Multilink Implementation and Air / Ground Application (ADS-C/EPP) Roadmap 2023

2022-122-SESAR Deployment Manager FPA
SGA MOVE/E3/SUB/2022-122/SI2.875834

Deliverable 5.2.1

11.07.2023

Authoring and approval – Control Page

Approved by	**Mariagrazia La Piscopia** Executive Director	**Date** 20/06/2023	**Signature** Signed
Reviewed by	**Erich Klock** Head of Strategy and Technical Execution	**Date** 20/06/2023	**Signature** Signed
Prepared by	**Multilink Working Group** (cfr. Table of represented entities at p155)	**Date** 20/06/2023	**Signature** Signed (on behalf of the Working Group) Thomas Koerber Peter Pravits

Document History

Edition	Date	Status	Author	Justification
D0000.1	*2022-12-07*		***SDM***	*First draft for comments in the plenary*
D0000.2	*2023-02-16*		***SDM***	*Second draft after chapter 4 contribution received*
D0000.3	*2023-02-22*		***SDM***	*Third draft for comments after working session 4*
D0000.4	*2023-03-06*		***SDM***	*Chapter 5 initial content provided by SDM&EUROCONTROL*
D0000.5	*2023-03-21*		***SDM***	*Chapter 5 & 6 update After Working Session 5*
D0000.6	*2023-03-28*		***SDM***	*Update after final Working Session 6*
D0000.7	*2023-03-30*		***SDM***	*Update after clean-up*
D0000.8	*2023-03-31*		***SDM***	*Editorial changes to ease reading of document*
D0000.9	*2023-04-04*		***SDM***	*Editorial changes to ease reading of document*
D0000.10	*2023-04-04*		***SDM***	*Editorial changes to ease reading of document*
D0000.11	*2023-04-04*		***SDM***	*Editorial changes to ease reading of document*
D0000.12	*2023-04-04*		***SDM***	*Editorial changes to ease reading of document*
D0000.13	*2023-04-04*		***SDM***	*Editorial changes to ease reading of document*
D0000.14	*2023-04-04*		***SDM***	*Editorial changes to ease reading of document*
D0000.15	*2023-04-07*		***SDM***	*Update after Management review*
D0000.16	*2023-05-25*		***SDM***	*Update after SCP Step 1*
D0000.17	*2023-06-20*		***SDM***	*Update after SCP Step 2*

Contents

List of Tables

List of figures

1. Executive Summary

SDM (SESAR Deployment Manager), in coordination with SESAR 3 Joint Undertaking (S3JU) and the Network Manager (NM) has organised a Working Group composed of experts from ANSPs (Airspace Users, Communication Service Providers -CSPs-, ESA, ESSP, Manufacturing industry, S3JU, NM and SDM, to develop a roadmap (the “detailed multilink implementation and Air/Ground application (ADS-C/EPP) roadmap” or “multilink roadmap” in this document) concerning the development and implementation of a European datalink infrastructure meeting performance needs for Air Traffic Services (ATS) and Airline Operational Control (AOC) Services from now until 2035, considering the perspective of Trajectory Based Operations (TBO) implementation.[1]

After assessing the views and analyses presented by the different Stakeholders, the Working Group has agreed that the multilink roadmap should be developed towards achieving the implementation of an ATN/IPS based infrastructure, consistent with the multilink FCI (Future Communication Infrastructure) principles demonstrated by SESAR. Such an infrastructure will offer a greater flexibility in the integration overtime of different datalink or ground communication solutions operating on IPS and will allow a performance-based management of the network with an optimized routing, an improved availability of the Air/Ground communications including safety critical applications and seamless switching between communication means. It is an open platform and provides mobility, multilink, safety and management features enabling all future data link technologies to work in an integrated and interoperable architecture.

Scenarios other than the ones presented in the FCI Business Case, such as “do nothing” or some specific “dual-links infrastructures”, were considered but assessed as not satisfying the required longer-term performance, flexibility and competition (e.g. between datalink solutions or between providers) requirements.

The Working Group considered the FCI Business Case (see below an extract concerning the evaluation of the costs) and assumed it was still valid. Considering the costs of the different scenarios compared with the gains which can be achieved through the deployment of the different technologies, the FCI Business Case concludes that Multilink/MULTIMODE is the scenario which reduces the overall technical risk whilst maintaining the competition for the Air/Ground services, for both ATS and AOC.

---

[1] *Table of participants can be found in chapter 9*

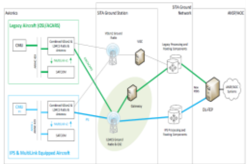
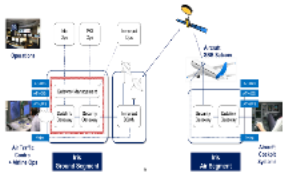
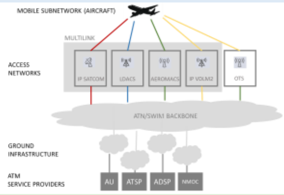
Scenario 1 LDACS	Scenario 2 OFF-THE-SHELF	Scenario 3 SATCOM NG	Scenario 4 MULTILINK/MULTIMODE
			
AUs CAPEX (ATC + AOC) • EUR 481 million (all new a/c by 2039) • **EUR 284 million** (59% fleet equipage by 2039)	**AUs CAPEX (**ATC + AOC) • EUR 300 million (all new a/c by 2039) • **EUR 70 million** (23% fleet equipage by 2039)	**AUs CAPEX** (ATC + AOC) • EUR 856 million (all new a/c by 2039) • **EUR 513 million** (60% fleet equipage by 2039)	**AUs CAPEX** (ATC + AOC) • EUR 769 million (all new a/c by 2039) • **EUR 422 million** (59% fleet equipage by 2039)
ANSPs OPEX (ATC only) • EUR 209 million (2025 -> 2039) • **EUR 15 million** (2039)	**ANSPs OPEX (ATC only)** • EUR 24 million (2027 -> 2039) • **EUR 8 million** (2039)	**ANSPs OPEX (ATC only)** • EUR 352 million + ? (2023 -> 2039) • **EUR 25 million** + ? (2039)	**ANSPs OPEX (ATC only)** • EUR 578 million + ? (2023 -> 2039) • **EUR 43 million** + ? (2039)

Figure 1. FCI Business Case scenarios and associated costs

To develop the multilink roadmap, the working group has also assessed which new datalink technologies / solutions (besides VDLM2) could be available over time with a sufficient performance level and maturity to start being put in operation for ATM and AOC information exchanges purpose. The assessment has led to the integration of three “datalink technologies / solutions” in the multilink roadmap:

- SATCOM Class B: an ATM service based on Aeronautical Mobile Satellite Service SATCOM Class B (Iris being the most advanced candidate service, it is the one represented in the roadmap).
- LDACS: a terrestrial-based radio access technology designed for aeronautical air-to-ground communication, i.e., optimized for aviation needs. It provides a native mobility solution and the LDACS ground subsystem was developed for optimal integration into the ANT/IPS Mobility and Multilink solution currently standardized by ICAO
- Hyperconnected ATM (COTS): use of public non-safety commercial communication systems (such as broadband Ka or Ku satellite systems, 4G or 5G.

However, the evolution from today’s environment to an ATN/IPS only infrastructure will not be realized in one go. Therefore, there will be a transition period where new datalink technologies will be operated in an ATN/OSI environment (e.g. the use of SATCOM/Iris to complement VDLM2 in the current ATN/OSI environment is expected starting from 2024 where it would be required performance-wise). Furthermore, ATN/OSI and ATN/IPS environments will have to co-exist, hence progressive implementation of the ATN/IPS infrastructure will require usage of OSI-IPS gateways.

In this multilink environment, seamless switching between links for aircraft with multiple links should be available. To increase the benefits of the business case, datalinks should be shared between ATS and AOC which is significantly contributing to safe and efficient flight operations.

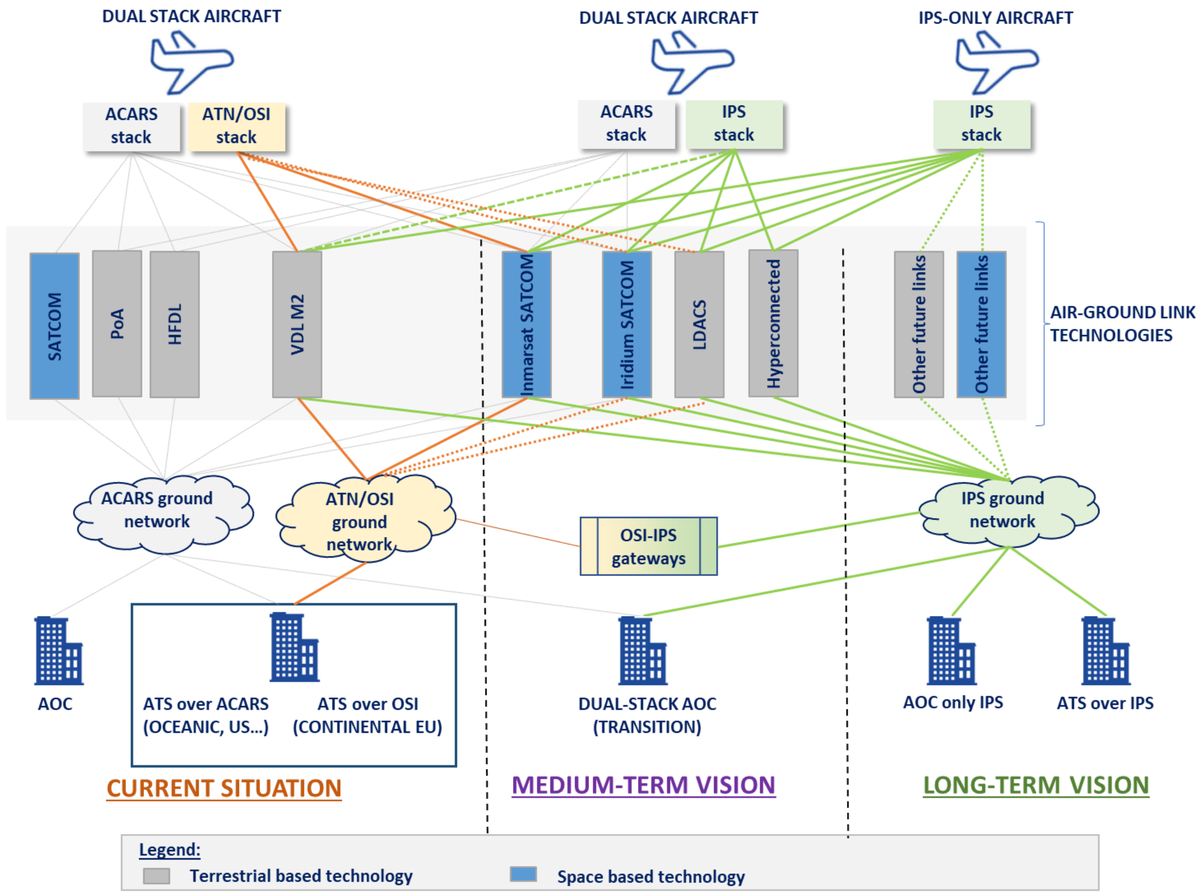


Figure 2. Today's DLS VDLM2 only and future IPS based DLS

Moreover, it is assumed that VDLM2 will be continued for an undetermined period of time as an alternate datalink and could be continued as the sole ATS datalink technology in those airspaces where its performance is deemed satisfactory and sufficient benefits of introduction of a new datalink are not demonstrated -assuming there will also be a certain rationalization and optimization of the VDLM2 infrastructure.

The multilink roadmap is described in three graphical representations (Overall, ground and airborne) generally including:

- decision milestones required for the development or the implementation of a technology based on foreseen maturity and availability of standards and products (these decision milestones are further elaborated in Chapter 5.4 Roadmap Overview in Table 9. Overall Decision Milestones);
- and implementation phases starting with milestones representing the earliest Initial Operational Capability of a technology.

The overall representation is included below:

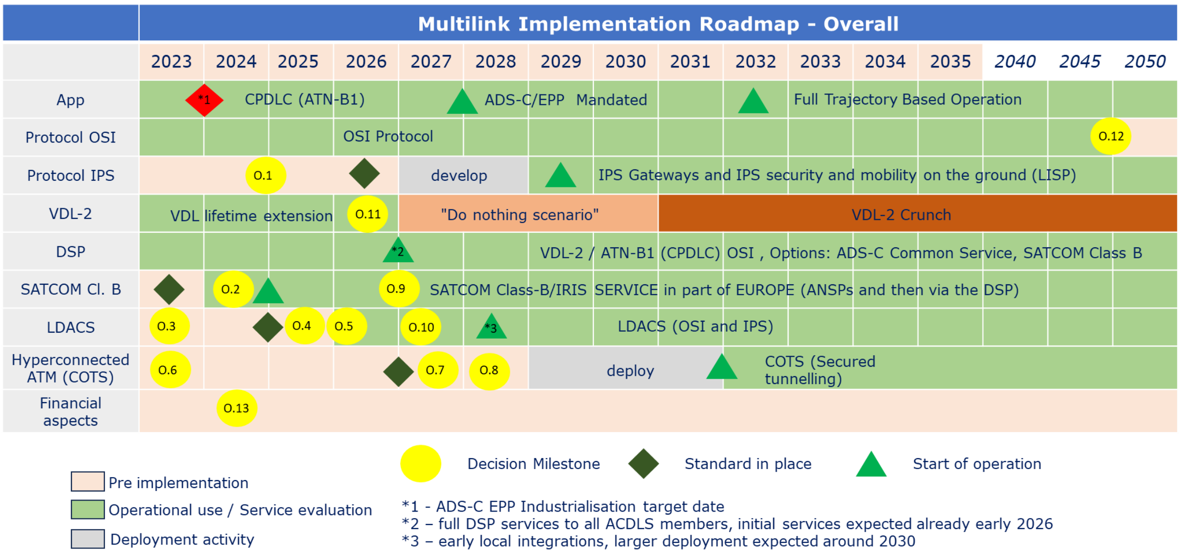


Figure 3. Multilink Implementation Roadmap: Overview early decisions

It is representing in different lines the ATM applications concerned, protocols and datalinks. It also includes the Datalink Service Provider (DSP) service that should be operated from 2025 onwards in Europe, providing the VDLM2 communication service to most if not all the EUR ANSPs.

