to a flight's operational safety and efficiency.
- **Aireon FLOW**: provides ANSPs with a high-fidelity, low-latency source of position data far beyond their own Flight Information Region (FIR) or Area of Responsibility (AoR) without the need to sign data-sharing agreements with neighbouring countries.

<table>
<tr><th>.Key partners/interfaces</th><th>Key activity</th><th>Customer relationship</th><th>Customer segment</th></tr>
<tr><td rowspan="3">Shareholders:
Highly interested ANSPs (who become partners/ shareholders: NAV Canada, ENAV, NATS, IAA and Naviair)
Iridium Next (constellation)
Key partners:
L3HARRIS (Harris Corporation): is the payload provider (81 ADS-B receivers).</td><td>Business development / dissemination of results
Service viability and certification
Service maintenance
Payload Development (initial, plus new capabilities)
SAR activities</td><td rowspan="3">Get
Events(Conference & Exhibitions, Congress, Symposium)
Website
Social Media
Free trials of data
Alliances: CANSO, FAA, Thales, EUROCONTROL.
Aireon's Distribution Partnership: Airsense, FlightAware, Passur.
Aireon's Channel Partnership: Airsense, Collins Aerospace, FlightAware, NavBlue, Passur, Searidge, SITA, theWeatherCompany
Keep
Good customer experience
Grow
Additional Services / functionalities</td><td rowspan="3">• ANSPs
• Network Manager
• Airlines
• Apps companies (Flight Radar 24)
• SAR</td></tr>
<tr><th>Key resources</th></tr>
<tr><td>ATMICs
Payload
Distribution network</td></tr>
<tr><th colspan="2">Value Proposition</th><th colspan="2">Distribution Channels</th></tr>
<tr><td colspan="2">Aireon delivers the following services:
• Global Air Traffic Surveillance
• Aireon Flow
• Aireon Insights</td><td colspan="2">• Aireon Distibution System
</td></tr>
</table>

• Aireon Stream • Alert Service • Global Beacon*	• Aireon's Distribution Partnership: raw data to the end customer. End-user has the means to process and extract the dataset through their own tools. • Aireon's Channel Partnership: processed data through their existing product to end user.
Cost Structures	**Revenue Streams**
• Payload development • Payload renovation costs • Constellation rental (initial + monthly) • Maintenance costs (Hosting and Operational Costs) • Financial Costs • R&Di for new capabilities • Deployments for new clients • Business development • Legal, certification costs	• Periodic contractual income for contracted services. • Different pricing depending on the service provided. • Punctual income for eventual data requests. * initial income (when joining the company): case of NATS for Aireon

Table 3: Aireon business model

1.2 Regulatory framework

CNS services in aviation are provided in a highly regulated environment: Acts, regulations, Licences, certificates, standards Regulatory Documents and guidance material: all these elements define the Regulatory Framework.

Several regulations applicable to the provision and use of CNS services and considered of special relevance and general application are described below[19].For each regulation the key points of interest for exposing the context for the CNS services are summarised.

The Single European Sky Regulation framework

The SES legislative framework (as amended by regulation (EC) No 1070/2009 to improve the performance and sustainability of the European aviation system) consists of four Basic Regulations on the framework for the creation of the single European sky (549/2004), the provision of air navigation services (550/2004), the organization and use of airspace (551/2004) and the interoperability of the European Air Traffic Management Network (552/2004 that is repealed by 2018/1139).

[19] When amended, the consolidated text is considered

Regulation (EC) No 550/2004 (as amended by regulation (EC) No 1070/2009) on the provision of air navigation services. It establishes common requirements for the safe and efficient provision of air navigation services.

- Article 7 requires that all air navigation service providers are certified by Member States, and this certification confers them the possibility of offering their services to Member States, other air navigation service providers, airspace users and airports within the Community.
- Article 10 states that when service providers avail themselves of the services of other service providers, they shall formalise their working relationships setting out the specific duties and functions assumed by each provider and allowing for the exchange of operational data between all service providers in so far as general air traffic is concerned.

The EASA Basic regulation

The Regulation (EU) 2018/1139 (as amended by regulation (EU) 2021/1087) defines common rules in the field of civil aviation and establishes a European Union Aviation Safety Agency.

- Article 41 requires ATM/ANS service providers to be certified.
- Article 45 requires providers of ATM/ANS to declare or to obtain a certification regarding that the ATM/ANS systems and constituents which are to be put in operation by those service providers comply with the essential requirements set out in Annex VIII.
- ANNEX VIII provides the essential requirements for ATM/ANS. "2. SERVICES" demands that CNS services achieve sufficient performance. "5. SERVICE PROVIDERS AND TRAINING ORGANISATIONS" requires that the service providers have directly or through agreements with third parties the means necessary for the scale and scope of the service. The CNS service providers shall keep relevant airspace users and ATS units informed on a timely basis of the operational status (and changes thereof) of their services provided for ATS purposes.

The ATM/ANS regulation

The Regulation (EU) 2017/373[20] (as amended by Regulation (EU) 2020/469) is laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight.

- Article 3 requires Member States to ensure that these services and functions are provided in accordance with this Regulation, in a way that facilitates air traffic and in fair competition when in a competitive environment.
- Article 4 states what are the competent authorities for the issuing of certificates to service providers. These are the national supervisory authority except for pan-European service providers, for which EASA is the competent authority.
- Article 6 demands that ATM/ANS providers hold a certificate and identifies what requirements these service providers must comply with to be granted a certificate, being these requirements in the annexes.

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[20] Summarised in https://eur-lex.europa.eu/EN/legal-content/summary/requirements-for-providers-of-air-traffic-management-and-air-navigation-services.html

- Annex III Subpart-A (GENERAL REQUIREMENTS) ATM/ANS.OR.A.045 requires service providers to coordinate between them when having dependencies with each other. They shall work together to assess and, if necessary, mitigate the impact of changes to their functional system.
- Annex III Subpart-B ATM/ANS.OR.B.005 demands that a service provider establishes formal interfaces with the relevant service providers to ensure that aviation safety hazards are identified and evaluated, and that it ensures that the services are provided in accordance with the requirements of this Regulation.
- Annex IV Subpart-A ATS.OR.200 requires an air traffic services provider to coordinate an emergency response planning with other service providers that interface with the ATS provider.
- Annex VIII Subpart-A CNS.OR.100 demands that CNS services providers ensure availability, continuity, accuracy and integrity of their services and confirm their quality level.
- Annex VIII requires that CNS service providers working methods and operating procedures comply with the relevant standards of Annex 10 to the Chicago Convention.

Technical regulatory requirements on CNS services

- First, in the design phase, the safety requirements for the applicable Communication, Navigation, and Surveillance systems are documented as failure classifications based on a Functional Hazard Assessment of each system. The failure classifications are further divided between loss of function hazards and misleading/erroneous data hazards. To each failure type and according to its criticality from “Catastrophic” to “No effect” classification, a Design Assurance Level (DAL) is identified for each CNS system installed in the aircraft designated by appropriate letters from “A” to “E” respectively from the more complex system design to the less one.
- Second, the regulations governing CNS systems are predominately operational regulations (e.g., 14CFR Part 121). The applicable regulatory requirements are included in standards to which the corresponding system need to comply with such as FAA Technical Standard Orders (TSOs)/European TSOs, FAA Advisory Circulars, and EASA Acceptable Means of Compliance (AMCs) for the applicable CNS systems. Those standards include system Minimum operational performances characteristics which should ensure that the system will be able to meet its expectations.
- Finally, systems and installation are also subject to some general requirements which are dictated in some general standards such as RTCA DO-160/EUROCAE ED-14 on “Environmental Conditions and Test procedures for airborne equipment”. System Performance, installation, and airworthiness approval considerations should be the initial objectives that may help to formulate system design constraints.

The ICAO Global Aviation Security Plan (GASeP)

The security of the ATM/ANS system is essential when enhancing digitalization and virtualization of the provision. ICAO already added cyber resilience in the Global Air Navigation Plan. Cyber resilience is also set as an ICAO priority for the 41st session of the ICAO Assembly and for the next triannum[21].

[21] ICAO EUR/NAT DGCA meeting, 10 May 2022

EUROPEAN PARTNERSHIP

Co-funded by the European Union

The ICAO Global Aviation Security plan will be updated soon and the GASeP – which is part of the ICAO Global Planning framework – will have to be considered when defining cyber resilience requirements for CNS services in Europe.

1.3 Research and vision documents describing an evolution in CNS services

In this context reference documents span between 2018 and 2020. Any new development since then is based on further discussions on the subject made in different forums: the development of the Virtual Centre concept and the activity of the first CNS Advisory Group in 2021 and the following one in 2022.

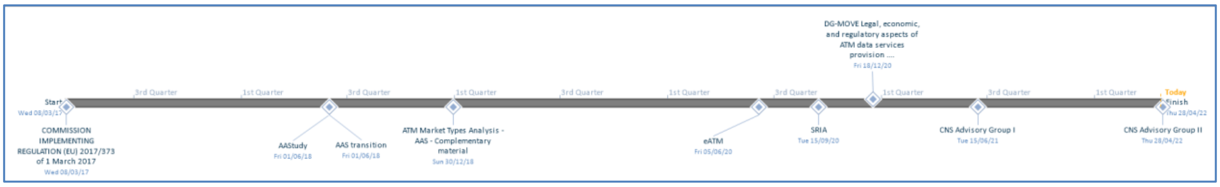

Figure 3 Vision and Research documents timeline

Already in 2004[22] the EC expressed the following: “The provision of communication, navigation and surveillance services, as well as aeronautical information services, should be organised under market conditions whilst taking into account the special features of such services and maintaining a high level of safety.”

The CNS services are part of the ATM and ANS system, which provides the separation service to the airspace users and direct support to the airspace users for other ATM functions. The current ATM system is the outcome of decades of layers contributing to the provision of the above-mentioned services. Meanwhile, the technology, the threats, the traffic density have changed and patching up the current ATM system is deemed insufficient to cope with the upcoming – and sometime daily – challenges. The European Commission and the stakeholders of the ATM systems have worked together to organize the evolution of the ATM system into a more resilient, more flexible, cheaper and performance-based organization.

Among the main concepts which have been developed are:

- Decoupling of the Air Traffic Service Provision from the rest of the ANS services such as CNS, MET and AIS;
- The notion of ATM data services: ATM data services should enable the creation of a common data layer, through an increased level of interoperability, a more resilient and flexible data provision, and ultimately by feeding all air traffic services providers with the same, high-quality data, irrespective of their area of responsibility and/or their geographical location.

[22] REGULATION (EC) No 550/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 10 March 2004 on the provision of air navigation services in the single European sky

- Decoupling of the services from a system based or national/geographically limited approach (e.g., space technology and Communication Networks have greatly evolved) to a Performance based approach wherein quality of the service is also underscored;
- Development and evolution of the role of the ATM Data Service Provider[23] (ADSP)

The scope of the ATM Data Service provider is still in evolution due to the subsequent studies which have analysed further aspects of this role:

- The Future Airspace Architecture Study (AAS) Market analysis makes *"an analysis of characteristics of 'markets' for air navigation services in the European context. It looks at elementary patterns of the possible markets using generalised business concepts."* The analysis strengthens the decoupling of the ATS service from the rest of the ANS services whilst defining high level market roles but does not identify the specific services leaving it open to further development. This analysis is at the basis of the further studies and developments made in the rest of the reference material.
- The AAS provides a proposed amendment to the categorisation and taxonomy of air navigation services, as they are defined in the Single European Sky related legislations. According to this proposal, ATM data services should be defined independently from ATS, as well as from the ancillary services (such as CNS, AIS and MET).

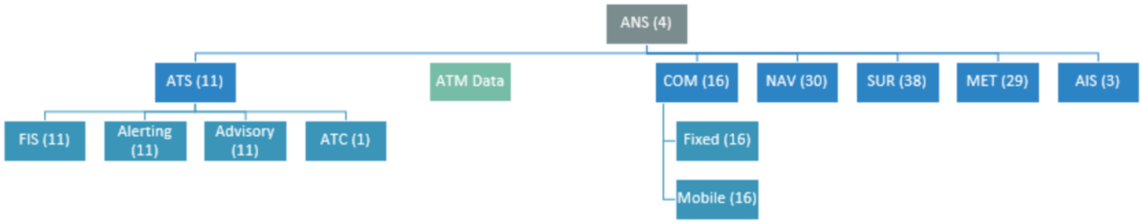

Figure 4: proposed extension of the SES ANS taxonomy for ATM Data services

However, the AAS also noted (as reflected in the latest eATMMP) that the maximum scope of service delivery by ADSPs could also include the provision of AIS, MET and CNS services[24].

In the AAS the ADSP is defined as:

- ATM data services provide air navigation services providers, airspace users, airports, and other operational stakeholders with information on the intended movement of each aircraft, or variations therefrom, and with current information on the actual progress of each aircraft, based on operational data received from surveillance (SUR), aeronautical information services

[23] EASA plans to develop an amendment to EU 2017/373 in order to introduce the common requirements for the provision of ATM Data Services.

[24] A legal entity should be able to provide more than one service defined under the Common Requirements (Commission Implementing Reg No. 2017/373) for air navigation services. Each one would need to be certified separately. This is in line with the current ANSP certification model, where multiple services are provided by the same entity.

(AIS), meteorological services (MET), network functions and any other relevant operational data.

- ATM data services also provide decision advisory services to Air Traffic Service Units based on advanced data processing and transformation technologies (safety nets, machine learning, AI, etc.).
- An ATM data service provider may provide all of the above-defined services/information, or only subsets thereof.

For the purpose of the study,

- the boundary between ATM data services and data production is initially defined at the point where operational data enters the surveillance data processing systems (trackers) or the flight data processing systems or the more advanced tools (applications) based on these.
- the boundary between ATM data services and air traffic services is initially defined at the point, where the data/information/application is presented on the screens of the controller working positions.

The above definition underscores the separation of three service layers into data production; data processing and air traffic services, thus also creating a further role which is the Data Producer.

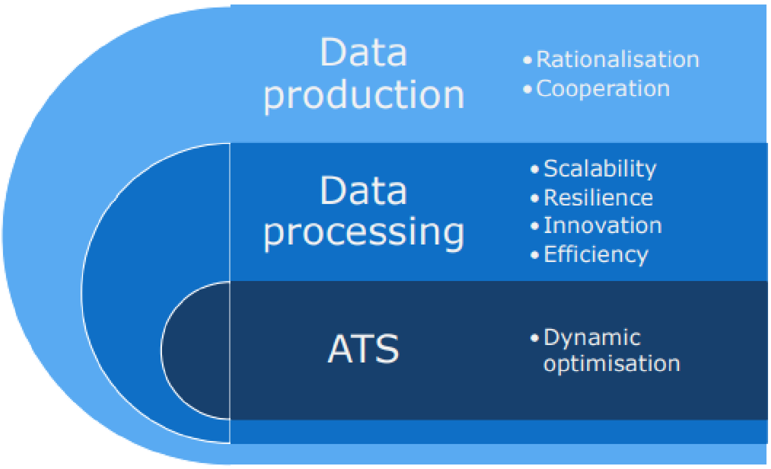

Figure 5 Benefits of ATM data services [10]

The introduction of ATM data service providers would not be mandatory, and ATSPs could choose to remain in the current vertically integrated model (see also figure 7). The scope of service delivery by ADSPs would not be fixed, only the maximum scope is identified. Also, the boundary between an AD service provider and CNS service provider is not fixed, a same entity could be providing ATM data and C, N or S services, and even ATS services.

The following sections are describing how some major prospective and planning documents have shaped the ATM of the future. In this transformation, the document will focus on the CNS services and their relationship with other services – current or new – how they are described and organized, their expected benefits and their constraints, and how they contribute to an upgraded European ATM system. Some information, concept or conclusion may appear several times across the following section. They have been kept in the description of each document because they are depicted in a different context or perspective which is enriching them as the documents are explained.

1.3.1 The Airspace Architecture Study (AAS)

The SJU published in 2019 "A proposal for the future architecture of the European airspace" mandated by EC/MOVE/E3. This publication is known to say as the "Airspace architecture study" (AAS) and this PJ14 deliverable will refer to this SJU publication as the AAS.

