Preliminary Concept of Operations (CONOPS) for Data Driven Cost Effective 5G Integrated CNS As a Service

Deliverable ID:	**D2.1**
Project acronym:	**ANTENNAE**
Grant:	**101167288**
Call:	**HORIZON-SESAR-2023-DES-ER-02**
Topic:	**HORIZON-SESAR-2023-DES-ER2-WA2-1**
Consortium coordinator:	**Collins Aerospace**
Edition date:	**11 June 2025**
Edition:	**01.02**
Status:	**Official**
Classification:	**PU**

Abstract

The performance requirements for communication, navigation, and surveillance (CNS) systems are becoming increasingly complex and demanding, particularly in low altitude operations. ANTENNAE project will develop a techno-economic framework for the deployment of communication (C), navigation (N), and surveillance (S) as separate services, as well as an Integrated-CNS (ICNS) offered as a service or "CaaS" enabled by prevailing 3GPP standards and technologies for 5G/5GA networks.

The ANTENNAE project considers the performance requirements of CNS as part of a holistic Integrated-CNS (ICNS) infrastructure, to achieve cost-effective integrated CNS operations. These represent the pillars for the integration of aircraft in a CNS architecture that streams surveillance and navigation data

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through closed-loop A2G datalink transport, to support a digital terrestrial integrated CNS as a service (CaaS).

The progressing technology evolution of 5G/5GA (3GPP) standards aligns with the expected technology evolution of CNS and the SESAR JU Program's expected timeline regarding the maturity of CNS deployment scenarios (solutions). Emerging 6G technology has the potential to enhance the longer-term operation of a CNS network via the application of KPIs and incorporation AI to further optimize required performance while maintaining backwards compatibility with 5G/5GA.

This preliminary Concept of Operations (CONOPS) document describes how the cost-optimized ICNS considered within the single SESAR solution (ANTENNAE-01, STELLAR Solution ID 0521) could be implemented and effectively operated, to cover the scope of the HORIZON-SESAR-2023-DES-ER2-WA2-1 topic and **ANTENNAE's General Objective (G0.1) [1]**:

To develop and demonstrate through dedicated 5G network system level simulations a cost-effective setup of integrated communications, navigation and surveillance services enabled by emerging 3GPP standards and technologies for 5G and Beyond 5G networks for IAM operations in low-altitude airspace.

Authoring & approval

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VTT	31/03/2025

Rejected by[1]

Organisation name	Date

Document history

Edition	Date	Status	Company Author	Justification
00.01	18/10/2024	Draft	COLLINS	Initial Draft
00.02	30/03/2025	Draft	COLLINS	Updated Draft
01.00	31/03/2025	Final	COLLINS	Submitted to S3JU

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[1] Representatives of the beneficiaries involved in the project.

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01.02	11/06/2025	Final	Collins	Updates based on review comments from S3JU are finalised

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1   Introduction

1.1   Purpose of the document

This document is intended to become the reference material describing the operational environment, supported services, target levels of performance, safety and security requirements, and operational cost considerations associated with offering Integrated CNS (ICNS) as a Service (CaaS).

This document encompasses the objectives of **ANTENNAE Work Package 2, Task 2.1 Define Preliminary Concept of Operations [1]**.

The objectives of this CONOPS are to:

- Provide a definition of "Integrated" with respect to ICNS,

- Provide a definition of "Low Altitude" with respect to the ICNS,

- Describe the critical Communication (C), Navigation (N), and Surveillance (S) requirements for both **Manned Aircraft, Air Traffic Management (ATM)** and **U-space** or **Unmanned Aircraft System (UAS) Traffic Management (UTM)** within low level altitudes,

- Explain the Concept of Operations (CONOPS) components, based-on 3GPP (5G) standards, which will run the ICNS (provide CNS-as-a-Service) and support the Required Commination Performance (RCP) of critical C, N, and S safety services,

- Summarize the potential functionality and operation of the ICNS.

1.2   Intended readership

This document is addressed to a broad audience of stakeholders, ranging from ANTENNAE project partners and SESAR JU stakeholders to stakeholders involved in regulating and developing European airspace. The audience includes, but is not limited to:

- ANTENNAE project and solution partners: to collectively develop content and track its progress,

- SESAR Joint Undertaking: to follow the progress of the project in its capacity and for its feedback on the present document,

- Air Navigation Service Providers (ANSPs): to understand the purpose of the solution and potentially prepare for its integration,

- Manned Aircraft, Air Traffic Management (ATM) and Unmanned Aircraft System (UAS) Traffic Management (UTM) service providers: to understand how the ICNS solution supports both ATM and UTM,

- Standardization bodies: to establish new standards adapted to the new use of Airspace and U-space/UTM, CNS technologies,

- Airport and Vertiport owners/providers: to monitor developments in low-level (Low Altitude) air traffic,

- Airspace and U-space/UTM users: to adapt to the arrival of low-altitude operations and to understand how they will be integrated into the airspace,

- Aerospace industry: to understand advances in ICNS regarding the development and regulation of low-altitude operations,

- Scientific community: to keep abreast of innovative advances in CNS technologies.

1.3 Structure of the document

This CONOPS is composed of different parts:

- Section 1 introduces the proposed ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) concept, topology, and logical architecture,

- Section 2 describes the operational environment by identifying the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) stakeholders, key operational roles/responsibilities, relevant operational scenarios, and User Stories,

- Section 3 defines the CNS services supported by the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521),

- Section 4 defines the target levels of performance regarding safety, security, and operational costs, for the CNS services supported by the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521),

- Section 5 describes the commercial network services which may be involved in the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521), to support the CNS services.

1.4 Glossary of terms

Term	Definition	Source of the definition
5GA	In Rel. 18, the 3GPP envisions to enhance the performance of the current 5G standard enabling new use cases, bringing energy efficiency, intelligent Radio Access Network (RAN) automation, non-terrestrial networks, Multiple Input Multiple Output (MIMO) evolution, and including services that focus on uplink communication and connect people moving at high velocities.	3GPP Third Generation Partnership Project [4]
Air Traffic Management (ATM)	The dynamic, integrated management of air traffic and airspace including air traffic services, airspace management and air traffic flow	ICAO 4444 [5]

	management – safely economically and efficiently – through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions.	
Unmanned Aircraft System (UAS) traffic management (UTM) system	A system that provides UTM through the collaborative integration of humans, information, technology, facilities and services, supported by air, ground or space-based communications, navigation and surveillance.	ICAO, Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization [6]
U-space	U-space airspace means a UAS geographical zone designated by Member States, where UAS operations are only allowed to take place with the support of U-space services U-space service means a service relying on digital services and automation of functions designed to support safe, secure and efficient access to U-space airspace for a large number of UAS	Commission Implementing Regulation (EU) 2021/665 of 22 April 2021 on a regulatory framework for the U-space (C/2021/2671) [7] SESAR Smart ATM U-space and urban air mobility [8]
Vertiport	Dedicated areas that supply the infrastructure needed for safe commercial air transport of passengers or goods that travel by VTOL aircraft.	EASA, Vertiports in the Urban Environment [9]
Unmanned Aircraft Systems (UAS)	Unmanned aircraft system (UAS) means an unmanned aircraft and the equipment to control it remotely.	Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems, European Commission, 2019, C/2019/1821 [10][11]
Low Altitude	**Altitude within 8 300 metres or 27 230 feet above Mean Sea Level (MSL)**	**ANTENNAE project preliminary definition** **Original to this Deliverable: ANTENNAE_D2.2 – DES-ER02 Operational Service Environment Document (OSED) [12]**

Above Ground Level (AGL)	The vertical distance of an aircraft above ground level. Also known as Absolute Altitude	pilotinstitute.com [13]
Mean Sea Level (MSL)	The vertical distance of an aircraft above mean sea level. Also known as True Altitude	pilotinstitute.com [13]
Integrated CNS (ICNS)	**Unified system that enables interdependency between communications, navigation, and surveillance (CNS) technologies, taking full advantage of cross-domain synergies to improve service quality, spectrum efficiency, and CNS capabilities.** ICNS is a contemporary concept that considers use of the same technology stack and a single framework with minimal hardware, to deliver essential services across the Communication, Navigation, and Surveillance domains. ICNS is envisioned to improve service quality, spectrum efficiency, communication capacity, navigation predictability, and surveillance capabilities.	**ANTENNAE project preliminary definition** **Original to this Deliverable:** **ANTENNAE_D2.2 – DES-ER02 Operational Service Environment Document (OSED) [12]**
User Story	Within contemporary project management methodologies, a User Story is a simple, concise statement of a problem to be solved, written from the perspective of the end user.	Scrum Alliance [14]
Very Low-Level Altitude	Altitude below 150 meters or 500 feet AGL	ICAO, Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization [6]

Table 1: Glossary of terms

1.5 Background

Low altitude CNS provisioning challenges from aeronautical perspectives:

Emerging U-space/UTM and IAM/AAM concepts envisage a new generation of small, highly manoeuvrable, and highly automated aircraft operating at low altitude, alongside existing helicopter and general aviation users. Coordination and deconfliction of large numbers of such aircraft, operating in primarily urban environments, requires new Communications, Navigation, and Surveillance (CNS) infrastructure to ensure safety of passengers, the public, and other stakeholders, while supporting complex operations within low-level altitudes.

5G technology capabilities and benefits:

Leveraging the scalable waveforms of 5G New Radio (NR), modern IP-based software-defined networking, and distributed computing capabilities, the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) proposes a flexible and resilient integrated CNS-as-a-Service model supporting both low-level (Low Altitude) piloted and U-space operations, and builds upon the mature and growing family of 3GPP 5G standards including system architecture, deployment models, and commercial implementations.

1.6   Overview of the ANTENNAE ICNS Solution

While ANTENNAE will focus on validating the applicability of the 3GPP global telecommunications standards to deliver low altitude CNS functions, the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) architecture will consider integration of terrestrial and non-terrestrial networks to deliver the full range of CNS services to all classes of aircraft operating at Very Low and Low Altitude, while supporting key ATM stakeholders including USSPs, ANSPs, and aircraft operators.

1.6.1   Defining "Integrated CNS (ICNS)"

The ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) envisions all future aircraft equipped with 5G transceivers: integrated as "alternative" technology into legacy avionics for manned aircraft and/or added as "primary" technology in Unmanned Aircraft Systems (UAS). The current CNS systems, originally designed for manned aircraft and ATM, provides very little coverage for low altitude or very low altitude airspace. And, U-space solutions and services are needed for the exponentially growing UAS global market. Interconnectivity between ATM and U-space is crucial, and one of the keys to this interaction is the development of Integrated CNS (ICNS).

Currently, the CNS landscape remains fragmented. Each domain (Communication, Navigation, and Surveillance) is allocated its own equipment on board aircraft and on the ground, sending information over different frequency bands, resulting in inefficient use of spectrum, equipment requirements (space and power). See Figure 1 below.
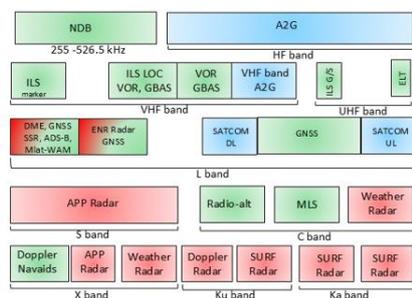
Figure 1: Fragmented CNS services

The ICNS proposed by the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) will support unified use of the same technology stack for services across the domains. The full range of CNS services could therefore be issued to all classes of aircraft operating at very low altitude and low altitude,

optimizing performance, spectrum usage, safety services, and network access security (increased resistance to jamming and spoofing). These efficiencies are expected to also result in an overall reduction of CNS costs and minimize onboard equipment size and power consumption.