It indicates particularly the need for decisions at an early stage to ensure harmonised deployment.

It is to be noted that the developed multilink roadmap does not provide any view to any "mandate" on implementation of the communication links. It is the common opinion that different users, AUs and ANSPs, may contract different sets of link technologies depending on their particular needs and provided that the quality and the performance of the datalink service is ensured (performance / market driven environment). It is however assumed that this "freedom of choice" is also based on co-ordination between the air and the ground actors.

Finally, the Working Group reflected on recommendations in different areas (technical, financial, organizational…) concerning the future related activities and the possible implementation of the multilink roadmap. A summary of the main ones is provided below.

Concerning technical activities, it is recommended to S3JU to complete the Research & Innovation process for LDACS & Hyperconnected ATM to bring the maturity up to TRL 8[2] (LDACS 2027; Hyperconnected ATM 2031) and to different concerned entities (CSPs, DSP, SDM…) to launch VDLM2 capacity crunch mitigation activities as soon as possible. In the organizational area, it recommends the need for Stakeholders and

[2] Including ATN/OSI

representative fora to endorse the multilink roadmap, in particular the transition towards the FCI multilink objective and full ATN/IPS. It also recommends setting up the appropriate organizational framework to maintain and execute the multilink roadmap, acknowledging in that framework the need of a CNS Program Manager and the roles of collective bodies and fora such as the SDM, the S3JU, EUROCONTROL, ACDLS to foster collaboration between individual air and ground implementation Stakeholders.

In the regulatory domain, the freedom of choice of technologies based on operational needs, market aspects and on a cooperative decision between air and ground actors is recommended. If any mandate would be required in the future, it is recommended it is based on a performance-based approach, allowing competition while ensuring the required Quality of Service.

The Working Group also identified the need to clarify financial mechanisms (e.g. charging schemes, incentives…) in the appropriate bodies or through a dedicated Task Force.

2. Introduction

2.1. Context

The SESAR Deployment Program 2022 provides a common workplan to all operational stakeholders involved in the deployment of six Pilot Common Project ATM functionalities (AF) mandated by Regulation (EU) 2021/116, so called Common Project One (CP1), clearly defining the scope of the implementation activities, the synchronisation needs, as well as the suggested deployment approach.

AF6 (Initial trajectory information sharing) implies in particular the start of the exchange of 4D trajectory data between the air and the ground systems (ADS-C/EPP already in the CP1 Regulation) which will only increase overtime through the progressive implementation of Trajectory-Based Operations (TBO), enabled in particular by ATS-B2, as targeted by the SESAR ATM Master Plan while other needs (e.g. AOC related communications) require also to be catered for.

However, CP1 does not mandate any deployment activity related to Air-Ground communication technologies to ensure that air-ground datalink capacity matches growing needs while it is already assessed that the current datalink network -based on VDLM2 communications between the air and the ground- may come into saturation from 2027 in some airspaces with high traffic volume.

Therefore SDM (SESAR Deployment Manager) took the responsibility, in coordination with SESAR 3 Joint Undertaking (S3JU) and the Network Manager (NM) to organise a Working Group composed of experts from ANSPs (ENAIRE, ENAV, , NATS, ROMATSA, Skyguide,), Airspace Users -AUs- (IATA, A4E, Air France), Communication Service Providers -CSPs- (Collins Aerospace, SITA for aircraft), ESA, ESSP, Manufacturing industry (Honeywell, Airtel, Airbus, Collins Avionics, Inmarsat), S3JU, NM and SDM, to develop a roadmap (the “detailed multilink implementation and Air/Ground application (ADS-C/EPP) roadmap” or “multilink roadmap” in this document) concerning the development and implementation of a European datalink infrastructure, from today’s ATN/OSI based VDLM2[3] infrastructure, meeting performance needs for Air Traffic Services (ATS) and Airline Operational Control (AOC) Services. The ACDLS Datalink Executive Board also contributed and took part in the Working Group.

[3] At the time of writing first airplanes are equipped with SATCOM Class B ATN/OSI

2.2. Scope

This document aims at describing the multilink roadmap as referred in the previous section. It also aims at capturing the different Stakeholders' assessments that contributed to its development.

The multilink roadmap has been developed to consider:

- the perspective of TBO implementation and not only of AF6 (Initial trajectory information sharing) as mandated by CP1. Therefore
- the continuous increase of air/ground data exchange for airlines (AOC)

It is developed considering a timeframe extending to 2035.The multilink roadmap should be considered as a view of the potential development and implementation phases of the different air and ground technologies (e.g. datalinks, networks) that could compose the European multilink environment over time, based on a best assessment of the Working Group.

Many decisions will be required over time so that development and implementation phases can be confirmed and actual plannings can be further developed. The multilink roadmap integrates some of these main types of decisions as "decision milestones".

Of course, any implementation should also be dependent on positive CBA results. For the development of the multilink roadmap, the Working Group has considered that those of the SESAR Future Communication Infrastructure Business Case (FCI-BC)[4] were applicable. It is assumed that the actual implementation decisions (on the air and ground) will require the development of CBAs specific to the technology to be implemented and the scope of implementation (e.g. a fleet, a specific airspace….).

In the development of the multilink roadmap, the Working Group needed to agree on some assumptions, technical or of another nature, concerning the multilink environment development and implementation. These assumptions have also been described in the document.

The Working Group is aware that multilink implementation and operation may impact business models and associated financing schemes such as current charging mechanisms. Discussions have occurred within the Working Group whose main elements are also captured in the documents.

Finally, the document identifies some recommendations associated with the multilink roadmap, in particular looking at those main activities or decisions at short-term that would allow to foster its actual implementation.

[4] [01] FCI Business Case, V18, 21 April 2022, presented at JCSP7 (May 2022) [updated by SESAR20202 PJ14 Solution 77, deliverable D5.1.500, Nov. 2022

2.3. Structure of the document

The document is structured as the following:

- Chapter 1 *Executive Summary* provides with an Executive Summary of the context and outcome of the document, i.e. the multilink roadmap.
- Chapter 2 *Introduction* provides information concerning the context in which the document was developed, the scope of the document / of the multilink roadmap and the :content of the different chapters of the document.
- Chapter 3 *Problem Statement* describes the most important current or foreseen issues (e.g. "VDLM2 crunch") that the multilink roadmap needs to address as well as the most important constraints / requirements it shall also consider in its development (e.g. global harmonization) . It is therefore divided in different sections addressing those various matters.
- Chapter 4 *Solutions Identification* provides with an extended description of the different Stakeholders' (e.g. ANSPs, AISPs) and other types of contributors' (e.g. S3JU concerning R&D) assessments regarding the various potential elements of a multilink roadmap. It is subdivided in various sections representing at a first level the "contributor" concerned and at a lower level, eventually, the subjects for which an input or assessment is provided.
- Chapter 5 *Consolidated Implementation Roadmap* provides with the outcome of the Working Group, i.e. the multilink roadmap, after its analysis of the various inputs considered and described in Chapter 3 and Chapter 4.
    - Chapter 5.1 *Summary of chapter 4 technologies* provides with an overview of the development / maturity status of the technologies (datalink and network/protocol) selected to be part of the multilink roadmap.
    - Chapter 5.2 *Scenarios that have been considered* describes the scenario (i.e. from which current "datalink infrastructure" to which "target datalink infrastructure" and through which steps) retained for the development of the multilink roadmap and upon which selection criteria.
    - Chapter 5.3 *Assumptions for building the Roadmap* describes different assumptions, technical or of another nature, that the Working Group has considered concerning the multilink environment development and implementation.

      Chapter 5.4 *ROADMAP – Overview* describes the multilink roadmap in different representations (Overall, Airborne, Ground).
- Chapter 6 *Final Recommendations & Way Forward* identifies some recommendations associated with the multilink roadmap, in particular looking

at those main activities or decisions at short-term that would allow to foster its actual implementation.

3. Problem Statement

This section is the entry point for discussion and definition of identified problems.

3.1. VDLM2 Capacity Crunch

In Europe, some areas are facing a lack of datalink capacity on VDLM2 Air/Ground links and the introduction of new ATS & AOC services (like ADS-C EPP, or Engine monitoring over AOC) will require even more bandwidth. There is an urgent need to provide sufficient datalink capacity on time.

SDM and the NM consulted several stakeholders that are operating mainly in the EUR core area (ANSPs, CSP and airlines).They all confirmed that the estimation provided previously is still valid, i.e., that the VDLM2 crunch can be expected around 2027-2030, initially in the core area. It was nevertheless recognised that the VDLM2 crunch may occur later out of the core area. All stakeholders therefore underlined the need to address the area that hosts most of the traffic where the crunch will obviously occur first.

DG MOVE received in early 2020 the SDMs "D11.1.1_Report on DLS Architecture and Deployment Strategy after SCP and CA comments_v1.0" see [RefDoc 02], which describes the main outcomes of the capacity study.

This report was based on the University of Salzburg study (USBG) that produced a capacity assessment of the VDLM2 lifespan with the conclusions:

- With the Common Signaling Channel (CSC) + 4 additional channels: in year 2024 at the latest the VDLM2 will become critical. However early degradations could start even before.
- VDLM2 with CSC + 6 additional channels (recently assigned by ICAO FMG in 2022 and under deployment) will reach its critical situation in year 2027.
- Even an extension to CSC + 8 channels will not improve the situation and VDLM2 reaches its critical situation in year 2030.[5]

Beside this capacity study, EUROCONTROL carried out analysis on the VDLM2 link utilization evolution. Figure 4 from the "Datalink Monitoring Report 2020" shows for the high traffic density area in central Europe the peak utilization of all deployed en-route frequencies and the margin to its maximum throughput (red stroked box). The CSC and deployed terminal frequencies, relevant in the current setup for AOC but with increasing demand for ATC with introduction of additional services, are not reflected.

[5] ICAO FMG recently assigned additional 11 former guard band frequencies to VDLM2. The use of guard bands have not been deeper analysed yet, but if feasible, the capacity crunch could be expected at a later point in time.

Below in Figure 4 the “2 ENR Freq.” scenario supports the en-route part of CSC+4 and “4 ENR Freq.” the en-route part of CSC+6.

Two conclusions have been drawn from this analysis:

The VDLM2 traffic forecast shows that in the coming years, even if the flight movements may remain lower compared to 2019 and considering a conservative approach on the evolution of services using the VDLM2 sub-networks, VDLM2 traffic in the core of Europe could reach critical levels sooner than the general crisis recovery trends indicate.

To meet the performance requirements with ever growing traffic, both the ground and the airborne components will need to improve.

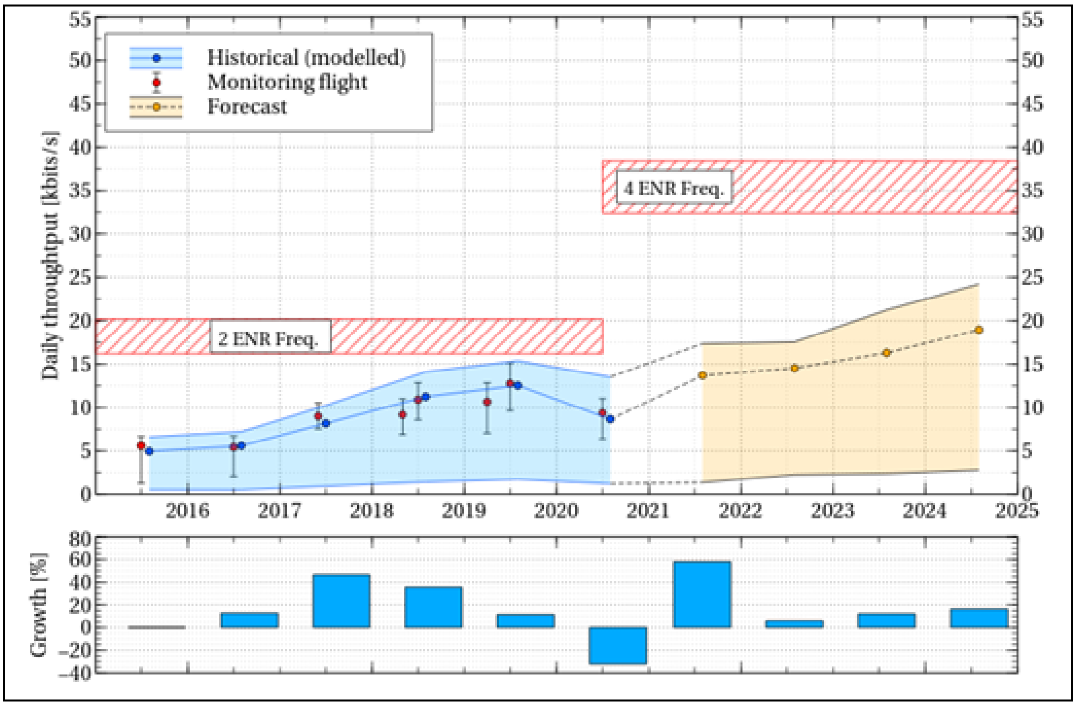


Figure 4. Global VDLM2 daily throughput evolution Source: EUROCONTROL

Reaching the bandwidth limits of VDLM2 will not occur all over continental Europe at the same time. The high traffic areas with the highest VDLM2 utilization, will come to the channel saturation first. In remote, or peripheral areas this will occur far later or even never.