The AAS is the vision aiming at solving the current European ATM system issues – such as En-route delays, congestion of air Control Centres, capacity crunch, and resilience – by deeply reorganising the structure of the Air traffic provision services including the supporting services, i.e., CNS services, to support Virtual Centres. This evolution will allow the future European ATM system to be efficient and able to cope with the upcoming challenges.

"*The focus of the AAS is link between the operational and technical dimensions – airspace, operations and technology, infrastructure, applications and data services*".[25]

The AAS and the AAS transition plan will be assessed against the evolution of the CNS services in the following sections.

1.3.1.1 The overarching vision

The shift from infrastructure ownership to the delivery of only CNS services will provide the following high-level benefits:

- Rationalisation and network optimisation at local/network level. New service delivery models could enable further rationalisation of the underlying infrastructure since the focus will move from investment in a specific infrastructure to provision of services complying with performance requirements and applicable to wider/international geographical areas. Rationalisation could also be applied beyond the geographical domain, to functions which could be better served by "*limiting the redundancy of primary means to the necessary level guarantying the service provision*"[26].
- Optimal technological and spectrum CNS synergies. The service-based and performance-based approach will favour potential synergies, technological and/or functional, across CNS, taking advantage of common system and infrastructure capabilities for the ground, airborne and space segments; guarantee spectrum efficiency before use of non-protected spectrum it requires deep in-depth analysis. Serving all the airspace users, including the drones, will foster operational and technical integration if the governance is inclusive for all airspace users.
- Cost effectiveness. CNS services can drive cost-effectiveness for ANSPs by supporting Make or Buy decisions for a customer, e.g., benchmarking internal and external delivery methods. In particular:

[25] A proposal for the future architecture of the European airspace, aka the "AAS", Ed 2019, page 11

[26] EBAA contribution to "SESAR 2020 Wave2 provision of Airspace users' expertise" EUROCONTROL contract 19-220819-C5 ed. 1st Dec 2021

- It limits the risks to only the consumption of the service;
- Suppliers can build efficiencies from provision to multiple customers
- Places increased emphasis on clear, well defined (contracted) customer specified and reporting mechanisms – consumer is detached one level from service management.

The AAS is proposing to use the service-oriented architecture (SOA) to achieve these benefits:

- Performance.

The increasing network bandwidth, increasing reliability and lowering latency, in particular for ground-based networks, enables re-architecting that was not possible before. As a result, networks are now able to provide secured high bandwidth, low latency networks for safety critical domains like aviation. Safety criticality from an operational perspective translates to time-criticality and cyber-security from a technical perspective.

- Service decoupling.

Service orientation enables splitting integrated legacy systems into independently operated services with minimised interfaces between them. End-user services consume integration services, integration services consume elementary services.

- Virtualisation.

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

- Re-integration of services.

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

- Interoperability.

Considering that in the global aviation context, no single service implementation of whatever nature will cover the whole world and that there will always be operations that require the successive services of different service providers, there is also an interoperability requirement on various ATM services within the same layer.

- Resilience.

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

- Scalability.

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

Note: Aside the AAS definition, scalability is usually the term describing a system's ability to cope with increased load. Thus, a scalable service is such if it has the ability to cope with increased load whilst maintaining the required performance /Quality of Service.

The AAS study defines the levels of services from the ATS supported by ATM data and integration services, down to the transversal services for virtualisation, which allows to decouple ADSP and ATSP, as detailed by the table below.

Service Name	Description
Air traffic services (ATS)	ATS is the core service that maintains separation between aircraft, expedites and maintains an orderly flow of air traffic. Clearances are issued by air traffic control units (ATCO) to pilots to provide separation. The provision of ATS by controllers relies on the underlying ATM data services.
ATM data services	The ATM data services provide the data required to provide ATS. It includes flight data processing related functions like flight correlation, trajectory prediction, conflict detection and conflict resolution, and arrival management planning. These services rely on underlying integration services for weather, surveillance and aeronautical information. They also include the coordination and synchronisation of ATM data in function of all trajectory interactions by the providers of ATS.
Integration services	The integration services for aeronautical information management (AIM), surveillance (SUR) and weather combine the geographically constrained scope of the underlying provision services in a service with a broader geographical coverage. By building on performance-based service requirements and standardised interfaces, these services can be built up from different underlying geo-graphically-fixed services with different qualities from different providers (e.g. satellite ADS-B or radar-based surveillance services, WAM,…).
Geographically-fixed services[27]	These are services that have a fixed relationship with a geographical location *but may not be linked to national borders*[28]. They include the provision of navigation signals, weather and surveillance sensors and the provision of air-ground *communication* antennae.
Network services	Including air traffic flow and capacity management (ATFCM), existing network functions and network crisis management.
Transversal services	Including system-wide information management (SWIM), ground-ground communications and security services.

[27] The services referred to here are only related to Infrastructure as a Service. Bundled services or vertical integration may well cover the end to end service.

[28] It is proposed to amend the original description with a reference to the disconnection to national borders and to add communication after air-ground for clarity.

Table 4 Levels of services from the AAS[29]

Note: the AAS concepts looks like the FAA at the data management level and the service-oriented architecture implementation, which potentially allows a seamless transition of the traffic from the US NAS to the European airspace[30].

The decoupling of integration services and underlying CNS infrastructure services, allows for a performance-based approach to CNS as defined in European ATM Master Plan through the CNS infrastructure and services concept. Decoupling is the condition for horizontal re-integration of services provides options for scalable services: "*Horizontal re-integration of services through consolidation of services within the same layer occurs when two or more service providers agree to offload a service of the same layer to a common provider of that service* [31]".

The32ecouplingg could be vertical and geographical and supports efficient and scalable services:

- Vertical decoupling

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

- Geographical decoupling

"*With the support of secured high bandwidth, low latency networks, all functions that are not directly linked to a geographically fixed entity, can now be run from anywhere. A consumer service can run in one place, and the provider service in another. This is called geographic decoupling.*[32]"

Note: Geographical decoupling is currently occurring in the majority of the COM Data Link Services domain (SITA/Collins)

The AAS foresees the CNS Services at the integration, geographically fixed and transversal service levels. CNS services will be provided through contractual relationships between customer and provider for clearly defined and harmonised services with agreed quality of service levels using Service Level Agreements (SLA), which covers performance metrics such as availability, integrity, safety and security requirements. An ANSP could, for example, contract a service based on operational needs; the service provider could then combine the available CNS technologies and provide the necessary service that

[29] AAS ed 109, page 47

[30] FAA AAtS (aircraft access to SWIM) version 2.0, 2013

[31] AAS, ed 2019, page 97

[32] AAS, ed 2019, page 96

meet the requirements. "*The maximum scope of service delivery by ADSPs covers the ATM data services … and includes the provision … CNS services.*"[33]

"*The implementation of the services is progressive, and the architecture is anticipated as flexible to allow the stakeholders to choose their implementation options. The logical architecture is the starting point for identifying a virtual infrastructure that enables vertical and geographical decoupling of services; this will enable the re-integration of services in a manner that increases flexibility, scalability and resilience.*[34]"

CNS technology using line of sight radio signals induces a geographical constraint to the ATS provision. Space based CNS infrastructure allows an extended coverage improving the services to otherwise limiting locations whilst allowing or improved airspace operations.

Figure 6 proposes an example of a service-oriented architecture depicting service (but not information) flows:

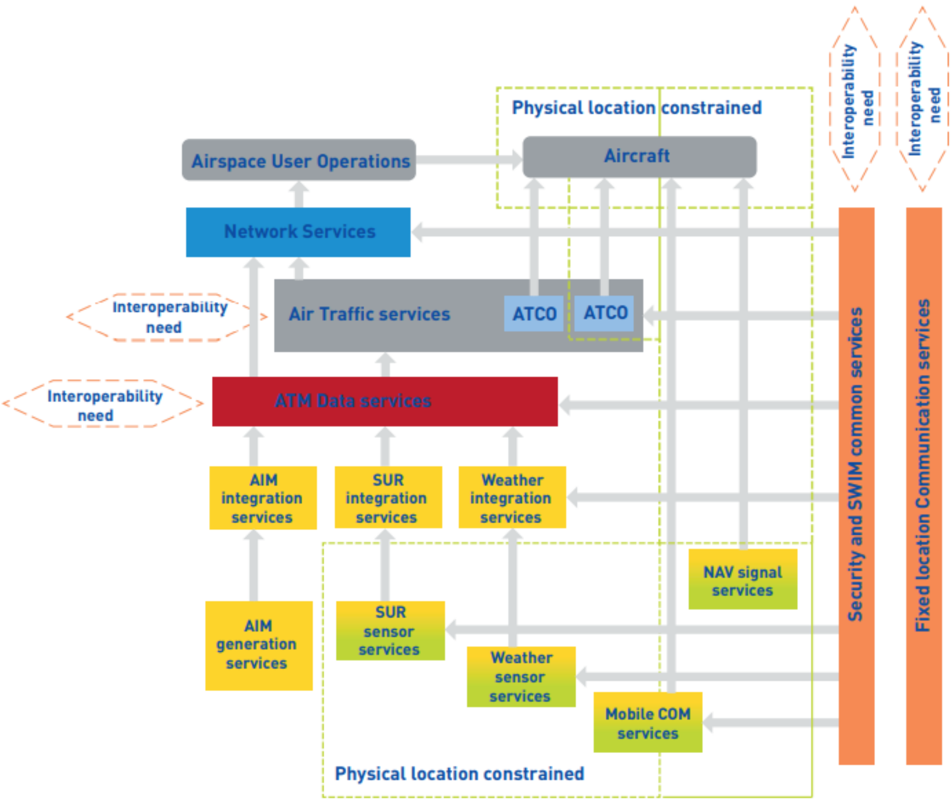

Figure 6 Example of SOA architecture

[33] AAS, ed 2019, page 14

[34] AAS, ed 2019, page 45

1.3.1.2 The AAS transition plan,

The AAS is accompanied by a transition plan linking the regulatory, technical, and current (PJ14-W2-76) and future[35] research areas. This transition plan provides concrete examples of evolution of some technologies, like datalink.

1.3.2 The European ATM Master Plan (eATMMP) – executive view 2020

Note: This section is using the 2020 edition of the eATMMP based on 2019 information and decisions.

The European ATM Master plan describes the required phases to transform the European ATM from a monolithic, product oriented and narrow supply base system to a distributed, service oriented and wide supply base system. The orientation to a service-based system is planned in phase B "Efficient services and infrastructure delivery" of the eATMMP and it assessed as essential to the implementation of phase C "Defragmentation of European skies and virtualization" (see Focus area 2 of the AAS "Scalability and resilience"[36]).

From the ATM architecture perspective, the current 3 layers (Airspace, air traffic services, physical) are by assumption replaced by more efficient and inclusive layers, such as higher airspace operations, identified network operations and U-space operations and in which air traffic services, CNS services, data provision and infrastructure are potentially separated.

The technical objectives of the transformation are:

- the increase in the overall performance of the ATM system,
- the rationalization of the CNS infrastructure and the best use of spectrum,
- a higher resilience to cyber threats
- the reduction of the overall environmental footprint of aviation.

These objectives are aiming at fostering the flexibility in the air traffic service provision and the digital transformation of ATM. '*Investment costs in the ANS infrastructures and their maintenance should be offset by benefits expected from CNS rationalisation, digitalisation and consequent reduction of assets and amortisation costs*[37]'.The future CNS must also have an increased robustness, support a higher interoperability between the air traffic service providers and include the civil military dimension.

Virtualization, automation, digitalization, and artificial intelligence are the high-level means to achieve these objectives.

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[35] "New technologies will arise, complying with the CNS performance-based approach as defined in the AAS. Building on the success of the EGNOS and IRIS, this may include, but is certainly not limited to, the further extension of performance-based satellite-based services", AAS transition plan, ed, page 64

[36] AAS, ed 2019, page 38

[37] Master plan Companion on the performance ambitions and business view Ed 2020 page 12

Service based is the common business and technical model promoted by the eATMMP. The CNS function supporting the Air traffic services is also split into its most essential components: Data, service provision and infrastructure.

Such an evolution in CNS is expected to allow:

- the emergence of a secured data ecosystem,
- a high bandwidth low latency CNS infrastructure service freed from a national ownership which is often limiting rationalization at the European level
- an open market for CNS services.

The Master Plan "implementation view" document considers that *'through a service-based approach, CNS services will be specified through contractual relationships between customers and providers, with a clearly defined, European-wide set of harmonised services and level of quality'*[38]. In addition, '*the changes in CNS will be driven by a service-based approach and a performance-based approach. This will enable the decoupling of CNS service provision from ATS and ATM data services. This change will make the European ATM system more flexible and resilient, allowing scalability. Cross-domains CNS should be privileged whenever possible to foster integrated CNS and optimized use of spectrum*[39]'.

In the specific domain of infrastructure, the eATMMP describes a '*change in focus from physical assets to delivery of services: In the context of the digital transformation of ATM and the move towards a data ecosystem, the CNS infrastructure needs to gradually move towards being provided as a service rather than operated as physical assets. This will enable the required flexibility to deal with the growing complexity of technological life cycles. It will also create a business environment that favours performance at all levels. Business models set up to operate the services could differ between COM, NAV and SUR services and even within COM, NAV and SUR services. Multiple service providers, including military providers, could offer their services in competition. Customers and providers could be the same or distinct. Associated to the service model, the maximum scope of service delivery by ADSP would include the provision of AIS, MET and CNS services*[40]'

Eventually, the disconnection of the CNS services from geography will enable ATS virtual centres, which are key to cost reduction and ATM resilience and the implementation of the 'capacity-on-demand service' allowing a higher scalability of the traffic in the European skies.

1.3.3 The CNS evolution roadmap and strategy

Note: This section is using the 2019 (Aug 30th) Edition 00.03.01 of the CNS evolution roadmap and strategy deliverable D2.1.300.

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[38] Master Plan Implantation view Ed 2021 page 12

[39] Master Plan Implantation view Ed 2021 page 22

[40] EATMMP Ed 2020 pages 98 and 106

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According to the CNS roadmap deliverable, the CNS domain evolutions will be driven by a service-based approach and a performance-based approach. This will enable the de-coupling of CNS service provision from air traffic services and ATM data services. This change will lead the European ATM system to be more flexible and resilient, allowing scalability.

The performance-based CNS approach sees an evolution from system/technology-based operations, where systems/technologies are prescribed, towards the delivery of performance-based services, which specify the performances to be achieved in each environment with its specific characteristics.

Performance based applications will be supported by a backbone of recent and global technologies, with the goal of providing secure CNS services. In parallel, cost, spectrum requirements and business cases will drive a rationalization process of the infrastructure including a seamless phase-out of legacy systems and smooth transition to the use of new, higher performance technologies, more efficient CNS services, or both. The development of a Performance Based CNS framework could also support flexibility for Air Navigation Service Providers and could enable them to define their own CNS service delivery model.

It is anticipated that this combined service-based and performance-based approach will favour potential technological/functional synergies across the communication (COM), navigation (NAV) and surveillance (SUR) domains, taking advantage of common system/infrastructure capabilities for the ground, airborne and space segments. A CNS service-based approach should provide a strong incentive for service providers to cooperate across national boundaries, to optimise the use of technologies as well as the geographical distribution of equipment (and hence optimise spectrum use). It will also provide a better environment for the integration of new CNS services – such as space-based automatic dependent surveillance broadcast (ADS-B) and satellite-based communications.

From a service standpoint the boundaries between the different domains will disappear progressively as the infrastructure moves to an integrated “digital” framework. It will be the most cost effective both for the providers and the users. Technologies will evolve over time without requiring the operations themselves to be revisited, if the requisite performance is provided by the system and guaranteed by the service provision[41].

The CNS Roadmap and Strategy deliverable establishes an overview of the evolution and transition path of CNS domains over a long-term period from today to 2035 and beyond. It proposes the evolution of the operational vision of these services, highlighting the underlying technologies and solutions that make this evolution possible, and describing the rationalization of the infrastructure, in line with the service-based approach and the MON (Minimum Operational Network)[42] concept. This concept is based on the rationalisation/optimization of CNS infrastructure resources, moving from an inefficient and costly traditional infrastructure with a high level of redundancy, to an optimized service-based network with domain integration, allowing higher cost efficiency through the decommissioning

[41] As stated in the eATMMP page 57: “For end-users, the technological solutions will be packaged or merged in a way that guarantees availability, integrity, safety and security, and performance requirements, as mandated by relevant authorities”

[42] Cf CNS Roadmap Strategy (from Sol 76) and “CNS infrastructure evolution opportunities” (CNS advisory group)

of obsolete/redundant systems and the deployment of new optimal and interoperable systems in addition of legacy CNS system acting as a back-up infrastructure in the event of contingencies of primary systems.