ICNS is a contemporary concept that considers use of the same technology stack and a single framework with minimal hardware, to deliver essential services across the Communication, Navigation, and Surveillance domains. ICNS is envisioned to improve service quality, spectrum efficiency, communication capacity, navigation predictability, and surveillance capabilities.

ANTENNAE project preliminary definition of ICNS [12]:

Unified system that enables interdependency between communications, navigation, and surveillance (CNS) technologies, taking full advantage of cross-domain synergies to improve service quality, spectrum efficiency, and CNS capabilities.

1.6.2 ICNS Conceptual Architecture

Existing CNS infrastructure designed for legacy commercial aviation has very limited coverage at low altitudes due to terrain masking of communications and airspace surveillance signals, with long revisit intervals permitted due to the relatively predictable trajectories of commercial aircraft at higher altitudes. Typically, the communications and surveillance functions have been deployed as isolated ground stations, often on hilltops, separated by hundreds of kms with a centralized data centre coordinating airlines, airports, and Air Navigation Service Providers (ANSPs).

The long-term vision of 3GPP 5G wireless technologies is to support ubiquitous mobile application verticals and services outside the traditional terrestrial mobile user base, including the support of novel aerospace application verticals empowered with high-capacity communications and alternative surveillance and navigation capabilities [15]. Although focused on U-space/UTM operations, these same capabilities may also support general low altitude operations. Figure 2 illustrates the conceptual architecture for the 5G, Integrated CNS (ICNS) which the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) will support for the variety of Very Low Altitude and Low Altitude aircraft users.

Due to the current generational approach taken by 3GPP in its mobile communication standards, the solution proposes not only investigate the current standard, 5G, but also the future standards that might follow 5G. The rollout of new mobile communication standards became very diligent since 4G/LTE, favoring gradual migration to the new standard, backward compatibility and coexistence with the previous standard. Therefore, the MNOs can commit to a long-term investment in updating their network due to the equipment long lifespan. Also, the end users have time to adequate with the new technology, since the previous standard will stay in service for 5 to 10 years, on average. Finally, the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) targets **xG**, which comprehends 5G and the further standards, but in this document, we refer to 5G due to the wide availability of documents, standards, and ubiquity in Europe.
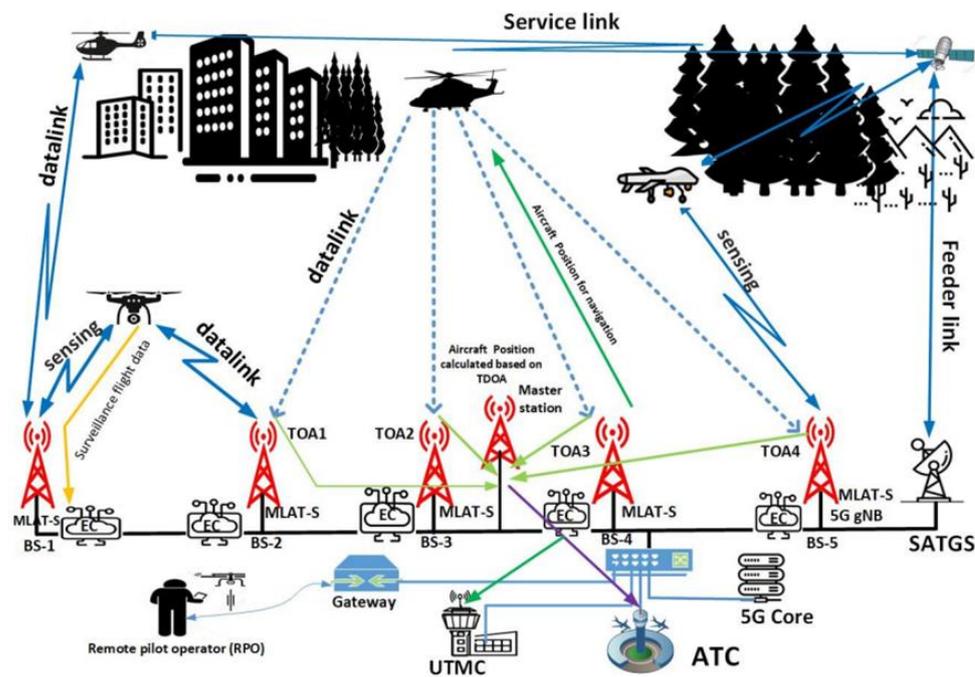
Figure 2: Conceptual architecture for the 5G ICNS

1.6.3   Airspace coverage

1.6.3.1   Geographic coverage

The ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) proposes the implementation of a private, 3GPP standard (5G/5GA), terrestrial-based, Radio Access Network (RAN), to provide optimal 5G coverage for Very Low and Low Altitude airspace within the vicinity of an airport. For the scope of ANTENNAE, it is recommended that a geographic coverage distance of ~5km to 10km be considered for the private, 3GPP standard (5G/5GA), terrestrial-based RAN serving the vicinity of an airport or vertiport. A reference for this recommendation is provided below.

REFERENCE [16]:

Class C airspace is usually a control zone (CZ) for a large airport. These areas usually have a 10-nautical-mile (19-20 km) radius and a height of up to 12,500 ft above aerodrome elevation (AAE).

Beyond the vicinity of an airport or vertiport (beyond the coverage of the localized, private RAN), it is envisioned, subject to research to prove the economic feasibility of operation, that existing, terrestrial 3GPP-standard 5G/5GA service (MNO service) and other Satellite or HAP services could be used to extend the ICNS broadly across land and oceanic regions. See Figure 3 below.

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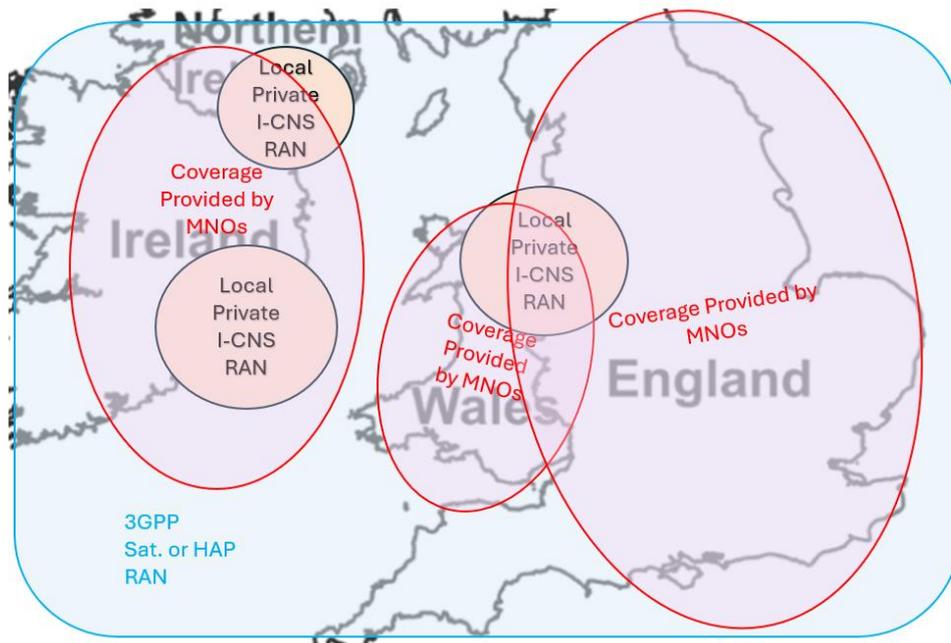
Figure 3: regional ICNS service

The ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) will need the ability to be scaled-up for a regional or global implementation as feasible, based-on technoeconomic analysis.

1.6.3.2 Defining "Low Altitude"

While there is no standards-based definition nor regulatory reference regarding what is considered "Low Altitude", for the ANTENNAE solution (Integrated CNS, SESAR Solution ID 0521), we will reference existing 3GPP (5G) standards to define Low Altitude. This will be important, to enable the potential use of MNOs' RANs for connectivity beyond localized, private 5G ICNS coverage.

There are some references for a definition of Low Altitude within 3GPP standards. 3GPP Release 15 provides some standards for the modelling a Radio Access Network (RAN) for support of AV and/or UAS operating within 300 m altitude [17][18]. Research from related EU projects such as FACT have shown that 5G macrocells configured with uptilted antennas (antennas with azimuths selected for air rather than ground coverage), can provide sufficient RF coverage to support ICNS services within a radial distance of nearly 3 000m [19]. And, various Proof-of-Concepts (PoCs) and Drone Use-case tests, including testing done by Science Foundation Ireland (SFI) and CONNECT in Dublin, have confirmed the Beyond Visual Line of Sight (BVLOS) operation of drones at an elevation greater than 300m above 3GPP small cell base stations (small cell eNodeBs mounted on municipal traffic or lighting poles) [20][21]. And, regulations which apply to populated areas provide a reference for Low Altitude.

REFERENCE:

U.S. FAA regulations regarding flights over congested areas [22] state, "Over any congested area of a city, town, or settlement, or over any open-air assembly of persons, an altitude of 1,000 feet (304.8m) above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft."

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ICAO's Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization document, Edition 4 [6], states that:

"A significant amount of UAS operations are expected in the low-level environment and above populated areas, with various types of operations and UA. This will likely include:

- operations at altitudes in the very low-level structure (e.g. below 150 metres or 500 feet above ground level (AGL))"

Thus, VLL operations may be considered those that are conducted within 150 metres or 500 feet AGL.

ICAO's EUR SIGMET and AIRMET guide, Edition 5, 2023 [23], states that:

"The main purpose of this document is to provide guidance for standardization and harmonization of the procedures and formats related to the occurrence or expected occurrence of specified hazardous en route weather conditions that may affect the safety of aircraft and low-level aircraft operations, known as SIGMET and AIRMET information."

The following definitions are provided:

GAMET: This is an area weather forecast for low-level flights, typically covering the airspace from the ground up to FL100 (10,000 feet). In mountainous regions, the upper limit can be FL150 (15,000 feet) or higher.

AIRMET is "Information concerning en route weather phenomena which may affect the safety of low-level aircraft operations."

These advisories are issued for weather conditions that may affect aircraft operations at altitudes below FL240 (24,000 feet). They provide warnings about moderate weather phenomena like turbulence, icing, and visibility issues.

The references considered in this section suggest that it is reasonable to define "Very Low Altitude" as below 150 m (500 ft). This will align with both regulations and technical standards while best enabling the use of terrestrial MNO networks for geographically broader ICNS service offerings. However, modern VCA, such as XTI Aircraft TriFan 600, are intended to operate at altitudes near 25000 feet [24]. Therefore, the preliminary definition of "Low Altitude" for this project (ANTENNAE) is as follows:

ANTENNAE project preliminary definition of Low Altitude [12]:

For the research to be conducted within the scope of this project (ANTENNAE), "Low Altitude" is within the altitude of 8 300 metres or 27 230 feet above Mean Sea Level (MSL).

