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PJ14-W2 I-CNSS

INTEGRATED COMMUNICATION, NAVIGATION AND SURVEILLANCE SYSTEM

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Abstract

This Contextual Note provides an overview of the SESAR Solution PJ14-W2-76 Integrated CNS and Spectrum in terms of scope, results and recommendations based on work done in SESAR 2020 Wave 2. Given that SESAR Solution PJ14-W2-76 is a transversal solution, there are a number of sections which are not applicable.

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1 Purpose

This contextual note introduces the SESAR Solution PJ14-W2-76 Integrated CNS and Spectrum with a summary of the results stemming from R&D activities contributing to deliver it. It provides to any interested reader (external and internal to the SESAR programme) an introduction to the SESAR Solution PJ14-W2-76 in terms of the scope, results and recommendations based on work done. This contextual note complements the data pack comprising the SESAR deliverables. Given that SESAR Solution PJ14-W2-76 is a transversal solution, there are a number of sections which are not applicable.

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2 Improvements in Air Traffic Management (ATM)

The C-N-S concept comes from the early days of aviation and remains an important safety principle. Developed during the days of single systems, the logic is that while one part of CNS can have a complete failure, the other two parts enable, as a minimum, safe landing of aircraft. This has led to functions such as the designation of one specific SSR transponder code to indicate loss of communication. With increasing levels of traffic, a significant failure of one of the CNS elements is no longer an option. Therefore, each CNS element has increased its level of reliability and safety by adding redundant and diverse systems or multiple system layers. Both the safety philosophy and the increasing complexity of CNS have led to COM, NAV and SUR developing their systems independently, without much consideration of other CNS evolutions. Because of the current mix of digital and analogue technologies, performance-based concepts, and the introduction of GNSS in multiple areas of CNS, the traditional single system CNS safety concept is becoming difficult to maintain. The Integrated CNS and Spectrum concept has been developed in the SESAR program in order to manage the CNS concept's change and to address the existing and upcoming CNS challenges: integrated CNS is about considering the C, N and S domains as one. Concerning the CNS applications, this concept would integrate the individual C, N and S Performance Based concepts into a harmonized CNS Performance-based framework. Concerning the CNS infrastructure, this concept would imply that one domain could be used as a support for another domain. Ultimately, the infrastructure might be integrated into one single system providing the C, N and S services, but such a system would need to meet safety requirements and ensure full interoperability during the interim deployment phase. This evolution is not foreseen at the time of this writing.

The Integrated CNS concept has been addressed through three main axes:

- CNS Evolution Roadmap and Strategy: any large CNS evolution needs to be coordinated amongst all stakeholders in a stepped approach.
- Performance-based CNS paving the way for a future integration of the individual C, N, and S performance-based concept (currently being developed).
- Service-based CNS supported by a Performance-based approach, foresees the evolution of CNS, enabling the de-coupling of CNS services' provision from Air Traffic Services and ATM data services.

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3 Operational Improvement Steps (OIs) & Enablers

As a transversal Solution, it does not address any Operational Improvement Steps and Enablers. However, as part of the Solution Task 5 “Support SESAR CNS architecture”, the OI Steps and Enablers of other CNS/SWIM Solutions have been created and managed in EATMA on their behalf.

As a result, the current status of the roadmap elements (Solutions, OI Steps and Enablers) of PJ.14-W2 CNS/SWIM Solutions in EATMA is presented on Figures 1, 2, 3 and 4.

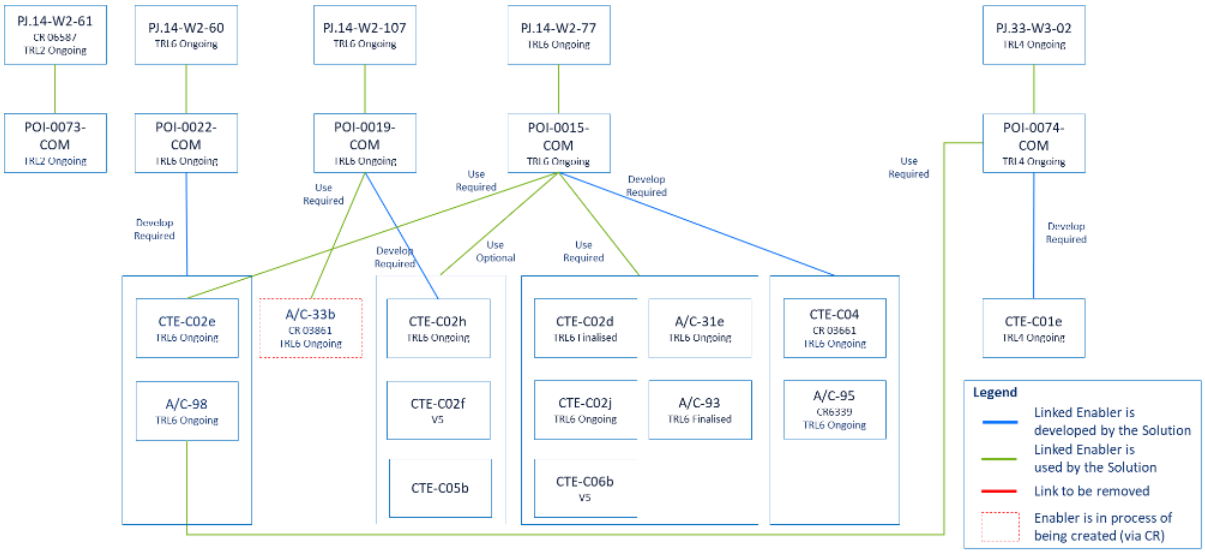

Figure 1:Overview of programmatic elements of Communication Solutions

Code	Title	Description
A/C-31e	Airborne part of A/G datalink exchange via ATN/IPS over VDLM2	Airborne part of the Air/ground datalink using ATN/IPS over VDL Mode 2.
A/C-33b	A/C SATCOM Long Term	An Aircraft Earth Station (AES) avionics equipment enabling the new SATCOM services defined in CTE-C02h. The changes include: - The air side of the new IPS SATCOM service, including the IPS data transport end point and the link status monitoring functions. (Should be software upgrade for the state-of-the art AES products.) - New interface to the airborne IPS system. (Depending on the particular aircraft architecture, this can be software-only or hardware + software change.)
A/C-93	Avionic Technology for the new Airport Data Link (AEROMACS) integrated with ATN/OSI and ATN/IPS	Avionic Technology for the new Airport Datalink (AEROMACS), based on IEEE 802.16 WiMax and supporting datalink exchanges over ATN/OSI and over ATN/IPS, both in standalone or multi-link environments. AeroMACS also supports the use of Digital Voice.