A clear example of this transition can be observed in the SUR domain, where the decommissioning of Mode A/C and Mode S radars, and the exploitation of mixed systems such as Mode S with ADS-B capability (integrating also Phase Overlay technology), allow an optimized and cooperative CNS infrastructure that facilitates the transition from a technology/system-based approach to a service-based approach. As this example shows, it is important to note that none of the CNS systems (ground-based, satellite-based, airborne) can be removed/decommissioned without providing alternative solutions to single point failures and any new CNS technology will not be approved for deployment without being safe, secure, and resilient.

To achieve the objectives set by the CNS roadmap, a strategy is needed. According to the CNS Symposium organised in Eurocontrol (2-3 October 2018) and to the feedback received from stakeholders in the World ATM Congress 2018 & 2019, several recommendations were identified, where some of them are being already under study in SESAR project (e.g., the inclusion of cyber-security in ASTERIX and ADS-B with the development of new messages formats), others are being under discussion in working groups (e.g., the increase of multilateration and ADS-B coverage in order to phase out Mode A/C messages and rely on ADS-B as the primary data source for surveillance) or the appearance of new systems that already apply the service-based concept (satellite-based surveillance constellations).

The primary lines of action of this strategy are to change the way spectrum is used in aviation (ensuring the spectrum availability for future operations), support standardisation progress to alleviate the risk to have technology ready but not implementable due to lack of associated standards and strengthen the civil-military collaboration in strategic development to achieve full interoperability.

1.3.4 The Performance based CNS deliverable

Note: This section is using the Edition 00.03.07 (1st September 2021) draft document of the Performance-based CNS deliverable (D2.1.300).

According to the Performance-based CNS (PB-CNS) deliverable, "*the PB-CNS concept means a transition from system/technology-based operations, where systems/technologies are prescribed, towards technical performance indicators definition for CNS systems to be achieved for specific operational needs and types of airspaces.*" To reach this goal, this concept is mainly oriented on the CNS service provision supported by satellite and/or ground infrastructure.

Therefore, the implementation of the PB-CNS concept requires compliance with the operational performance values defined for each service that wants to be provided (i.e., 5NM separation in high-density En Route airspace).

The performance-based approach will move from system/technology-based operations, where systems/technologies are prescribed, towards performance-based services, which specify the performances to be achieved in each environment with its specific characteristics. There is a tendency towards a service provision model: the compliance with the requirements of the technology supporting the service changes to the compliance with the minimum requirements established to enable air traffic management of the same or better level of quality. This new approach opens the possibility for a greater number of business opportunities opening the market to new players and improving cost efficiency.

For a better understanding, an example from the surveillance domain is used: currently, ANSPs are following the technology-based approach mandating the surveillance systems such as ADS-B to comply with standards such as ED-129B. However, with the new service-based approach, instead of requiring the systems to comply with the technological standards, the goal will be to meet the minimum performance requirements that ensure that aircraft can be comply with the operational and performance needs. In the case of the surveillance, it could be providing a minima separation distance of 8NM in ER high density airspace, regardless of the technology being used.

Thus, it does not dictate which technologies must be deployed to comply with these performance values, but it sets up the framework for the development of new solutions oriented to the provision of CNS services.

In the Performance-based CNS deliverable, the ICAO Document 9883 (Manual on Global Performance of the Air Navigation System) is referenced, providing a definition of the PB-CNS concept and its implementation in the Air Navigation Services (ANS): "*The Performance-based Approach (PBA) is a decision-making method based on three principles: strong focus on desired/required results, informed decision-making driven by those desired/required results, and reliance on facts and data for the decision-making*".

This approach enables the categorization of performance subject in ATM into 11 KPAs defined in ICAO Document 9854: Access and equity, Capacity, Cost effectiveness / Cost efficiency, Efficiency / Operational efficiency, Environment, Flexibility, Global interoperability, Participation by the ATM community, Safety and Security. These KPAs have their performance objectives, which are usually expressed in qualitative terms and include a desired or required trend. For this purpose, KPI are defined, which show current/past performances and the expected future ones.

For the systems and technological level, technical performance indicators can be defined within the performance-based approach to check if they are achieved. For example, considering a surveillance service with the objective to provide 8 NM separation minima in continental airspaces, several KPI could be defined to ensure the quality of the service such as the accuracy, the availability, the continuity and the integrity of the data[43]. Without them, the service would be degraded (the objective will not be achieved) and therefore, inefficient (as other methods would be used to achieve the goal or the objective would change).

With this approach, a new motive will appear to replace the legacy systems that are not easy to maintain, aiming at high-performance and secure systems that can integrate different functionalities or capabilities in a common system block while ensuring, at the same time, the low probability of a single point of failure occurrence. This will foster potential technological synergies across COM, NAV and SUR sections, taking advantage of a common system and infrastructure capabilities for the ground, airborne and space segments. Besides, the development of a PB-CNS framework could also provide flexibility for ANSPs to define their own CNS delivery model, enable the rationalisation of the airborne

[43] As required to a CNS service provider by (EU) 2017/373

systems, reduce annual operating costs and investment budget, allow performance requirements to fit into user's and operational needs while ensuring contingency and security of service provision, among other benefits.

1.3.5 The **Strategic Research and Innovation Agenda (SRIA) [11]**

Note: This section is using the 2020 edition of the Strategic Research and Innovation agenda based on 2020 information and decisions.

'The SRIA supports the delivery of the Digital European Sky… and presents

- *the scope and approach to further modernisation of Europe's air traffic management (ATM) capabilities and U-space*
- *presents the strategic research and innovation (R&I) roadmaps for the years 2021 to 2027 in order to deliver on the implementation of the European ATM Master Plan 2020 for the strategic phases C (defragmentation of European Sky through virtualisation) and Digital European Sky up to 2040+).* [44]*'.*

The SRIA roadmaps are developed on the basis of the adopted European ATM Master Plan 2020 and the Airspace Architecture Study (AAS) and its Transition Plan[45]*'* which ensures the compatibility between these documents.

The SRIA complements the eATMMP vision with more detailed and additional elements to ensure the success of the Digital European Sky implementation:

- New ways of working will include '*better regulations which will support innovation — through … focus on delivery of services — with an emphasis on what services should be provided and how, rather than on what technologies should be implemented*.[46]': The regulatory mandates will be adapted to the service-based, performance-based approaches.
- ATM and U-space are clearly considered in the SRIA as well as '*European space developments*[47]*'* including '*Galileo and IRIS*'. '*Ultimately, manned and unmanned aerial vehicles should operate in a seamless and safe environment using common infrastructure and services supporting a common concept of trajectory-based operations*[48]*'*.

The SRIA is also addressing infrastructure as a service. This information is important to better understand the expected relationship between infrastructure services and CNS services: '*through a*

[44] SRIA Ed 2020 page 5

[45] SRIA Ed 2020 page 6

[46] SRIA Ed 2020 page 17

[47] SRIA Ed 2020 page 21

[48] SRIA Ed 2020 page 30

service-oriented architecture (SOA), the infrastructure services (e.g., communication, navigation and surveillance) will be specified through contractual relationships between customers and providers with clearly defined European-wide harmonised service-level agreements. This approach will create business opportunities for affordable services with a strong incentive for service providers to rationalise and harmonise their own infrastructure in support of nominal and contingency operations and more generally the provision of safe, efficient, cost-efficient, interoperable, and standardised ATM and CNS services[49]*'*.

The service-based approach, automation and a well-defined required service level will help to achieve cost efficiencies. '*A service-driven approach, accommodating civil and military alike is needed to describe how the CNS services are delivered for navigation, communication, surveillance …, including cross-domain services (e.g., contingencies)*[50]'.

The SRIA is defining the maximum scope of the aeronautical data service providers, which here covers the ATM data services needed to realize the virtual defragmentation of the European skies and '*includes the provision of AIS, MET and CNS services*[51]*'*. This definition is stronger than the definition of the ADSP from the eATMMP since here the inclusion of the CNS services into the ADSP is unambiguous, and it was just a possibility in the eATMMP. This scope point requires clarification as the model is emphasizing the decoupling of data and CNS services.

Space-based systems and the IP technology are promoted: *'A large part of the CNS services will be provided through applications using space-based sensors. With regard to communications, the transition towards an IP-based environment will enable the location-independent transmission of data and/or voice. Possibly, a dynamic allocation of IP connections will reduce the need for VHF channels on the ground side and the need for the airborne side to switch frequencies several times during the flight. R&I needs to deliver solutions utilising infrastructure (CNS, IT, U-space, etc.) as a service, enabling new combined services*[52]*'.*

In addition, cyber resilience is addressed in support of the service provision in general *: 'The need for the efficient application of standards addressing safety, privacy and cyber resilience risks is obvious to ensure the protection of information and information systems, manage cyber-resilience risks, implement appropriate safeguards to ensure the delivery of services, identify the occurrence and continuous monitoring of cyber-resilience events, and respond to and recover from potential cyberattacks with a proper level of reactivity*[53]*'.*

[49] SRIA Ed 2020 page 49

[50] SRIA Ed 2020 page 68

[51] SRIA Ed 2020 page 52

[52] SRIA Ed 2020 page 49

[53] SRIA Ed 2020 page 51

The performance-based approach is also better specified in liaison with the Minimum Operational Network: '*To enable the deployment of a performance-based CNS service offer, industrial research and demonstration of an integrated performance-based CNS service offer will be required building on the industrial research on selected technologies (e.g., SATCOM, AeroMACS, LDACS, etc.) carried out in SESAR 2020. This unified framework, made up of a backbone infrastructure, supported by a backup minimum operational network, will maximise cross-domain opportunities and synergies and will support various airspace concepts. The development of non-safety-of-life ATM applications using commercially available services (e.g., 5G, open SATCOM) will be required in order to contribute to a hyper-connected ATM system*[54]'. This piece of text provides guidance upon the technologies which could be assessed as examples against the service-based approach.

1.3.6 The CNS Advisory group report

Note: This section is using the 23 April 2021 draft edition of the CNS Advisory Group report.

The CNS Advisory group report is mainly focusing on the CNS infrastructure and on the strategic management of the CNS evolution. The document is system oriented, with the infrastructure understood as a service.

Note: 'CNS service' is not defined and scarcely used in the document (14 times against 83 times for infrastructure). Data (in the context of CNS data provision) is only mentioned four times, demonstrating the strong focus on the CNS infrastructure in this document. Moreover, it introduces a potential bias in how to understand 'CNS service' when employed. The context of the section of the CNS advisory group report must been always checked to draw any conclusion from any piece of text in this report.

Nonetheless, the data/CNS service/ infrastructure concept is recognized as supporting rationalization of the CNS provision[55].

Some guidance is provided regarding the criteria against which the evolution of CNS should be assessed[56]:

- Technical performance (e.g. accuracy, availability, latency, integrity…)
- Cost efficiency
- Spectrum efficiency

[54] SRIA Ed 2020 page 25

[55] '*The provision of pan-European and resilient CNS services through satellites, as well as sharing processed data more widely across borders through specialised data service providers under market conditions, will enable a further rationalisation of nationally operated terrestrial CNS systems*.' CNS Advisory Group report Recommendation 2

[56] CNS Advisory Group report Recommendation 3

- Coverage, environmental impact and world-wide interoperability

The CNS Advisory group warns against an excessive use of the performance-based approach which '*may lead to an excessive proliferation of technologies/solutions that would increase overall costs and technical/operational complexities.*[57]*'*. This provides an upper limit to the temptation of generalizing the performance-based approach in the service-based context without assessing its real cost benefit impact for each CNS service.

In the domain of validation of new CNS services, the CNS Advisory group requests that '*large-scale demonstrations should be conducted in realistic conditions combining both operational and technical elements, to validate interoperability requirements and confirm that the levels of technical performance can support the expected concepts of operations before deployment of a new CNS service*[58]*'*.

The importance of the MON is recalled in the process of rationalisation: '*The rationalisation of CNS infrastructure encompasses*

(i) *identifying the needed resilience while*

(ii) *(ii) removing the excessive redundancy, and*

(iii) *(iii) geographically relocating a limited number of existing CNS ground systems to achieve a Minimal Operational Network (MON). Such a network should guarantee that safety is not compromised in the case of an outage of the backbone infrastructure, that a minimal level of performance is provided to ensure an acceptable level of service continuity for civil users and for critical military missions.'*

The CNS Advisory group advises '*considering applying a holistic approach in which CNS services are technical enablers to support ATM operations, and then apply an integrated regulatory approach for CNS instead of having individual regulatory approaches per domain*[59]*.'* This recommendation is important in the context of this deliverable to seek for CNS services breaking the boundaries of the legacy, C, N and S domains.

As recalled in Appendix 2 of the CNS Advisory Group report, about the cyber resilience and the pan European Skies perspective, '*the safety and security of CNS services operations considering the evolution to digital technology'* must be ensured and '*the transition from locally operated CNS infrastructure to the delivery of cross-border and pan-European iCNS services, including through modernisation of the data delivery models.'*

1.4 Criteria to be applied for CNS services transition

[57] CNS Advisory Group report Recommendation 3

[58] CNS Advisory Group report Recommendation 7

[59] CNS Advisory Group report Recommendation 10

In the previous sections, the major documents have been assessed against their view upon the CNS services and the service-based approach.

Based on these focused summaries, the CNS services should be assessed against their:

1. **Potential** for
    - geographical and vertical decoupling
    - virtualization
    - re-integration into wider services
2. **Efficiency** of
    - their geographical provision
    - spectrum use
3. **Resilience** against
    - Lawful and unlawful interferences including Cyber attacks
    - Infrastructure failures
    - External events deeply impacting the aviation business
4. **Scalability**
    - Future technological leaps
    - Integration of AI technologies

Ideally, the evolution of a CNS service should be solely demonstrated by a positive "technical and business case" between the CNS service as proposed now and in the future architecture.

However, the integrated, performance based, service-based CNS approach would be better addressed holistically, since one isolated CNS service evolution might appear negative according to the abovementioned criteria but highly beneficial to the ATM performance, resilience, and efficiency at the global level, e.g., fostering the emergence of a secured data ecosystem. Conversely, a positive assessment of a single isolated CNS service could not be the best option for the whole ATM system, all things being considered.

Vertical decoupling is an interesting element to carefully look after, because it depends upon the possibility of separating data, service, and infrastructure, and releasing the legacy sovereign approach to managing CNS services. We have seen that virtualization is deemed as essential to move to phase D of the eATMMP and defined as the "*transition to virtual centres*"[60]. In practice, it consists of identifying CNS services as ATM data services and in decoupling the provision of ATM data services from ATS.

The data are one of the keystones of the entire future ATM architecture. The data have many properties that need to be defined and addressed to assess the relevance of vertical decoupling: for example,

- are they ephemeral or do they need to be stored?
- Are they critical – i.e., worth being secured – or not critical?

[60] AAS, page 38 table 3 in "Focus area 2: scalability and resilience"

- Are they required for real-time live operations or offline monitoring?
- How much do specific data contribute to a potential re-integration?

The data quality, which is fundamental for further virtualization must be completed by its usefulness. The data storage need is directly bound to the actual use of data, especially because data storage is a huge consumer of energy, and an excess of storage of data would impede the objective for a greener aviation.

Such a study on data has not been made yet, which makes difficult to decide upon the relevance of decoupling data from some CNS service.

The resilience of the business case of the future CNS provision is one of the lessons learned from the recent sanitary crisis. Sustainability is today not only striving for an industry preserving the environment, but it now also includes this financial element. The evolution of CNS must take its share in this necessary evolution of the global aviation business case. The recurrent costs of the CNS provision cannot be taken for granted any longer when the airlines are forced to strongly limit their operations. A better balance between recurrent and operating costs must be found in the new CNS provision system. The decoupling should help in achieving business resilience: some elements of the CNS provision chain should be flexible enough to be reoriented from a business perspective to temporarily alleviate the recurrent costs burden.