Figure 5 depicts a gridded map of core of Europe showing the Peak Instantaneous Aircraft Count (PIAC) within the radio coverage of each cell’s centre. As the VDLM2 traffic is observed to be proportional to the number of aircraft, this map also represents the geographical distribution of VDLM2 traffic the red area, central Europe, will most probably have the earliest demand for complementing links to give relief to the VDLM2 link.

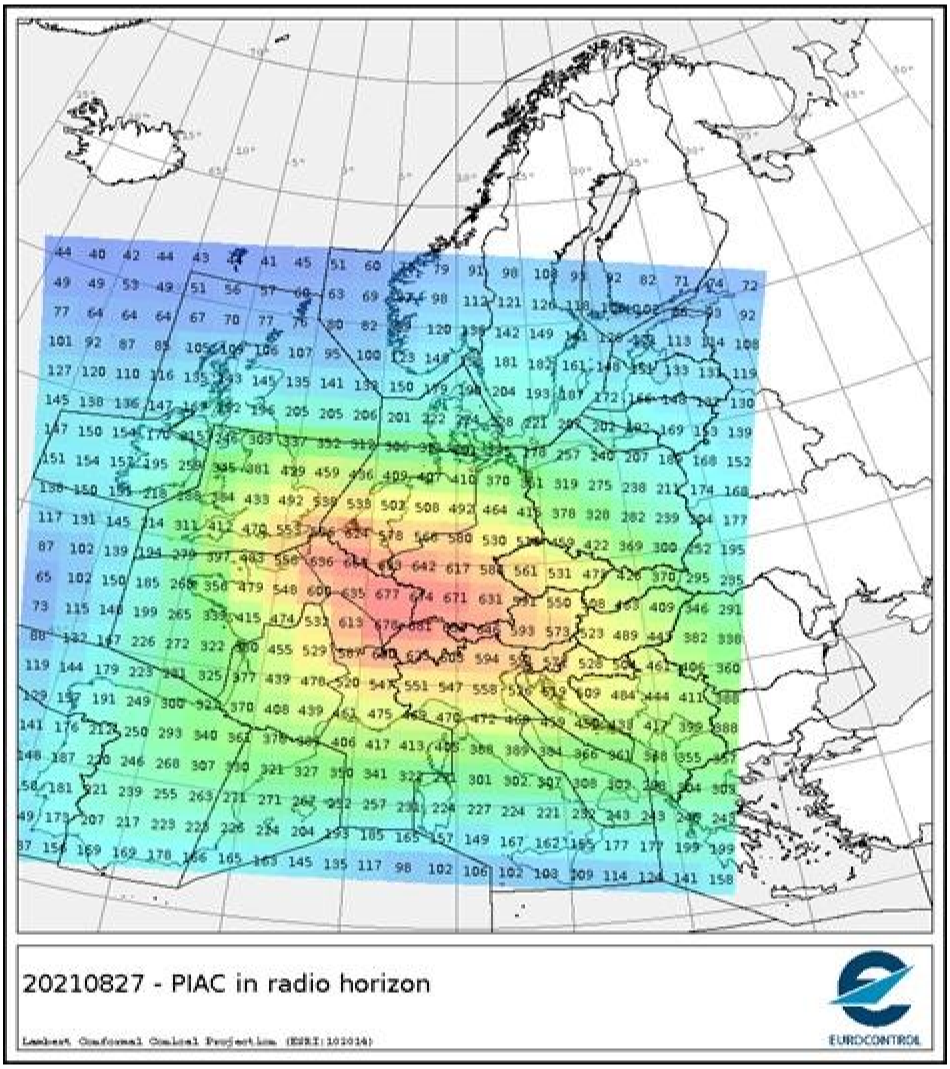


Figure 5. Number or Peak Instantaneous[26] Aircraft Count (PIAC) in radio horizon

The SDM capacity study completed by the university of Salzburg in 2019 (See ”D11.1.1_Report on DLS Architecture and Deployment Strategy after SCP and CA comments_v1.0” [RefDoc 02]) concluded that the VDLM2 capacity will reach its limits by the end of this decade. The EUROCONTROL link utilisation evolution and short-term forecast is consistent with the capacity study results.

3.2. The need for AOC Development

Airline Operational Control (AOC) datalink is key for safe, efficient, and on-time airline operations and becomes more and more mission critical. AOC services have been developed for decades over Plane Old ACARS (POA) and then ACARS Over AVLC (AOA) with VDLM2, in order to improve airline operations and maximize efficiency. It has to be noted, that in Europe later ATN communication was added to the same VDLM2 link.

Operations in high traffic density airspaces and stronger requirements for efficient operations increased the flight related data demand, on-board as well as on ground in the Operational Control Centers and for Maintenance Operations Control.

Alongside with more demanding operational requirements and technological improvements the adaption of operational concepts is essential. SDM together with relevant stakeholder created the very first Multilink CONOPS see [RefDoc 03] “D1.1 – CONOPS for Multilink Operation Version 1.2, 02 February 2022”. The consulted and published document addresses ATS & AOC operational needs on a worldwide basis. Deployment of Multilink will require adoption of the Multilink CONOPS as well.

At the same time, several mandates have been introduced requiring use of datalink, in some case close to real-time through the entire flight.

For the intended readership, it is important to understand AOC needs. Therefore, a deeper explanation of AOC is given below.

The generic term AOC can be split into four major domains:

Aircraft Real Time Monitoring and Health Monitoring

AOC is used by airspace users to monitor real time status of aircraft in flight, and to perform health monitoring of aircraft systems and engines targeting:

- First objective is flight safety: real time monitoring of parameter exceedances and system warnings, monitoring of critical or sensitive parameter evolution or drifting, monitoring of failure messages with no notification to crew onboard.
- Second objective is operational. Airspace Users extensively use AOC to anticipate on maintenance actions before aircraft lands, in order to prepare spare parts/workforce, organize maintenance actions in order to minimize impact on aircraft turn around (delay, cancelation).
- Third objective is financial: by using AOC, health monitoring allows to anticipate replacement of parts before failure consequences become much costly. This is for example the case for engines. AOC allows to optimize engine replacement timing.

Modern Engines and aircraft systems are designed to be highly efficient.

The increase in efficiency introduced more technological complexity which requires closer monitoring and even more than that, closer real time monitoring.

With new aircraft capabilities, airspace users are investing, and will invest more and more, in big data, to analyse low noise signals, and reinforce their proactive maintenance.

Air Traffic Service related

This cluster provides flight crew and ground with data and information supporting flight optimization. The today's Flight Management Systems (FMS) are fed with the Flight Plan and related Wind Information. The granularity of Flight Plans increases steadily. The more detailed the FPL data is entered into the FMS, the more precise the prediction of the flight path, which is key for optimum use of ADS-C/EPP data by ATC. Those flight plan and wind data are transferred into the FMS via AOC today, which brings two advantages: higher granularity and better quality. In addition, it saves time for flight crews during turn-around.

Besides that, this domain hosts messages related to flight crew real-time information, like weather information (ATIS, TAF, METAR, SIGMET via A623 or company), Clearances (PDC, DCL), FANS and Oceanic Clearance), CDM data exchange (TOBT, Slot, De-Icing) and meteorological data to enhance weather forecast provided to MET service providers (AMDAR).

Airline Operational Control

In this domain, also, AOC plays a very important role in airline operations.

AOC data is deeply integrated in airline digital processes, in flight and during turn arounds. Unavailability of AOC involves strong consequences on operations as back-up processes are not optimized (delays, cancelations).

In the recent years, Airspace Users have been mandated to gather specific flight related data, such as 4-D position data to comply with aircraft tracking requirements or Re- and Defueling information for Carbon Dioxide emission trading.

Furthermore, with increasing air traffic, on-time performance has become more and more important, which is achievable only with communication ability between airline and flight deck throughout the entire flight, e.g. for the exchange of free text messages, on-time delivery of load-sheets or flight crew information.

In addition, airlines need event information like OOOI, door status, Diversion information or ETA change to optimize ground handling processes and connecting flight prioritization.

Electronic Flight Bag

In the last 10 years, Airspace Users have been installing Electronics Flight Bags (EFB), with first objective to reduce paper documentation in the cockpits.

Then, the availability of COTS tablets in the cockpit, combined with the availability of secured IP links between the aircraft and the ground through available communication channel, allows the emergence of new applications which bring significant improvements for airline operations: flight optimization, communication with ground.

As experienced for public mobility (applications on smart phones), a strong evolution can be expected in the coming years, with the emergence of new ideas and projects. This will request higher communication availability, capacity and security. The increasing data demand requires links with higher capacity. However, today, most of AOC data is still sent through VDLM2 and will be needed for the decades to come.

To relieve and avoid further congestion of VDLM2, when it is technically and economically viable, some Airspace Users already offload some AOC data, on some identified aircraft, to other links. These links are mainly the so-called COTS (e.g. 4G/5G on ground, Passenger In-Flight Entertainment air/ground link (Ku/Ka-Band) or SBB SATCOM) with some limitations:

- Not all avionic systems or aircraft types allow connectivity through other links than ACARS (VDLM2, SATCOM)
- 4G/5G available on ground only and not at all airports
- Ka/Ku SATCOM reliability/availability not in line with needed AOC operational performance
- Retrofit costs often dissuasive, SATCOM is today economical only on aircraft operating in remote areas (operational and installation costs)Obligation to deploy or use costly ground proprietary IT solution (license fees, commercial conditions, hardware, etc.)

The multilink needs for Airspace Users are driven by following point:

Link requirement depending on the type of operation, e.g. SATCOM on long range aircraft is a must, while on many short range airplanes it is not economical today due to high installation and operational costs[6].

Far higher communication costs in areas with single provider infrastructure.

[6] To be noted that line fit of the latest SATCOM solutions with native IP (vs ACARS) will bring ops benefits in continental airspace too by offloading VDLM2 for ATM (TBO) and AOC purpose.

3.3. The need for ATM Digitalisation Towards TBO (Supporting Green Aviation)

Trajectory Based Operations (TBO) is an ICAO and global (endorsed at Assembly 40) strategic operational goal, which can be summarised as “enabling a fully collaborative environment where each flight trajectory is shared, maintained and used by all the concerned actors during all phases of flight”.

Flight and flow Information for a Collaborative Environment (FF-ICE) is part of the ICAO Aviation System Block Upgrades (ASBU) and refers to the processes allowing the members of the ATM community to share and maintain information about a flight and flow. It starts with the early submission of flight information by the airspace users to the ATM system and ends with archiving the relevant information after the flight. It concentrates on global needs for sharing flight information but also accommodates regional and local needs.

The early steps in Europe towards the full implementation of TBO will increase steadily the demand for digital air/ground data exchange, which started in the first steps with Controller/Pilot communication (ARINC 623, CPDLC) increasing with future use of complex clearances and complemented more and more by machine-to-machine interfaces in the first step with ADS-C/EPP trajectory downlinks.

Europe is still in a ramp up phase for the CPDLC use. While the CPDLC equipage rate of flights passed the 80% mark[7], logon rates of equipped flight are still below the 70% mark in central European ACCs[8]. The introduction of ADS-C/EPP has just started and only about 200 aircraft are currently equipped.

On top of the data exchange requirement for the pure ATN communication (CPDLC, ADS-C/EPP), the AOC demand will increase to support the various ATS applications:

- FF-ICE will improve the granularity of Flight plan data. To achieve the best optimum trajectory data in the ADS-C/EPP application, the pre-departure Route uplink into the on-board Flight Management Systems need to match the eFPL data as much as possible. With the increase in granularity, the message length will grow.
- The ADS-C/EPP trajectory downlink precision would increase if the best available wind data is uplinked via AOC into the FMS (predicted wind data).
- The support of Collaborative Decision Making (A-CDM) increases the need for information exchange between flight deck and various operational stakeholders.

[7] see EUROCONTROL DPMG#13 Data Link Performance Monitoring Review Deployment status: airborne side

[8] see EUROCONTROL presentation “DSG#8 How to improve CPDLC Usage?”, slide “Datalink Performance: week 9 (2022)”

EC Implementing Regulation (EU) 2021/116 (also known as Common Project 1 -CP1) mandates some of the FF-ICE 1 services (e.g., the Filing Service) as well as the ADS-C/EPP, which is part of ATS B2. This includes deployment of ADS-C/EPP capability on-board new aircraft (forward-fit mandate from 31 Dec 2027 onwards) and the ground distribution of the EPP data to all concerned European ANSPs and the Network Manager (NM).