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Code	Title	Description
A/C-95	Airborne part of ATN/IPS and Multilink (FCI)	Evolution of the Airborne part of the A/G infrastructure to support multi-link (IP Router).
A/C-98	Avionic Technology for New A/G datalink using ATN/IPS over L-band	Avionic Technology for a new terrestrial A-G datalink (LDACS) to augment the VDL2 supported A-G datalink services based on ATN/IPS and operating in the L band.
CTE-C02d	Ground Technology for the new Airport Datalink (AEROMACS) integrated with ATN/OSI and ATN/IPS	Ground Technology for the new Airport wireless Datalink (AEROMACS), based on IEEE 802.16 WiMax and integrated with ATN/OSI and ATN/IPS, both in standalone or multi-link environments, as a new standard for airport surface communications (ATS, AOC and Airport Authority Communications) for the Aircraft and Vehicles. AeroMACS also supports the use of Digital Voice.
CTE-C02e	Ground Technology for new A/G datalink using ATN/IPS over L-band	Ground Technology for a new terrestrial A-G datalink (LDACS) to augment the VDL2 supported A-G datalink services based on ATN/IPS and operating in the L band.
CTE-C02f	Future Satcom for ATM: SATCOM Class B in Multilink	A new satellite A/G datalink to provide service redundancy to the existing terrestrial datalink VDL2, adapting the existing commercial SATCOM systems (i.e. SBB) and supporting also continental airspace in Europe, both in multilink and in a standalone environment.
CTE-C02h	Future Satcom for ATM - Long term Satcom (class A Satcom)	A new satellite A-G datalink to provide service redundancy to the new terrestrial datalink.
CTE-C02j	Ground part of A/G datalink terrestrial Infrastructure via ATN/IPS over VDLM2	Ground part of the Air/ground datalink using ATN/IPS over VDL Mode 2 to support continental ATC services.
CTE-C04	Future Communication Infrastructure - ATN/IPS and Multilink	Evolution of the Ground part of A/G infrastructure to support multi-link (IP Router).
CTE-C05b	Digital Voice / VoIP for ground segment of Air-Ground voice	Voice over IP (VoIP), based on ED137B VOL1: RADIO, is deployed for the Ground-Ground segment of the ATM Air-Ground voice communication. Networking of Radios is implemented to support the Dynamic Cross-border sectorization.
CTE-C06b	PENS - Phase 2	PENS phase 1 and in addition connectivity to other ATM Users and new datalink systems (SATCOM, AeroMacs, LDACS) as they become available. Covers potential infrastructure improvements to cover new requirements (i.e. multicasting etc.)

Table 1: Enablers description for Communication Solutions

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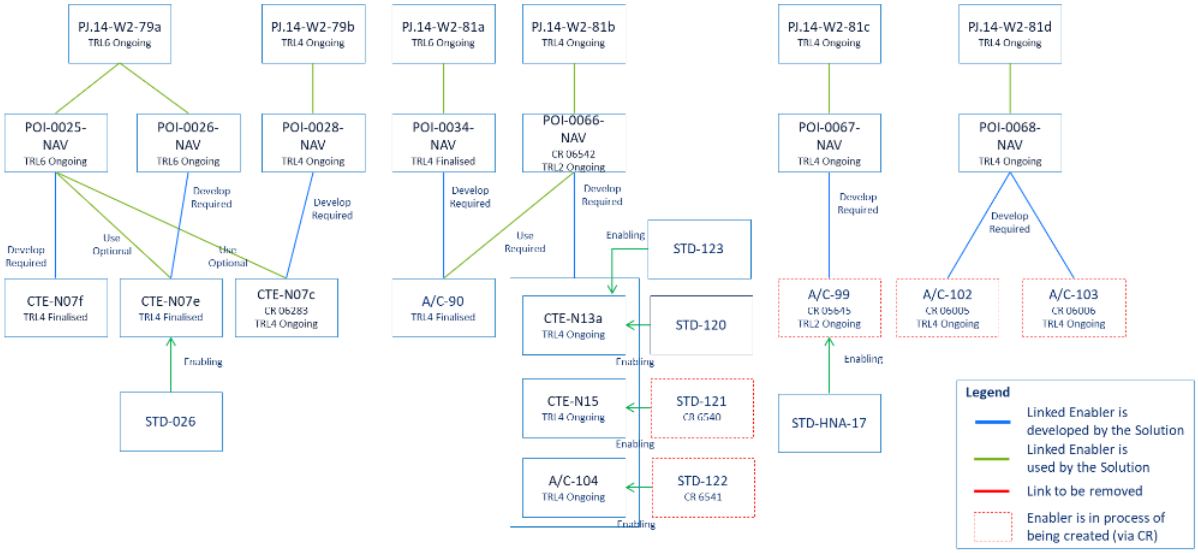

Figure 2: Overview of programmatic elements of Navigation Solutions

Code	Title	Description
A/C-90	Multi-DME positioning for RNP navigation	Provision of Multi-DME positioning supporting mid-term A-PNT solution fully compliant with RNP navigation requirements.
A/C-99	Use of LDACS for alternative Position, Navigation and Timing	Integration of LDACS to support PBN operations during an outage of GNSS.
A/C-102	Vision based navigation	Vision based navigation represent new innovative onboard navigation solution based on radar aiming at low visibility conditions and GNSS denied or degraded environment for approaches phase.
A/C-103	Terrain aided navigation	Terrain aided navigation represent new innovative onboard navigation solution based on Terrain map, Radar altimeter, Barometer and Inertial sensors aiming at low visibility conditions and GNSS denied or degraded environment for En-route phase.
CTE-N07c	GBAS Cat II/III based on Dual-Frequency / Multi-Constellation (DFMC) GNSS (GPS + GALILEO / L1 + L5)	Dual-Frequency / Multi-Constellation (DFMC) GBAS Cat II/III will support Cat II/III operations.
CTE-N07e	GBAS CAT II/III based on Single-Constellation / Single-Frequency GNSS (GPS L1) extension to equatorial and Nordic regions	GAST D extension to geographical areas with severe ionospheric conditions such as equatorial and Nordic regions. Monitoring and mitigation techniques are required to cope with the adverse ionospheric conditions.
CTE-N07f	GBAS robustness towards interference	This technical enabler supports GBAS CAT II/III SC/SF solution operating in airport environments that face technical problems related to RFI and jamming threat conditions.