Finally, the governance of the CNS services is a necessary structural element of the future evolution of the CNS Services, as it drives their evolution, harmonisation, the buy-in of the stakeholders, and provides an open, fair, and transparent service-based environment. Governance has been put out of the scope of this PJ14 solution 76 task. Thus, a definite assessment cannot be conducted in this deliverable.

It is therefore concluded that, once an additional study on the data is conducted, a holistic methodology taking into account the technical, conceptual, organisational (including governance), business and operational constraints and benefits must be developed, tested, validated and implemented before decisively deciding if and how a CNS service should evolve.

Such development goes beyond the scope of this deliverable, which is providing the criteria as described in the major supporting documents in the technical domain.

2 The services in the future airspace architecture

2.1 Definition of Service

Services are the non-physical, intangible parts of our economy, as opposed to goods, which we can touch or handle. Economists divide all economic activity into two broad categories, goods and services[61]. A service industry is an industry in that part of the economy that creates services rather than tangible objects. Two definitions of services are hereafter provided which are assumed to fit within the ATM domain:

1) From the ITIL[62]: “A service is any means of enabling value co-creation by facilitating outcomes that the customer wants to achieve, but without the customer having to manage specific costs and risks… For services to provide true value to the business, they must be designed with the business objectives in mind.”Which could be summarised as:

   “A service is something that meets a need or fulfils a demand.” Whilst inherently including the ability to consider and potentially measure the level of service design and delivery success.

An ITIL service-based approach implies a service strategy, service design, service transition, service operation, continual service improvement with a lifecycle quality control.

ITIL defines three types of service providers

- Type I: internal service providers “embedded into the business units they serve”
- Type II: shared service providers “leveraging opportunities across the enterprise and spread costs and risks across a wider base”
- Type III: external service providers “offering competitive prices and drive down units by consolidating demand”.

2) From ISO [3]: A Service:

   - is a logical representation of a set of activities that has specified outcomes;
   - is self-contained;
   - may be composed of other Services;
   - is a “black-box” to consumers of the Service.

[61] https://www.britannica.com/topic/service-industry

[62] The Information Technology Infrastructure Library (ITIL) v4 [2]

A Service can have one or more providers or consumers and the consumers may not know how the Service is implemented but do establish/negotiate the performance levels through requirements to be reflected in a contract or SLA.

The ISO and ITIL definitions complement each other. The ISO definition is high level and applies to any services as the ITIL definition is tailored to IT services and particularly relevant to the data centred CNS evolution.

2.2 The data centred (ADSP) approach

2.2.1 The ADSP approach conceptual elements

Objective:
One of the key final objectives driving the evolution of the CNS services is enabling virtual centres, by "*Defragmentation of European skies, through virtualisation and enabling a free flow of data across borders among trusted users.*"[63]
As such, "*By 2030, ATM will rely largely on shared data and related services, providing more flexibility, scalability and reduce the need of ground-based infrastructure significantly*."[64]

Context:
"*The Airspace Architecture Study clearly highlighted the lack of flexibility in the sector configuration capabilities at pan-European level. This is caused by the close coupling of ATM service provision to the ATS systems and operational procedures, preventing air traffic from making use of cloud-based data service provision. A more flexible use of external data services, considering data properties and access rights, would allow the infrastructure to be rationalised, reducing the related costs. It will enable data sharing, foster a more dynamic airspace management and ATM service provision, allowing air traffic service units (ATSU) to improve capacity in portions of airspace where traffic demand exceeds the available capacity. It furthermore offers options for the contingency of operations and the resilience of ATM service provision*."[65]
"*With the delivery of ATM services irrespective of physical infrastructure or geographical location, the defragmentation of European skies can be realised through virtualisation: i.e., decoupling the provision of ATM data services from ATS, allowing them to be provided from geographically decoupled locations*."[66]

The ADSP, a new key stakeholder:

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[63] AAS transition plan page 15

[64] SRIA page 53

[65] SRIA page 48

[66] SRIA page 50

"*Data-sharing supports the progressive shift to a new service delivery model for ATM data, through the establishment of dedicated ADSPs. A common EU-wide ATM data service layer will enable all ATM service providers to benefit from the cross-border sharing of data. The ADSP would provide the data and specific applications (e.g., STCA, Correlation, etc.) required to provide ATM services.*
The data can be delivered in raw format or be processed to allow the delivery of services"[67] and "*future ATM services will rely on enhanced provision of shared data and will allow ATSU to select one or more ADSP for the data required to guarantee a safe and efficient flow of traffic. By rationalising and harmonising the ATM infrastructure, the ATM service costs will be reduced significantly.*"[68]
The ADSP contributes to the establishment of a new and flexible relationship between infrastructure, service and data. Flexibility allows to maximize the benefit of the vertical decoupling.

Scope of the ADSP:
"*There is potentially a large scope of services that could be provided by the future ADSPs, whatever their model and legal set-up. The nature of these services is described in section 1.3.1.1 and in particular table 2* [in the SRIA]*; although further definition of individual services is required. These data services are currently provided and used by the "legacy" ATSPs. The establishment of ADSPs covers the notion of two new services, namely the "Integration services" to be provided by ADSPs and the "Geographically-fixed services" which will be an input to ADSPs*."[69].
"*The maximum scope of service delivery by ADSPs covers the ATM data services (such as flight data processing) needed to realise the virtual de-fragmentation of European skies and includes the provision of AIS, MET and CNS services. Data will no longer be produced at every ATSU and information will be shared throughout the ATM value chain and can be made available more widely to the aviation value chain. Data will be the key asset for future ATM service provision and will be transmitted on dedicated and secured network services*"[70]
On the 14th of October 2020, during the seminar organized by EC/Mobility and Transport [10], the consortium developing the project from a "Legal, economic and regulatory aspects of ATM data services provision and capacity on demand as part of the future European air space architecture" presented the following points:

- the boundary between ATM data services and Air Traffic Services is defined at the point where the data / information / application is presented on the screens of the controller working positions •
- the boundary between ATM data services and data production is initially defined at the point where operational data enters the surveillance data processing systems (trackers) or the flight data processing systems or the more advanced tools (applications)

Moreover, as an example of a new concept of traffic management, U-Space[71] is the new scheme designed to manage highly automated, operationally flexible new entrants as UAS. U-Space is natively

[67] SRIA page 49

[68] SRIA page 52

[69] AAS page 134 and 135

[70] SRIA page 52

[71] U space is regulated by EU 2021/664

defined as a set of services. The Common Information Service (CIS) is a central data repository available to all the U-Space services for U space safety critical data. In the U-Space regulation, the CIS is anticipated to play a central role in the management of UAS operations in the U-Space airspace.

Risks associated to the data centred approach:
"*The increase in the number of connected devices, data-sharing and common standards will lead to an increase in vulnerabilities, threats, emerging risks, and the possibility of cyber-attacks… It will also be necessary to further develop cyber resilience guidelines and procedures for ATM, based on existing guidelines and procedures from other domains (e.g., system design principles, cryptography, block chain, software-defined networking).*"[72]

Enabling the ADSP:
The sharing of data through interoperable platforms and, the exchange of open data between trusted partners, combined with open architecture policies, will allow improved collaboration between the different actors and the optimisation of services and processes for all partners in the aviation value chain. Such data exchange shall occur on established concepts such as SWIM and consider the associated cyber-resilience aspects. Data will be even more critical in future and not only data-sharing, but also proper data structure and storage will have to be provided. On the Network level and on the local ATM side, this will allow for big data analytics, which will pave the way for future more efficient ATM operations, thereby optimising the network at strategic level.
"*A Europe-based cloud infrastructure is available to support the secure exchange of data between ADSPs/ ADSPs and ADSPs/ATSUs in 2026.*"[73]

Ensure performance of the ADSP
The EASA Basic Regulation and the Common Requirements Regulation organise the certification, oversight and enforcement functions. Whatever the model implemented, ADSPs need to be certified in line with certification standards drawn up in the Common Requirements Regulation (EU) 2020/469 in order to be able to offer their services within the EU.
This Regulation currently contains Annexes describing the requirements for certification of ATS, C, N, S, MET, AIS and DAT services, but does not contain yet identification of ATM data services and a description of the requirements for certification.
In a future context, in order to satisfy the obligation to secure certification of ADSPs, the first task would be to identify and define precisely all the services possibly provided by ADSPs and identify the gaps with the existing regulatory framework. EASA should then, on this basis, be invited to develop the requirement for their certification, create a specific Annex of Regulation 2017/373 for this purpose and, as necessary, review and update the existing annexes of the Regulation, to avoid gaps or overlaps.
It should be noted that an organisation certified as an ADSP could also provide the other ANS (ATS, CNS, AIS, MET) so long as they are also certified for those services. When doing this, EASA could also address and provide guidance or regulation on the issue of data access and ownership.

Consideration about the CNS data

[72] SRIA page 51

[73] SRIA page 50

Data production/data processing/data consumption: ADSP is central in this data management.
The Communications, Navigation and Surveillance domains have specifics in the production, collection, processing, and use of data. Each domain has been separately optimising this flow according to its specific needs and available technology. The data centred approach will aim at optimizing from a data perspective. It will modify the current state for CNS data.

Enabling the ADSP (ATM Data Service provider) and the relationship with the ATSP
"*With the prerequisites related to the regulatory framework and standardisation*"[74], "*Once airspace reconfiguration and harmonization of operational excellence is in place, planed implementations related to mature SESAR solutions are realized and SESAR delivery is accelerated, the Europe-wide implementation of fully interoperable air traffic management data service providers (ADSPs) will be enabled.*"[75]

The relatIonship between ATSP and ADSP
The creation of an ADSP could be decided by legal, prescriptive, obligations like the ones adopted in other regulated activities. In this respect, the "decoupling" provisions established in rail transport or energy legislation (separation of network management from service provision, and separation of accounts) could serve as examples.
More flexibly, the study proposal uses the verb 'decouple' in the sense of moving towards a situation where ADSPs are legally decoupled/ separated from the ATSPs, should the ATSPs, and the States which have certified them, wish to proceed to this step. ADSPs are supposed to 'work on their own', in a legal entity which is separate from the legal form of the ATSP. The decoupling can result in different modes of relationship between ATSP and ADSP."[76]

Flexibility
ATM data service provision develops into an activity that may be carried out through ANSP alliances, separate service providers and in the most ambitious model, specialised service providers in a market-oriented environment (see figure 7).
The starting point is the decoupling of ATM data service provision from the 'core' services provided by ATSPs; ATM data service provision is then provided by 'an entity' which is separate/independent from the ATSP, according to the three identified models below:

- Model 1 – ANSP alliances: ATSPs continuing to provide 'core' ATS services create 'alliances', a 'joint venture', referred to as a 'dedicated jointly owned entity', which is responsible for the provision of ATM data services in 'their' airspace;

[74] "Specification on ATM data service definition and requirements"; a framework standard defining functional and interoperability requirements applicable to services entities/providers that includes quality of service parameters, performance, interfaces, harmonised service level agreements and virtualisation. This standard will support EASA regulatory action for ADSPs, certification, procurement and performance monitoring. (AAS transition plan pages 44 and 46)

[75] AAS transition plan page 20

[76] AAS, page 133

- Model 2: Separate integrated ADSP: Certain ATSPs transfer their entire data infrastructure, systems and operations to an independent entity from which they would "acquire" ATM data services for a 'fair price';
- Model 3: Specialised data service providers: The entities are legally separate from the ATSPs and focus on certain parts of the "ATM data service" value chain and could be created through competitive entry or partial transfer of existing activities by the ATSP. In such model, it could be that, rather than buying and operating an ATM system, the ATSP buys the "ATM data service" (potentially from the manufacturer of the system).

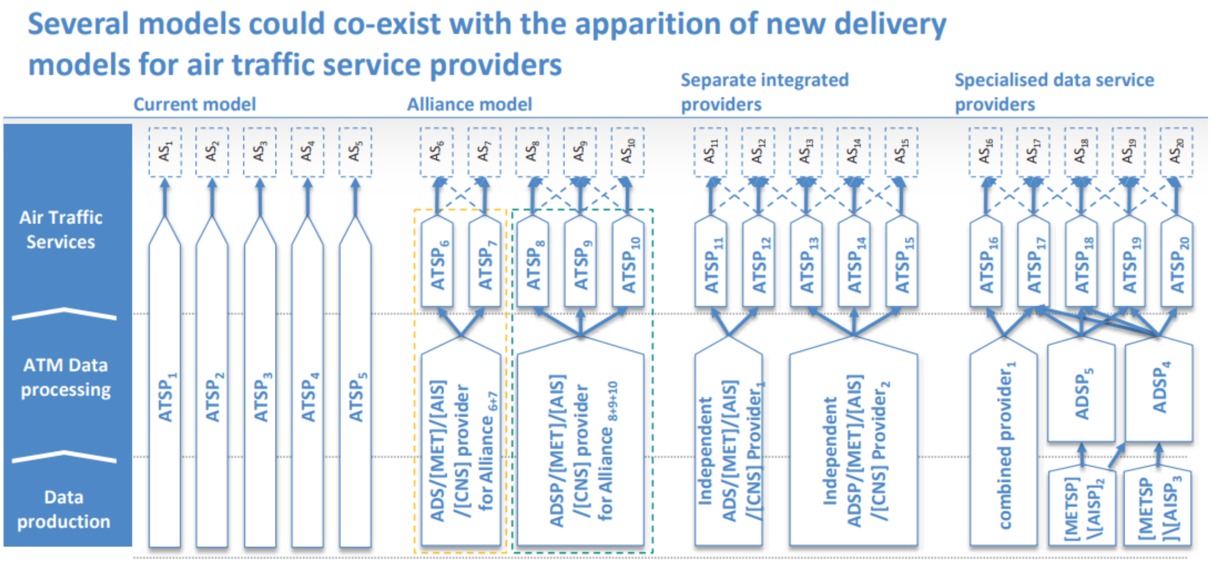


Figure 7 ATSP / ADSP models[77]

"It is acknowledged that these models are not intended to be exhaustive but illustrative and that they can be implemented simultaneously by different States or groups of States or implemented with nuances. Their examination however allows getting a fair view on the applicability of basic models, which can then by applied to intermediate or different ones."[78]

2.2.2 Virtualization concept and current implementation

Today[79], 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

[77] AAS page 56 Figure 26

[78] AAS page 132

[79] Emerging-Technologies_Virtualisation - CANSO

working. Virtualisation is achieved by providing the services independent from the location of the infrastructure (geographically independent), e.g., remote tower deployments.
Digitalisation (Digital Sky SRIA) of information directly supports and enables virtualisation: for ATM greatly facilitated by the System-Wide Information Management (SWIM) concept (and services) and a 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.
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 or the ADSP versus the ATSP). 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.