Beyond CP1 AF6, with the introduction of ATS B2 complex using CPDLCv2 the control loop for the flight will be closed:

- Enhanced vertical clearances
- EPP provides ground with desired vertical profile
- Ground uses this intelligence to compose vertical clearance avoiding intermediate level-offs
- ATS B2 clearance via CPDLCv2 to be auto loaded to the FMS
- Expected to further improve efficiency of vertical profiles
- Uplink 2D trajectory revision, allow for complex clearances consisting of multiple TCPs

That will enable new separation handling methods at ATC level and to a degree substitute vector + resume own navigation.

New 2D routes will be composed by the ground system and automatically loaded into the FMS.

It is expected that the TBO target scenario will have more demanding performance requirements to communication link service levels like bandwidth, security and latency. To address these needs, the capability of current VDLM2 setup needs to be assessed and VDLM2 needs to be complemented.

Further digitalization projects started or are planned to achieve efficiency targets contributing to Green Aviation.

3.4. The need for Technological Communication System Innovation

Looking at the current European ATS Datalink System infrastructure based on VDLM2, and SATCOM for Oceanic Areas, several shortcomings were already identified by several working groups and task forces, implemented over the ATN/OSI and ACARS protocols, the usage of communications' technologies such as VHF/HF means to achieve Air/Ground communications, or X.25 for Ground/Ground communications' purposes, poses several challenges to the airspace community in the (very) near future.

Issues can be enumerated related with, but not limited to:

- Technology obsolescence: Growing shortage of available equipment on the market to cope with the replacement of existing infrastructure components.
- Increasing costs to maintain current systems' operation (1): As the current technologies' equipment grows shorter in the market, the costs involved on their replacement grows exponentially higher.
- Increasing costs to maintain current systems' operation (2): As the current technologies age, so do the available professionals mastering them, in the sense of a growing shortage of professionals' proficiency on the installation/configuration/maintenance of the current infrastructures. The available expertise on these technologies is sparse and, when solicited, implies high expenditures for their service.
- Lower performance: The airspace community, driven by the high exposure to public scrutiny and to the need to provide a safe, secure, and reliable service to their users, is well known to be a slow adopter of new technologies. The conservative usage of technologies and the restrain on evolving to newer, better performing, and scalable solutions, penalizes the performance of the existing solutions, when faced with an increasing demand on their usage, as we are facing today on a post Covid-19 pandemic scenario.
- Low interoperability and integration with new CONOPS: New concepts of operation being designed and specified for the future of aviation, such as Trajectory Based Operations (TBO), Unified Traffic Management (UTM), etc., envisage a high volume and diversity of data being exchanged amongst all aviation actors, requiring a highly performing and resilient infrastructure, able to cope with all evolutions envisaged for the next two decades.
- Security: In the past decade, reality has shown to the airspace community that safety cannot be the only forward driven force to comply with. Security has become as important as safety, and that it has a direct implication on safety as well. The current technologies were not initially designed to answer to security requirements. There is a growing need to strengthen the aeronautical communications, to protect them against already existing cybersecurity threats.

3.5. The need for Global Harmonisation

The need for sustainable and efficient air-ground data communication is identified in the SESAR vision for the Single European Sky (and the ATM Master Plan), based on the ICAO Global Air Navigation Plan (GANP) and Global Air Traffic Management Concept.

As the commercial air transport is a global business, the technological solutions employed to facilitate the air-ground data communication globally need to be fully interoperable. That will enable the users to operate seamlessly without having the differences in the performance, equipage requirements or even procedures to be followed. These principles should always be 'built in the design' when it comes to the topics relevant to the global interoperability meaning that the major aircraft manufacturers should always be an integral part of these activities.

To achieve the required interoperability and coordination in harmonising the transatlantic traffic, EASA and FAA have engaged in a joint activity together with Boeing and Airbus to reflect on the current and future challenges of aviation connectivity and communication, and to develop joint proposals to address those challenges. As an outcome, a common vision is proposed herein for the future aviation connectivity and communication landscape at the time horizon of 2035. This vision is to serve as a strategic guidance to operational stakeholders to address their own planning and challenges in this area and to prepare for the implementation.

From the regional European perspective, there are two important turning points envisaged:

- In 2027, when ATS-B2 solution (CPDLC and ADS-C, including ADS-C/EPP downlink) is required.[9]
- In 2032, when air-ground IPS network capability should be operational as part of operating the ATS-B2, with the advanced ATS-B2 services fully operational starting from 2035.

The challenges that operational stakeholders might face in making this plan a reality, will be elaborated in the section 4 of this document.

Two open questions have been highlighted in the proposed vision, both related to the need for IPS mandates - on the ground and in the air.

An additional question that also needs to be considered is – how to ensure that other regions (e.g., Asia, Pacific) also adopt a similar way forward so that global interoperability is ensured.

The Multilink working group has noted the EU/US task force White Paper 'Future Connectivity for Aviation' prepared by FAA, EASA, Boeing, Airbus during the

[9] Forward fit if Industrialisation gate end of 2023 is successfully passed.

preparation of this document. However, it should be mentioned that this White Paper was not consulted.

4. Solutions Identification

This chapter intends to discuss potential solutions to address chapter 3 Problem Statements, coming from Operational Stakeholders and DLS Community.

The solutions, positions and needs to chapter 3 identified problems are provided in the view of ANSPs, AUs, Research & Innovation, Manufacturers and Operators, the identified deployment actions can be identified in the following chapters.

4.1. Operational stakeholder view

4.1.1. Airspace Users view

4.1.1.1. Airlines' view

Situation today:

Airspace Users are operating in a multilink environment already today with AOC and ATC outside the ATN scope, e.g. CPDLC and ADS-C in the FANS context per ARINC 622, Clearances and information as defined in the ARINC 623 standard.

Multilink Status Quo in AOC and ATS (non-ATN)					
	VHF	VDL	SATCOM	COTS airborne (e.g. Ku/Ka SAT)	COTS ground (e.g. 4G/5G)
AOC ACARS	IN OPS	IN OPS	IN OPS (class C or B)(1)		
AOC IP			IN OPS (class B) (1)(3)	IN OPS (1)(3)	IN OPS (1)(2)(3)
ATS ACARS	IN OPS	IN OPS	IN OPS		
(1) – depending on aircraft equipage and ground infrastructure for IP (2) – available locally only, on ground only if not via alternate links, e.g. Ku/Ka (3) – IP not supported by all integrated avionics ATS – ARINC 622 and 623 applications					

Table 1. Multilink Status Quo in AOC and ATS (non-ATN)

Mainly the long-range fleets are equipped with legacy SATCOM systems to ensure connectivity also in remote areas especially to support CPDLC and ADS-C in the FANS context. Such Performance based approach e.g., PBCS provides capacity increase for example in NAT HLA airspace allowing airlines to fly optimized trajectories. Modern airplanes are using additionally IP links through SATCOM, such as Inmarsat SB-S or Iridium Certus for FANS.

However, the legacy links, POA, VDLM2 or Legacy SATCOM systems like Inmarsat Aero H+ or Iridium are already today not supporting some AOC requirements of modern aircraft types or flight operation supporting applications.

To address the higher AOC bandwidth demand, some modern aircraft are equipped with IP based SATCOM systems like Inmarsat SBB (SB-S for FANS) or Iridium Certus over time.

As airlines are not paying directly for ATC communications, they would likely select the best performing available link, whereas for AOC communications airlines usually privilege cost driven link selection policies and select among various links (4/5G, satcom, etc.) depending on sector, phase of flight or applications, where possible for AOC traffic.

Airlines started using Commercial of the Shelf technology (COTS) on ground with 4G/5G connectivity to enhance the information available to the flight crew, required for more safe and efficient flight operations, as well as the granularity and frequency of maintenance data for which the VDLM2 bandwidth is insufficient. Especially modern aircraft with efficient engines have a higher real time monitoring demand.

Common architectures are ACARS over IP architectures or implementation of applications previously supported by integrated avionics into Electronic Flight Bags, also supporting the transfer of non-time-critical Maintenance data.

As per today, the 4G/5G links have some weaknesses:

- Most integrated avionics as per today do not have access to such link
- The network is available on ground only
- Some airports have poor coverage on the apron
- Globally are different standards/frequencies in use
- Airframe Manufacturer provided solutions have no open standard and dedicated ground systems have to be used where the data ownership is not clear

More recently, the first initiatives started to use airborne available links dedicated to passenger in-flight entertainment for the exchange of non-critical data, in most cases Ku/Ka Band SATCOM systems. With the below weaknesses:

- Most integrated avionics as per today do not have access to such link
- Not available on all aircraft types
- Service Levels need improvement to allow the use for critical messages

The links complementing VDLM2 today differ per airline, aircraft type, role and mission.

Today the SATCOM links are the most expensive ones but at the same time neither essential nor bringing operational benefits for operations in continental Europe and Airlines prefer cost driven link selection policies where possible for AOC traffic.

While Satellite based high performing IP based links are available already today (Inmarsat SBB or Iridium Certus), terrestrial high performing IP links today are either available on ground only (4G and 5G) or limited in their services for safety critical messages (Passenger In-flight entertainment systems).

Multilink Limitations today:

- Not all Airframe Manufacturers' integrated avionics have access to complementary links
- Today's avionics are not compatible with geostationary (Inmarsat) and Low Earth Orbit Constellations at the same time, a provider change requires hardware changes
- Legacy SATCOM systems, POA and VDLM2 do not provide state of the art Link security and bandwidth
- SATCOM systems today have significant higher cost for installation and operation compared to terrestrial links, justifiable only with additional capabilities or in remote areas where terrestrial links are not available

Performances limitations of VDLM2 observed today on ATN/CPDLC applications are confirming that VDLM2 cannot be used as primary means of communication to support the future of ATM in the TBO context

Today's aviation Satellite communication systems rely on private, Satellite constellations and therefore should be backed-up by terrestrial links to mitigate potential risks:

- Market monopoly situation with disproportional communication costs
- Potential non-access to the link due to sanctions or intended or unintended satellite outages
- Potential discontinued services due operator business model change or no investments into replacement satellites at satellite end-of-life

The obvious need of low latency/high bandwidth solutions to support CPDLC as primary means of COM for at least en-route and TMA seems not achievable with the current VDLM2 network and should also be complemented by high performing IP links via various infrastructure to avoid monopoly situation and to address redundancy needs.

The need for high performing IP links is there already today. Currently some of the used links are available only on ground and not at all locations. Additionally, cost vary per region. Links need to be adapted or new links must be introduced to achieve required performance levels

Way forward:

- The need for CPDLC as primary means of COM for at least En-Route and TMA, requires low latency and guaranteed sufficient throughput link solutions. Current links commonly used for AOC shall be adapted to make them ATN ready where technically feasible and economically justifiable.
- Avionics need adjustment to allow appropriate link usage per Operating Environment e.g., 5G on ground; new Terrestrial link or SATCOM while airborne.
- Standards have to be open to allow end-to-end communication between aircraft and Airline.
- To reduce ground/space infrastructure and airborne equipment costs, any new link technology shall support both AOC and ATC.
- New Terrestrial high performing IP based multi provider network should be envisaged and deployed to support future ATM and AOC needs based on performance and to mitigate the risks associated with SATCOM infrastructure.
- IP is the target for the future.
- Take benefit of any installed system meeting performance requirements. Ground multilink architecture shall be technology agnostic and accommodate any existing or future IP air/ground communication system providing appropriate service levels.
- In the ramp-up phase, CAPEX and OPEX for early implementers shall be incentivized.
- Homogeneity in Europe is a must.
- For future aircraft airlines need rationalization on board. Implementation of new communication technologies must be the opportunity for aircraft manufacturer to rationalize on board communication system architecture, by reducing number of legacy system equipment’s or reconsider system redundancy with new operational requirements.
- For the future both either ATN/OSI together with ATN IPS have to be accommodated by the ground systems.
- Link selection policy for AOC should be defined by the users.
- Easy and fast track change of links will be possible, once links are available. Similar to today's implementation.

- Bandwidth capacity studies will be also needed for multilink new providers, to help adequate dimensioning according to actual use and evolving needs.

Timeline:

AOC already today has a need for IP based high performance links. Some are already emerging successively, at least on ground. The next critical mark must be seen in 2028 with the increased ramp up of ADS-C/EPP use as mandated by the CP1 regulation. This will put additional load onto the VDLM2 channel and potentially degrade the ATN performance, which is already today not at its target levels.

The final milestone will be marked for 2032, where EASA and FAA set the target date for full TBO implementation and at this point in time at latest, the VDLM2 network will be not sufficient to support link performance requirements e.g., latency and will not support state of the art security.

Risks:

A VDLM2 only or "do-nothing" scenario will limit the ATS B2 deployment under full TBO operation and degrade the minimum airborne AOC demand needed to improve flight efficiency. This will negatively impact the aviation efficiency targets envisaged for end of this decade.

Air/Ground datalink communication is becoming more and more essential in aviation and with that requiring more link security. The legacy links, VDLM2 in the current configuration as well as non-IP SATCOM architectures do not provide state of the art security mechanism.

The implementation of ATN capability into single Satellite based communication systems only will not provide a back-up solution in case of disrupted network access but could foster a monopoly situation and probably increase communication costs. Note: today's avionics are not compatible with both currently deployed geostationary and Low Orbit constellations used by aviation at the same time.