Operational altitude within 4 000 ft (about 1200 m) includes VLL altitudes, which is 500 ft (150 m). As stated earlier, 3GPP specifications ensure cellular network coverage up to 1 000 ft (300 m). The ANTENNAE project will investigate whether the same set of technological solutions can ensure CNS services across the entire operational altitude, up to 1200 m AGL, or if two different solutions will be required to serve the lower and higher ranges of that altitude.

1.6.3.3 Above low altitude coverage

For higher altitude ("above low altitude") ICNS RF coverage, projects related to ANTENNAE such as the EU ETHER project [25] have modelled a path loss for HAP and Sat. networks. For the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521), we can align with 3GPP Release 15 [17] regarding Low Altitude yet incorporate support of a separate path loss for the steering of data (IP) traffic to HAP or Sat. network links for "above low altitude" CNS RF coverage.
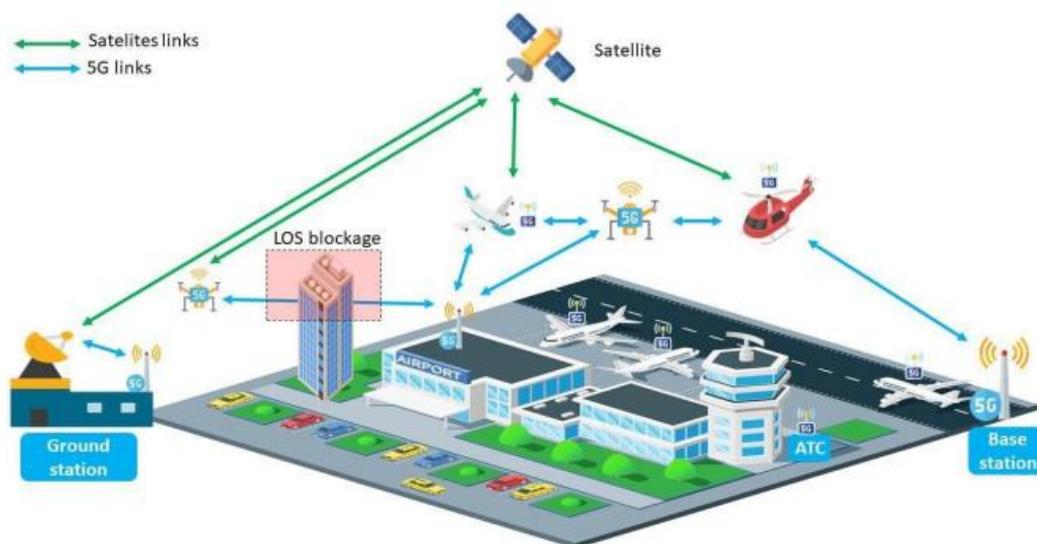
Figure 4: airspace scope

1.6.4 Network topology

Figure 5 presents a high-level representation of the topology for the 5G Network (5GNR RAN and 5GSA Core) which would support the localized low altitude ICNS within an airport vicinity.

The localized 5G network would interconnect with stakeholders' platforms using secure and redundant (cloud-based or direct) IP connections. The 5GSA Core would be integrated with other neighbouring networks for the optimized hand-over of connected aircraft to broader MNO 5G RAN coverage areas or hand-over of connected aircraft to Sat. networks.
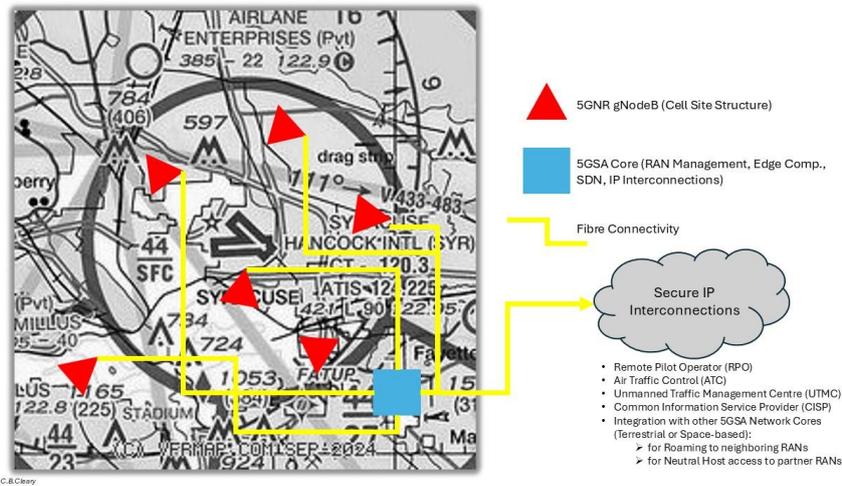
Figure 5: network topology of the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521)

To reduce CAPEX and OPEX costs, existing structures or towers within the vicinity of an airport would be prioritized for the placement of 5G gNodeB Radio Units (RUs) and/or Antennas. Public and/or regulatory databases can be referenced to identify existing mast locations. These databases typically provide the following:

- the location of every mobile telephone mast,

- the operator which owns or controls each mast,

- the types of mobile services provided at each mast.

EXAMPLE:
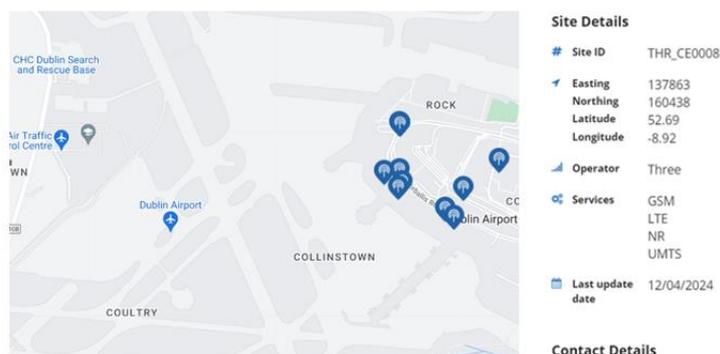
Figure 6: example Dublin Airport

To provide optimal RF coverage and capacity (number of sites and cell sectors) for localized ICNS, and to ensure a minimum number of sites (base stations) to exceed Alternative Positioning, Navigation, and Timing (A-PNT) implementation and performance requirements as well as exceed performance

requirements for Assured Surveillance (A-SUR) and Communications. The topology will consider the following implementation selections:

- Placement of five (5) or more 5G gNodeB (macro cells), on 50' to 100' structures, providing coverage of the airport vicinity,

- Assume the coverage distance of ~5 to 10 miles - as a reference, Class C airspace is usually a control zone (CZ) for a large airport. These areas usually have a 10-nautical-mile (19 km) radius and a height of up to 12,500 ft above aerodrome elevation (AAE).

1.6.5 Radio Frequency Spectrum

Regarding Spectrum and Regulations, sub-6GHz Bands sit within the "5G" n78 and wider n78 Bands and align with the CBRS Band used globally. These Bands have been targeted for 5G/5GA services. Other high-frequency Bands such as the ~25GHz "mmWave" Bands targeted for 5G/5GA services are not as well suited for the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521), since their higher-frequency does not provide the RF propagation required for consistent connectivity to aircraft equipped with a compatible 5G transceiver. So, modelling the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) based-on sub-6GHz spectrum is recommended.

5G NR Frequency Bands

NR Band	Frequency Band (MHz)	Uplink (UL)/ Downlink (DL) (MHz)
n77	3700	3300 - 4200[2]
n78	3500	3300 - 3800
n79	4500	4400 - 5000
n90	2500	2496 - 2690
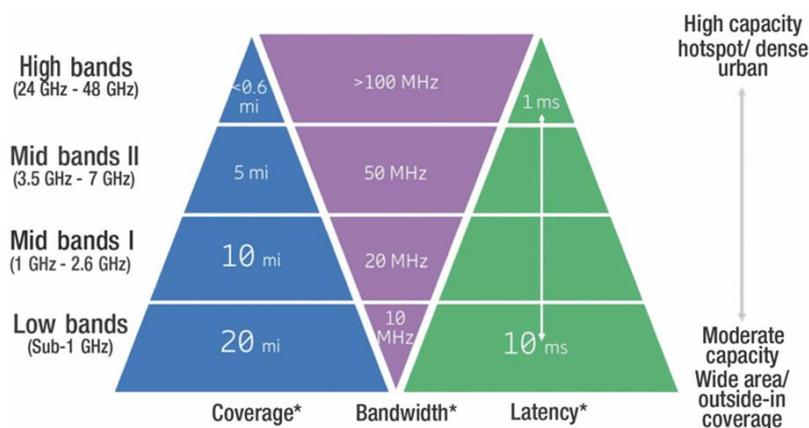
Figure 7: 5G NR Frequency Bands

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More specifically, since the 3.6GHz and 3.8GHz Bands are licensed Bands, EU regulations can be referenced to determine the broadcast limitations and operational obligations. These regulations can help specify details such as the Max EIRP, 5G TDD Framing Format for DL and UL timeslots, and required Block Edge Mask (BEM) for using a customized framing format which we would most likely choose to make the most efficient use of DL and UL timeslots. Pasted below are references from the regulations for the 3.6GHz licenses in Ireland which sit within the "5G" n78 and wider n78 Bands.

DL/UL ratio	Timeslot or Subframe number									
	0	1	2	3	4	5	6	7	8	9
3:1	D	S	U	D	D	D	S	U	D	D

4. Conditions for using the Restrictive Block Edge Masks

(1) Other Frame Structure — the technical conditions for Restrictive Block Edge Mask set out in Section 2 shall apply where a Licensee's Base Station complies with the Other Frame Structure as outlined below:

    (a) All frame configurations that are not compatible with TD-LTE frame configuration 2 (3:1) with special subframe configuration 6 or equivalent frame structure whose transmit and receive periods are aligned with this configuration are permitted;

    (b) Licensees shall co-operate to minimise Harmful Interference caused by sub-frame overlaps if different technologies are used; and

    (c) Licensees using the Restrictive Block Edge Mask shall not cause Harmful Interference to those Licensees' networks that use the Default Frame Structure (or equivalent). Achieving this may include applying internal guard bands and/or reduced in block power levels in blocks adjacent to those Licensees' networks that use the Default Frame Structure (or equivalent).

Figure 8: DL/UL ratio

Additionally, within some EU States, the 3.8GHz (3.8GHz to 4.2GHz) Spectrum is used for the grant of Trial licenses, so the use of the 3.8GHz Band for modelling would align with any future continuation of project ANTENNAE through higher TRLs (into a PoC).

Based-on these regulatory references, the following criteria is considered for the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521):

- Assume the ability to operate the macro cells with an output power of <45dBm (~31W),

- Model the 5G base stations to use sub-6GHz (3.6GHz or 3.8GHz) licensed spectrum in compliance with EU regulations (SI-532),

- Model the 5G base stations to support 5G broadcast channels ranging in size from 5MHz to 100MHz.