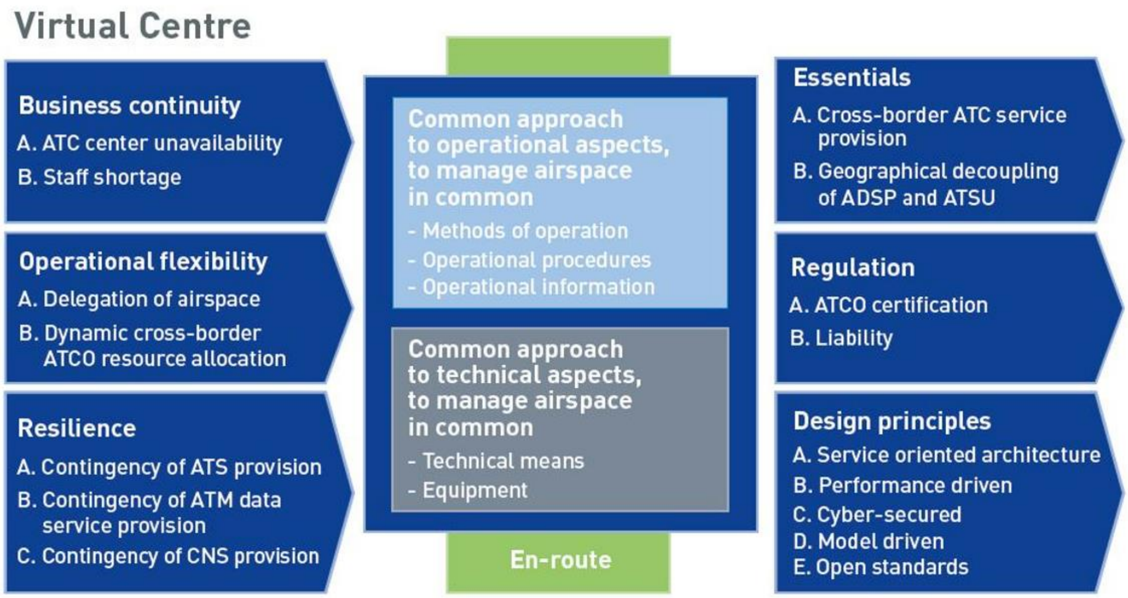
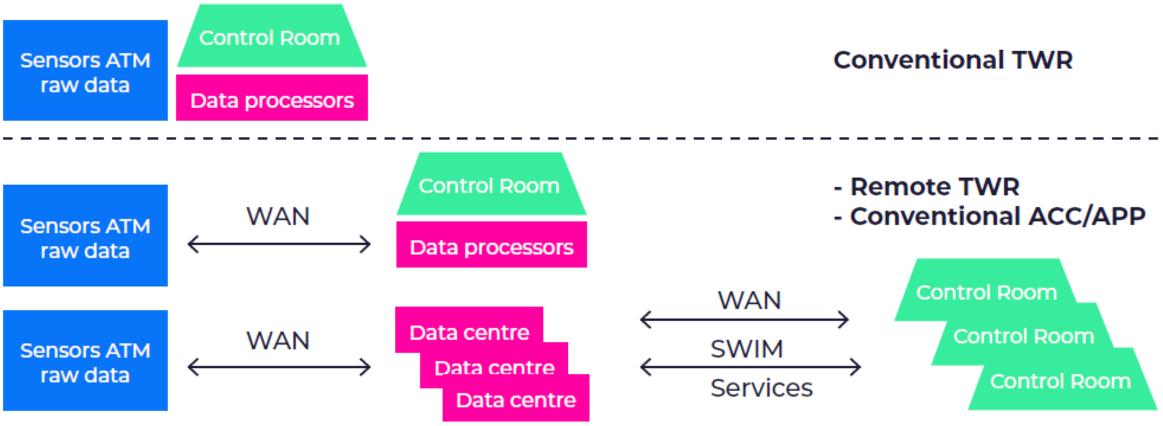


Figure 8- The virtual Centre concept as presented by the AAS

In particular the following figure illustrates the main features of Virtualisation in the context of Tower[80] (currently implemented at certain European airports – example follows) and ACC Control Room[81] (the later exhaustively being the objective of SESAR projects since 2014 and the subject of standardisation work by EUROCAE WG122[82] – ATM Virtual Centre)



Note: *the SWIM services are mentioned here as key enablers for operational interoperability of virtual centres (please refer to SWIM section 4.1)* ***but are not a pre-requisite***.

Figure 9 – Main Features of virtualisation of ATS

[80] In 2021 London City Airport transitioned to RVT as several others before.

[81] Trials are been conducted by NAVCANADA and Skyguide, with different maturity levels whilst ANSPs like Estonia/Finland intend to go ahead with such shared concept (Links to Finland and Estonia will create joint air traffic control centre | TheMayor.EU ; https://www.themayor.eu/en/a/view/finland-and-estonia-plan-merger-of-air-traffic-control-systems-8111)

[82] WG-122 ER76 - Virtual Centre standardisation strategy_Phase 1

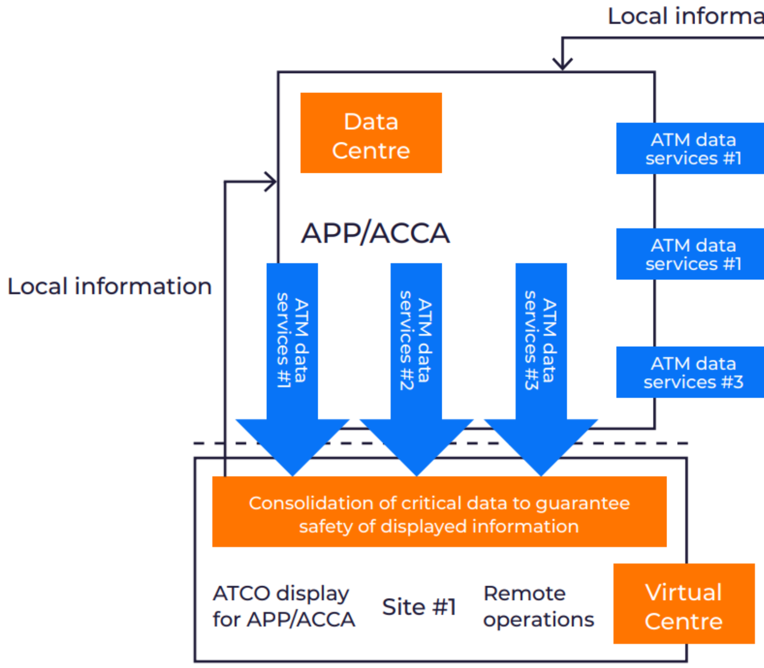


Figure 10 Possible infrastructure with data centres and virtual centres within the same ANSP[83]

- 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)

Virtualisation example: Remote and Virtual Towers

The Remote and Virtual Tower (RVT), or Remote Tower centre (RTC), is a novel concept[84] where the air traffic service (ATS) at an airport is performed somewhere other than in the local control tower. Instead of being in an airport tower, the air traffic control officer (ATCO) or aerodrome flight information services officer (AFISO) work at a remote tower centre (RTC) from where they provide the ATS. The data comes from airport cameras and sensors rather than from an out-of-window view, which

[83] See Skyguide's program and architecture as an example.

[84] The first remote tower implementation providing aerodrome ATS was introduced into operations in Sweden in 2015, with further implementations in other EASA Member States well underway. In 2019, Scandinavian Mountains Airport in Dalarna, Sweden has been the world's first airport built without a traditional tower, to be controlled remotely.

is reconstructed as a high-resolution video panorama on a large screen or series of screens. They are being developed by several industrial companies and used by many ANSPs.

EASA in the remote aerodrome ATS GM[85], to support the application of Reg. 2017/373, identifies the following enablers for RTC regarding CNS services:

- Communication means to provide aeronautical mobile service, aeronautical fixed service, and surface movement control service. And these services must be provided in the same conditions as in a local tower; for example, the aeronautical mobile service shall support air-ground communications enabling direct, rapid, continuous, and static-free two-way communications with equipped aircraft operating nearby the aerodrome.

- Monitoring of the navigation services. The RTC infrastructure should enable the ATS unit to be kept informed of the operational status of navigation aids essential for take-off, departure, approach, and landing procedures.

- Where required, dedicated means to facilitate the detection and identification, as well as enabling automatic following, of aircraft or vehicles in the visual presentation. This could be achieved by overlaid labels based on data from ATS surveillance systems/sensors such as ADS-B, PSR, SSR, and A-SMGCS, complemented by flight plan correlation when available, commonly referred to as 'radar tracking'.

These enablers may require additional consideration regarding the transmission of data between the aerodrome and the site of the digital tower facility, which is typically done via a wide area network.

The final objective is to maintain a safety level equivalent to the one achieved in a local tower.

2.2.3 Separation of infrastructure and service

This concept is the keystone of all the studies used as reference in this document in particular the AAS and the latter together with the SRIA, including new proposals for regulation. The main discussion is with regards to the monopolistic structure in place in most of Europe which is based on ATS providers also being ANS providers and owning the infrastructure, legacy of the national character of the airspace, its control, security and ultimately the responsibility required towards the Member state.

The Communication[86], Navigation and Surveillance infrastructure is the foundation of Air Navigation Services. It is based on on-board, ground and space system components; including the radio spectrum they rely on to operate. These systems do not only enable airspace capacity and efficiency, but also contribute to environmental sustainability while ensuring the overriding highest safety standards. CNS infrastructure should be operated to support the achievement of the Union-wide targets set under the

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[85] European Union Aviation Safety Agency (15 February 2019) "Guidance Material on remote aerodrome air traffic services. Issue 2"

[86] CNS Advisory Group report Draft 3.3

performance and charging scheme in the SES, to enable the implementation of cross-border and pan-European service delivery models and to contribute to security and defence needs.
The CNS infrastructure is not directly delivering operational benefit: it is a technical enabler providing operational benefits to ATM and airspace users. The separation from ATS or the Pan-European availability of CNS services is a major step towards the European SES2+ objectives, the virtualisation of the ATS and the fulfilment of all the operational benefits delivered by SESAR and the decreasing dependency on nationally limited systems.
Alternative models that break the current monolithic model already exist such are the ones provided by both certified (e.g., Aireon, ESSP_EGNOS, MET agencies, etc..) and uncertified providers (e.g., Collins, SITA, GALILEO, GPS, etc…). However, the dichotomy still exists in the relations between the different stakeholders on the definition of Client, Provider, and end-user (such as for the Navigation domain). Agreements with the CNS service provider are nonetheless signed by the ATSP since ultimately, it is responsible towards his NSA/EASA and in charge of designing the airspace, managing the safe Separation, and charging the Aus for the services provided.

The future space-based CNS service provision, where the new entity such as the ADSP could appear provides a good example of what the separation between infrastructure and services could look like. For the safety critical infrastructure used for both civil and military operations they are considered to remain state owned. The reason is related to the fact that any business model has an advantage of cost-effectiveness due to competition between service providers but from the other side the disadvantage is related to world economy impact such as financial crises, which could make it difficult to maintain a service provision.
Another important point that keeps the balance between full split of infrastructure and service and keeping state owned infrastructure is the responsibility of parties. At the end of the day the National Authority is responsible for flight operations in their airspace, which obliges the ANSP usually combined both Civil and Military to maintain the backup network for CNS services provision.

2.2.4 Separation of infrastructure and data

During the latest discussions that were made in the CNS Performance Based activities of the SESAR PJ 14 Solution 76, it was decided to leave these discussions to other forums to tackle.

The CNS Advisory Group extract states for example the following: "*The MON, to be determined in the CNS evolution plan, should define a cost-efficient CNS infrastructure that guarantees agreed levels of performance and acceptable levels of safety and security to all users. However, it is not realistic or cost-efficient to expect that the MON will guarantee over time the full business continuity to all airspace users in all possible degraded conditions*[87]".

In the context of Surveillance, which produces large quantity of data for ATM/ANS, the activation of the MON due to an event impacting the CNS infrastructure would significantly reduce the available data.

[87] CNS Advisory Group report, page 12

Maintaining the level of safety in that case is ensuring that the level and quality of the data provided by the infrastructure (or transiting via the infrastructure) to the CNS services will meet the safety requirements at the ATS level (e.g., ensuring aircraft separation).

This creates a new criterion to consider in defining the infrastructure and its relationship with the data to support the evolution of the CNS services.

The geographical location of the infrastructure could support the decoupling of the data service provision from infrastructure, especially for the space-based systems substituting to terrestrial systems (ADS-B) as main systems.

The shift from infrastructure ownership to the delivery of CNS services is expected to provide the following high-level benefits:

- **Rationalisation and network optimisation at local/network level.** New service delivery models could enable further rationalisation of the underlying infrastructure since the focus will move from investment in a specific infrastructure to provision of services complying with performance requirements and applicable to wider/international geographical areas. Rationalisation could also be applied beyond the geographical domain, to functions which could be better served by "*limiting the redundancy of primary means to the necessary level guarantying the service provision*" [8].

- **Optimal and harmonized deployment of technological and spectrum CNS synergies**. The service-based and performance-based approach will favour potential synergies, technological and/or functional, across CNS, taking advantage of common system and infrastructure capabilities for the ground, airborne and space segments; guarantee spectrum efficiency before use of non-protected spectrum it requires deep in-depth analysis. Serving all the airspace users, including the drones, will foster operational and technical integration if the governance is inclusive for all airspace users.

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- **Cost effectiveness.** CNS services can drive cost-effectiveness for ANSPs by supporting Make or Buy decisions for a consumer (customers), e.g., benchmarking internal and external delivery methods. In particular:
    - It limits the risks to only the consumption of the service;
    - Suppliers can build efficiencies from provision to multiple customers
    - Places increased emphasis on clear, well defined (contracted) customer specified and reporting mechanisms – consumer is detached one level from service management.

  All these benefits are based on simple terms of service-oriented architecture (SOA) described in the Airspace Architecture Study.
- **Performance.** The increasing network bandwidth, increasing reliability and lowering latency, in particular for ground-based networks, enables re-architecting that was not possible before. As a result, networks are now able to provide secured high bandwidth, low latency networks for safety critical domains like aviation. Safety criticality from an operational perspective translates to time-criticality and cyber-security from a technical perspective.

- **Service decoupling**. Service orientation enables splitting integrated legacy systems into independently operated services with minimised interfaces between them. End-user services consume integration services, integration services consume elementary services.
- **Virtualisation**. If services are provided purely using digital means, and their implementation is decoupled from the physical hardware on which they are executed, the virtualisation of services (i.e., moving part or all functionality into a private or public cloud environment) can be enabled.
- **Re-integration of services**. The re-integration of services through consolidation of services enables similar organisations to consume a service from one or more providers, giving them the same capability, they would normally have provided themselves, but at a scalable operating cost rather than a rigid and often inefficient capital investment.
- **Interoperability**. Considering that in the global aviation context, no single service implementation of whatever nature will cover the whole world and that there will always be operations that require the successive services of different service providers, there is also an interoperability requirement on various ATM services within the same layer.

2.3 The ADSP and the CNS providers

The evolution of CNS will enable the virtualisation of ATM (consisting in decoupling the provision of ATM data services from ATS, thus allowing virtual centres) and will enable ANSPs to make implementation choices about how new services are provided; whilst the CNS providers "*confirm that the levels of technical performance can support the expected concepts of operations*"[88].

ADSPs are intended to provide additional value from the CNS data. The scope and limit of ADSP are not defined yet by regulation but, in a wider sense, CNS providers could be ADSPs.

As discussed above, the decoupling of CNS infrastructure provision away from the use of CNS services at the ANSP user level, allows for service-based choices to be made by the ANSPs, including 'make or buy' type choices based on cost effectiveness versus operational objectives.

As ANSPs move to characterising their CNS needs in terms of provision of specific data/services, in support of specific operational objectives then the 'CNS market' will open to allow for greater reliance on third-party providers for these services. This is where a service-based approach to CNS can cross and neatly integrate with the concept of ADSPs.

The framework within which ADSPs will operate allows for flexibility in terms of the level of data processing and integration involved in the services offered by individual ADSPs. In the context of CNS services, this means that an ADSP can operate anywhere from just above the CNS infrastructure provision level, delivering ostensibly 'raw' CNS data either to ANSPs or other ADSPs down the chain, all the way through to a much more integrated level providing enriched data services based upon data captured by the ADSP itself or provided by other ADSPs. This idea is illustrated in Figure 11 below, again colour coded against definitions presented within the AAS (see table 2 of this document).