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Code	Title	Description
CTE-N13a	Enhanced DME (eDME) ground transmission to enable alternative Position, Navigation and Timing	Provision by a DME ground transponder of active (conventional two-way) and passive (one-way) ranging including uplink data transmission of station ID code.
STD-026	ED-114B, MOPS for GBAS ground systems to support precision approach and landing (CATIII)	GPS L1 Operations, planned by EUROCAE for Q2 2018.
STD-128	provisions for LDACS (L-band Digital Aeronautical Communications System) including SARPS, Validation Report and Manual	To be checked that this will indeed address also the navigation part of LDACS.
STD-HNA-17	Harmonizing standard for 'A-PNT (Alternative Positioning Navigation and Timing)'	Standardization activity either on-going or planned by EUROCAE.
STD-123	Update of EUROCAE ED-57A for eDME	Update of the EUROCAE ED-57A to address eDME functionalities.
STD-121	Update of EUROCAE ED-54 for eDME	Update of EUROCAE ED-54 for eDME to enable processing of one-way ranging.
STD-122	Update of MIL-STD-291C to support eTACAN	Update of MIL-STD-291C (US Department of Defense Military Standard: Standard Tactical Air Navigation (TACAN) Signal) to support eTACAN A-PNT operations.

Table 2: Enablers description for Navigation Solutions

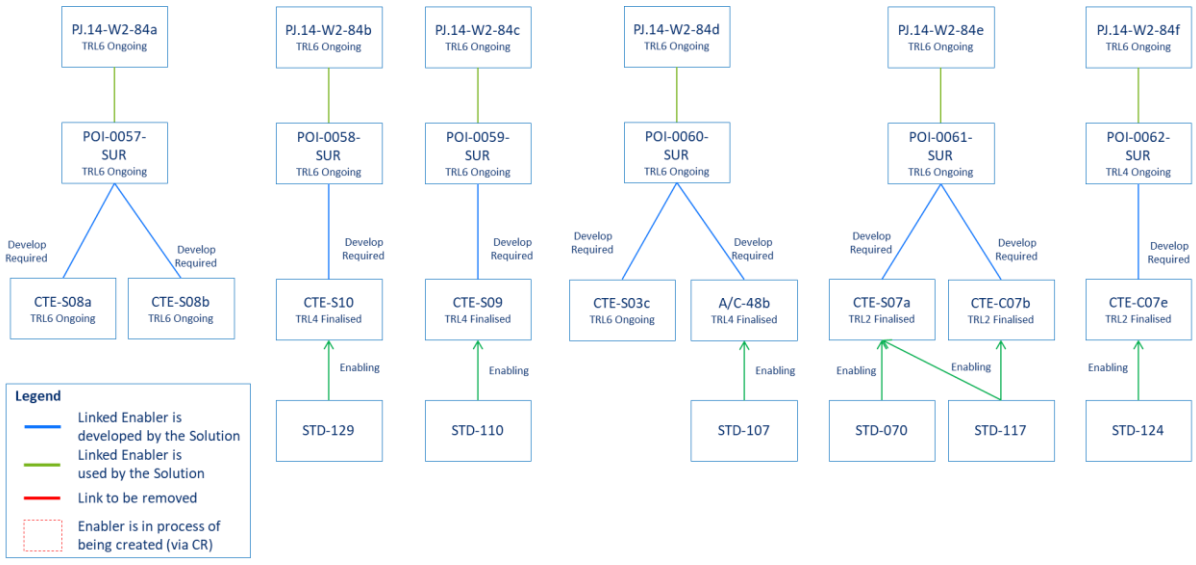

Figure 3: Overview of programmatic elements of Surveillance Solutions

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Code	Title	Description
A/C-48b	Air broadcast of aircraft data (ADS-B OUT) compliant with new DO260C standard	Air broadcast of aircraft data (ADS-B OUT) compliant with new DO260C (e.g. phase modulation, additional 4DT data to support ASAS separation, static/dynamic wake turbulence data and other weather hazards, etc.)
CTE-S03c	New ADS-B station for future ADS-B applications	ADS-B station for provision future ADSB applications, receiving ED102B Phase overlay squitter format.
CTE-S07a	Coop sensor SPM Tool – ER & TMA	Surveillance Performance Monitoring Tools, seeking to identify surveillance degradation trends early, using both off-line and in continuous quasi real-time processes, applied at sensor level (cooperative, supporting En-route and TMA).
CTE-S07b	Coop sensor SPM Tool – Surface	Surveillance Performance Monitoring Tools, seeking to identify surveillance degradation trends early, using both off-line and in continuous quasi real-time processes, applied at sensor level (cooperative, supporting airport surface).
CTE-S07e	SUR Chain SPM Tool – ER & TMA	Surveillance Performance Monitoring Tools, seeking to identify surveillance degradation trends early, using both off-line and in continuous quasi real-time processes, applied at the output of the entire surveillance chain sensor level (Cooperative & Non-cooperative, supporting En-route and TMA).
CTE-S08a	SUR Chain ER & TMA (MSPSR)	Enhancement of the data fusion for ER and TMA surveillance chain integrating new non-conventional NC sensor MSPSR and investigating new surveillance features such as the on-line monitoring of the surveillance chain levels of services.
CTE-S08b	SUR Chain ER & TMA (Space-based ADS-B)	Enhancement of the data fusion for ER and TMA surveillance chain integrating space-based ADS-B source.
CTE-S09	Secured surveillance	Secured surveillance functionality enables the detection, reporting and when possible, mitigation of security threats of different nature that could affect to the surveillance chain.
CTE-S10	MRTC – Surveillance (Multi-Remote-Tower-Control-Surveillance)	The Multi Remote Tower Module is complemented with a cost-efficient surveillance solution that integrates new combinations of Non Cooperative Surveillance Sensors and Cooperative Surveillance sensors. Data fusion of Electro-optical sensor, Mini-MLAT, non-rotating Mode S radar and ADS-B will be investigated.
STD-070	ED-142A Technical Specification for Wide Area Multilateration (WAM) Systems	Technical Specifications for ground components of the ADS-B / WAM system solutions. ADS-B + WAM composite surveillance.
STD-107	EUROCAE ED-102B / RTCA DO-260C	Minimum Operational Performance Standards (MOPS) for airborne equipment for Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Service – Broadcast (TIS-B) utilizing 1090 MHz Mode-S Extended Squitter. This document supersedes ED-102A and contains the following main changes: • Addition of Phase Overlay Modulation • Support for Flight Deck Interval Management Applications

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Code	Title	Description
		• Improved Geometric Altitude Reporting • Specification of a Position Message Format Algorithm • Deletion of T-Bit Handling • Transmission of Air and Pilot Weather Reports • Transmission of Reply Rate Monitor Message • Support for UAS/RPAS Operations • Support for Sub-orbital High-Velocity Operations.
STD-110	ASTERIX Cat 246 - Transponder validation report	The purpose of the CAT 246 transponder validation report is to provide a container for the provision of validation information regarding the behavior of a specific transponder. As the plot is moving along the surveillance chain, beginning with its generation to its final processing by the SDPS providing the situation awareness, the CAT 246 report is designed to collects information provided by multiple systems. In addition to the provision of a specific validation result, a design goal for CAT 246 was to be able to preserve meta data (data describing data) e.g. the system identification which conducted a specific validation.
STD-117	EUROCAE ED-129C	A new version of existing EUROCAE ED-129B standard related to technical specification for a 1090 MHz extended squitter ADS-B surveillance system.
STD-124	EUROCAE ED-261 Safety and performance requirements standards for a generic surveillance system	EUROCAE ED-261 related to safety and performance requirements standards for a generic surveillance system.
STD-129	Update of EUROCAE ED-87	Update of the EUROCAE ED-87 standard to cover a performance class below current A-SMGCS.