1.6.6 5G Network Slicing and Features

For the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) IP-based data packet routing algorithms and network slicing, fundamental to 5G, will be leveraged to create logical data pathways and control/management functions specific to each CNS service. This will include considering the use

of 5G/5GA features such as URLLC (Ultra Reliable Low Latency Communications), eMBB (enhanced Mobile Broad Band), and mMTC (massive Machine Type Communications) or RedCap which targets IoT services needing a higher data rate than mMTC but lower data rates than eMBB, while simultaneously reducing 5GNR transceiver complexity.
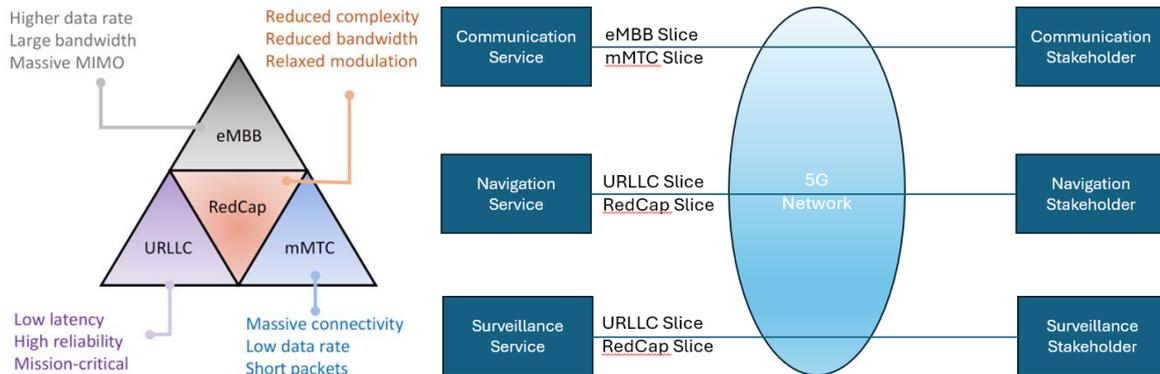
Figure 9: 5G Features and Slicing

For integration of CNS services (ICNS), the use of SDN, the 5G ATSSS (Access Traffic Steering, Switching, and Splitting) framework, and advanced antenna steering algorithms will be leveraged for Performance-based and Cost-based routing of traffic via TN and NTN connections.

It is expected that the very flexible 5GNR OFDM waveform and the standardized features of 5G technology will fully support the critical Communication (C), Navigation (N), and Surveillance (S) requirements for both Manned Aircraft U-space Traffic Management within relevant Low Altitude airspace. For A-PNT, robust positioning and integrity algorithms that leverage the advanced signal processing capabilities of 5G networks will be researched; for A-SUR, performance models for conveying surveillance data over 5G data links will be investigated to supplement traditional ADS-B systems.

2 Operational environment

2.1 Operational Context

This section sets the contextual framework in which the ICNS operates. The context is defined by:

- A service-oriented framework for the future provision of CNS capabilities, and the role of service providers, aircraft operators, and ATM/U-space stakeholders,

- The European ATM Master Plan, 2025 Edition [26] which lays out the implementation strategy of CNS as a service, and how it is driven by operational changes,

- The SESAR Concept of Operations, Edition 2019 [27] which indicates the envisioned European ATM operation of the future, with a focus on the operational improvements developed under the SESAR 2020 program to be supported by the ICNS as a technical enabler.

2.1.1 CNS as a service

As described in Section 1 of this document, the current CNS landscape remains fragmented. Each domain (Communication, Navigation, and Surveillance) is allocated its own equipment on board aircraft and on the ground, sending information over different frequency bands, resulting in inefficient use of spectrum, equipment requirements (space and power). And, historical national ownership of CNS infrastructure, as well as the need to support a variety of heterogeneously equipped aircraft, has led to an inefficient distribution of equipment when taking performance needs in relation to air traffic into consideration. In addition, some technologies still in operation have overlapping capabilities and, in a context of steady growth, may not be able to provide the required performance to deliver the SESAR vision. Therefore, the main challenge is to optimize the infrastructure and rationalize it both on the ground and in the air.

The future CNS infrastructure will be based on an ICNS backbone. ANTENNAE envisions a future in which all aircraft are equipped with 5G transceivers: integrated as "alternative" technology into legacy Avionics for Manned Aircraft and added as "primary" technology in UAVs/UASs. The ICNS considered for the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) will consist of the deployment of a hybrid (Terrestrial and Non-terrestrial) SDN-enabled network that can offer cost-effective integrated communication, navigation and surveillance (I-CNS) services, as illustrated previously in Figure 2, Section 1 of this document.

By leveraging hybrid networking (TNs and NTNs), Hyperconnected ATM (HCATM) modelling, and the use of both private and commercial 5G networks, the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) will aim to show the techno-economic feasibility of offering reliable (resilient), cost-effective, and scalable 5G-based ICNS to all CNS stakeholders.

2.1.2 The SESAR Concept of Operations

The SESAR CONOPS [27] describes areas identified by the SESAR Vision documented in the European ATM Master Plan [26] where Operational Improvements (OI) are supported by technical enablers to

bring performance gains and yield the overall performance expected in SES High-Level Goals. Three operational Key Features are identified:

- Optimised ATM Network Management,

- Advanced ATS,

- High Performing Airport Operations.

The enhancements described in the three Key Features will be underpinned by an integrated and rationalised aviation infrastructure providing the required technical capabilities in a resource-efficient manner. This feature will rely on enhanced integration and interfacing between aircraft and ground systems, including ATC and other stakeholder systems, such as flight operations centres and military wing operations centres. CNS systems, SWIM, trajectory management, Common Support Services and the evolving role of the human will be considered in a coordinated way for application across the ATM system in a globally interoperable and harmonised manner.

The development and deployment of new communication technologies should converge towards a service and performance-based integration approach. The introduction of U-space/UTM services to support access to airspace for many unmanned vehicles (RPAS) requires ATM capabilities to be interoperable with manned aviation capabilities and compliant with local air/ground communication procedures.

2.2 Actors, roles and responsibilities

This section identifies the CNS stakeholders, together with their associated functionalities (roles and responsibilities) within the operational environment.

- **Air Traffic Service Provider (ATSP):** integrated national ATS provider responsible for producing part of the data required for ATS, processing and combining this data to make it available to their controllers and using that data to provide ATS to aircraft via datalink. ATSP are usually part of the Air Navigation Service Provider (ANSP) domain,

- **ATM Data Service Provider (ADSP):** provider of data and applications supporting the provision of ATS and aircraft operation. The ADSP can be part of ANSP domain or be an entity independent to the ATSP. ATM data relies on underlying integration services for weather, surveillance and aeronautical information. Data services include flight data processing functions like flight correlation, trajectory prediction, conflict detection and conflict resolution, arrival management planning, and Aeronautical Information Management (AIM)/Meteorological Information Management (MET),

- **Communications Service Provider (CSP):** The CSP provides communication services for air navigation and operation. This involves providing the network connectivity between ground and/or aircraft located IPS hosts, the movement across the infrastructure in the role of Mobility Service Provider (MSP), and security related features. The CSP may also be an Access Service Provider (ASP) to provide access to aircraft, in which case it is called an A/G Communications Service Provider (ACSP). For this purpose, CSPs can establish and manage relationships with ASPs. In the future it is foreseen that the CSP role is to be managed at a common European service provision level, at a minimum for ATN datalink backbone services,

- **Access Service Provider (ASP).** The ASP is the operator of Radio Access Technology (RAT) providing A/G datalink communications with aircraft accessing the network. This role is dependent on the functions (medium access, link control, handover, roaming, and Layer 2 security) supported by the specific radio communication infrastructure technology (e.g. L-band Digital Aeronautical Communications System (LDACS), Aeronautical Mobile Airport Communications System (AeroMACS), Internet Protocol (IP) Satellite Communication (SATCOM) or IP Very High Frequency (VHF) Data Link Mode 2 (VDLM2)),

- **Network manager (NM).** The Network Manager manages regional air traffic management network functions as well as scarce resources (e.g., radio frequencies), in Europe. It monitors the performance of ATC datalink and reports appropriate statistics for the network datalink to allow stakeholders to understand how well the system is performing on a regional (Europewide) basis. The NM will also provide insight as to why the system is performing the way it is and recommendations on how to tackle system-wide issues,

- **Aircraft (A/C).** This actor involves the ensemble of human (flight crew) and automated systems on-board an aircraft operated by an airspace user, communication functions (including radio) and managing applications on Internet Protocols Suite (IPS) hosts within the aircraft mobile subnetwork,

- **Flight Operations Centre (FOC).** This actor represents an airspace user coordination hub centralizing the tasks of flight planning and monitoring. The FOC manages the AOC communication with its operated A/C, and shares ATM information for coordination and situational awareness with ADSP.

- **Remote Control Station (RCS):** A dedicated station which controls and monitors UAS using Command and Control (C2) link.

ICNS Stakeholder	Associated responsibilities
Air Traffic Service Provider (ATSP)	Provide ATS and Digital Voice services to A/C and other ATSPs Ensure end-to-end datalink service performance, security and safety levels Manage service contract with CSPs providing connectivity to ICNS Establish and manage ATS and Digital Voice applications
ATM Data Service Provider (ADSP)	Provide ATSP with integrated ATM data required to provide ATS Perform flight data processing functions (potential future evolution) Ensure end-to-end ATM data service performance, security and safety levels Manage service contract with CSPs providing connectivity to ICNS Establish and manage ATM data applications

	(weather/aeronautical information including AIS/MET, flight information for TBO)
Communications Service Provider (CSP)	Provide end-to-end connectivity, mobility and communications services to air and ground IPS hosts running ATM applications
	Provide access to ground network infrastructure (e.g. IP BB, NEW PENS…). Optionally, provide access to air/ground datalink infrastructure (if also an ASP)
	Manage service contract with ATSP, ADSP and airspace users (FOC and A/C). Ensure levels of security, safety and performance as compliant with service level agreements in service contract
	Monitor network performance and events, and share with NM for system-wide monitoring
	Apply NM directives to improve network performance
Access Service Provider (ASP)	Provide accessibility to access network via air/ground datalink infrastructure
	Provide status of radio link with aircraft in the access network
	Manage service contract with CSP and airspace users (A/C). Ensure levels of security, safety and performance as compliant with service level agreements in service contract
	Monitor access network performance and events, and share with NM for system-wide monitoring
	Apply NM directives to improve access network performance (e.g. radio resource allocation)
Network manager (NM)	Monitor system-wide performance of ground network and access radio networks in ICNS.
	Publish appropriate performance statistics and reports
	Provide recommendations for corrective action on network-wide issues to appropriate stakeholders (CSP and ASP)
Aircraft (A/C)	Ensure the correct operation of on-board A/G datalink capability, and ATM applications (ATS, Digital Voice, AOC, AIS/MET)
	Monitor datalink avionics status and record logs for performance monitoring
Flight Operations Centre (FOC)	Provide AOC services to A/C operated by the airspace user
	Ensure end-to-end AOC service performance, security and safety levels

	Manage service contract with CSPs providing connectivity to ICNS Establish and manage ground AOC applications
Remote Control Station (RCS)	Allow pilots to remotely guide, monitor, and manage the UAS's flight Provide real-time data on the UAS's position, performance, and other operational parameters Facilitate communication between the ground station and the UAS

<div align="center">**Table 2: ICNS stakeholder responsibilities**</div>

2.3 Operational scenarios

Within contemporary project management methodologies, a User Story is a simple, concise statement of a problem to be solved, written from the perspective of the end user [14]. In the context of ANTENNAE, an end user could either be an aircraft operator or a CNS service stakeholder. This section describes some fundamental, reference scenarios (User Stories) which could be solved via the use of ICNS. To evaluate the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) specific Use Cases will be considered and referenced in the ANTENNAE Operational Service Environment Document (OSED) [28].