[88] CNS Advisory Group report, page 14

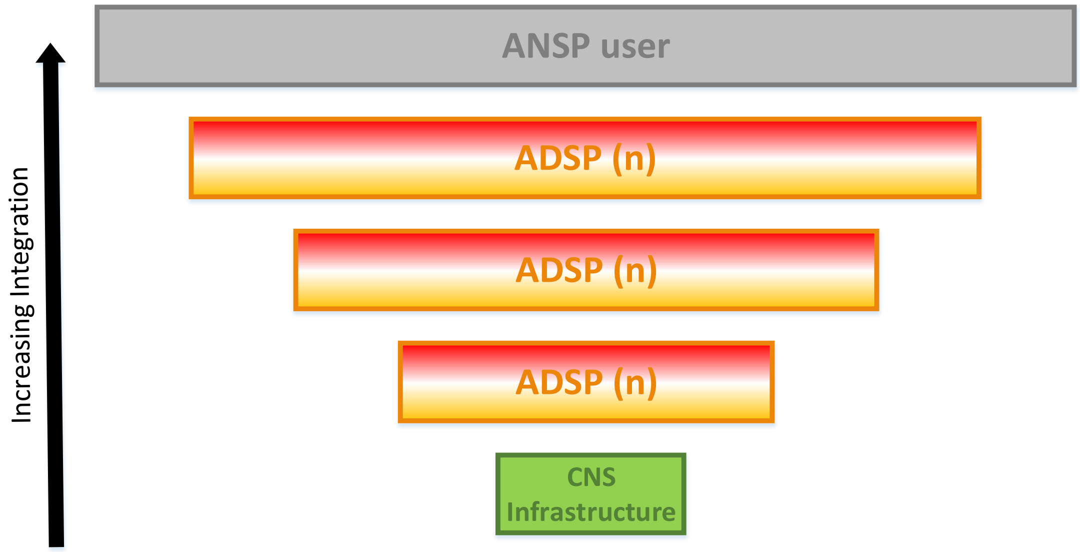

Figure 11 Integration levels from the CNS infrastructure up to the end user

CNS services are perfectly suited to the ADSP type model which also allows for ADSP entities to specialise across layers of the ATM data provision model (as noted in the AAS) and so also maximise their own business efficiency potential.

Within the CNS domain, as the focus shifts more towards provision and or capture of various data types and Air/Ground connectivity becomes an ever more critical commodity than today, this will mean that new service provision entities will enter the 'CNS market', including ADSPs.

Scope and limit of ADSP are not defined yet by regulation but with the current understanding, CNS providers could be ADSPs, as well as ADSPs are intended to provide additional value from the CNS data in certain domains.

2.4 "Service based environment"

This section looks to characterise what a service-based environment may look like for an ANSP. Today ANSPs have various versions of service-based approaches implemented to suit their operations, but this section tries to set out what a more theoretical 'fully' service-based approach may look like.

"Service" is extensively used in industry. It generically describes an arrangement between a customer and a provider. But each industry has its own definition of "service" and ATM/CNS has characteristics which require having a specific definition of "service". The CNS services are specific services in the sense that the well-defined relationship between the customer and the provider in a service-based environment is more complex.

Service-based approach will encourage CNS services provision through contractual relationships between customers and providers, with a clearly defined, European-wide set of harmonised services and levels of quality. In addition, the separation of CNS data from the CNS service – as much as practicable – allows technical and business opportunities for those providing affordable services, with a strong incentive for service providers to compete resulting in cost-efficient services.

The progressive introduction of a service-based approach to CNS will enable the virtualisation of ATM and will enable ANSPs to make implementation choices about how new services are provided. A service-based approach to CNS should provide a strong incentive for service providers to cooperate across national boundaries and to optimise the use of technologies and the geographical distribution of equipment (and hence optimise spectrum use and lower interference). It will also provide a better environment for the integration of new CNS services, such as space-based ADS-B and satellite communications.

Performance requirements can be expressed with respect to various airspace user types and various environments, with the aim of optimising overall performance with no degradation for the least capable airspace users. For end-users, the technological solutions will be packaged or merged in a way that guarantees continuity, availability, integrity, safety and security, and performance requirements, as mandated by relevant authorities.

It must be recognised that CNS systems/capabilities/services, however they are labelled, are always present to serve a purpose. This purpose is to enable ATC to perform their role correctly and effectively.

This perspective helps to define a service-based approach where the provision of appropriate CNS services is answering the needs and the performance of the operational ATC service. For example, the need for a service could be “I -the customer – now ask for a service providing CAT-I performance at my airport (I do not specify that it has to be an ILS system)”: technology is what the service provider will need to look for to provide the customer with the required service performance.

From this basis, the first step to properly defining service requirements for CNS is to fully understand and characterise the operational ATC service, in terms of discreet requirements. To do this the ATC operation can be broken down into the various airspace management concepts that are employed. Each will have specific requirements. It is also useful to break these conceptual operational requirements down into supporting data requirements. It should be possible to characterise all CNS capabilities in terms of the data that is exchanged at either ground-ground or air-ground.

This characterisation of data requirements should be applicable to all current and future airspace management concepts such as (not exhaustive):

- Continental 3NM separation
- Continental 5NM separation
- Oceanic operations
- Free Route Airspace (FRA)
- Systemised Airspace
- Extended queue management
- Trajectory Based Operations
- Route (not radar) separation – i.e., procedural separation of flights following PBN routes on own navigation, dependent on PBN. In future potentially in vertical plane too
- Large sectors/dynamic sectorisation and flight-centric ops (will require an Air-Ground voice communications solution that is decoupled from geographic constraints (VHF line of sight frequencies)

In this way an ANSP will have a portfolio of targeted operational requirements from which complementary CNS performance-based requirements can be derived. The ANSP can then procure or build the required CNS services to suit those requirements most effectively.

Figure 12 below illustrates one way that the concept above could be structured hierarchically in terms of operational requirements, through support tools and CNS service and infrastructure requirements.

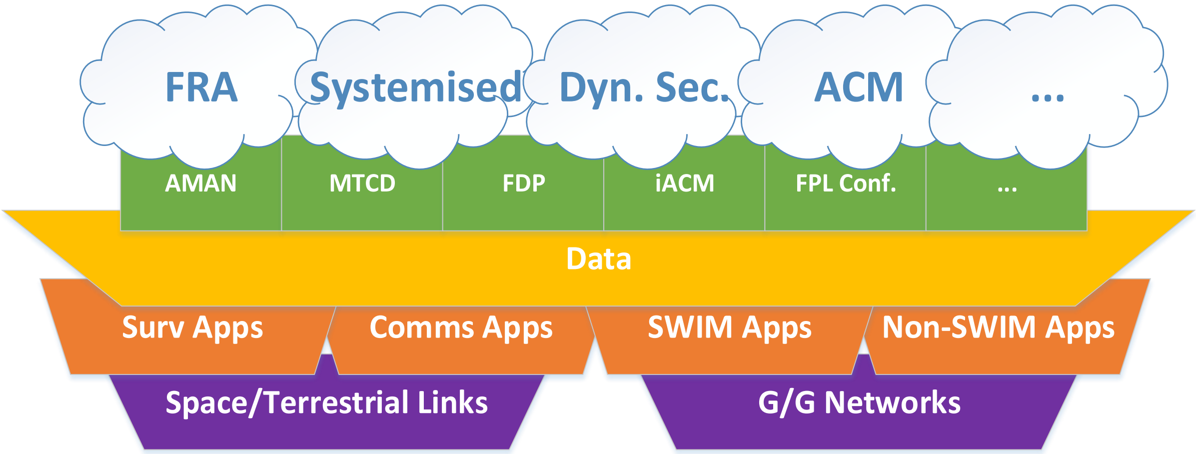

Figure 12 example of structure of the service based environment

Summary of risks and benefits of the CNS service-based approach
Benefits

- Applicable to all elements of ANSP operations essentially, can be applied to both internal and externally provided services equally – hence good as a basis for make/buy decisions internal/external
- Allows solutions to be agnostic of underlying architecture (as much as practicable)
- Good approach to bound risk, from a financial perspective – by passing risk of additional burden in non-nominal times to supplier
- Can drive cost-effectiveness, especially in areas which have a wide market base – although this benefit is not guaranteed
- Allows suppliers to potentially build cost efficiencies from provision to multiple customers, and focusing on specific specialisms, e.g., cyber security, data processing etc…
- Maximising spectrum efficiency can be included as a key service requirement, making use of multiple technologies for instance
- Allows a specialist supplier to build flexibility and value through innovation in technology
- Does not require a Performance Based approach as a pre-requisite to developing services and a service-based delivery approach (Performance Based will increase the ability of suppliers to be flexible and add value)
- A service-based approach is a pre-requisite, and enabler for the development of common services.

Risks

- Safety accountability remains the responsibility of the end user/consumer. This must be a focus when specifications and contracts are arranged in terms of monitoring/reporting/maintenance/restoration, and can be a challenge when dealing with external suppliers who are more financially focused – especially when dealing with 'COTS' providers whose main revenue is not generated by providing services to safety critical users

- Puts strong focus on a strong and rigorous definition of service terms, and building flexibility to adapt service requirements at the outset of the contract – risk that deviations and changes will incur significant costs during run-time
- User/consumer is detached one further level from the service delivery itself, and so risk that fault diagnosis/restoration and required changes to service may be delayed – which can be a challenge in a safety critical/24-7 environment such as ATM
- The flexibility afforded to suppliers on architectural and technology choices, must be bounded/controlled through effective governance, either local or regional

2.5 Relationship between integrated, performance based and service-based CNS

Integrated Communication, Navigation and Surveillance (iCNS), performance-based and service-based approach are strongly inter-related concepts. This section provides some clarification on how these concepts are related in the European ATM architecture.

The Integrated CNS concept has been developed in the SESAR program [1] to support the CNS evolution and to address the existing and upcoming CNS challenges: integrated CNS is about considering the C, N and S domains under a single framework. So far, C, N and S contribution to the airspace concept were mainly considered in isolation. A harmonized view of these contributions across CNS would improve the overall CNS efficiency. An Integrated CNS framework can drive efficiencies and economies of scale in the suppliers' delivery.

The Performance based concept intent is to write requirements that focus on what needs to be achieved operationally, without being overly prescriptive about how the performance should be achieved or how the related functions should be implemented. As such, the choice of the actual sensors or systems used remains flexible. This is also called "technology agnostic". An underlying idea is to allow a match and mix of different technologies to optimize the available capabilities. This has been applied for example to navigation and surveillance systems, where different layers and diverse systems support the same main function in a very robust way. However, in safety certified systems subject to economic constraints, there are limitations to how open approaches can be: normally there is a limited list of standardized systems which can be used.

The Service based approach can drive a market-based approach, especially for more common generic services, leading to potential cost reductions for an air navigation service provider (ANSP). The service-based approach is a pre-requisite to drive development of 'Common Services'. The figure below summarizes the relation between these concepts referring to EATMMP pages 55-56. The service-based approach is also presented as logical complement of the performance-based concept and the integrated CNS concept to achieve the global cost reduction objectives.

Relationship between the approaches

A Performance Based approach allows flexibility of delivery by supplier and thus, enables cost reduction for airspace users and fosters the development of CNS Services. However, the performance-based concept is not a pre-requisite for the development of CNS Services. The performance-based concept facilitates and enhances the service development. However, Integrated CNS is not a pre-requisite for the service-based approach. Figure 13 aims at describing the relationship between performance-based, services and integrated CNS approaches.

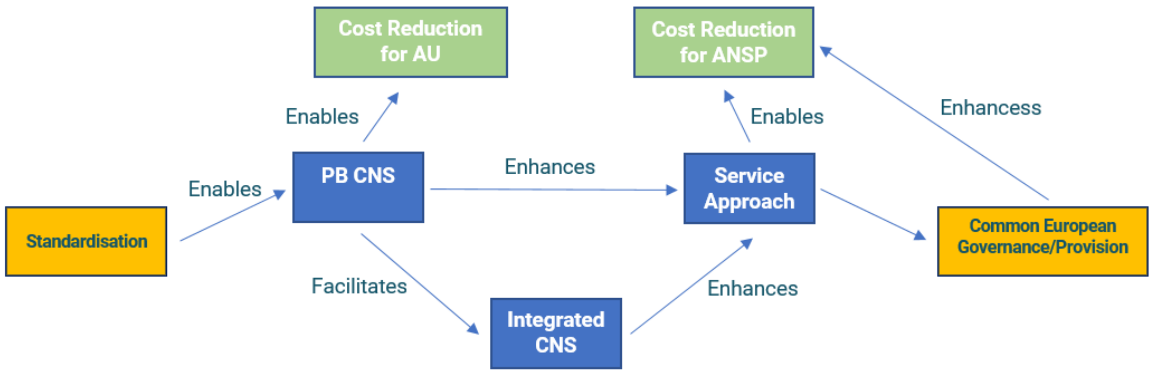

Figure 13 the Integrated, Performance based CNS service approach

An "integrated approach towards CNS services" aims at taking advantage of "interdependencies between previously separate activities and introduces new requirements in terms of robustness, spectrum use, interoperability and service quality for all airspace users, including military."….this is addressed through "the evolution from the current fragmented infrastructure, which is built around separate areas of functionality, towards a harmonised and cost-efficient infrastructure which features common performance criteria. In terms of performance expectations, a holistic analysis of the technical and safety requirements of the current and future CNS systems will highlight opportunities where the efficiency, safety, resilience, and interoperability of the CNS infrastructure can be improved."

It is inherent that if you contract a service, that you also ask for it to comply with the applicable regulation, standard or required level you need it to support your operation or functions. The ATSP needs services to execute its functions (ATS is the core service that maintains separation between aircraft, expedites and maintains an orderly flow of air traffic). Clearances are issued by air traffic control units to pilots to provide separation. The provision of ATS, by Air Traffic Controllers, relies on the underlying ATM data services and clearly defined CNS service performances on which it will design/determine the architecture of the airspace and operate it under its responsibility (although the final users not the client may be different depending on the characteristics/type/domain of the service provided). Of course, operational, and technological enhancements will support the improvements to the services generally in a push and pull scenario.

Let us be reminded that aviation is also subject to the evolution to a totally digital era wherein data will have a central position in all services becoming the common denominator.

2.6 A changing landscape: space-based CNS services

Space based CNS services in the planned evolution context

Space based services have a specific characteristic due to their special geographical position. Space based systems are natively able to cover wide areas with few assets, thus the geographical decoupling. Technology allows today to have good performance despite some initial weaknesses of space-based systems such as low signal levels. The vulnerability of the space-based systems against solar storms or space debris remains a challenge that require backup systems to achieve the resilience.

The current performance of space-based systems makes them interesting candidates for primary CNS systems enabling space-based services.

Examples of successful Space based CNS services

Space based technology has and is allowing wider access to CNS services with performances meeting strict requirements of the aviation industry both in Safety critical and non-safety critical applications worldwide.

In aviation in particular GPS and the upcoming Galileo constellations are delivering Navigation services to aviation within the required performances on a worldwide basis. Specifically, to the European Region the ESSP provides the certified (EASA Pan-European CNS provider) EGNOS Safety of Life service in navigation by improving (augmenting) the performance of the above-mentioned constellations.

In Surveillance Aireon's space-based ADS-B system (Iridium payload) provides a worldwide Surveillance service to aviation that satisfies very strict performance requirements[89]. In Europe Aireon is certified by EASA and provides Air Traffic Management (ATM)/Air Navigation Service (ANS) surveillance services.

In the Communication domain two constellations Inmarsat (Geo) and Iridium (LEO) which offered worldwide communication to aviation are expected soon to also be the industrial partners in support of a certified service provision. In Europe in particular the IRIS datalink communication service provider (ISP) is planned to be set up and certified by EASA (as Pan-European service) by mid-2023, providing ATN based datalink based upon INMARSAT(Geo) constellation.

Many more programs aiming at delivering CNS based services are also in their initial stage such as STARTICAL which aims both at delivering ATS communication, voice, and ADS-B Surveillance. Intention as to certify as CNS service provider is unknown.

[89] designed to meet the EUR OCAE ED-129B and EUROCONTROL GEN SUR SPR specifications and supporting the current ADS-B DO-260B/ED-102A

3 Integrated approach to CNS service delivery

The integrated approach to the delivery of CNS services is based on the fact that the airspace design defined by the ATSP and the operations it can execute/allow are – among other things – dependent on the performance of the CNS services. Depending on the performance provided by, or requested to, one or many CNS service providers, a different airspace is constructed which will be managed by the ATSP.