Table 3: Enablers description for Surveillance Solutions

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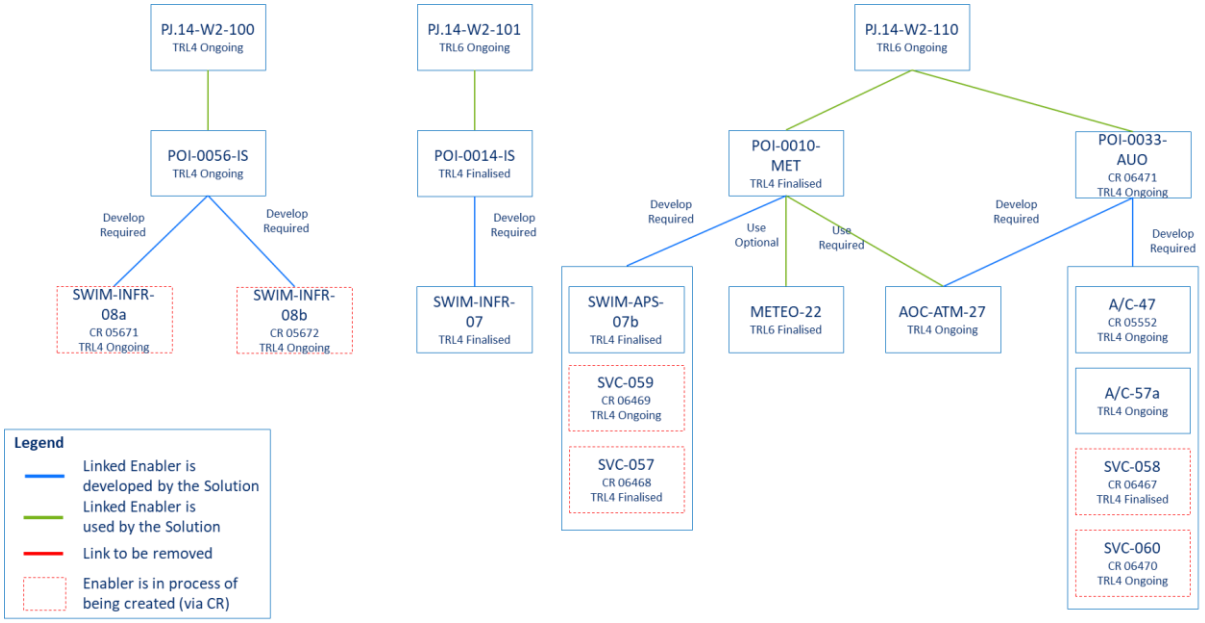

Figure 4: Overview of programmatic elements of SWIM Solutions

Code	Title	Description
A/C-47	On-board management of meteorological data from on-board sensors for sharing and integration by ATM and ATM-MET systems	On-board management of meteorological data acquired or derived from on-board sensor for the downlink to the ground system. This includes the data acquisition and derivation itself and the hand-over to on-board systems. The information can be used to improve nowcast and forecast capabilities that enable ATM systems or the information can be used directly by ATM systems. This does not include the downlink to the ground which is covered by other Aircraft enablers according to the use of the data.
A/C-57a	Management of MET, and AIM and other operational Information for use in aircraft information domain	The on-board processing and distribution of MET and AIM and other operational information including the interpretation and representation of this information within the aircraft information domain.
AOC-ATM-27	AOC/FOC subsystem providing preliminary filtering and pre-processing of MET, AIM and other operational information	An AOC/FOC subsystem which obtains MET, AIM and other operational information from external ground and on-board sources and provides preliminary filtering and pre-processing of the acquired information in order to support collaborative strategic trajectory management.
SVC-060	Space Weather Management	GNSS data from external sources, from ground and aircraft is used to elaborate expected GNSS performance reports or maps. The respective functions and FB are summarised in this Enabler.
METEO-22	Processing of Convection Cell detection	Abstraction and processing of input data like radar, satellite, and lightning data to derive convection cells.
SVC-058	Aircraft Derived Turbulence and Wind	Service representing downlinking of wind and turbulence (EDR) data derived from aircraft.

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Code	Title	Description
SVC-057	Cb Turbulence	Thunderstorm information derived from satellite data is combined with aircraft derived turbulence information for better information and awareness of weather hazards En-route.
SVC-059	Consolidated Turbulence	Aircraft derived turbulence data is collected from several aircraft and for a longer time frame. The service provides turbulence information for a requested area. The service design allows to enrich and combine aircraft derived turbulence with turbulence information from other sources (e.g. NWP, pilot reports).
SWIM-APS-07b	Consumption by Ground Systems of Meteorological Information services for Trajectory Based Operations	Ground systems evolve to consume SWIM enabled services for meteorological information exchange.
SWIM-INFR-07	Ground/Ground SWIM technical infrastructure for civil-military SWIM-based on-high-critical exchanges	This SYS EN is dedicated to the SWIM Technical Infrastructure Green Profile (GP) aiming at supporting ground/ground civil-military SWIM-based on high-critical exchanges. In Wave 1, the baseline for GP is the EUROCONTROL Yellow Profile (YP) 1.0 specification. GP encompasses Quality of Service (QoS) extensions to YP 1.0 to enable a wider scope of SWIM services requiring more security, resilience, performance (time-constraint SWIM services) and the support of sensitive data. Civil and military stakeholders willing to use SWIM services requiring this extended QoS should deploy GP SWIM nodes (technical systems).
SWIM-INFR-08a	Ground side SWIM technical infrastructure for safety critical Information Sharing	Ground Purple Profile is a Technical System representing the ground SWIM Node of the Air–Ground SWIM infrastructure for safety-critical information sharing. It provides ground side functionalities like secure and reliable messaging, overload protection, monitoring and recording supporting the 4D Trajectory exchanges, and other safety/time critical uplink and downlink exchanges based on SWIM Services between the Aircraft and ground systems.
SWIM-INFR-08b	Air side SWIM technical infrastructure for safety critical Information Sharing	Air Purple Profile is a Technical System representing the air SWIM Node of the Air–Ground SWIM infrastructure for safety-critical information sharing. It provides air side functionalities like secure and reliable messaging, monitoring, and recording supporting the 4D Trajectory exchanges, and other safety/time critical uplink and downlink exchanges based on SWIM Services between the Aircraft and ground systems.