If decisions for the deployment of future links will not be taken in time, the AOC/ ATC (ARINC 622/623) and the ATN links will diverge and increase future CAPEX as well as OPEX for an ATC dedicated link.

Conclusion:

With the increasing need for AOC communication together with the introduction of new ATC applications requiring capacity demanding ATN air/ground communication together with improved latency and link security requirements, the today's VDLM2 link will need complementary links capable to replace VDLM2 in the long term for ATN and AOC (including non-ATN based ATC services like ARINC 622/623), see [RefDoc 025] 'Network and Information System (NIS) Directive (EU) 2022/2555 (known as NIS2)'.

Flexibility and sustainability are essential concerns for multilink. As such, Airlines consider that new ground multilink infrastructure shall be designed, from day one, to accommodate any existing or future IP air/ground communication system providing appropriate service levels.

Commonly used AOC links, (e.g. IP SATCOM systems and COTS), should be made ATN capable. Additionally, at least one in-flight available, terrestrial link capable to handle upcoming link performance demands (high bandwidth, security features and low latency) needs to be deployed or adapted for ATC, AOC and ATN in a multi provider set-up to address:

- Avoidance of a potential monopoly situation with only one high performing link
- Reduction of the operating costs
- Mitigate risk of non-access to the link due to sanctions or intended or unintended satellite outages
- The new terrestrial network should aim for a globally harmonized deployment

Multilink shall support any future emerging air/ground IP technology (e.g., new LEO constellations)

To avoid any new service fragmentation in Europe, and encourage deployment of FCI technologies, it is essential that multilink service is offered by all European ANSPs. Finally, cost model of multilink services needs to be addressed.

4.1.1.2. Business aviation view

For Business Aviation Inflight communication is paramount, this is valid for the ATS as for the Cockpit and Cabin services (Office in the sky). The links must provide the expected services. Solutions must be "Global", interoperability as continuity of the service must be guaranteed, automatic log-on as automatic transfer from one link to another must be the rule. The mandated services (ATS/AIS) must be certified in agreement with the RCPs required and to guaranty the interoperability, “end to end” certified.

By November 9th, 2022, EASA-FAA in coordination with Airbus-Boeing have published a White Paper "Future Connectivity in aviation". A document which is in line with Business Aviation needs and requirements. The "Detailed Multilink Implementation and Air/Ground application (ADS-C/EPP) Roadmap " must follow the "White Paper" recommendations, this will allow a smooth certification of the required services (ATS/AIS) and a harmonious development and a rapid deployment of the "Cabin Connectivity links" and of the associated services.

For Business Aviation, communication services to the passengers are essential, such services (voice, internet, video conference, TV…) are requesting large bandwidths and secure communications. These links will also be used for AOC services and for cockpit information (EFB). As indicated in the EASA-FAA White Paper, these links will also be used in backup mode to provide ATS/AIS services. Most Business Aircraft are equipped with integrated avionics suites, and the avionics manufacturers are proposing to the operators all the communication services they need to operate to monitor and to support their operations. It is possible to indicate "Garmin Connext", "Honeywell Forge" or Collins ARINCDirect.

As the exchanges are using Internet Protocol and Internet addressing system, these services can use the different links available (SATCOM as Terrestrial) and even the most efficient ones.

Numerous of these links are today in service and new ones are in development. It's a market which is growing rapidly. It is possible to indicate the classical ones as “Inmarsat SwiftBroadband”, ‘Iridium” and the newcomers as “Iridium Certus”. There are also the “Ka”, “Ku” links with ViaSat and even the “LEO” constellations with “Starlink” or “OneWeb” and the 4G” & “5G” ground networks with “GOGO”. This market is Business Driven and so will have to be submitted to the minimum certification requirements; they will have to demonstrate that they will not adversely affect the ATS/AIS services.

Today in Europe ATS/AIS services are relevant of the ANSPs and of the National Authorities. Tomorrow, the deployment of Multilink will impose Europe to put in place a “Common/Centralized Service”. Deployment of such service at European (NM) level will impose the publication of a mandate.

It is only following publication by EASA of the revised CS A-CNS and publication by EC of the decision relative to CP1 AF6 "Maturity Gate", that the need and status of this "Common service" will be known.

As in the future, all links will use Internet protocol, it is recommended that "Multilink Common Service" will only accommodate IPS/IP links. Use of other protocols will impose to put in place useless complex and costly gateways.

Such deployment must be justified by a global positive CBA, nevertheless funds will have to be provided to the users which will have a negative CBA. Exemptions might be considered for some specific users.

As indicated in the "EASA-FAA White Paper", with the development of UAS there is a need to consider the development and deployment of C2 links. Use of C2 links will not be limited to UAS, it will also be used on aircraft for reduced crew operations. For CS-23 single pilot aircraft, Garmin has developed and certified the HALO Emergency Autoland System, today it is a fully autonomous system. Tomorrow with a C2 link, it will be possible to communicate with the system and for example it will be possible to modify the destination airport.

4.1.2. ANSP view

CP1 Regulation Compliance Deadline

EU ANSPs delivering services above FL285 are to comply with the AF6 part of the CP1 mandate (IR 2021/116) by 31. Dec 2027 and providing initial trajectory information sharing above flight level 285. The implementation of ADS-C/EPP, as part of ATS B2 and conditional upon the passing of the maturity gate in 2023, will increase the load of the VLDm2 system. The ADS-C/EPP forward fit equipage of Aircraft started already and will lead to a gradual ramp-up on DLS demand with an acceleration following CP1 mandate deadline. A way to control the increasing load of the Air/Ground COM system is to implement the ADS-C Common Service before the 2027 CP1 mandate.

VDLM2 capacity crunch

The VDLM2 capacity crunch is expected by 2030 at least in high traffic areas due to the continuous AOC and ATS data volume increase to reach capacity and sustainability targets and manage air traffic complexity as well as capacity according specific ANSP's business targets.

FABEC ANSPs proposal is to adopt emerging technologies and in particular SATCOM (IRIS) as soon as certified (expected by 2024) and LDACS as terrestrial system to complement VDLM2 in the long term (by 2030). This new terrestrial system will also increase the resilience of the Air/Ground COM.

ENAIRE supports the modernization of the Air/Ground Datalink and supports the introduction of new datalink communications technologies. However, as the VDLM2 capacity crunch is still in a far horizon for many and large parts of Europe, even more with the foreseen VDLM2 identified improvements, the new technologies should be considered complementary to VDLM2 and their adoption be optional for each particular user. Consequently, the multilink technical solutions shall support that different users adopt a different set of datalink technologies, and define their own link use policy for each individual service (CPDLC, ADS-C, AOC, etc.) under its responsibility. Additionally, ENAIRE considers that the multilink and the participating technologies should be provided to users, at least to ANSPs, by a common European service provider, the ACDLS provider.

Transition from ATN/OSI to ATN/IPS

The transition towards ATN/IPS need to be smooth and safe and backward compatible. Considering that the SATCOM[10] and LDACS systems are IPS native we expect to have ATN/OSI to ATN/IPS gateways in place by 2030 or even before to accommodate IPS aircraft.

[10] Refer to the Iris roadmap as per the ESSP view section.

The migration to IPS will permit the introduction of new performing Air/Ground COM systems supporting the full TBO operation and facilitate the global harmonization expected from 2032 on. The ANSPs view for the full B2 implementation would be a common approach.

The ANSPs main drivers are:

- CP1 mandate (IR 116/2021) compliance
- Service improvements targeting full TBO
- Costs optimization
- ATM system modernization
- Promote equipage with complementary technologies on the airborne side, which needs a coherent aligned roadmap - having access to 'multilink' as an ANSP is useless if there is not a significant population of aircraft equipped with the technologies
- A clear decision on how to proceed about the multilink deployment roadmap is required by ANSPs not later than end 2023 to allow continuous planning and a harmonized deployment approach to solve the identified problems in due time.

Need to define the responsible entity for determining the multilink operational/financial strategy.

4.1.3. Military view

Civil and Military Aviation activities are tightly interlinked, as they share the same airspace considered as a continuum. The Military are at the same time Airspace User, Air Navigation Service Provider to military and to civil aviation, Airport Operator (in some cases of military airports opened to civil aviation), Airspace Manager and Regulator.

The Military have developed a set of high-level principles[11] that should be considered in the development of any new Communication infrastructure that may affect them in those different roles:

Military needs:

To handle military aircraft using civil services, infrastructure, and systems at a network scale through compatibility and interoperability between military Airspace Users and civil Air Navigation Service Providers operating VFR or IFR.

To handle military flights using military services, infrastructure, and systems at a network scale through compatibility and interoperability between military Airspace

[11] See the pragmatic approach to a CNS military strategy.

Users and civil Air Navigation Service Providers as civil ANSP provide services to military operating VFR or IFR.

To ensure compatibility between civil AU and mil ANSP as military provide ANS in upper airspace.

To ensure interoperability for data exchanges related to ASM, AIM, voice, flight/trajectory data and surveillance data between civil and military units and centres.

Military limitations:

A fundamental military concern for the future when adopting ATM/Communication capabilities is security for airborne and ground sides. The required resilience of communications limits the use of civil datalink systems.

Some military aviation systems (particularly fighters and RPAS) have some aircraft equipage limitations due to, amongst others, cockpit integration constraints, airframe structure and payload requirements.

Certain military ATC functions (ATC and C2/Air Defense) are dependent of information exchanges which require seamless interoperability with civil ATM systems via interfaces, such as New PENS, messaging, voice over IP and access to SWIM services and technical infrastructure. In this area security for exchanges between classified and non-classified environments is not yet ensured. This calls for adequate interfaces and security measures to be implemented and ensure data integrity and availability. Dissemination of military information in the civil environment shall be done with protection of sensitivity.

Military ANSPs will continue to provide service to civil through ground radio telephony/ATS voice communication.

Military requirements:

Ensure civil ANS (particularly above FL285 as per D/L regulation) through radio data link/ voice communication until technical solutions for inclusion of fighter/RPAS platform and to solve cyber and resilience issues have been developed.

UHF or 25kHz VHF must continue to be provided by civil ANSPs to accommodate a residual number of non-8.33 kHz equipped State aircraft flights or use specific 25KHz VHF capabilities (limited in channels).

Interfacing policies and security, protection of sensitivity of military data, availability, and integrity of civil data.

Military aircraft require the ability to limit and/or anonymise the transmission of specific data using ATS data links.

4.1.4. European Datalink Governance (ACDLS)

The ACDLS (ATS Common Data Link Service) Governance has been established by European ANSPs intending to contract a Datalink Service Provider (DSP) providing ATS Datalink Services to the ANPS becoming a member. ACDLS Governance will be in line with current and existing related regulatory activities and assets such as the European ATM Master Plan and SESAR Deployment Programme, and closely coordinated between the relevant Parties.

The ACDLS Governance refers to 18 ANSPs who have signed a Memorandum of Cooperation in October 2021 for the deployment and future operational exploitation of a harmonized telecommunication infrastructure supporting current and future ATC datalink services in Europe. This harmonization objective will be reached via the common contracting of a unique Datalink Service Provider (DSP) supported by the established Aeronautical Communication Service Providers (CSP) and providing services to ANSPs. Current plans assume that the DSP contract will be signed beginning 2025 and full DSP operations will be available beginning 2027. The geographical area in which harmonized DSP operational services will be provided is the airspace area under responsibility of those ANSPs members of the ACDLS Governance who will decide to sign a contract with the selected DSP.

The role of the ACDLS Governance is key to the future European datalink environment because it will manage, though the DSP, a large part of the ground telecommunication infrastructure required to support those ATS services. The main expected improvement of the ACDLS scheme compared to the present way datalink services are provided in Europe is a defragmentation of these services, a global improvement of the performances and mutualization of the associated costs.ACDLS position as regards FCI and multilink is driven at first by the common view that datalink services are bringing significant operational benefits to ATC. This is already clearly observed with the increasing provision of the ATS B1 services mandated by EC Reg. 29/2009. Despite the fact that VDLM2 service still faces some problems which need to be solved (details can be found in the DSG database) , ATCOs from ACDLS members express their overall satisfaction with these initial services. They improve automation, contribute to reducing the workload of ATCOs and pilots and allow to increase ATC sector capacity. Strong expectations are now largely shared about enhanced operational benefits to be brought by the future ADS-C/EPP service which will prefigure the deployment of ATS B2 and later on the deployment of the ICAO and SESAR Trajectory Based Concept (TBO).

The only air/ground link available today to provide En-route ATN datalink services is VDLM2. It is a mature technology provided at acceptable costs to ACDLS ANSPs. However, it still faces technical limitations (e.g. bandwidth) which lead to the common ACDLS view that a complementary air/ground technology will be required in some areas of Europe, to secure the deployment of future datalink services.

The so-called VDLM2 crunch is feared by some ACDLS members. The question is when this crunch will happen? The only VDLM2 capacity study available is dated prior to the COVID crisis and its update is very difficult to perform because it depends on estimates of data increase for ATS and AOC services. Our observation is that estimates of future data traffic from airlines, aircraft and engine manufacturers are not easy to obtain.