2.3.1 Fundamental reference scenarios (User Stories)

User Story A

"As a manned aircraft operator or UAS operator, I want access to Communications, Alternative Positioning, Navigation, and Timing (A-PNT), and Alternative/Assured Surveillance services that will provide performance and accuracy exceeding current technologies such as GNSS and including the availability of such services at Low Altitude." – This relates to Use Case 3.3.2.5.3 – Safety applications in the OSED [28].

User Story B

"As a CNS service provider, I want a techno-economically feasible solution for offering advanced CNS technologies to all categories of aircraft (manned aircraft and UAS) and all ATM and UTM stakeholders." – This relates to Use Case 3.3.2.5.1 – Cellular network optimization for aerial users in the OSED [28].

User Story C

"As a manufacturer of manned aircraft or UASs, I would like to minimize the size, weight, complexity, and power consumption of onboard CNS hardware while fully supporting all current CNS capabilities and enabling innovative alternative CNS technologies." – This relates to Use Case 3.3.2.5.2 – Hybrid connectivity in the OSED [28].

3   ATM and U-space/UTM applications over the ICNS

ATM and U-space/UTM rely significantly on the timely exchange of information between all participating actors, and especially on the exchange of information between air and ground. The use of ATM and U-space Applications over the ICNS will therefore, over time, continue to increase both in volume and scope. New applications such as digital voice and A-PNT for Low Altitude will have more stringent performance requirements. The ICNS infrastructure can be leveraged to support current and future applications.

This section describes critical applications the ICNS will be expected to support. As the ANTENNAE project progresses additional critical ATM and/or U-space applications will be identified for consideration.

3.1   Air Traffic Services (ATS)

As defined by ICAO Annex 11 [29], Air Traffic Services comprise the set of services provided, in order to fulfil the following objectives:

a) Prevent collisions between aircraft,

b) Prevent collisions between aircraft on the manoeuvring area and obstructions on that area,

c) Expedite and maintain an orderly flow of air traffic,

d) Provide advice and information useful for the safe and efficient conduct of flights,

e) Notify appropriate organizations regarding aircraft in need of search and rescue aid, and assist such organizations as required.

The following set of Air Traffic Services are defined in ICAO Annex 11 [29]:

- **Flight Information Service (FIS)** - fulfilling objective d)

- **Alerting Service** – fulfilling objective e)

- **Air Traffic Advisory Service**

- **Air Traffic Control (ATC) Service** – fulfilling objectives a), b) and c)

Today, these services are mainly provided via voice, and in some cases via datalink. While voice will continue to be used for provision of Air Traffic Services (specially for time-critical and non-routine messages as well as for communications with specific aircraft), SESAR Master Plan 2020 [26] recognizes datalink as the main communication means for the provision of Air Traffic Services.

3.1.1   Flight Information Service (FIS)

Flight Information Service is provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights. FIS commonly include aeronautical and meteorological services - AIS/AIM and MET services are specifically addressed in section 3.2.

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A FIS may be provided on its own or in conjunction with an Air Traffic Control Service. In the second case, ICAO Annex 11 [29] requires the provision of air traffic control service shall have precedence over the provision of flight information service whenever the provision of air traffic control service so requires. However, it is recognized that, in certain circumstances, aircraft may require to receive without delay essential information other than that pertaining to the provision of air traffic control service.

FIS include the provision of:

- Operational flight information Service (OFIS) broadcast,

- Automatic Terminal Information Service (ATIS) broadcast,

- VOLMET broadcast.

FIS can be provided via HF/VHF voice channel or via datalink. Datalink Flight Information Services, such as D-ATIS and D-VOLMET allow a pilot to request and receive FIS from ground systems via data link.

3.1.2   Altering Service

Alerting service is part of air traffic service and is therefore provided by ATS units (e.g. area control centres, flight information centres, etc.). The main task is to promptly notify the appropriate organizations (e.g. Search and Rescue) about the situation and provide relevant information about the aircraft in distress.

3.1.3   Air traffic advisory service

Air traffic advisory services are provided on specific types of airspace, when no Air traffic Control service is provided, to ensure separation, in so far as practical, between aircraft operating on IFR flight plans.

3.1.4   Air Traffic Control (ATC) service

ATS Baseline 2 defines a set of ATC Services enabling initial Trajectory Based Operations (TBO) and convergent datalink standards supporting global operations. EUROCAE ED-228A [30] identifies three different datalink applications:

- CPDLC - Controller Pilot Data Link Communication: the CPDLC application allows controller and flight crew to exchange information via data link. By using CPDLC, controller and flight crew can exchange messages for the following purposes: general information exchange, clearance delivery, request, and response, altitude/identity surveillance, monitoring of current/planned position, advisories request and delivery, system management functions; and emergency situations,

- ADS-C - Automatic Dependant Surveillance – Contract: the ADS-C application allows the ATSU to obtain information from an aircraft on request, at a specified reporting interval, and/or when logic within the avionics triggers one or more different types of events. The information downlinked can contain one or more of the following data sets: projected profile, ground

vector, air vector, meteorological information, extended projected profile, TOA range, speed schedule, RNP profile and final approach speed. Additionally, ADS-C provides functionality which allows the aircraft system to provide an emergency and/or urgency alerts to the ground,

- CM - Context Management: the Context Management application provides initial manual "logon" capability to flight crew when entering an ATSU domain of responsibility. It should be noted that the CM services are not intended to achieve a certain operational goal rather CM is a pre-requisite for the use of CPDLC and ADS-C applications.

3.2 AIS/MET datalink services

The availability of timely, accurate and relevant Aeronautical Information Services (AIS) and Aviation Meteorological (MET) information in the cockpit is critical to the safe, regular and efficient conduct of flight. The ability to create an accurate temporal aeronautical information environment shared by all relevant actors involved (Aircraft, FOC, WOC, ATSU, ADSP and NM) constitutes an essential component of the future ATM system and therefore the ICNS needs to support the continuous update of AIS/MET data via datalink exchanges between aircraft and ground systems.

Datalink services incorporating AIS and/or MET are intended for:

1. Pilot decision support,

2. Collaborative Decision Making between ground services, the flight deck, Air Traffic Control (ATC) and, as appropriate, Flight Operations Centres (FOCs) in all flight environments for flight efficiency and/or hazard avoidance.

Four different transmission modes that may be used for transmitting AIS and MET information. The modes below refer to high-level functionality and are agnostic from underlying datalink and network architecture. The ICNS must support such capabilities.

AIS/MET transmission modes at application level	
Broadcast Data Link	A broadcast data link provides continuous, repeated transmissions of AIS/MET information to all aircraft within communications range. The broadcast network has no knowledge of which aircraft are receiving the data link transmissions. To receive AIS/MET information from a broadcast data link, no specific pilot action is required other than to turn on the data link radio receiver. If acknowledgement is required, it may be handled via voice or other appropriate communication.
Demand Data Link (Two-Way)	The demand mode requires a two-way data link system. It provides the opportunity to make an individual request for specific data link information and then receive a single response of the requested information. The request may be through individual pilot action or automatically generated by cockpit avionics based on pilot preferences. If the Demand includes requests for multiple types of information, the request may also specify a priority of need for the different information types.

Downlink Data Link	The downlink mode supports the transmission of AIS/MET information from an aircraft to the ground. Downlink transmissions are automated and may occur on a time-controlled, altitude-controlled, distance-controlled basis or be event-driven. The basis for the occurrence of downlink transmissions is normally pre-programmed but may be specified (or changed) through a ground-initiated Demand request if a Command and Control (C2) capability has been established.
Crosslink Data Link	The crosslink mode supports the transmission of AIS/MET information from an aircraft to other aircraft in the vicinity.

Table 3: AIS/MET transmission modes at application level

3.2.1 AIS services

The AIS data link is intended to provide real-time distribution of aeronautical information through the establishment of AIS data link services (AISLINK). The intent is to augment and eventually replace the current AIRAC system based on the 28-day cycle and textual NOTAMs. It is also envisaged that, in addition to current aeronautical data, additional data, such as airport mapping databases, may be made available and considered for the AIS data link services. Two different types of AIS data link services are defined: Aeronautical Update Service and Baseline Synchronization Service.

3.2.1.1 Aeronautical update service

The Aeronautical Update service is a datalink service that provides both permanent and temporary changes to the cockpit throughout the 28-day AIRAC cycle where the pilots or on-board systems can then include that information in their decision-making process. The Aeronautical Update service does not physically modify or change any data contained within the on-board navigation or charting databases but provides up-to-date data that may supplement the data contained in those databases.

The objective of the Aeronautical Update Services is that ATM community members on the ground and in the air, work based on a common data set and share situational awareness, providing for a more effective collaborative decision making.

The timely availability of digital Aeronautical Updates is intended to replace the current means of disseminating permanent and temporary changes (e.g., paper NOTAM), allowing on-board avionics to display the data either as text or as a graphic overlay to the baseline. For aircraft not equipped with datalink, currently existing procedures for exchanging aeronautical data, (e.g., VHF voice communication, NOTAM, and ATIS) will continue to exist.

Various aeronautical information intended for both pre-flight and inflight use are included in the Aeronautical Update Service description. Aeronautical information datalink update is relevant to enhance flight safety and will mitigate the risks associated with events such as runway incursions, pilot deviations into Temporary Flight Restriction/Temporary Segregated Areas airspace or flying without complete and current aeronautical information.

Special Use Airspace (SUA) - [including Temporary Flight Restriction/Temporary Segregated Areas]
NOTAMs

| BIRDTAMs |
| SNOWTAMs |
| ASHTAMs |
| Airport surface moving map |
| Global Navigation Satellite System (GNSS) outage depictions |
| alternate airport diversion information |
| Noise-sensitive environmental impact areas |

Table 4: Aeronautical update services - list of possible aeronautical updates

3.2.1.2 Baseline synchronization service

The Baseline Synchronization service refers to the update via datalink of aeronautical data that is resident in the aircraft's on-board database(s). Currently, most databases on board aircraft are maintained under the ICAO AIRAC system and need to be uploaded manually to aircraft every 28 days. Baseline synchronization provides for more frequent updates of the on-board database but not necessarily on a regular cycle. This concept breaks the paradigm of the 28-day cycle, with the intention of laying the foundation for future real-time provision of aeronautical data.

Two different operating principles are applicable to the use of the Baseline Synchronization service:

a) Complete Sync, which replaces an entire database in the Aircraft Data System,

b) Update Sync, which contains only the aeronautical information that has changed since the previous sync specific to the dataset.

It should be noted that Complete Sync may require extensive data link capacity since it involves the upload of potentially large amounts of data. It is envisioned that Update Sync would be the preferred method of maintaining the on-board databases, thereby minimizing data link usage. Complete Sync is envisioned to be primarily used while the aircraft is on the ground.

3.2.2 MET services

A broad portfolio of Aviation Meteorological (MET) products and services is used by pilots to support aircraft operations as described in ICAO Annex 3, Meteorological Service for International Air Navigation [31]. Today, MET information is mainly provided in paper form for pre-flight planning and by voice radio contact during flight. Once pilots depart the briefing environment and, with the exception of broadcast information obtained from the ATIS, VOLMET, D-VOLMET and similar services, they generally lack the means to access timely and up-to-date MET information. This lack of availability has significant consequences in terms of enhanced flight safety, efficiency, and economy. Similarly to AIS, the ability to have in-flight access to MET information that was previously available only during preflight briefings will also greatly enhance collaborative decision-making processes in ATM.