Table 4: Enablers description for SWIM Solutions

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4 Background

This SESAR solution is a transversal solution and thus, does not follow the validation process defined for an industrial solution. However, this solution has been matured through a series of expert analysis by means of communication, dissemination, and review. Deliverables have benefited of wide consultation within the CNS community:

- SESAR Digital Academy
- Communication, Navigation and Surveillance EUROCONTROL Steering Groups
- ITU webinars
- EUROCONTROL Aviation Learning Centre webinars
- Meetings of the National Military Experts nominated to SESAR (MEPS)
- AEROSPACE TechWeek
- ICNS Conference

All three deliverables from Solution Data Pack D2.2 - PJ14-W2-76 iCNSS Transversal Version 2 have passed the following stages of internal and external review:

1. Intermediate and final drafts were reviewed by Solution members.
2. After internal approval the final draft deliverables were distributed to the SESAR PJ14 Project Manager and PJ14 Solution leaders.
3. Finally, the external review was carried out by experts from the Joint CNS Stakeholder Platform (J-CSP).

Moreover, in addition to the formal review process, the deliverables were considered as reference by the CNS Advisory Group (established by DG MOVE) and ICAO Integrated CNS and Spectrum Task Force.

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5 Results

D2.2.100 - PJ14-W2-76 CNS Service Assessment Version 2

The deliverable D2.2.100 extensively studied and cross-checked the findings and results of several key documents and regulations. This work highlighted a strong consistency between all the reference documents, which allowed to gather in one single document all the information related to the service-based approach in CNS. It also supports the idea, under certain conditions, of transition from a technology-based approach to a performance-based approach.

The analysis of the stakeholders in a CNS service-based environment shows that the current stakeholders will be impacted by such transition and that new stakeholders – or current stakeholders with a different portfolio - will have to be set up and position themselves into the future business environment. Decoupling followed by the reintegration into other services will have to be carefully managed to avoid service duplication or shortage.

The potential CNS services' transition decision should be assessed against the minimum following criteria:

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

Ideally, the evolution of a CNS service should be solely demonstrated by a positive "technical and business case" between the CNS service as currently provided and within the future architecture. But this document does not provide a complete set of criteria because the governance aspects are still to be defined by the relevant stakeholders. Only the technical criteria are assessed and an example in each domain is provided, including the data services. Resilience and scalability remain topics difficult to forecast due to the continuous technological evolution in the information technologies and the high rate of obsolescence of technology in general. Finally, a summary of benefits and risks linked to the CNS service-based approach is provided.

D2.2.200 - PJ14-W2-76 CNS Evolution Roadmap and Strategy Version 5

Key achievement of this solution is the maintenance of the CNS roadmap and strategy initially developed under SESAR 2020 PJ14.01.01, defining the short, medium and long-term evolution of the CNS infrastructure and application.

The development of this roadmap took as inputs relevant strategic documents such as FlightPath 2050, IATA Vision 2050, the ICAO Global Air Navigation Plan and the European ATM Master Plan and is the result of applying a combined top-down and a bottom-up approach. The top-down approach considered the SESAR vision for the evolution of ATM and in particular, the essential operational changes on the CNS infrastructure. This vision foresees the evolution of CNS towards a service-based approach and a performance-based approach, enabling the de-coupling of CNS services provision from ATM data and air traffic services. The bottom-up approach identified the CNS systems being developed. Given that developing, standardizing and deploying a system in aviation requires more than a decade, the identification of the current development provides a fair view of the short to mid-term evolution.

The combination of the top-down and bottom-up approach led to the definition of CNS target architecture, the development of a transition path, and the identification of the CNS rationalisation opportunities. The CNS target architecture will be composed of three layers: performance-based CNS applications supporting the operational services, a backbone of recent and global technologies, in the form of secure CNS services, and minimum operational networks (MON) of the legacy infrastructure providing a back-up or an efficient supporting backbone. The development of a transition path towards that target architecture identified a 2025 rendezvous with the deployment of an efficient multi-datalink capability, the composite surveillance and the use of dual-frequency and multi-constellation GNSS. Along the transition path, legacy systems can be rationalised, most of the rationalisation being enabled by this 2025 rendezvous.

The initial version of this roadmap developed in SESAR PJ14.01.01 has been widely reviewed by the CNS community at both technical and decision-taking level through the EUROCONTROL working groups (Navigation Steering Group, Communication Steering Group, Surveillance Steering Group, Joint CNS Stakeholder Platform, Agency Advisory Board); the SJU agreement with airspace users, and the 2018 CNS symposium organised by EUROCONTROL and bringing together more than 350 participants from the community. Following the agreement reached during this wide review, the core content of this document has been updated and fully incorporated into the 2020 Edition of the European ATM Master Plan.

Within SESAR PJ14 Solution 76, additional content has been developed in the subsequent version of this document, providing a better context on the CNS evolution, increasing the readability of the document but also clarifying some specific topics addressed in dedicated annexes. However, core content (key implementation technology and dates) remained unchanged, ensuring a full alignment between this document and the 2020 Edition of the European ATM Master Plan.

D2.2.300 - PJ14-W2-76 CNS Performance Based Version 4

Continuity, Availability, Integrity performance requirements are the same for CNS and positional Accuracy is a key parameter for NAV and by default is a requirement for SUR when we consider ADS-B. It is important to highlight that Accuracy parameter is strictly connected to Time Accuracy which is playing a key role for COM (datalinks), NAV (ranging function), and SUR (MLAT and data fusion). CNS infrastructure monitoring performance requirements described in ICAO and EUROCAE standards and parameters that are monitored are found to be not fully compliant. This confirms that there is a transition still ongoing from describing systems/technologies specifications to performance-based requirements or parameters.

The Performance-based CNS approach by its nature gives the possibility to select the most appropriate equipment to perform a safe flight operation, however it may also lead (in different countries) to an

excessive fragmentation of proposed equipment and systems requiring even more costly adaptation by the end-users. In order for this risk to be mitigated interoperability and standardisation should be underscored as well as a strong, agile and consolidated governance built on consensus but from the other side it could bring a wide range of potential CNS technologies that at some point will need to have end-user equipment on-board of the aircraft and fit to the flight management system. The transition period requires a good planning as for getting the benefit the most fleet should be equipped. This is also opening the discussion related to the most sensitive resource for all CNS systems which is spectrum. There are two major paths for moving to performance-based CNS, the long-term path is to complete development and start deployment of new technology, and the short term is to adapt and update currently installed on-board capabilities. In any case both ways would require a strong accent on cyber-security aspects and monitoring of a wider range of spectrum.