Other factors contribute to explain the different visions among ACDLS members about the date of the VDLM2 crunch, such as:

- Significant differences in the current and planned volume of En-route traffic.
- Variable analyses about the impact of new frequencies recently allocated to datalink on VDLM2 lifetime
- Variable analyses about the speed at which airlines will equip with a complementary technology
- Change in VDLM2 protocols and operational use

Based on data available and their associated level of reliability, the ACDLS members from the Core Area estimate that VDLM2 crunch will start around 2027, when ACDLS members from areas with less dense traffic are confident that they will not face the VDLM2 crunch before at least 2030 or even later. The need to start deploying a complementary air/ground technology is therefore not so urgent for the latter group, when ACDLS members from the Core area (see heatmap of the capacity study) consider it is urgent to start now preparing the deployment of such link, especially when considering the time needed in the aeronautical community to deploy a new technology at a very large scale.

To foster deployment at a very large scale, meaning seamless provision of DLS based on complementary technologies a common sense underpinned by decisions on deployment steps and areas is required.

Independently of the variable assessment about the start of the VDLM2 crunch, ACDLS members all agree that the only available technology which could complement VDLM2 for ATS Traffic in a near future is IRIS/SATCOM and there is a need to continue supporting other technologies such as LDACS. IRIS/SATCOM service will be available from 2023 onwards. It offers a large coverage (both continental and oceanic) and promising performances. When Multilink is deployed, ACDLS members also agree that it must be made in a way that ATS service continuity is ensured through interoperable technologies. Such objective can only be satisfied if switching from one technology (e.g. VDLM2) to the other (e.g. SATCOM) is seamless. In the current pre-commercial trial implementation, due to current technical implementations, the way such switch is implemented in existing IRIS/SATCOM avionics, the continuity of datalink services with aircraft equipped with a dual stack VDLM2/SATCOM can only be guaranteed in a geographical zone covering airspace under responsibility of

ANSPs having contracted the IRIS/SATCOM service in addition to VDLM2. The ACDLS members recognize that these technical constraints have to be resolved before that IRIS/SATCOM becomes operational.

The unknown pricing model of the IRIS/SATCOM service is presently a blocking point for ACDLS members. Investing in IRIS/SATCOM is not considered in the coming years by these ANSPs unless the proposed pricing model is acceptable and in addition to other remaining issues (e.g. number of aircraft equipped, impact of IRIS/SATCOM costs in P&C scheme on top of VDLM2 costs, degree of development of other emerging Multilink technologies such as LDACS, Iridium, no current financial incentivation scheme). ACDLS members also consider that the cost of IRIS/SATCOM avionics could be a showstopper for a rapid equipment of the fleet. That's why all 18 ACDLS members (together with 11 other ANSPs) have co-signed the document [IRIS/SATCOM Implementation Plan for ATC operations]. This proposal has been sent to EC DG MOVE end 2022 with the objective to explain the future need of deploying this technology, but also the necessity to set up financial incentives to create the right momentum allowing both ground and airborne stakeholders to invest and boost the expected obtention of initial ATS B2 (ADS-C/EPP) operational benefits.

Deploying IRIS/SATCOM also means deploying the initial phase of the Multilink concept, with two technologies first over ATN/OSI before going to ATN/IPS. All ACDLS members support the Multilink concept which must favor competition and preserve the possibility for airlines to choose their airborne telecommunication equipment, as long as interoperability is maintained. This freedom is not questioned by ACDLS members who recognize the usage of the air/ground link is to satisfy AOC data exchange, not precluding that the path used for ATS Traffic is decided by the ATS Units. Multilink framework increases the cost of datalink and is another reason why financial incentives are essential to preserve competition and allow global deployment of ATC datalink services as well as the impact on the performance charging scheme. Datalink communications costs distribution model is not agreed among stakeholders so far, it needs to be discussed and decided at European level.

ACDLS members also consider that Multilink should only be deployed in the frame of the future DSP set up, including the Common European ATN backbone (CEAB) and ATN OSI/IPS gateways as soon as they are available. These features are essential to ensure fair competition between all types of air/ground technologies in the future, including LDACS, IRIDIUM and Hyperconnected ATM when available.

These cost considerations lead ACDLS members to request EC to think about the impact of these new investments in the RP4 framework, since it might be difficult to reconcile reduction of costs requested by RP4 and new investments required to deploy new datalink services.

The next expected air/ground link targeted by ACDLS members after IRIS/SATCOM is LDACS. LDACS technology is expected to progressively replace VDLM2, at acceptable costs, nevertheless cost distribution again needs to be clarified . It brings a lot of promising features (in addition to good performances and a secured link) such as the possibility to set up a progressive deployment plan (thanks to dual LDACS/VDLM2 radios) transitioning the current VDLM2 infrastructure into a LDACS infrastructure. Political support will however be needed to promote the ACDLS support for LDACS since it is not in line with the recent white paper from EASA, FAA, Boeing and Airbus.

In conclusion, from all these considerations about datalink benefits, risks in VDLM2 future, IRIS/SATCOM availability, Multilink support and LDACS expectations, the common short/midterm view of ACDLS users in terms of FCI and Multilink deployment is an early deployment and operational use of IRIS/SATCOM. In the IRIS test and validation period a set of ANSPs will gain experience with SATCOM Service. Once IRIS is certified it is expected that ANSPs start to offer SATCOM Service. In the frame of the DSP the ANSPs can contract SATCOM as an optional service.

The geographical area for first deployment could be the European Core where early VDLM2 capacity crunch is expected. It would make sense to expand the area as soon as possible to the South-east axis along major traffic flows of Europe (see map below). This IRIS initial coverage area might be progressively expanded as soon as neighboring ANSPs start facing the VDLM2 crunch, taking into account other available technologies by the time being. It offers a reasonable scheme of seamless VDLM2 / IRIS switches.

The figure below shows the possible initial IRIS/SATCOM coverage through the DSP. It is important to note however that, at this stage, this common ACDLS view does not represent a formal commitment from the ACDLS Governance members to contract IRIS/SATCOM service through the DSP, since it is subject to a positive business case resulting from the DSP Call for Tender, possibly complemented by local CBAs performed individually by each ANSP considering signing a contract with the DSP.

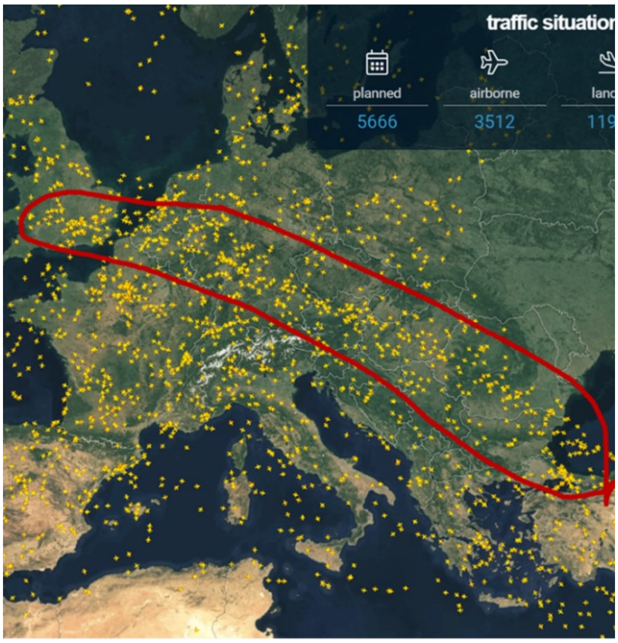


Figure 6. Possible SATCOM Deployment along S/E Axis of traffic flows

4.2. Technological view

4.2.1. Research & Innovation View

4.2.1.1. Future Communication Infrastructure (FCI)

PJ.14-W2-77 Solution: "FCI Services"

Europe's future communications will need to support an increased number of aircraft, new types of manned and unmanned craft, as well as military air traffic. This demands higher datalink communication capacity and better performance than any kind of current communication system. SESAR is focused on developing an air-ground communication infrastructure capable of supporting future air traffic services in addition to flight operations centres (or military wing operations centres). A key part of resilient air-ground communications is the development of a future communications infrastructure (FCI) network infrastructure to support future service concepts and the migration towards internet protocol. The extension of a common, shared, integrated and resilient network infrastructure is necessary to enable SWIM applications and interfaces between all parties, including the military.

Timely access to airspace management data and information services is the first step towards enabling real-time sharing of trajectories in 4D. The SESAR 2020 PJ14 Wave 2 Solution 77, "FCI Services", has completed the technical specifications for the FCI network infrastructure and it has validated the concept and the prototype implementations up to the TRL6 maturity level.

The FCI Solution developed in SESAR PJ14-W2-77 is based on the integration of the different datalink Access Networks, namely LDACS, SATCOM, IP VDLM2 and

AeroMACS and it supports ATN/IPS multilink capability and aircraft mobility between the different datalink systems. It also addresses civil-military interoperability requirements for ground/ground network interfaces, safety and security requirements.

It is the only solution currently validated up to the TRL6 maturity, which allows, through monitoring of the status of the different links and traffic prioritization based on QoS/CoS, to realize a Performance Based Approach with optimized routing and increased Availability of the Air/Ground Communications for Safety Critical applications. Furthermore, it supports also an “administrative policy” based approach, through implementation of link preferences, which coexists with the previous one.

In PJ14-W2 Solution 77 validation exercises, the ATN/IPS multilink has been proven to achieve performances in compliance with the EUROCAE ED-228 RCTP/RSTP and, also, in compliance with the performance requirements for future ATS-B3 applications that, although not yet standardized, have been studied and defined in the SESAR 1 Programme by industry and end user expert groups.

Multilink performance-based policy

This scenario represents the selection of alternative datalinks among available radio access technologies for an IPS equipped aircraft, according to the acceptability of the performance level achieved. Figure 7 below illustrates the scenario depicting different overall levels of performance (GREEN for high, YELLOW for medium, RED for low)[12] for different datalinks which are simultaneously available to an aircraft. This scenario is complementary with administrative multilink policies.

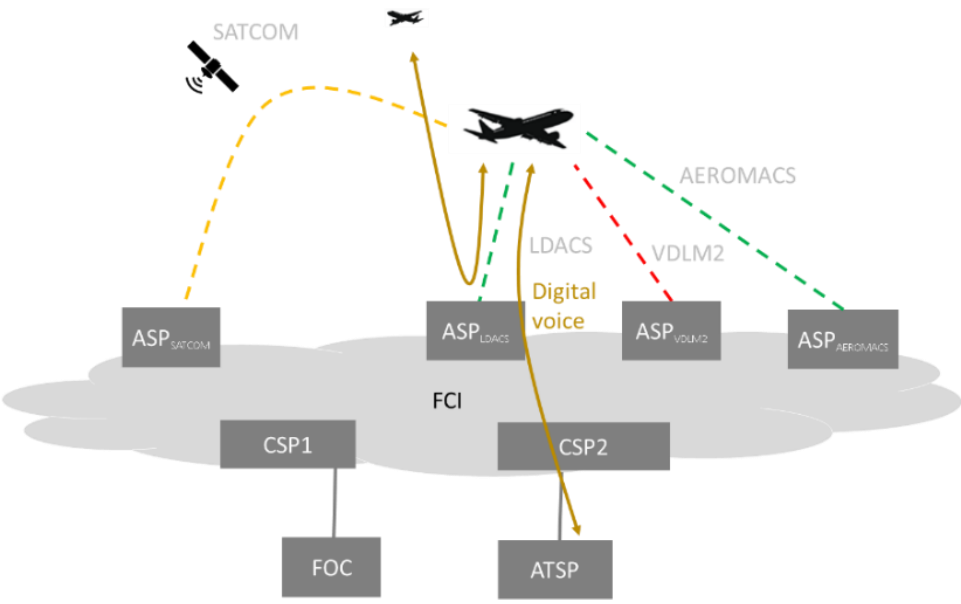


Figure 7. Performance based Multilink policy

12 Colour codes do not have an intrinsic significance in FCI. They are just to illustrate datalinks can offer different levels of performance. Note that the assignment to a colour to a specific datalink is an arbitrary example and does not intent to convey the capacity or limitations of a particular technology.

The actors present in the scenario are:

- ATSP, providing datalink services (ATS B2/B3, AIS/MET, Flight information) and digital voice to aircraft, and end to end service monitoring. ATSP may be associated to a specific airspace volume (oceanic or continental) or according to other operational scope.
- FOC, providing AOC services to aircraft, and end to end service monitoring.
- CSP(s), providing network connectivity and monitoring between ATSP or FOC and aircraft. The radio access segment of the air/ground communications is supported by an ASP specific for a datalink technology. CSP either operates one or more access networks or establishes agreements with an ASP to support its communication services.