Meteorological data link (METLINK) services providing timely distribution of MET information both to and from aircraft will support pilot decision applications (i.e., flight planning decisions, near-term

decisions and/or immediate decisions) as well as provide aircraft MET data for use by aircraft in the vicinity and for use in ground weather applications and interpretation by computer-based systems.

A non-exhaustive list of possible MET Datalink service products is provided in Table 5 and Table 6, below. The tables below identify the service suitability for each of the decision support classifications, which are dependent on the intended application and human factors considerations.

MET Service	Pilot decision support time	
Weather Planning Decision Service (WPDS)	> 20 min	Planning decisions relate to a longer time horizon where pilots have the time to deliberate and perhaps coordinate with ATC/AOC prior to taking action on a new or revised piece of information received from any source (in this context, via data link). Pilot action resulting from a planning decision is usually a change in routing or altitude in advance of a potential impact or opportunity related to the current planned flight trajectory. Time is available to identify and evaluate alternative courses of action, and to seek additional information to support the decision.
Weather Near-Term Decision Service (WNDS)	3 min < 20 min	Near-term decisions are of a planning nature, but with limited time available for comprehensive deliberation and/or coordination with ATC/AOC. They become more of a "tactical" nature when new METLINK information reveals hazardous or adverse conditions close to the aircraft's current position. Near-term decisions can take the form of reroutes, altitude changes, or operational status changes such as alerting and securing the aircraft cabin prior to a possible encounter with turbulence. There is usually time to identify and evaluate available alternative courses of action, and perhaps to seek additional information. Near-term decisions are made mostly to address the safety benefits described in EUROCAE ED-151 Section 3.1 [32].
Weather Immediate Decision Service (WIDS)	<3 min	Immediate decisions are those taken by the pilot within a few seconds to 3 minutes in order to avoid or mitigate an in-flight hazard, or to make a commitment to land or take off. They are generally unilateral decisions made by the pilot with very little

		or no deliberation. Such decisions are generally rule-or procedural based in nature.
Weather Downlink and Crosslink Service	-	In addition to METLINK transmissions of meteorological information to aircraft, aircraft can be used to carry sensors to detect and report meteorological and other environmental information and transmit that information to the ground and other proximate aircraft. Parameters such as temperature, wind, humidity, turbulence, icing conditions, volcanic ash, and other aircraft parameters as appropriate for wake vortex avoidance can be transmitted.

Table 5: MET services for pilot decision

Candidate METLINK Product	MET Data Category	Pilot Decision Support			Refresh Rate (+)	Validity (hours)	Common Usage Category (#)			
		WPDS	WNDS	WIDS						
Aerodrome Information										
* METAR	P	X	X		24-48	0.5-1	A	B		D
* SPECI	P	X	X		24-48	0.5-1	A	B		D
* Local Special Report	P	X	X	X	24-48	0.5-1	A	B		D
* Local Routine Report	P	X	X	X	24-48	0.5-1	A	B		D
* Trend Forecast	P	X	X		24-48	0.5-1	A			D
* TAF	P	X			1-6	6-30	A	B		D
Aerodrome Forecast - Tabular form	P	X			1-6	24				
Local Area Forecast	T	X			1-4	6				
* Aerodrome Warning	T	X	X		0-12	12				
* Wind Shear Warning	T		X	X	24-48	0.5-1				
* Forecast for Take off	P	X			48	0.5	A	B		
* Actual QNH	P	X	X		24-48	0.5-1				

Legend

MET Data Category		Pilot Decision Support Product Classification		Common Usage Category (circa 2007/8)	
P	Point Data	WPDS	Planning	A	Preflight planning
T	Text Area	WNDS	Near-Term	B	Displayed for crew and operators
V	Vector Graphic	WIDS	Immediate	C	Low level flight
G	Gridded Data			D	In-flight

Table 6: Extract of table 7-1 in EUROCAE ED-151 [32] (showing only aerodrome information products)

3.3   Aeronautical Operational Control (AOC)

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Airlines rely on AOC for communication between the flight crew and the Airline's Operational Control Centre (AOC) for flight regularity and efficiency purposes. AOC is also used by the flight crew to request weather information at airports or NOTAMs. AOC applications use either voice or data communication between the aircraft and the AOC centre, company, or operational staff at an airport. AOC communications are identified as necessary for continued efficient operation by airspace users. AOC services are concerned with the safety and regularity of flight and as such are defined in ICAO Annex 10 [33].

It is recognized that the number of AOC messages exchanged between flight crews and AOC, as well as their size will continue increasing and therefore the ICNS needs to provide for the necessary means to accommodate potentially high bandwidth demanding AOC data without prejudice to ATS other safety critical services. Identified AOC services are listed in Table 7, below.

Identified AOC datalink services		
AOC Data Link Logon (AOCDLL)	Airline Aircraft sequencing	FMC AOC reports
Out-Off-On-In (OOOI)	Airport Delay information	FMC PRG Progress Report
Notice to AirMen (NOTAM)	Airworthiness Statement	Flight Crew Recency Registration
Free Text (FREETEXT)	Autoland Registration	Flight Deck Duty Time Registration
Textual Weather Reports (WXTEXT)	Baggage Loading	Flight Journal Documentation
Position Report (POSRPT)	Catering inventory	Flow Control (CTOT & Routing)
Flight Status (FLTSTAT)	Central Maintenance Computing System	FOQA Data Transfer (DFDR/QAR bulk data download)
Fuel Status (FUEL)	Climb Wind Uplinks	Fuel Tickets / Fuel Release
Gate and Connecting Flight Status (GATES)	Company NOTAM's	Handling process Monitoring
Engine Performance Reports (ENGINE)	Company NOTAM's	Hijack report
Maintenance Problem Resolution (MANTPR)	Credit Card Authorisation service	In flight preparation of next Flight plan
Flight Plan Data (FLTPLAN)	Crew Briefings/Bulletins	In flight, Flight plan destination renegotiation

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Load Sheet Request/Transfer (LOADSHT)	Crew List	Landing Performance Calculation
Flight Log Transfer (FLTLOG)	Crew Rotation / Planning / Scheduling	Load documentation Acceptance/Rejection - eSignature
Real Time Maintenance Information (MAINTRT)	Delay Reports (Departure, Take off, Enroute, Gate)	Notice to Captain (NOTOC)
Graphical Weather Information (WXGRAPH)	De-Icing Request	On Board video
Real-time Weather Reports for Met office (WXRT)	Descent Wind Forecast	On ground 4D Business Trajectory negotiation
Technical Logbook Update (TECHLOG)	Diversion message	Optimisation of Flight Plan and Information on Weather and traffic Information
Cabin Logbook Transfer (CABIN LOG)	Electronic Flight Folder	Passenger Medical Examination
Update Electronic Library (UPLIB)	Electronic Airway bill	Passenger Information List/Manifest
Software Loading (SWLOAD)	Emergency Data Transfer	Pre-Flight Inspection Signoff
AOC Link Test (Company link Test)	Emergency Report	SIGMET update
Air-to-Air Free text	ETA	Software Loading (Part 25)
Aircraft Briefing Cards	ETA Management	Software configuration management
Identified AOC Datalink Services		
Aircraft Conditioning Monitoring System	ETS Report	Take-off Performance Calculation
Aircraft Door movements	Enroute Wind Uplink	Transfer Passenger Information

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Aircraft Health Management (monitoring)	ETOPS monitoring	Turbulence reporting
Aircraft Rotation/Flight Progress	e-Charts Update	Marketing Announcements
Aircraft Technical Log Rectification	e-Graphical Weather	Passenger e-mail/text messages
Aircraft Telemetry service	e-Reporting	

Table 7: Identified AOC services

3.4 Digital Voice

The ICNS is expected to support digital voice communications for the provision of ATS, and possibly AOC. A summary of the current voice operations, and status of future voice concepts are outlined in this section.

3.4.1 Overview on current voice operations

This section describes the current concept of operations and procedures in place for ATS voice communications and is intended as background information for the development of air-ground digital voice.

The Aeronautical mobile service (air-ground voice communications) is currently provided over VHF, HF and Satellite Voice technologies, while the Aeronautical fixed service (ground-ground voice communications) is currently provided over ground-based IP networks using VoIP. Figure 10 shows an example of different environments and control areas where voice communications take place.

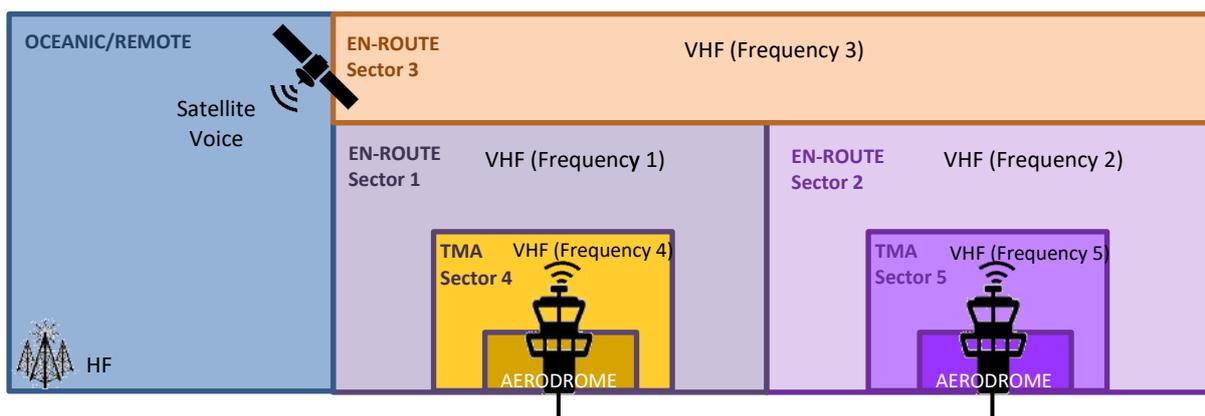

Figure 10: Voice communication environment

3.4.1.1 Air-ground (A/G) voice communications

ATS operations in controlled airspace are based on continuous two-way radio communication between pilot and controller. ICAO Annex 11 [29] requires air-ground communication facilities to enable two-way communications between a unit providing ATC service and appropriately equipped aircraft flying

anywhere within a given control area. Whenever practicable, the two-way communication should be "direct, rapid and continuous". Further details on Voice Communication Systems can be found in ICAO Annex 10, Volume III, Part II [35].

Continental airspace and Airport operations

On continental airspace, and according to each ANSP frequency planning, each airspace sector (En-Route/TMA) or aerodrome service (Ground control, Apron control, Delivery) has a VHF frequency assigned. Aircraft flying in a given sector or making use of a given aerodrome service need to use the defined frequency for receiving and transmitting voice communications. Currently deployed and operational radiotelephony VHF technology provides quasi-instantaneous transmission over the air from radio equipment to aircraft.

It is important to note that all information exchanged over a given frequency between controller and pilot, or between pilot and pilot is open to all other aircraft flying in the same sector, thus enhancing situational awareness. In addition, pilots are aware of the frequency usage, which minimises the chances of simultaneous transmissions.

Oceanic or Remote airspace

Air Traffic Control over oceanic or remote areas may, due to lack of VHF coverage, involve voice communication over satellite or over HF frequencies. Aircraft stations are required, if possible, to communicate directly with the air-ground control radio station. If unable to do so, aircraft stations shall use any relay means available and appropriate to transmit messages to the air-ground control radio station.