Performance-based CNS can offer different technological solutions which could fit the need of the stakeholders. This risk appears in case of regional implementation of a specific technology so far it is mitigated through ICAO Global Air Navigation Plan (GANP) Aviation System Block Upgrade (ASBU) implementation. This is also planned to be ensured through the CNS Programme Manager proposed by CNS Advisory Group Report, where the mitigation to avoid 'excessive proliferation of technologies/solutions that would increase overall costs and technical/operational complexities' is planned to be done by a balanced approach using the CNS evolution plan that should define a limited number of interoperable solutions that AUs can choose and ANSP have to support, to meet operational needs.

D2.3.120 - PJ14-W2-76 Report from simulation with pilot in the loop Version 2

EUROCONTROL completed a study in SESAR Wave 2 PJ14 Solution 76, investigating the functionality, performance and operational use of holding functions available in different aircraft Flight Management Systems. The study was based on aircraft flight manual reviews, review of standards (ICAO Doc 8168 Vol II, RTCA DO-236C/EUROCAE ED-75D and RTCA DO-283B) and simulations using professional EASA Level D certified flight crew training simulators. The simulators were equipped with digital data recording and video recording functions. The holding function was evaluated in 10 aircraft types with different Flight Management Systems.

Different sets of procedure design criteria for holding in ICAO Doc 8168 (PANS-OPS) were reviewed. There are currently two sets of criteria for RNAV holding: RNAV holding requiring an RNAV holding function and RNAV holding not requiring an RNAV holding function. Requirements for the latter are based on the conventional holding criteria. There are currently no developed industry standards for an RNAV holding function although the MASPS and MOPS (RTCA DO-236C/EUROCAE ED-75D and RTCA DO-283B) have criteria for RNP holding.

The characteristics of the available holding functions in the 10 aircraft / FMS combinations were investigated and are documented. A set of 32 holding scenarios was flown with maximum wind from four different directions, using holding entry procedures from four different directions. Both timing and distance-based holding patterns were flown. The flown holding trajectories were sorted and plotted for each aircraft type, for the four different wind directions and for both the time and distance-based holding patterns.

The plotted tracks were compared with the primary protection areas for both RNAV holding requiring an RNAV holding function and for RNAV holding not requiring an RNAV holding function. It was found that all the tracks were within these protection areas. Based on the visualised tracks, the assumptions in PANS-OPS regarding the criteria for RNAV holding requiring an RNAV holding function were

evaluated. Whereas in some quadrants, the recorded tracks were close to the protection areas, in other quadrants the protection areas have a relatively large volume of unused airspace. Most of the volume of the protection areas is consumed by the holding entry procedures. Because the aircraft needs to overfly the holding fix before starting the entry procedure, large overshoots of the inbound holding axis happen on the non-holding side, especially for parallel and direct-close-to-parallel entry procedures. This is not the case with RNP holding including the RTCA DO-236C/EUROCAE ED-75D and RTCA DO-283B recommended entry procedures. The latter function is only available in a subset of the fleet currently but has great potential to significantly reduce the required airspace for holding procedures.

D2.3.230 - PJ.14-W2-76 Support to SESAR CNS Architecture Version 3

As part of the PJ.14-W2-76 Task 5, the following results have been achieved:

- Up-to-date programmatic elements (Solutions, OIs, Enablers) of CNS/SWIM Solutions in EATMA that will be reflected in ATM Master Plan roadmap.
- Modelled architecture content of sufficient quality of all CNS/SWIM Solutions in EATMA.
- Coherent and consistent architectures and requirements of CNS/SWIM Solutions.

A detailed overview was presented in Section 3.

6 Recommendations and Additional activities

D2.2.100 - PJ14-W2-76 CNS Service Assessment Version 2

The definition of CNS services and CNS service provision will provide a global framework for services which are different in nature and in their relationship with the CNS data services. The governance of the CNS services is not addressed in this deliverable, which does not allow this document to provide a full set of criteria for concluding on the potential for transitioning to a service-based approach. The governance of the CNS services is the main topic to clarify at the current stage of development of the CNS services. Once this essential point defined:

- The business models and service levels could be expanded to every CNS service, beyond the examples given in this document.
- The charging scheme will most probably have to evolve to take into account the specifics of the implementation models.

On the technical side, the CNS services must be designed from an end-to-end perspective to comply with specific end-to-end performance requirements This will require for example to include the ground-ground communications which have not been developed in the context of this deliverable.

Some technical criteria listed in CNS Service Assessment deliverable results (Section 5) for transition to a service-based solution have been consolidated from the reference documents. These criteria must be complemented by the ones coming from the governance scheme still to be designed by the relevant stakeholders (e.g., defining the new ATM roles within an updated regulatory framework of the CNS Data Provider, the Common Data Layer Provider and the ATM Data service Provider and of the other stakeholders).

D2.2.200 - PJ14-W2-76 CNS Evolution Roadmap and Strategy Version 5

EUROCONTROL CNS Symposium 2018

To reach the operational, technological and human goals set out for the CNS domain through the long-term roadmap, it appears as urgent to take this domain in consideration and to dedicate proper effort. As outcomes of the CNS Symposium organized by EUROCONTROL on October 2018, and the feedback received from stakeholders at World ATM Congress 2018 & 2019, the following recommendations were identified:

1. **Strong leadership and a program management approach is required with the proper governance**: a seat to all stakeholder should be ensured.
2. **Generate trust**: confidence on the roadmap implementation is needed for investment plans
3. **Costs need to be compensated with benefits**. Route charges need to evolve in order to:
    - better distribute the benefit from CNS evolution
    - better reflect what is being used by Airspace Users

In particular, these recommendations could be detailed as:

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1. **To challenge and change the way spectrum is considered in aviation and to establish a proper spectrum management approach.** This approach should ensure spectrum availability for future aviation operations by developing an agreed spectrum long-term view and strategy and by improving the collaboration between strategic policy makers, CNS development and spectrum experts.
2. **To tackle the security challenges, including cyber-security** of evolving from fully open C-N-S services to a fully secured CNS service.
3. **To support standardisation**, considering that an average of 10 years is necessary to develop a standard, this would alleviate the risk to have technology ready for the long-term objective but not implementable due to lack of associated standards.
4. **To strengthen the civil-military collaboration in strategic development** to achieve a full and seamless interoperability.
5. **To prioritize the CNS development** on the following critical areas:
   - Support the development of an efficient and high bandwidth datalink system: AeroMACS for surface operation, LDACS for continental operation, SATCOM for oceanic or remote operation at first. SATCOM could be extended to continental operations over time, where its capabilities are able to meet the appropriate requirements in a denser airspace
   - Study the potential use of a next generation datalink system for CNS services
   - Support the development of future IP-based communications
   - Support the development of DFMC GNSS for all phases of flight associated with the implementation of PBN procedure and precision approach down to CAT III
   - Support the development of an Alternate Position Navigation and Timing (A-PNT) system that would meet the performance requirements, would be spectrum and cost efficient, and would provide backward compatibility and support legacy systems
   - Support the development of Performance-based Surveillance applications
   - Support the development of efficient Surveillance systems capability (ADS-B, MSPSR etc.) enabling ground and airborne applications
   - Support the development of integrated CNS Performance-Based concept
6. **Develop incentive programmes** to break the vicious circle of airlines not equipping because procedures do not exist and ANSPs not developing procedures because airlines are not equipped. These programmes should be inclusive, available for all and realistic in terms of required resource to claim them. An appropriate indicator of the relevance of such programme may be the consistency between the level of use of the network and the level of access to them.