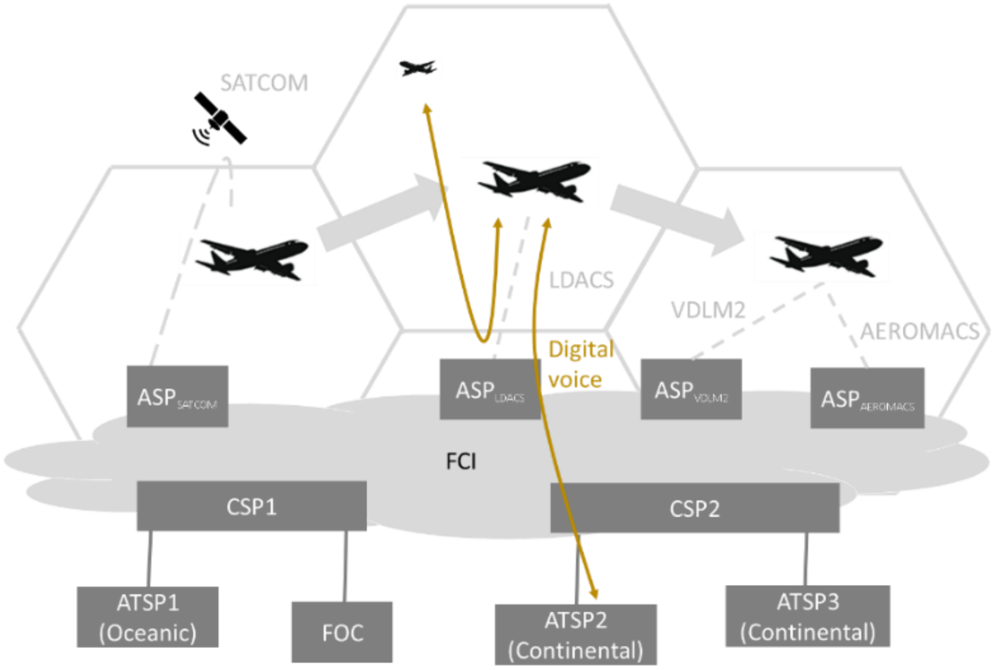
Aircraft equipped with an IPS mobile subnetwork and IPS datalink radio systems.

Under performance-based Multilink, link selection is based on the acceptability of a datalink quality to guarantee the performance levels for a particular application. A datalink will not be authorised for the provision of an ATM service whose required performance is above that considered to be guaranteed by the access network. As a result, different services (e.g., ATS, AOC, digital voice) may use different datalink depending on whether they are considered by the system to comply with the QoS parameters configured for the CoS assigned to the service. When two different services are transmitted over the same datalink, QoS configuration allows for prioritization.

The multilink has the aim to maximize the availability of A/G connectivity. Link selection will be AU policy driven, selecting from the datalinks available, based on all accessible ground and airborne infrastructure at that specific aircraft location, taking into account minimum service specific performance needs, while simultaneously allowing to minimize communication costs. Moreover, the performance-based Multilink optimized on QoS/CoS covers also the current need for an offloading of AOC data.

Multilink – administrative policy

This scenario represents the selection of alternative datalinks among available radio access technologies for an IPS equipped aircraft, following the preferences and constraints defined by administrative policies illustrates this scenario depicting an aircraft flying on different flight domains with different associated Multilink policies. This scenario is complementary with performance-based Multilink.



[13]

Figure 8. Administrative Multilink

The actors present in the scenario are:

ATSP, providing datalink services (ATS B2/B3, AIS/MET, Flight information) and digital voice to aircraft, and end to end service monitoring. ATSP may be associated to a specific airspace volume (oceanic or continental) or according to other operational scope.

FOC, providing AOC services to aircraft and end to end service monitoring.

CSP(s), providing end-to-end network connectivity and monitoring between ATSPs, or between ATSP or FOC and aircraft. The radio access segment of the air/ground communications is supported by an ASP specific for a datalink technology. CSP either operates one or more access networks or establishes agreements with ASP to support its communication services.

Aircraft equipped with an IPS mobile subnetwork and IPS datalink radio systems.

The selection of datalink(s) to be used depends on pre-defined policy or preferences. Policies set by national regulators can be mandatory (e.g., datalink not certified for use) or recommended, and must be endorsed by AUs and ATSPs in the applicable region. Link preferences respond to preferences or constraints from the current ATSP or the airspace user, and criteria such as geographical location, altitude, airspace region, or phase of flight.

This can obey to commercial, regulatory, or other reasons. This results in ATM service providers making use of the datalinks that are preferred, or authorized, among the

[13] Figure 8 is out of the PJ.14 Solution 77 activity and is not covering the ACDLS DSP implementation

available datalinks. CSPs maintain the connectivity and network routes to accommodate end-to-end communication over the selected access network.

Note: It is assumed the datalinks remain within acceptable performance. Performance-based datalink selection is described in the previous scenario.

Link selection policy may be defined per application. For example, ATS and AOC may be configured to follow different paths. This is implemented via defined Classes of Service (CoS) which drive the routing policies associated to the configured administrative policies. Following the preferences defined per CoS, different applications can be transmitted over different datalinks, or over the same datalink (for which different priorities and QoS parameters may be applied).

AGMI & GB-LISP Interface Protocols

The ATN/IPS mobility & Multilink solution validated in SESAR has its core functionality based on the following two interface protocols:

- Ground Based LISP (GB-LISP)
- Air/Ground Mobility Interface (AGMI)

Which are now standardized in the new Edition 3 of ICAO Doc 9896 (ATN/IPS Manual).

GB-LISP is a specific profiling for the aeronautical applications of the LISP protocol (Locator/ID Separation Protocol), which is an industry IETF standard with many years of proven operation in other industry sectors.

AGMI is a protocol interface designed specifically to support the ATN/IPS mobility and Multilink, which allows aircraft IPS-enabled to communicate to the ground IPS-enabled mobility network both the Link Status of each datalink in use and the Link Preferences, as configured in the aircraft IPS system by the aircraft operator.

Benefits of the FCI IPS Mobility & Multilink (M&ML) Solution

The foreseen benefits from the FCI Multilink & mobility solution are the improvement of safety and security, of cost efficiency, of interoperability and of civil-military coordination, with enhancement of the efficiency and flexibility of the overall datalink communication system, through the provision of resilient Multilink and mobile communications capabilities to the aircraft.

More in detail, the following benefits have been identified during the development of the FCI Business Case [RefDoc 01] "FCI Business Case, V18, 21 April 2022, presented at JCSP7 (May 2022) [updated by SESAR20202 PJ14 Solution 77, deliverable D5.1.500, Nov. 2022":

- The Safety analysis conducted in SESAR on the FCI Multilink and the ICAO WG-I conclusions show that the major benefit of the ATN-IPS Mobility & Multilink Solution is to be able to achieve the necessary performances required to comply with availability requirements from Aeronautical Standards as EUROCAE ED-228A. Whereas the expert opinions matured in both ICAO and SESAR are that with only a Single Link a complete fulfilment of these requirements would not be achieved.
- The FCI IPS M&ML Solution enables more competition in the flexibility and configurability on board of the different datalinks, allowing AUs more options to choose from for optimization of their operations. Such benefit is in fact a key factor for Airspace Users.
- It supports a Performance Based communication routing previously described, which allows to achieve optimized communication routing, enabling not only a solution for the current need of AOC traffic offload, but even more functionality in support of future Datalink services.
- It is the only concept that provides a standardized framework, which enables the future technologies to be integrated and interoperable. One example is the support of future ATM applications using Simulcast (i.e., transmission of the same messages over multiple datalinks).
- It allows leverage of a much broader community of experts worldwide, whereas ATN-OSI is very specific and currently developed only by few companies.
- It enables a seamless Interoperability among the related datalink technologies, whereas without it, and with AUs being able to select independently which datalink technology to use, the ground infrastructure would have to implement all of the selectable technologies, involving additional gateway and network coordination functionality and, therefore, sustaining additional costs.

Status of the Standardization

Besides all the different standards associated with each datalink technology, relevant for the FCI Mobility & Multilink Solution are the following ones:

- The ICAO ATN/IPS SARPs (Annex 10, volume III, part 1, Chapter 3), which is undergoing an update expected to be applicable in Nov 2024
- The ATN/IPS Manual (Doc 9896), whose Edition 3 is undergoing the ICAO final review process for publication and is expected to be applicable in Nov 2024
- The EUROCAE/RTCA IPS MASPS, which is expected to become applicable in 2024

- The EUROCAE/RTCA IPS Profiles (EUROCAE ED-262), whose first version is already available and currently being updated, targeting the new Version A (ED-262A) with applicability date also in 2024
- The AEEC Project Paper PP858, whose first version has been published in 2021 and which is currently undergoing an update
- The following IETF LISP RFCs, which will be updated with specific GB-LISP profiling for the Aeronautical Application validated in SESAR by PJ14-W2-77 FCI Services
- Doc 10045 IPS Security Risk Assessment (SRA), [RefDoc 06]
- Doc 10095 Manual of Public Key Infrastructure (PKI) Policy for Aeronautical Communication, [RefDoc 07]
- Doc. 10090 Manual of Security Services for Aeronautical Communications, [RefDoc 08]

Future SESAR 3 activities

Starting from the TRL6 maturity achieved in SESAR 2020, the FCI technology is ready to be proven in Digital Sky Demonstrator projects and matured to operational maturity (TRL8/TRL9) in the coming years.

Furthermore, there are plans for further development and validation in SESAR 3 of additional features, currently being discussed in the ICAO ATN/IPS WG-I, which will further enhance performances, safety and interoperability.

4.2.1.2. SATCOM NG

SATCOM Evolution towards IPS-based FCI

The latest ATM Master Plan explicitly acknowledges the role of the SATCOM component in the development of the ATM Future Communication Infrastructure (FCI). SESAR SATCOM solutions, from SESAR1 to SESAR2020 Wave 1 and Wave 2, support the European ATM Master Plan, and will enable a large range of economical, safety and environmental benefits.

In the FCI context, SATCOM, together with terrestrial communication systems, will enable the future concepts, which are being developed in the context of the SESAR, NextGen and CARATS ATM Modernisation Programmes.

SATCOM is an essential part of the seamless, resilient and integrated FCI, for both the continental and remote/oceanic regions, needed for supporting the performance and safety objectives for real-time sharing of 4D trajectories and timely access to ATM data and information services. SATCOM technology for ATM improves cost efficiency, datalink availability and capacity, and improves safety and security.

The datalinks for ATM will be based on the Future Communication Infrastructure (FCI), encompassing the following datalink technologies:

- Terrestrial communication system, named LDACS (L-band Digital Aeronautical Communication System);
- Surface communications in airports with high density traffic, named AeroMACS (Aeronautical Mobile Airport Communications System);
- Satellite based communication system (SATCOM), developed in cooperation with the ESA Iris Programme.

Figure 9 and Figure 10 provide a picture of the SATCOM system as part of the IPS-based FCI, in a Multilink context, and a view of how the Airport, Continental and Oceanic Operational Environments are covered by the different data link technologies.

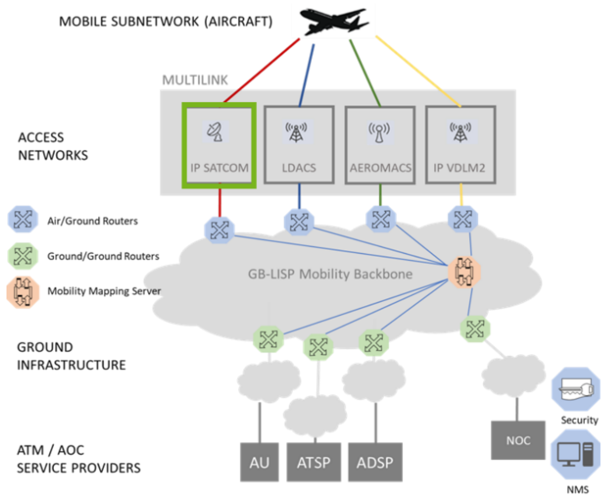


Figure 9. SATCOM as part of the IPS-based FCI

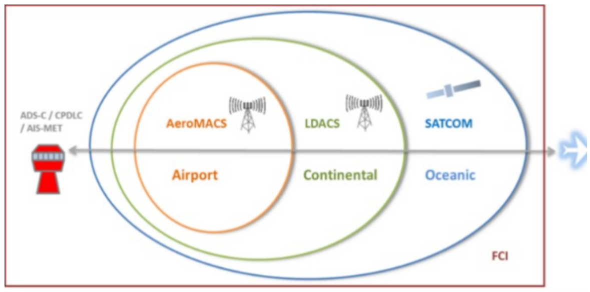


Figure 10. Coverage of the Operational Environments

SATCOM as part of the IPS-based FCI. with SATCOM, the entire communication system based on satellite access is identified. The system architecture is composed of segments, which are mainly airborne, space and ground as shown in the figure Figure 10.

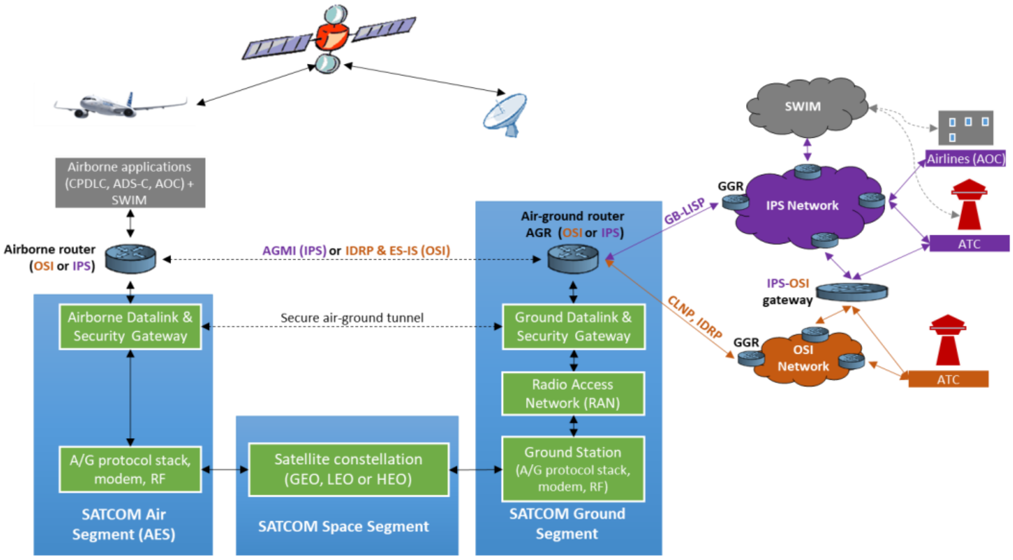


Figure 11. SATCOM High Level Architecture

On the ground, the SATCOM system will interface to the existing ATN/OSI network or to the Future Communication Infrastructure (FCI) based on IPS network technology. The aircraft will be equipped with either ATN/OSI or IPS protocol stack and the interoperability between OSI and IPS will be handled through ground adaptation gateways.