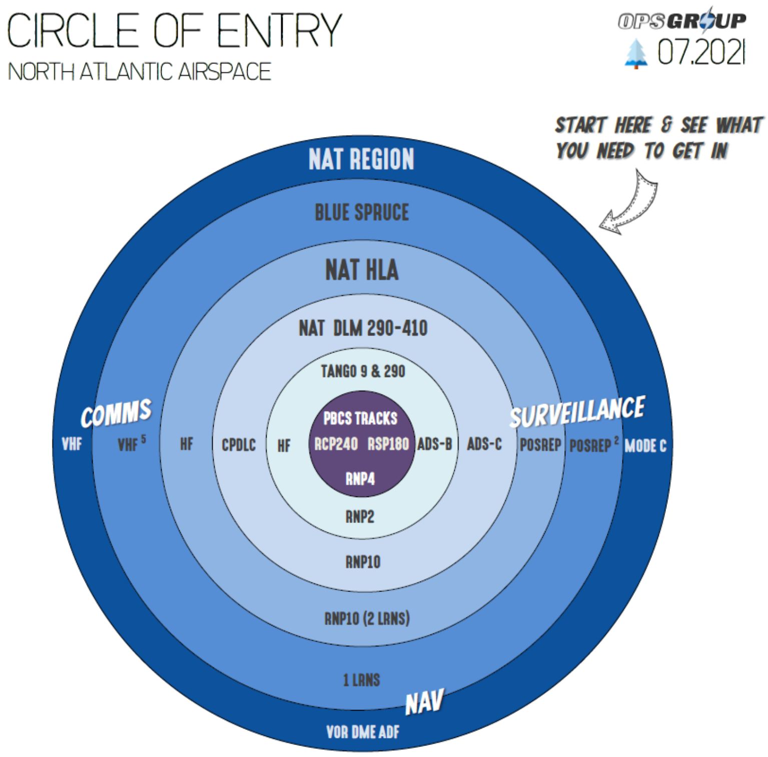

Figure 14 the OCEANIC CIRCLE of Entry[90]

Figure 14 provides a visual example of this integration and link between airspace and RCP/RNP/RSP in the North Atlantic Airspace (NAT).

3.1 New organisation for CNS services: the integrated services

The objectives of CNS/ATM systems are set in the ICAO Global Aviation Navigation Plan (GANP) [7] (see figure 15)

[90] Courtesy of the OPSGROUP

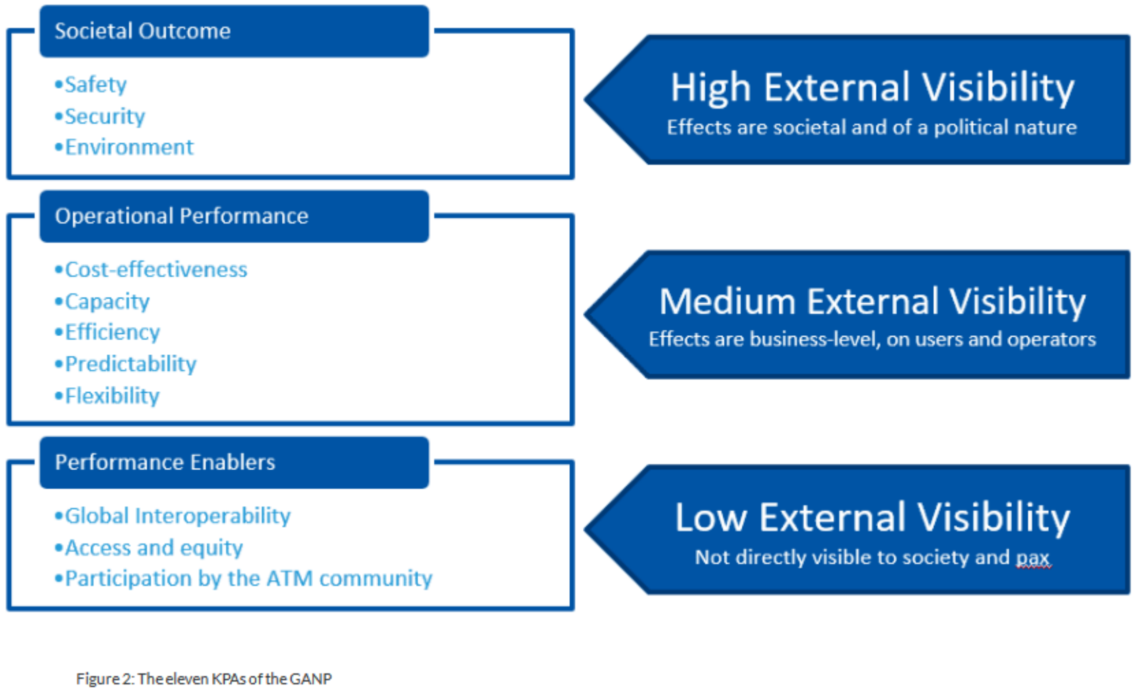

Figure 15 objectives of the CNS/ATM system according to the GANP

This document is focusing on some of the medium external visibility elements related to CNS services such as cost-effectiveness, efficiency, and flexibility; capacity and predictability being operational benefits of compliant CNS services.

The identified stakeholders are, in relation with the ANSP:

- Airspace users
- Industry
- States / CNS infrastructure managers

The GANP proposes to "accelerate the transition towards a total performance management system in which airspace users and other aviation stakeholders will be able to make orchestrated and/or choreographed collaborative decisions based on their business and mission objectives".
The challenge is to go:

- from a system-based approach, in which the services are subsequent to the infrastructure technical manager,
- to a service-based approach, in which not only the infrastructure is decoupled from the CNS Service, but the relationship between the stakeholders has been revolutionized and in which the States have less impact on the implementation choices than before.

This is a complex situation to manage for all the stakeholders, from an administrative, a business and a coordination perspective. The importance of this change must not be underestimated to achieve the success of the new approach. The vision of the GANP to accelerate the process must be tempered by the understanding of the difficulties of such a change, which looks more like "a revolution in CNS affairs".

Switching to a full-service environment and using new technologies may require a phased approach, supported by strong initial governance and an efficient monitoring, available immediately to avoid any disruption in the quality of the CNS service. Such governance would contribute to ensure a continuous performance improvement by setting a trustful environment.
The transition phase from a system oriented to a distributed model, in which data play a key role, must be addressed carefully, first for services which are easier to virtualize, provide a positive CBA for all the stakeholders with great care to cyber resilience issues, can easily be monitored, Trust in the fair and efficient implementation will be the key factor to develop the concept to additional services.
The setup of the transition phase will require specific studies in order to assign the best way forward for all the potential services. The Future Communications Infrastructure Study confirms that the work to be undergone in each CNS domain requires resources beyond the scope of this task.

The implementation of the objective of the GANP for CNS/ATM systems requires consistency with global/regional/local implementation constraints and operational objectives. Today, the CNS systems are providing the performance expected by the end users whilst maintaining or improving on the safety levels. The evolution[91] of CNS, to meet traffic change and societal expectations, will be supported by differently organised CNS Services and the implementation of those concepts as the Digital Sky and virtualization. The future CNS Services only make sense if they provide at least the same level of performance than today and if they satisfy to additional needs like environment. Some current CNS services may not be superseded if is not proven that the new scheme provides benefits to the stakeholders.

Figure 8 in section 2.2 shows the different delivery models possible supported by the AAS and expanded by the DGMOVE study: they are referenced to the current situation (left side of the diagram) although it does not fully picture the current CNS service provider scenario. Nonetheless the models are interesting since they offer various opportunities for transition.

The U-Space example: how integrated, performance based and service-based CNS are to be implemented
U-Space is defined as a set of services, including CNS Services, supporting UAS operations in the European airspace. The EU 2021/664 regulation [9] provides requirements for this new way of managing traffic in an airspace volume. U-Space is natively service oriented. Therefore, the implementation of U-Space will provide a strong experience on the generalization of services in supporting an operational environment.

CNS services used in ATM will be also used in the U-Space environment (e.g., GNSS). Any evolution of these CNS services will have an impact on U-Space. The CNS services will no longer be limited to ATM but will have to take into account U-Space needs. The CNS services model presented in this document will have to integrate U-Space stakeholders into the governance of these CNS services. Such integration will require U-Space to be much better structured than it is today. This is a challenge for the U-Space implementation.

[91] GANP conceptual roadmap

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If the CNS services do not involve the U-Space stakeholders in their evolution, there is a possibility to have several infrastructures, services and dataset for the same volume of airspace, when operationally implementing the dynamic reconfiguration of airspace as defined by EU 2021/664. This could lead to a loss of completeness and loss of integrity of both dataset, which is not acceptable. The generalization of segregation by "dynamic airspace reconfiguration" is a risk identified by EBAA if the needs of all the airspace users – including the drones – are not integrated from the onset in the definition of the CNS services. [9]
The definition, the deployment and the governance of the future ATM CNS services might therefore have to take into account the U Space environment depending on the mandated level of consolidation between ATM and U Space.

3.2 Definition, roles and interfaces of customer/client, end-user and providers

Importance of the role of the regulator

In the CNS service-based environment, because it is strongly regulated, the actual customer is not the end user. The regulator acts as a proxy for the end user, by setting the rules, managing the relationship between the end user and the provider and maintaining the level of safety through actions like certification/approvals and/or oversight.

The end user is mostly limited to expressing its dissatisfaction, when the service is not as expected or actually regulated. And the regulator takes the appropriate measures to correct the situation.

There are therefore three actors in the CNS service-based environment as defined and regulated today:

- The regulator, which is setting the rules and control their implementation;
- The service provider, which is expected to provide the service as it is regulated;
- The end user, which is using the service and can verify if the service provided performs is as expected.

Importance of the relationship and role of the customers and providers

The relationship between the actors in a CNS service-based environment must take into account these differences and adapt the regular service-based concept to this reality of the organisation of the provision in a wide sense. This organisation of the service provision includes the governance of the service which is not as simple as organizing and managing between two actors, because the regulatory framework already embeds part of the governance functions.

As stated in the CNS roadmap, *"through a service-based approach, the CNS services will be specified through contractual relationships between customers and providers with clearly defined, European wide harmonized services and level of quality"*. In the current paradigm, usually the ANSPs (customers) are dependent to buy and install technologies from external companies (providers) to give C, N and S services to the airspace users.

With the new approach, ANSPs can take full control of their implementation decisions, as they are now capable of deciding if they want to be involved in the production of the data (e.g., participating in the implementation of the CNS infrastructure systems) or if they want to use several sources of data for different locations (e.g., the use of satellite-based data as primary source in oceanic and remote airspaces and as secondary or complementary in continental airspaces). Nevertheless, in all this cases, both the data provider and the ANSP agree in the quality of service needed in order to comply with the performance base requirements.

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

With this new paradigm, the roles are limited to three actors:

- **Data provider (ADSP):** responsible for deploying technology systems, creating a rationalized and harmonized infrastructure, in order to provide customers with CNS data with an agreed quality level in a cost-efficient way.
- **Customer (ATSP):** entity responsible of proving CNS services to the end-user through the acquisition and manipulation of CNS data from the ADSP. This role is done by the ANSPs.
- **End-user:** user or entity which will take benefit of the CNS services provision. It could be related to the customer itself or apply to external users.

The table 5 focuses on the CNS services and how the stakeholders are positioned in this paradigm, but the concept of the ADSP is certainly wider and may include for example the provision of integration services such as Safety Nets (e.g. Conflict Detection and Alerting Solution) to the ATSP.

	(ATN, Voice, G/G Network…)	Client/ Status monitoring/End-user	End-user
	(AOC)		Client/End -User
		Client/ Status monitoring	End User
Surveillance	Surveillance data (primary and/or secondary)	Client/ Status monitoring/End-user	End-user[92] and Producer
	GADSS		Client/End-User

Table 5 Difficulty of assigning a fixed role depending on the domain and service

The above table is an attempt to describe from left to right the SLA relationship (Client) and the end user of the data[93]. It must be seen as an example for a potential template, not as an input.

[92] In the case of ADS-B IN and the associated operational concepts based on this application; other concepts for self-separation (e.g. ASAS - old acronym – etc.…); or the need for Situational Awareness (e.g. GA UAT).

[93] With new regulation and definition of the ADSP certification, relations among the stakeholders may change

4 Implementation of the new CNS services

4.1 SWIM as a global CNS services enabler

System-wide information management (SWIM) allows seamless information access and interchange between all providers and users of ATM information and services. It is based on SOA that is a general concept used for information exchange, which means that an information provider publishes and exposes its information and capabilities as services for the use of information consumers. The aim of SWIM is to provide information to users with access to relevant and mutually understood information in an interoperable manner for the ATM stakeholders operating at local, regional and global level. Interoperability is the ability of diverse systems belonging to different organizations to exchange information. This includes the ability, to not only communicate and exchange data, but also to interpret the information exchanged in a meaningful manner. This does not imply that all information exchange standards and infrastructure need to be harmonised. Globally applicable standards will focus on the information exchanges required between both air and ground-based global actors.

According to the definition of SWIM, there are three main pillars used to achieve fully interoperable global air traffic management system:

- Information Services. Are the means by which organisations exchange information, or make their information available, in line with their business objectives.
- Information. It is the result of the assembly, analysis, formatting, and documenting of data, to make the data useful in an ATM context.
- Technical Infrastructure. It is a collection of software and hardware used to allow the provision of information services.

With respect to CNS, SWIM will enable data provision at a global level based on the SWIM technical infrastructure that allows the implementation of interfaces between systems, providing technical capabilities for the secure, high-performance and reliable exchange of information. The New PENS is planned to ensure Network Connectivity between European ATM actors using a common IP-based network infrastructure for SWIM services provision.

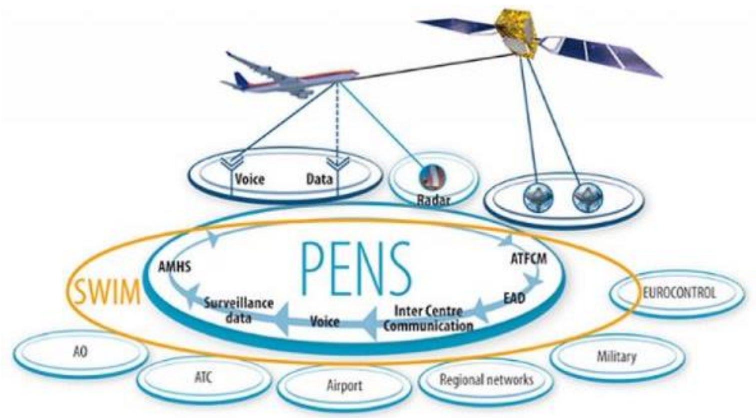

Figure 16: PENS as SWIM transport service

The current phase of SWIM implementation is called Initial SWIM (iSWIM), where the regulatory framework lists four areas for information exchange: aeronautical information exchange, meteorological information exchange, cooperative network information exchange and flight information exchange. Therefore, current strategy of SWIM implementation predicts Air – Ground Communication Technologies transition to SWIM, but only when their performance requirements can be met with SWIM specifications.

4.2 Application of service levels to a set of CNS services

This section looks at how service levels can be abstracted throughout the end-to-end CNS delivery cycle. As defined previously, CNS services can be flexibly broken down at various levels of integration depending on user needs, or business drivers. The colors used in this section match table 4 of this document.

This section aims at providing examples across CNS of possible service definition levels, and these are illustrated through a series of diagrams. The principles which underpin these diagrams are:

- CNS Services can be theoretically defined at many levels – and in the following examples we use levels 0-4 (as examples)
- The service types which are defined by varying levels of service/data integration are aligned with the relevant definitions and colourings provided by the AAS definitions (as in section 1.3.1.1 above)
- (Grey) Shaded parts signify 'x' other services that can be combined to provide the required service level at the level above
- All levels of service could be managed internally or externally to ANSP (make or buy from the user)
- All defined service levels are candidates to be offered by a service provider to multiple customers, e.g., providing like services for many users, e.g. ADSP, ANSP.
- All defined services can theoretically also be candidates to form the basis of regional 'common services'
- Some of the example service level lend themselves more naturally to being 'unbundled' than others (recommendations for these are given in later figures)

Navigation: Final approach example

By way of an example to show how Navigation service levels can be abstracted and defined, the following picture provides a possible view of a break-down of Navigation services at various levels of integration. The example focuses on ILS service and how this can be included at various levels of service provision. Note, in this example 'ILS' denotes the delivery of an ILS service including signal in space, however it is also true that a further level of abstraction could comprise of simply infrastructure maintenance and administration.