European Commission CNS Advisory Group

The content from this document has been fully incorporated in the ATM Master Plan Edition 2020. Following the development of this edition of the Master Plan, DGMOVE established a CNS Advisory Group to develop recommendations to ensure the best possible management and implementation of the CNS infrastructure. The CNS Advisory Group has identified the following key issues that hamper successful CNS implementation:

- Pan-European CNS deployment is slow.
- The CNS infrastructure redundancy layers and geographic locations are not optimised.
- The variety of airspace users' needs and constraints prevents efficient and timely deployment.

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- CNS infrastructure is not sufficiently spectrum-efficient, and is not sufficiently protected against security threats.
- CNS interoperability requirements and compliance demonstration have not been fully addressed. The lack of harmonized compliance framework resulted into additional delays, duplication of efforts, and costs for airspace users and ANSPs.
- There is a lack of European wide CNS Programme Management addressing the full life cycle of the CNS infrastructure.

The CNS Advisory Group has developed the following recommendations, aimed at achieving a more comprehensive, reliable and accurate planning for CNS implementation; proposing incentives for voluntary implementation complemented by smart(er) regulations; improving management and governance; and consider human dimension aspects:

1. Translate the Master Plan's CNS roadmap into a 'CNS evolution plan' with short, medium and long-term objectives, priorities and decision points.
2. Improve cost-efficiency through rationalisation, including decommissioning of CNS facilities, maintaining robustness while ensuring safety and security.
3. Implement CNS infrastructure applying a technical performance[1] based approach in a way that is simple and cost-efficient.
4. Conceive an integrated CNS evolution maximising synergies and addressing security for Communication, Navigation and Surveillance services.
5. Develop a long-term EU strategy and policy to improve aviation spectrum efficiency as a driver of the CNS evolution.
6. Reduce the greenhouse gas emissions of the CNS infrastructure to maximise aviation's contribution to achieving European net zero carbon emissions targets.
7. Demonstrate operational and technical interoperability and scalability[2] of the infrastructure before deployment.
8. Develop robust CNS implementation business cases involving stakeholders at the earliest possible opportunity.
9. Ensure smart use of incentives to support stakeholders in implementing the CNS evolution plan.
10. Apply a smart(er) approach when developing technical CNS regulations to support the implementation of the CNS evolution plan.
11. Establish a holistic CNS programme management to ensure successful implementation of the CNS evolution plan using or adapting existing entities to maximum effect.
12. Consider the importance of the human dimension aspects related to the evolution of the CNS infrastructure.

[1] If not otherwise specified, this term refers in this report to the technical performance of CNS systems (e.g. accuracy, availability, latency, integrity,…) and should not be confused with the definition in the ATM performance and charging scheme in the SES (i.e. safety, capacity, environment, and cost-efficiency).

[2] Scalability is defined here as a system's ability to increase or decrease in performance and cost in response to changes in the operational requirements.

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Although these recommendations do not strictly come from the SESAR PJ14 Solution 76, the solution supports these recommendations and they represent a fair, sustainable and coordinated evolution of the initial recommendations established within this solution.

D2.2.300 - PJ14-W2-76 CNS Performance Based – Version 4

The Performance-based approach for CNS requires a comprehensive number of performance-based specifications and requirements in order to meet operational needs while ensuring safety, security and cost-efficiency. It is important to make such developments in a coherent manner across all the CNS domains. The Civil-Military Performance-based CNS aspects highlight that the complex interdependencies between civil and military stakeholders need to be examined to enable appropriate performance measurements in a spirit of balanced consideration between commercial needs and security and defence requirements.

Applying of Performance-based CNS approach to the Airspace Concept such as Free Route Airspace (FRA) would require further improvements. There are a few recommendations were drawn up based on analysis and further steps were proposed to apply Performance-based CNS approach to any specific Airspace type:

- Establish a Required Data Performance framework as a part of Performance-based CNS approach, based on the needs of ATC tools to manage specific Airspace type.
- Integrate Security Performance Requirements into Performance-based CNS framework.
- Develop strong CNS governance functions in order to harmonise Performance-based approach implementation and maximise efficiency of deployment and interoperability aspects.
- Address flight and other ATM support data, in addition to CNS, in terms of Performance-based approach.
- Complete work to provide specifications within RCP/RSP frameworks necessary to adequately cover the needs of new Airspace Concepts and separation standards.
- Characterize each Airspace type with its Communication (Voice and Data), Navigation and Surveillance needs in terms of performance specifications.

D2.3.120 - PJ14-W2-76 Report from simulation with pilot in the loop Version 2

The overall recommendation is to further develop and implement RNP holding functionality in current and future aircraft. The specification is available (RTCA DO-236C/EUROCAE ED-75D) but implementation is lacking, despite the well demonstrated potential airspace benefits. Further work is currently ongoing to analyse the holding functionality and performance of the ECAC fleet at higher altitudes (FL140) where it is expected that overflying the holding fix will further increase the consumed airspace due to the higher groundspeed, which stresses again the need to shift to RNP holding.

D2.3.230 - PJ.14-W2-76 Support to SESAR CNS Architecture Version 3

To ensure the correct reflection of all CNS/SWIM Solutions in ATM Master Plan roadmap, it is recommended to capture outcomes of Maturity Gates of the Solutions and reflect them in EATMA/SE-DMF.

7 Actors impacted by the SESAR Solution

Due to the transversal nature of this SESAR Solution all major actors in the aviation domain are impacted such as: ATS, CNS service providers and Airspace Users. In practice, it should contribute to the future implementation of a combined CNS Service-based and Performance-based approaches.

The CNS Service-based approach should induce a strong incentive for competing service providers to offer their services across national boundaries leading to the promotion of common service architecture across the European ATM System.

The CNS Evolution Roadmap and Strategy provide a support to identify synergies across Communication, Navigation and Surveillance domains, resulting in a possible seamless exchange of information between domains. The integrated concept combined with a civil-military interoperability vision support the sharing of infrastructure across domains, institutions and potentially countries.