When operating over HF frequencies, the direct pilot-to-controller relationship that occurs on VHF air-to-ground channels is often replaced by communication through a communications operator. Use of SELCAL (Selective Call) is described in ICAO Annex 10 Volume II [34].

3.4.1.2 Air-air (A/A) voice communications

Although very rarely used, aircraft flying in the same sector (and therefore tuned to the same frequency) are technically able to communicate among themselves over the frequency in order to exchange messages related to safety and regularity of flight. In such cases, the duration of communication is controlled by the aircraft station, which is receiving, and the aeronautical station maintains watch on the frequency. A/A voice communications generally make use of specific voice channels allocated in 123.45 MHz (for oceanic airspace in line with ICAO provisions) or in state allocated frequencies (for continental airspace). The latter assignments are intended for General Aviation in non-controlled airspace, or in special events, and are not aimed to provide line pilots a frequency for private talks while crossing a sector.

3.4.1.3 Ground-ground (G/G) voice communications

The telephone call types needed to meet the operational ground communications requirements of ATM are known as "primary user ground telephone facilities" and are used for routine and urgent communications between ATS units.

The operation of primary ground telephone facilities between ATS units for ATC purposes is described in Annex 10, Volume III, Part II [35]. Further details on G/G voice communications can be found in ICAO

Doc 9804 – "Manual on ATS Ground-Ground Voice Switching and Signalling" [36] for legacy technologies and in EUROCAE ED-136 [37], ED-137 [38] and ED-138 [39] standards for implementation of ATM VoIP on the ground. These standards include supplementary ground telephone facilities defined in order to support primary ground telephone facilities (e.g. call identification, call priority, call intrusion or conferences).

3.4.2 Digital voice over SATCOM

Both SSPs (Iridium and Inmarsat) [40] have historically been using bespoke circuit-switch digital voice protocols and codecs on the air-ground link and PSTN on the ground-ground links. The ground-ground links operated by CSP (SITA, Collins) are now migrating towards VoIP. With the arrival of Inmarsat's SB-Safety [41] and Iridium's Certus [44] services, the two cockpit voice channels are also migrating towards a combination of circuit switch (1st channel) and VoIP (2nd channel) or 2x VoIP on the air/ground link. Nevertheless, it needs to be noted, that the choice of VoIP vs. CS voice on the air-ground link is driven primarily by the nature of the new systems, which are designed primarily to support IP data services. A bespoke CS voice is (and always will be) more bandwidth efficient than VoIP. It also needs to be reemphasized, that the use of any particular technology on the air-ground and ground-ground links is independent and none of the currently foreseen concepts for cockpit voice services assumes the use of end-to-end VoIP (i.e. all combinations of ground-ground VoIP or PSTN with air-ground VoIP or CS are supported and are transparent to the users). End to end VoIP calls can still be made using the native non-safety IP services of the SATCOM systems (e.g. use the onboard IPv4 service to connect from a laptop to a Skype, Teams, ZOOM or other type of call).

Future Low Earth Orbit (LEO) SATCOM constellations are expected to support 3GPP 4G and 5G services for digital voice over SATCOM. This will be investigated within the ANTENNAE research, as one of the options to better enable broader ICNS deployment.

3.5 Flight information exchange for Trajectory Based Operations (TBO)

The TBO concept assumes that ATM service providers, aircraft, and their FOCs adopt capabilities as dictated by ATM performance needs through-out the aircraft's trajectory. As the system evolves, some key properties of this evolution are:

a) **Pre-Departure Trajectory Information Sharing & Negotiation:** Considering the airspace known constraints, the airspace user shares its trajectory preferences, including alternative routes, with the ASPs [42][43].

b) **Post-Departure Trajectory Information Sharing & Negotiation:** The continuous and consistent sharing of flight information between the ground systems and airborne crew to ground with the goal of meeting the flight business objectives and trajectory predictions in all flight phases [42][43].

c) **Air-Ground Trajectory Synchronisation:** the use of data communication to deliver the air and ground predicted trajectory to the aircraft automation trough structured complex clearances for supplementing the basic trajectory information and avoid trajectories [42].

3.6   Application categorisation based on criticality

The applications described in this CONOPS will rely on the ICNS to provide the necessary means for A/G and G/G data exchanges. It is thus crucial that the ICNS provides an appropriate level of safety and performance, in line with the requirements of the above-mentioned communications. Table 8, below, provides an assessment of applications based on criticality.

	Tactical	Strategic
Safety-critical	ATS: • Future ATS • ATS-B2 (CM, CPDLC, ADS-C), • FIS, • Alerting Service. AIS/MET: • Aeronautical Update Service (DAUS), • WIDS, • WNDS. Flight information for TBO (may be supported by ATS B3): • Post-Departure Trajectory, • Information Sharing & Negotiation, • A/G trajectory synchronisation. Digital Voice: • AOC, • Emergency Report, Emergency Data Transfer).	ATS: • Air Traffic Advisory Service, • Civil/Military Coordination. AIS/MET: • Baseline Synchronization Service, • Ground AIM and MET dissemination. Flight information for TBO: • Pre-Departure Trajectory, • Information Sharing & Negotiation. AOC: • Flight plan, FOQA, AIS/MET information like NOTAM, weather report.
Non-safety-critical	AIS/MET: • WPDS.	AIS/MET: • Weather Downlink and Crosslink Service.

	AOC:	AOC:
	• Airline Aircraft Sequencing, De-Icing Request.	• Crew registration, Engine performance.

Table 8: Assessment of criticality of ATM applications

The quadrant in Table 8: Assessment of criticality of ATM applications proposes an initial categorization of ATM applications based on their safety-criticality and time-criticality. This represents a notional classification which sets the base for the security, safety and performance targets in Section 4.

Safety criticality. A service is considered safety-critical if it is necessary to provide traffic separation and weather avoidance, and a failure in the provision of these services create a safety hazard. Non-safety-critical services do not have an impact on these functions if they cannot be executed.

Time criticality. A service is considered tactical if it falls within the short-term timeframe (i.e. it needs to be completed within seconds or minutes to be a successful transaction). Strategic services fall within the long-term framework (hours or days).

3.7 Traffic Load Assessment

The objective of this section is to quantify the data traffic load expectations in the ICNS in the foreseeable future in order to derive operational requirements on volume and scale of supported traffic.

Table 9 depicts a sample projection over 20 years of the target fleet, both in terms of number of aircraft and in number of flights.

	2025	**2030**	**2039**
#aircraft	6,665	7,417	8,564
#flights	7.6M	8.5M	9.8M
#daily flights (assuming uniform distribution)	20,821	23,287	26,849

Table 9: Forecasted yearly aircraft and number of flights for target fleet

The peak application throughput would in this case be sufficient to estimate maximum traffic load expected on the ICNS network overall. Adjustments can be made to flatten the value considering that not all A/C make use of the peak throughput at the same time.

Table 10 provides a forecast of data rate for different categories of applications.

Application type		Peak throughput (kbps)		
		2020	2030	2040
Air Traffic Services (FANS 1/A, ATS B1, B2, B3)	Uplink	12.0	104.0	254.2
	Downlink	26.4	137.3	317.6
AOC (ACARS AOC, future evolution)	Uplink	3.8	19.0	39.4
	Downlink	3.5	18.4	40.9
AIS/MET (future aircraft information/meteorological services)	Uplink	-	7,261	15,000
	Downlink	-	161	405
AISD (airline information services)	Uplink	-	5,413	11,747
	Downlink	-	3,651	10,374
Voice (point-to-point SATCOM voice)	Uplink	118.9	178.4	246.6
	Downlink	86.2	129.3	178.7

Table 10: Peak throughput per application for ECAC

To estimate an overall data load in the ICNS network for a situation with a specific number of daily flights in the ECAC space, the following formula will be applied:

Data load $_{ICNS}$ = P $_{flights}$ * #daily flights * SUM $_{applications}$ (F * Application $_{peak}$).

Where:

P $_{flights}$ = % daily flights that are simultaneously operating during peak moment (rule of thumb 15-20%).

F = Correction factor if lower than peak application traffic is to be considered. If worst case (peak application traffic), then F = 1.

For example, to calculate the total data load for Uplink ATS + AOC in 2030, in a worst-case scenario:

*Data load = 0.2 * 23,287 * (104 + 19) = 572,860 kbps = 572 Mbps.*

4   Performance, safety and security targets

This section identifies preliminary end to end performance, safety and security targets for the provision of applications over the ICNS, based on the application classification in terms of safety and time criticality.

4.1   Performance targets

This section describes the currently applicable end-to-end performance targets for applications over the ICNS. These targets apply to the applications that are classified as time sensitive. Performance is mainly defined in terms of maximum transaction times. In addition, availability, continuity, and integrity figures define reliability of communication which also affects successful transaction time of the service.

4.1.1   ATS baseline 3

Table 11 compiles the preliminary performance requirements identified for ATS B3.

ATS-B3 Application	Required Performance	1-way e-t-e delay RCP [s]	1-way 95% e-t-e delay RCP [s]	Integrity RCP	Availability P RC
ADS-C	RSP 60	60	25	1E-5 per FH	0.999
CPDLC	RCP 60	60	30	1E-5 per FH	0.999
	RCP 240	240	110	1E-5 per FH	0.999

Table 11: Performance requirements for ATS B3

4.1.2   ATS baseline 2

Table 12 compiles the preliminary performance requirements identified for ATS-B2.

ATS-B2 Application	Required Performance	1-way e-t-e delay RCP [s]	1-way 95% e-t-e delay RCP [s]	Integrity RCP	Availability P RC
ADS-C	RSP 160	160	90	1E-5 per FH	0.989
	RSP 180	180	90	1E-5 per FH	0.989 (safety)

					0.9899 (efficiency)*
	RSP 400	40	300	1E-5 per FH	0.989
CPDLC	RCP 130	130	67	1E-5 per FH	0.989
	RCP 240	240	210	1E-5 per FH	0.989 (safety) 0.9899 (efficiency)*
	RCP 400	400	350	1E-5 per FH	0.989

Table 12: Performance requirements for ATS B2

* Note: This value applies to services supporting operational efficiency and orderly flow of air traffic.

4.1.3   Digital Voice

Performance levels for Digital Voice concept will be based-on typical voice performance requirements for 3GPP VoLTE (Voice over 5G).

4.1.4   AIS/MET

Table 13 compiles the preliminary performance requirements identified for time-critical AIS/MET Applications.

FIS Application	Operational Environment	Datalink Mode	e-t-e delay RCP [s]*	95% e-t-e delay [s]* RCP	Integrity RCP	Availability P RC
D-AUS	En route	Broadcast	260	180	0.999999	0.999999
		Demand				0.999999
		Contract				0.999999
	Terminal	Broadcast	90	45	0.999999	0.999999
D-WPDS	En route	Broadcast	260	180	0.999	0.999

		Demand	440	210	-	-
		Contract	260	180	0.999	0.999
	Terminal	Broadcast			0.999	0.999
		Demand	180	90	-	-
		Contract			0.999	0.999
	Airport	Broadcast	240	120	0.999	0.999
		Demand	440	210	-	-
		Contract	240	120	0.999	0.999
D-WNDS	En route	Broadcast	210	105	0.999	0.9999
		Demand			0.9999	
		Contract				0.9999
	Terminal	Broadcast			0.999	0.9999
		Demand				-
		Contract	90	45	0.9999	0.999
	Airport	Broadcast	120	60	0.999	0.999 9
		Demand			0.9999	-
		Contract				0.999
D-WIDS	En route	Broadcast	-	30	0.99998	0.99999
		Contract	-	30	0.99998	0.99999
	Terminal	Broadcast	-	10	0.99998	0.99999
		Contract	-	10	0.99998	0.99999
	Airport	Broadcast	-	30	0.99998	0.99999
		Contract	-	30	0.99998	0.99999

Table 13: AIS/MET performance figures

4.1.5   AOC

Table 14 recuperates the preliminary performance requirements identified for time-critical AOC.