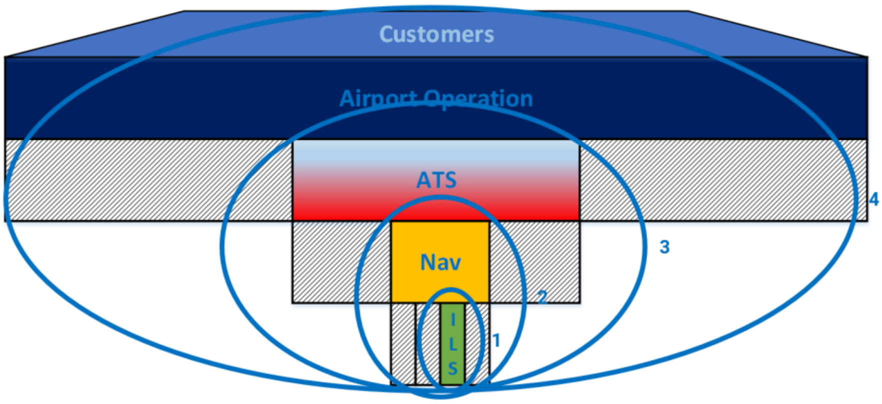

Figure 17: Example of Navigation service definition

There are some points that may be highlighted from the diagram:

- Level 1 is feasible, especially if supplier has multiple customers
- Many ANSPs currently provide services at levels 3 and 4, with some also providing at level 2
- The 'Nav' level is the first level of integration as described by AAS definitions
- The 'ATS' level also includes the provision of a full set of relevant CNS services included as part of the 'ATS' service delivery

Surveillance: En-route example

By way of an example to show how Surveillance service levels can be abstracted and defined, the following picture provides a possible view of a break-down of Surveillance services at various levels of integration. The example focuses on ground -based ADS-B service and how this can be included at various levels of service provision. Note, in this example 'Ground-based ADS-B' denotes the delivery of an ADS-B service including the capture of the signal in space, however it is also true that a further level of abstraction could comprise of simply infrastructure maintenance and administration.

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This section aims at providing examples across CNS of possible service definition levels, and these are illustrated through a series of diagrams. The principles which underpin these diagrams are:

- CNS Services can be theoretically defined at many levels – and in the following examples we use levels 0-4 (as examples)
- The service types which are defined by varying levels of service/data integration are aligned with the relevant definitions and colorings provided by the AAS definitions (as in section xx above)
- (Grey) Shaded parts signify 'x' other services that can be combined to provide the required service level at the level above
- All levels of service could be managed internally or externally to ANSP (make or buy from the user)

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- All defined service levels are candidates to be offered by a service provider to multiple customers, e.g. providing like services for many users, e.g. ADSP, ANSP.
- All defined services can theoretically also be candidates to form the basis of regional ‘common services’
- Some of the example service level lend themselves more naturally to being ‘unbundled’ than others (recommendations for these are given in later figures)

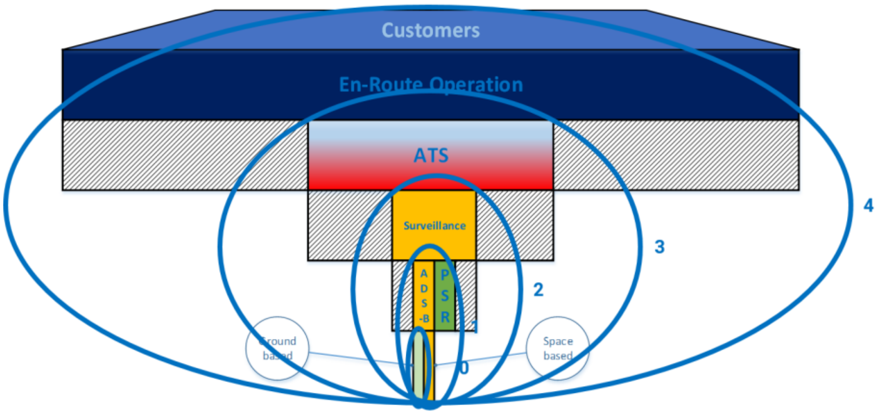

Figure 18: Example of Surveillance service definition used in En-Route

There are some points that may be highlighted from the diagram:

- Level 0-1 could be provided by individual airports, or other providers
- Level 0, Space based ADS-B already has an example provider in existence which fits to this level
- The ADS-B models here very easily lend themselves to integration at Level 1, especially on a regional basis as the nature of ADS-B deployment can be most efficient at this regional level
- Level 1-2 are feasible, and potentially beneficial to be managed as a common service

Air-Ground Communication: En-route example

By way of an example to show how A/G Communication service levels can be abstracted and defined, the following picture provides a possible view of a break-down of A/G Comm services at various levels of integration. The example focuses on ground-based VDL Mode 2 service and how this can be included at various levels of service provision. Note, in this example ‘Ground-based VDL Mode 2’ denotes the delivery of a VDL Mode 2 A/G service including signal in space, however it is also true that a further level of abstraction could comprise of simply infrastructure maintenance and administration.

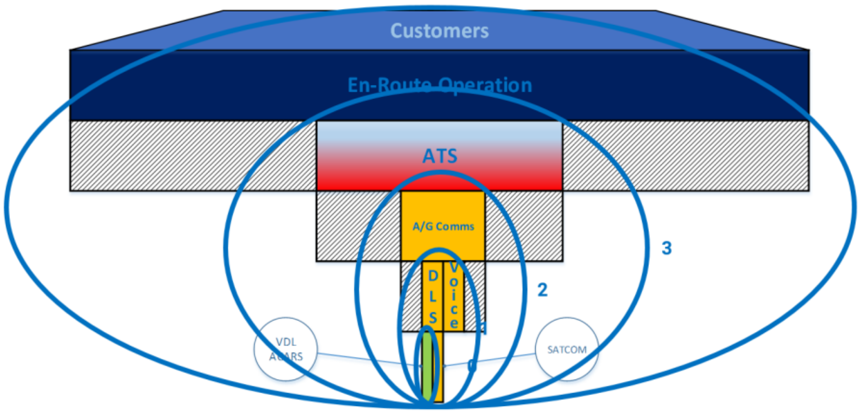

Figure 19: Example of Communication service definition used in En-Route

There are some points that may be highlighted from the diagram:

- Level 0, VDL Mode 2 can be likened to the existing VDL Mode 2 provision model managed by Collins/SITA supporting ATN in Europe
- Level 0, SATCOM already due to have separate provision model in Europe to support ATN
- Level 1, integrated A/G DLS provision can be likened to the services provided by Collins/SITA around the world supporting FANS, including North Atlantic Oceanic support
- Level 1, can be likened to the concept being developed for Europe around a DSP
- Level 2, could be feasible, but potentially complex due to nature of services, and fixed nature of A/G voice deployments around Europe.

4.3 Transition criteria applied to a set of CNS services

This section is looking at forecasting the feasible levels of integration that could be offered across a service-based CNS landscape in the future for discussion. This builds on the premise that any level of service is feasible to offer from a service provider, if the provision makes business sense essentially, but that there may be sweet spots to highlight in terms of integrated services as well as common service provision.

This task is not tailored to address in depth the assessment of all the CNS services using these criteria. The transition criteria listed in section 1.4 have been applied to some services in COM, NAV and SUR.

The detailed table is provided in Appendix A. The selected criteria seem appropriate for a high-level assessment of the potential for a CNS service to be transitioned according to the AAS concept but cannot formally conclude because of the lack of criteria related to governance.

This assessment is showing that if decoupling seems globally applicable, the benefits besides of efficiency appear contrasted. Especially, everything that is bound to the security when fully digitalized or the use of AI requires specific investigations to be proven positive.

5 Recommendations

The scope of this deliverable and the composition of the working group has limitations which did not allow to fully address the issues, concerns and also benefits raised by transitioning the CNS services to a service-based approach.

The governance of the CNS services is the main topic to clarify at the current stage of development of the CNS services. Once this essential point defined:

- The business models and service levels could be expanded to every CNS service, beyond the examples given in this document.
- The actual cost of all the different services and their dependencies will be related to the governance of these services

On the technical side, the CNS services should be designed from an end-to-end perspective as much as practicable. This will require for example to include the ground-ground communications which have not been developed in the context of this deliverable.

Some technical criteria for transition to a service-based solution have been consolidated from the reference documents. These criteria must be complemented by the ones coming from the governance scheme still to be designed by the relevant stakeholders. Future activities should include a full assessment of the candidate services to apply such criteria beyond the examples in Annex A.

Future solutions and projects are currently being discussed in SESAR3, as well as the continuation of SESAR2020 Wave 2 projects. These new solutions will have to consider the vision established throughout this document and will follow the service-based and performance-based approach. Therefore, it could be considered as a first approximation that the AAS is applicable.

6 References

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[2] Information Technology Infrastructure Library (ITIL) – Framework to deliver quality Service Management

[3] ISO/IEC 18384-1 – Information technology – Reference Architecture for Service Oriented Architecture (SOA RA) – Part 1: Terminology and concepts for SOA.Regulation (EC) No 549/2004 of the European Parliament and of the Council of 10 March 2004 laying down the framework for the creation of the single European sky (the framework Regulation)

[5] A proposal for the future Architecture of the European Airspace, Edition 2019, SESAR Joint Undertaking

[6] The three services are explained in detail in each Service Definition Document (https://egnos-user-support.essp-sas.eu/new_egnos_ops/documents/field_gc_document_type/egnos-sdd-89)

[7] Global Air Navigation Plan (GANP). Doc 9750

[8] EBAA contribution to "SESAR 2020 Wave2 provision of Airspace users expertise" EUROCONTROL contract 19-220819-C5 ed. 1st Dec 2021 U-space regulation (EC) 2021/664

[10] https://transport.ec.europa.eu/system/files/2020-11/2020-10-14-ads-presentation.pdf and "Legal, economic, and regulatory aspects of ATM data services provision and capacity on demand as part of the future European air space architecture" final report

[11] Strategic Research and innovation Agenda (SRIA)

7 Acronyms and terminology

Term	Definition
AAC	Airline Administrative Communications
AAS	Airspace Architecture Study
ACC	Air Control Centre
ADSP	ATM Data Service Provider
ADS-B	Automatic Dependent Surveillance – Broadcast
AeroMACS	Aeronautical Mobile Airport Communication System
AIS	Aeronautical Information Service
ANS	Air Navigation Service
ANSP	Air Navigation Service Provider
AOC	Airline Operational Communications
APC	Airline Passenger Communications
ARINC	Aeronautical Radio, Incorporated
ARTAS	Air traffic management surveillance tracker and server
A-SMGCS	Advanced surface movement guidance and control system
ASTERIX	All Purpose Structured Eurocontrol Surveillance Information Exchange
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
ATSP	Air Traffic Service Provider
ATSU	Air Traffic Services Unit

Term	Definition
CNS	Communication, Navigation and Surveillance
COM	Communications (ATC)
CSP	Communication Service Provider
DAL	Design Assurance Level
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
eATMMP	European ATM Master Plan
EC	European Commission
EDAS	EGNOS Data Access Service
EGNOS	European Geostationary Navigation Overlay Service
ESA	European Space Agency
ESSP	European Satellite Services Provider
EU	European Union
EUSPA	EU Agency for the Space Programme
FMS	Flight Management System
FRA	Free Route Airspace
GA	General Aviation
GANP	ICAO Global Air Navigation plan
GASeP	ICAO Global Aviation Security Plan
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HF	High Frequency

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Term	Definition
iCNS	Integrated CNS
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
ITIL	Information Technology Infrastructure Library
LDACS	L-band Digital Aeronautical Communication System
MET	Meteorology
MON	Minimum Operational Network
NAV	Navigation
NSA	National Supervisory Authority
OLDI	On-Line Data Interchange
OS	Open Service
PBA	Performance Based Approach
PB-CNS	Performance-based CNS
PBN	Performance Based Navigation
PENS	Pan European Network Service
PSR	Primary Surveillance Radar
RPAS	Remotely Piloted Aircraft System
RTC	Remote Tower centre
RVT	Remote and Virtual Tower
SARP	Standard and Recommended Practices (from the Annexes of the Chicago Convention)
SESAR	Single European Sky ATM Research Programme

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Term	Definition
SIS	Signal In Space
SITA	Société internationale de télécommunication aéronautique
SJU	SESAR Joint Undertaking
SLA	Service-Level Agreement
SSR	Secondary Surveillance Radar
SOA	Service Oriented Architecture
SoL	Safety-of-Life
SSR	Secondary Surveillance Radar
SUR	Surveillance
SWIM	System Wide Information Management
TCAS	Traffic alert and Collision Avoidance System
TAWS	Terrain Awareness and Warning System
UAS	Unmanned Aircraft System
UAT	Universal Access Transceiver
VDL	VHF Data Link
VHF	Very High Frequency
VOR	VHF Omnidirectional Radio Range

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Appendix A Examples of application of the transition criteria to CNS services

Domain	Service Level		Notes	Current Example	Potential For...			Efficiency of...		Resilience against...			Scalability for...	
	Feasible Now	Future Target			Geo and Vert De-coupling	Virtualisation	Re-integration into wider services	Geo Location	Spectrum Use	Interference and cyber attacks	Infrastructure Failures	External Events Impacting Aviation	Future Tech Leaps	Integration of AI
COM	Level 1 - DLS Service	Level 2 - A/G Comm	Reflects current provision of FANS DLS, as well as plan for DSP in Europe (ATN DLS). Includes integration of terrestrial and space-based means; Feasible at pan-European level Future target would need to involve provision of A/G voice also.	Collins/SITA DLS provision										
NAV	Level 2 - Nav Service	TBC	Includes provision of terrestrial based Navaids service, as well as integration and management of GNSS/SBAS use and risk mitigation	Each ANSP										
SUR	Level 1 - ADS-B Service	Level 2 - Sur Service	Includes provision of terrestrial ADS-B, and integration of space-based ADS-B Feasible at pan-European level Future target would need to involve the integration of individual Mode-S/PSR and other sensors as necessary as an integrated service	Selected ANSPs										
DATA	Level 1 - ADS-C Service	Level 2 - TBO Service	Includes provision of ADS-C data services captured through terrestrial and space based infrastructure, including ADS-C common server etc... Feasible at pan_European level Future target would involve capturing airborne flight data from various A/G and G/G sources; processing and providing data driven services to multiple ANSP users	None										

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Legend

Note: the colours are referring to the technical assessment. Other criteria coming from the governance side would have to be added to definitively conclude on the potential benefits of the transition to a service.

- (Green) Indicates potential technical value in this area
- (Yellow) Indicates some potential technical value under certain conditions in this area
- (Red) Indicates potentially no technical value in this area

Explanations on the colours of Annex A table

COM example

- (Red) Integration to wider services –Datalink has always been fully delivered by 3rd party services, and the scope for integrating the infrastructure further is very limited. Of course, looking at potentially integrating different services into a single offering or even using LDACS for more than datalink then there are possibilities, but it seems outside this category
- (Red) Cyber resilience – Integrating datalink services more fully wouldn't increase the cyber resilience of the overall service, in fact too much centralisation/integration could make cyber resilience more critical.
- (Yellow) Infra failure resilience – Depends how the integration is done. If multilink can be delivered fully then there would be resilience to failure.
- (Red) Events in aviation resilience – DLS already 3rd party, so would not offer any additional resilience here in particular
- (Red) AI – view is that scope for integrating AI from integrating DLS services is limited (Albeit that in the future AI could reasonably be consider supporting dynamic multilink operation so this could be considered but not at this stage).

NAV example

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- (Red) Events in aviation – Certainly GNSS monitoring/mitigation can be a green in this category on its own, however looking at the benefits of integrating services, there is any 'additional' benefit in this category from combining and providing an integrated terrestrial/GNSS service.
- (Red) AI – Same as above AI functionality can aid in GNSS detection/mitigation etc… however as nav terrestrial aids are not really suited to act 'on demand' then there is not much scope for AI benefit when 'integrating' services

SUR example

- (Red) Cyber – No additional cyber benefit in integrating services, over and above the cyber protection in individual services, in fact as we say, the more we combine and rationalise networks, potentially the cyber risks and potential impacts grow
- (Red) Events in aviation – this choice is valid if we think of the integration of ADS-B services and to provide these as third-party services, then this category can be a green in fact
- (Red) – As above for NAV, there would be no additional cyber benefit from integrating services, maybe higher risk if rationalising networks

DATA example

- (Red) Cyber –Rationalising networks/services may even increase the cyber risk that needs to be mitigated
- (Yellow) Infra failure resilience – Yellow because it depends how this integration would be deployed – can be done in order to ensure resilience for benefit

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