The definition of CNS Performance-based relies on the required operational performance, in opposition to a system-oriented approach, hence it will allow the CNS service providers to potentially combine different systems and technologies in order to scale their services and adapt to the operational demand.

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8 Impact on Aircraft System

This transversal Solution identified high-level CNS Evolutions but the impact on aircraft or ground system will be managed by dedicated technical solutions.

EUROPEAN PARTNERSHIP

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9 Impact on Ground Systems

This transversal solution identified high-level CNS Evolutions but the impact on aircraft or ground system will be managed by dedicated technical solutions.

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10 Regulatory Framework Considerations

The following list identifies the main regulatory documents that were considered as references in this Solution. More detailed explanation of the following documents considerations can be found in Section 2 'Individual Performance-based CNS Concepts' of deliverable D2.2.300 - PJ14-W2-76 CNS Performance Based.

1. Commission Implementing Regulation (EU) 2017/373 of 1 March 2017 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight.
2. Commission Implementing Regulation (EU) 2018/1048 of 18 July 2018 laying down airspace usage requirements and operating procedures concerning performance-based navigation.
3. Commission Implementing Regulation (EU) 2019/123 of 24 January 2019 laying down detailed rules for the implementation of air traffic management (ATM) network functions.
4. Commission Implementing Regulation (EU) 2020/208 of 14 February 2020 amending Regulation (EC) No 29/2009 laying down requirements on data link services for the single European sky.
5. Commission Implementing Regulation (EU) 2021/116 of 1 February 2021 on the establishment of the Common Project One supporting the implementation of the European Air Traffic Management Master Plan.
6. Commission Implementing Regulation (EU) No 1207/2011 of 22 November 2011 laying down requirements for the performance and the interoperability of surveillance for the single European sky.
7. Commission Regulation (EC) No 29/2009 of 16 January 2009 laying down requirements on data link services for the single European sky.

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11 Standardization Framework Considerations

Although legislation is the driver for the regulatory processes, in practice the applicable documents are industry standards. The following list identifies the main technical standards that were considered as references in this Solution adopted by EUROCAE and ICAO. More detailed explanation of the following documents considerations can be found in the Section 2 'Individual Performance-based CNS Concepts' of deliverable D2.2.300 - PJ14-W2-76 CNS Performance Based.

1. EUROCAE ED-120 - Safety and Performance Requirements Standard for Air Traffic Data Link Services in Continental Airspace, EUROCAE.
2. EUROCAE ED-122 - Safety and Performance Standard for Air Traffic Data Link Services in Oceanic and Remote Airspace, EUROCAE.
3. EUROCAE ED-136 - Voice over Internet Protocol (VoIP) Air Traffic Management (ATM) System Operational and Technical Requirements, EUROCAE.
4. EUROCAE ED-138 - Network Requirements and Performances for Voice over Internet Protocol (VoIP) Air Traffic Management (ATM) Systems (Part 1: Network Specification – Part 2: Network Design Guideline), EUROCAE.
5. EUROCAE ED-228A - Safety And Performance Requirements Standard for Baseline 2 ATS Data Communications (Baseline 2 SPR standard), EUROCAE, March 2016.
6. EUROCAE ED-78A - Guidelines For Approval Of The Provision and Use Of Air Traffic Services, EUROCAE.
7. ICAO Annex 10 - Aeronautical Telecommunications - Volume I - Radio Navigational Aids. 7th edition.
8. ICAO Annex 11 - Air Traffic Services. 15th edition.
9. ICAO Doc 10037 Global Operational Data Link (GOLD) Manual. 2nd edition.
10. ICAO Doc 8071 Manual on Testing of Radio Navigation Aids - Volume I - Testing of Ground-based Radio Navigation Systems. 5th edition.
11. ICAO Doc 8168 Procedures for Air Navigation Services (PANS) - Aircraft Operations - Volume II Construction of Visual & Instrument Flight Procedures. 7th edition.
12. ICAO Doc 9574 Manual on Implementation Vertical Separation. 3rd edition.
13. ICAO Doc 9613 Performance-based Navigation (PBN) Manual. 4th edition.
14. ICAO Doc 9849 Global Navigation Satellite System (GNSS) Manual. 3rd edition.
15. ICAO Doc 9869 Performance-Based Communication and Surveillance (PBCS) Manual. 2nd edition.
16. ICAO Doc 9937 Operating Procedures & Practices for Regional Monitoring Agencies in Relation to the Use of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 inclusive. 2nd edition.

12 Solution Data pack

SESAR Solution PJ14-W2-76 Integrated CNS and Spectrum is a transversal solution, aiming to identify potential technological and functional synergies across the Communications, Navigation and Surveillance domains, and to take benefit from common infrastructure and/or system capabilities for both airborne and ground segment. The solution followed up the work done in Wave 1 under PJ14.01.01 and paved the way for the development of a dual Service-Based and Performance-Based approach.

The D2.2 - PJ14-W2-76 iCNSS Transversal Version 2 Data Pack contains the following deliverables:

- D2.2.100 - PJ14-W2-76 CNS Service Assessment Version 2
- D2.2.200 - PJ14-W2-76 CNS Evolution Roadmap and Strategy Version 5
- D2.2.300 - PJ14-W2-76 CNS Performance Based – Version 4

D2.2.100 - PJ14-W2-76 CNS Service Assessment Version 2

The CNS Service assessment document provides a global view of the future Communications, Navigation and Surveillance in the context of service provision. It identifies the logic supporting each domain, contributing to CNS performance-based approach. The definitions of CNS services and CNS service provision proposed in the deliverable will provide a global framework for services which are different in nature and in their relationship with the CNS data services. Some examples of transition from the system-based approach to the service-based approach are provided.

D2.2.200 - PJ14-W2-76 CNS Evolution Roadmap and Strategy Version 5

The CNS Evolution Roadmap and Strategy provides a global view of the future Communication, Navigation and Surveillance services, with the associated paths for systems integration. It identifies potential synergies across the domains, contributing to CNS services and systems roadmap with mature or maturing candidate systems within short term, mid-term and long-term evolution. Finally, it provides an in-depth analysis of a future set of CNS services delivered by an appropriately “integrated as much as possible” system of system being resilient, safe, cost and spectrum-wise efficient.

D2.2.300 - PJ14-W2-76 CNS Performance Based Version 4

The Performance-based Communication, Navigation and Surveillance (CNS) is considered by SESAR as one of key aspects of CNS evolution. A general idea of performance-based CNS was presented in PJ14-01-01 deliverables D2.1.010 - CNS evolution roadmap and strategy and D2.1.020 - Performance based integrated CNS. This deliverable is a continuation of work done in Wave 1 of SESAR 2020 and focuses on Performance-based CNS and provides results of detailed analysis as well as insights and strategic view on possible ways of integration of performance-based Communication, Navigation and Surveillance on development of this specific subject.

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