	1-way 95% e-t-e delay	**1-way 95% delay CSP/SSP**	Integrity	Availability CSP/SSP	Availability AIRCRAFT
AOC Services	90s	45 seconds	1E-5/FH	0.999995	0.99

Table 14: AOC performance figures

4.2 Safety targets

These provisions affect the CNS services classified as safety-critical (i.e. ATS and TBO flight information, AIS/MET, Digital Voice, and safety-critical AOC).

4.3 Security targets

The changing role of data communications has a very significant impact on the communications services and requires an appropriate level of security if data communications is to become acceptable. Introducing one or more levels of security in ICNS is a demanding balancing act between security requirements, safety requirements, flight regularity, economic impact on stakeholders and technical interoperability.

The required security criticality (The need for protection against modification of message attacks, leading to loss of separation and denial of service attacks) is determined using a qualitative value (high, medium, low), for which it considers 3 parameters: Availability, Integrity and Confidentiality. The values of these parameters are part of the QoS policies configured for reliable applications. The ICNS should also provide a mechanism to log and report security events to support security audits.

Security attacks are common in IP networks. In the ICNS, where air/ground and ground/ground networks are interconnected, unauthorized electronic interactions can affect the integrity and availability of the entire communication infrastructure. Intentional modification of messages or masquerading a controller or pilot may lead to a loss of separation or confusion.

The goals of authentication and Integrity are to:

a) Prevent unauthorized modification of messages (loss of integrity),

b) Provide data origin authentication for uplink and downlink messages to prevent mis-delivery.

The network layer assumes that radio links are properly authenticated, authorized, and accounted in the lower layers. It is also assumed that in the upper layers the Baseline 2 defined context management (CM) is available for implementing certain required security functions that does not need to be repeated in the network layer. That could mean that no additional authentication or authorization is needed in the network layer.

However, security measures to improve protection against intentional breach of integrity and misdelivery are still required. This may include the use of IPSec, a public key infra-structure (PKI) for mutual peer authentication, verification and authentication of routing information exchanged over an air/ground data link, message integrity verification, and verification of packet source network address.

Denial of Service (DoS) attacks are the most common in IP networks, and can include packet flooding, radio jamming, and masquerading of routing information. Although it is assumed that radio subnetworks will support Layer 2 access authorization mechanisms, thus mitigating security attacks entering through the air interface, network measures need to be implemented to mitigate DoS impact and support a quick recovery of the system. This may include techniques such as packet filtering, port filtering and firewalls.

In addition, technical and legal measures would need to be implemented to identify, trace and pursue unauthorized radio transmissions. Also, physical security mechanisms have to be deployed by Administrations and Service Providers to prevent access to their Ground Networks to unauthorised parties, thus limiting opportunities for this mode of attack.

It is assumed that datalink encryption is implemented by underlying RAT, and end-to-end encryption is implemented at application layer (e.g. TLS/DTLS). Network layer encryption in the ICNS for ATM applications is thus considered optional. However, control plane information and applications for network management need to be adequately protected.

4.4   IP networks

The ICNS is expected to leverage the high standardisation and interoperability level of IP protocols and architectures to provide interoperable interfaces with other IP networks. This will enable dissemination of ATM information for stakeholders and relevant users outside the ICNS.

4.5   U-space/UTM networks

The European Commission has developed a vision for the phased introduction of procedures and services to support safe, efficient and secure access of UAS to airspace, called U-space/UTM. EASA Opinion No 01/2020 [45] proposes a regulatory framework for manned and unmanned aircraft to operate safely in the U-space/UTM. Since, the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) envisions all future aircraft equipped with 5G transceivers: integrated as "alternative" technology into legacy Avionics for Manned Aircraft and/or added as "primary" technology in Unmanned Aircraft (UAS), the ANTENNAE solution must support the current requirements of ATM and the developing requirements of U-space/UTM.

For U-space/UTM, the operation of UAS at Low Altitude and within dense urban environments where ground clutter (structures and terrain) create Line-of-Sight (LOS) challenges regarding RF coverage and where very specific Low Altitude flight paths may be specified, current GNSS services may not provide the positioning accuracy, reliability, and resiliency required for safe operation. Therefore, new A-PNT and A-SUR technologies may be needed.

In 5G networks, the Location Management Function (LMF) is a key network function (NF) responsible for determining and managing the location of user equipment (UEs), enabling precise positioning for various applications. The LMF receives location data from the Next Generation Radio Access Network (NG-RAN) and the UE and uses this information to compute the UE's position. Additionally, the phased-array antennas of 5G and future 6G network may be leveraged for A-SUR (radar sensing capabilities). The ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521) will investigate the use of 5G technology to optimize ICNS services for U-space/UTM.

5 Commercial networks, QoS and economics

There is a myriad of IP-based networks used for commercial purposes outside aviation, including cellular and satellite communication networks, and which provide exponentially increasing communication capabilities which could support future ATM and U-space/UTM concepts. It is reasonable to assume that the ICNS may interface with and leverage the use of these commercial networks to provide CNS as a Service (CaaS) across broader regional areas and at various altitudes.

5.1 Commercial network QoS

Quality of Service (QoS) must be maintained across all segments of the ICNS including private network segments directly controlled by the ICNS, CNS as a Service (CaaS) provider and those segments provided by other network operators (MNOs, Sat. providers, etc.).

5.2 Commercial networks and economics (comparative cost analysis and LCR)

The research to be conducted within ANTENNAE will include a techno-economic comparative analysis for 5G ICNS deployment, specifying the geographical coverage region and candidate reference network configurations (shared and dedicated) for low-altitude operations.

Research work will involve construction of an analytical model of revenue estimation which will be further used for the techno-economic analysis. This work will generate CAPEX, OPEX, and TCO for each configuration. Then, the recommended 5G Integrated CNS (ICNS) solution will be compared with one or more alternative solutions based-on other technology such as LDACS.

Additionally, for optimal routing of data traffic through the Integrated ICNS, both Fixed Network Costs (FNCs) and Variable Network Costs (VNCs) will need to be identified and validated for the Private 5G RAN and the use of other networks (MNO RANs, HAP, Sat.).

A central database will need to relate the following:

- KPIs and Performance Requirements

- available data "Routes"

- UE data (metrics)

- Route "Costs"

APIs could be used to access the centralized data, perform calculations, and provide the Least Cost Routing (LCR) of specific services (Communications, A-PNT, A-SUR).

LCR is a concept traditionally and very effectively applied to traditional voice telecom. networks where each direct or indirect network interconnection between end networks is assigned a cost per Minute of Usage (MoU). In combination with the application of network performance requirements such as Network Availability (minimum Blocking) and Latency, LCR ensures traffic is routed through a network at the least (optimal) cost. LCR can also be applied to an Integrated CNS.

6 Conclusion

This CONOPS describes the operational use of the 5G, Integrated CNS (ICNS) proposed for the ANTENNAE solution (ANTENNAE-01, STELLAR Solution ID 0521). It provides a preliminary definition of "Integrated" and provides a preliminary definition of "Low Altitude", with respect to the ICNS. This CONOPS describes the critical Communication (C), Navigation (N), and Surveillance (S) requirements for both Manned Aircraft, Air Traffic Management (ATM) and Unmanned Aircraft System (UAS) Traffic Management (UTM) within relevant (low-altitude) classes of Airspace and explains the Concept of Operations (CONOPS) components, based-on 3GPP (5G) standards, that will run the ICNS (provide CNS-as-a-Service) and support the Required Communication Performance (RCP) of critical C, N, and S safety services. Finally, this preliminary CONOPS summarises the potential functionality and operation of the ICNS.

Many of the concepts and requirements referenced in this preliminary CONOPS will continue to be research and will be refined within the subsequent CONOPS deliverables.

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8   List of acronyms

Acronym	Description
3GPP	3rd Generation Partnership Project
5G	5th Generation of Cellular Network
5GA	5G Advanced
A2X	Aircraft-to-Everything
ACARS	Aircraft Communication Addressing and Reporting System
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependant Surveillance – Broadcast
ADS-C	Automatic Dependent Surveillance – Contract
ADS-L	Automatic Dependant Surveillance – Light
ADSP	ATM Data Service Provider
AeroMACS	Aeronautical Mobile Airport Communications System
AIM	Aeronautical Information Management
ANSP	Air Navigation Service Providers
AOC	Air Operator Certificate
A-SUR	Alternate Surveillance
ATC	Air Traffic Control
ATS	Air traffic services
ATSP	Air Traffic Service Provider
ATSSS	Access Traffic Steering, Switching and Splitting
BS	Base Station
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CNPC	Control and Non-Payload Communications
CNS	Communication navigation surveillance
CPDLC	Controller Pilot Data Link Communications
CSP	Communications Service Provider
DME	Distance Measuring Equipment

ESA	European Space Agency
FAA	Federal Aviation Administration
FOC	Flight Operations Centre
GA	Grant agreement
GEO	Geostationary Earth Orbit
GNSS	Global Navigation Satellite System
HAPS	High Altitude Platform Station
ICAO	International Civil Aviation Organization
ICNS	Integrated CNS
ID	Identifier
ILS	Instrument Landing System
INS	Inertial Navigation System
IP	Internet Protocol
KPA	Key Performance Area
KPI	Key Performance Indicator
LDACS	L-band Digital Aeronautical Communications System
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MET	Meteorological Information Management
MLAT	Multilateration
MNO	Mobile Network Operator
MSP	Mobility Service Provider
NDB	Non-Directional Beacon
NM	Network manager
NR	New Radio
NTN	Non-Terrestrial Network
OSED	Operational service and environment description
OFDM	Orthogonal Frequency Division Multiplex
PI	Performance Indicator
PPK	Post-Processing Kinematic
PSTN	Public Switched Telephone Network
RAT	Radio Access Technology

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RTK	Real-Time Kinematic
S3JU	SESAR 3 Joint Undertaking
SATCOM	Satellite Communication
SDN	Software-Defined Networking
SDO	Strategic Deployment Objective
SESAR	Single European Sky ATM Research
SESAR 3 JU	SESAR 3 Joint Undertaking
SJU	SESAR Joint Undertaking
SRIA	Strategic Research and Innovation Agenda
TN	Terrestrial Network
TRL	Technology Readiness Level
UAM	Urban Air Mobility
UAS	Unmanned Aircraft Systems
USSP	U-space Service Provider
UTM	UAS Traffic Management
VCA	VTOL Capable Aircraft
VDL	VHF Data Link
VDL	VHF Data Link
VDL	VHF Data Link
VDLM2	VDL Mode 2
VHF	Very High Frequency
VOR	VHF Omnidirectional range
VTOL	Vertical Take-Off and Landing

Table 15: list of acronyms