SATCOM in aviation, is used for various types of communications and exchanges of data and voice, namely ATS (Safety of Life), AOC (regularity of flight) and APC (passenger communications).

The main activities related to SATCOM in the two SESAR1 SATCOM projects as well as the current SESAR2020 SATCOM solution are not addressing APC communications. The focus in SESAR is primary on ATS and AOC communications as both are allowed to operate on the same frequency bands identified by the ITU for Aeronautical Mobile Satellite (Route) Service (AMS(R)S).

For the satellite communications data link solution, specific to long term air traffic management, L-Band frequencies, 1545 to 1555 MHz (satellite to UT) are allocated worldwide in non-contiguous blocks of 200kHz. System feeder links must operate in the frequencies identified for Fixed Satellite Services (FSS) (e.g., Ku band).

Other Frequencies will be considered as C-Band and Ku/Ka Band but for APC services.

SESAR 2020 solution PJ.14-W2-107 “SATCOM Evolution towards IPS-based FCI” addressed the technical specification, development and validation of the future satellite data link technologies, for both the continental and remote/oceanic regions needed for supporting the future concepts beyond 2025, covering the following aspects:

- SATCOM Long Term Technical Specifications

- Performance monitoring and control concept for Long Term SATCOM in ATN/IPS
- SATCOM voice
- SATCOM Validation at “TRL6 ongoing”
- Coordination with ESA Iris Programme and harmonisation at global level
- Support to standardisation

SATCOM Benefits

Future SATCOM Data Link will bring benefits that are common to all datalink technologies through the applications they are enabling (e.g., CPDLC, TBO, etc.). However, SATCOM includes some clear benefits that are specific to the technology and should be taken into account when planning deployment as they can make a significant difference to the airspace users and ANSPs business case.

They are detailed below:

The maturity of the technology is high, **the technology is proven** (the core technology has been used in the oceanic airspace many years).

The pan-European coverage does not need a ground infrastructure beside Ground Earth Stations GES already in place. By design, the SATCOM technology provides immediate and seamless coverage of the target airspace and beyond. Once an aircraft is logged onto the SATCOM service, the aircraft can use the link wherever it flies. This can bring additional benefits to airspace users compared with terrestrial-based technologies at the boundaries of European airspace (e.g., to aircraft arriving from the North Atlantic oceanic airspace or from the Middle East or Africa).

Beyond the continental airspace coverage, the FANS1/A service is provided using the same airborne SATCOM terminal. From an airline perspective, this means that a European airline choosing the solution will access additional services on a global basis on top of ATN in Europe. This is a clear immediate benefit for the long-range aircraft and also to the Narrow Bodies that fly outside of Europe (ETOPS) and using the TANGO routes. For long-range aircraft flying oceanic routes, all the SATCOM services (ACARS, ATN/OSI, IPS, cockpit voice and the native non-safety IP) are available on the same terminal globally for a seamless transition from oceanic to continental airspace.

Global expansion is also an important benefit from the airline perspective. Once the SATCOM datalink service is deployed and used, it will be available globally with only software changes to the airborne and ground infrastructure. This represents a strong enabler to TBO operations implementation in a consistent manner throughout many regions. ESA/Inmarsat are assessing how to manage the extension of Iris from the ground perspective outside Europe (the satellite network is already global).

Greening the CNS infrastructure: The SATCOM technology does not need an energy-hungry infrastructure on the ground as is the case with the terrestrial technologies. Recent analysis conducted by EUROCONTROL demonstrated that European ANSPs "are estimated to consume 1,140 GWh of electricity annually, roughly equivalent to 55% of the annual electricity consumption of Malta". It is also mentioned in the article on "Greening European ATM's ground infrastructure" (October 2021) that "switching to renewable energy and making energy-efficient investments could save ANSPs over 311,000 tonnes of CO_2 every year". SATCOM is one of these energy efficient investments that can help ANSPs meet their target for the reduction of Scope 2 CO_2 emissions.

Performance: The ICAO Performance-Based Communications and Surveillance (PBCS) Manual (Doc 9869) defines a framework to quantify the datalink system performance needed to meet operational requirements. It introduces two concepts:

- Required communication performance (RCP) applicable to two-way controller-pilot datalink communication (CPDLC) dialogues, and;
- Required surveillance performance (RSP) applicable to one-way transfer of surveillance data by contract-based automatic dependent surveillance (ADS-C).

Based on these concepts, EUROCAE ED-228A/RTCA DO 350A specify sets of requirements, RCP130 and RSP160 respectively, which are applicable to ATS B2 applications in continental en-route (ENR-1) and TMA airspace. Iris compliance is measured against these performance requirements.

Capacity: SATCOM can be relied upon to complement the VDLM2 network and create a datalink service infrastructure that is aligned with the most likely evolution of datalink usage in Europe.

Latency: SATCOM measured latency with ESA Iris and SESAR PJ.38 ADSCENSIO flight trials show compliance with the applicable RCP130 and RSP160 latency requirements.

Availability: Redundancy in the space segment needs to be sufficient to support service availability requirements. The baseline is the current fleet of Inmarsat 4 GEO satellites (3 x I4 + Alphasat), which will be complemented with Inmarsat 6 GEO satellites in the early 2020s. This may be augmented with further GEO satellites for availability (at least 3 GEO satellites)[14] . Non-GEO satellite constellations could be investigated to cover the residual GEO coverage gaps below 70° N latitude or enable coverage extension above 70°N latitude.

Safety, security and QoS aspects: SATCOM is developed against the safety service performance targets above. The SATCOM service provider (Inmarsat) has engaged with EASA for certification, with a target for an operational service by mid-2023. The state-of-the-art SATCOM services also integrate a cyber-security layer (PKI and VPN).

Ease of deployment and financial aspects: The main benefit of SATCOM is that there is no major new ground infrastructure deployment needed. This is a significant differentiator compared to all ground-based datalink technologies, mitigating risks, cost, boosting global usage as well allowing a rapid roll-out to an entire airspace.

SESAR background & Related projects

SESAR PJ.14-W2-107 "SATCOM Evolution Towards IPS-based FCI" technological solution, describe the SATCOM in terms of scope, main benefits, relevant system impacts, and a summary of its main achievements. Due to the importance and benefits that can be brought to the FCI by the SATCOM component, a whole line of studies is foreseen in SESAR, starting from Wave 1.

The figure below shows the background, ongoing and possible future SESAR SATCOM-related activities.

Figure 12. SESAR SATCOM-related activities background and next steps

Figure 12 shows how SESAR 2020 PJ.14-W2-107 is linked to other projects, such as ESA Iris programme (with synergies and cooperation on the validation execution), previous SESAR projects, other solutions within the SESAR 2020 PJ14 and other PJs, as well as standardisation groups and bodies for harmonisation at global level of proposed solution.

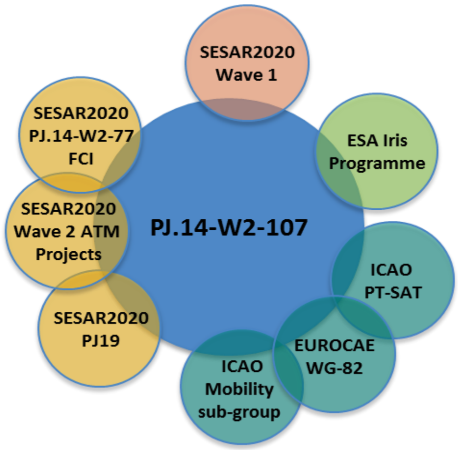


Figure 13. PJ.14-W2-107 Relations with other projects/solutions and entities

Solution 107 has continued and completed the work performed by PJ14.02.02 in SESAR 2020 Wave 1 on long term Class A SATCOM. PJ14.2.2 was in charge of the definition, at mission and user level, of the SATCOM Service requirements and their technical validation by executing dedicated validation exercises.

The SATCOM solution foreseen in SESAR and developed in the timeline described foresees, in addition to the work carried out within Sol 107, a close synergy with the ESA Iris programme. These synergies between the solutions related to SESAR 2020 SATCOM and the ESA Iris program are aimed at defining the ATM SATCOM service.

In this perspective the SESAR2020 SATCOM roadmap and the ESA Iris development roadmap have been executed in parallel, with SESAR2020 PJ.14-W2-107 providing the framework for the end-to-end validation of the ESA Iris SATCOM service in the FCI context of reference. ESA's Iris program has supplied the main ground infrastructure prototypes (IPS Gateway), airborne prototypes (AES) and Inmarsat's SB-S SATCOM service, to enable the SESAR2020 PJ.14-W2-107 validation campaign.

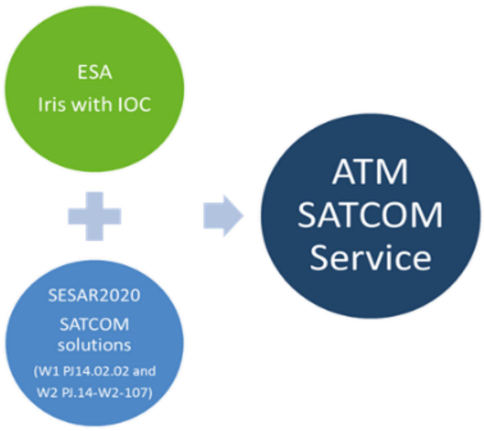


Figure 14. Relations between SESAR 2020 and ESA Iris Programme

ESA Iris Programme roadmap is shown in Figure 15 (October 2022):

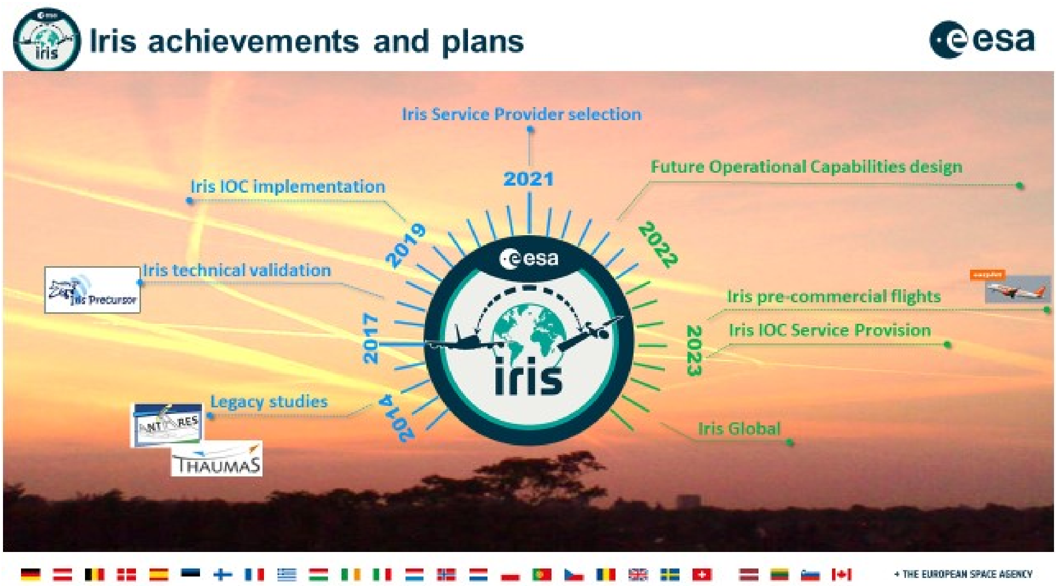


Figure 15. ESA Iris Roadmap (from FCI-Task Force of October 2022)

The Roadmap reflects the continuous growth of ATM services and CPDLC needs, to support Initial 4D trajectories operations for the IOC service and advanced 4D trajectories operations for the FOC service.

PJ.14-W2-107 Validation Process

The main objective of PJ.14-W2-107 validation is to assess compliance of SATCOM systems with the requirements defined by the Solution 107 TS/IRS (Technical Specifications/Interface Requirements Specifications).

The technology maturity aimed to be achieved in this solution is "TRL6 ongoing".

The TS/IRS requirements are meant to be generally applicable to any SATCOM system intended to be used as an element of the Future Communications Infrastructure (FCI). Nevertheless, Inmarsat's SwiftBroadband Safety Service is the only mature candidate available for validation, already TRL9 for European operation, adapted through the ESA Iris Phase 2 project to support IPS services (TRL6). Therefore, a very tight coordination between SESAR and ESA Iris is one of the key assumptions for the execution of the validation campaign.

Two validation exercises have been performed by the solution:

Objectives of EXE-1: IPS over Inmarsat SATCOM

Validate that the applicable requirements in [TS-IRS] can be met by at least one real SATCOM system

Demonstrate SATCOM as a mature and credible element of the IPS-based Future Communications Infrastructure (FCI)

Assess what (if any) performance margins the SB-S IPS service may be able to offer for the definition of future RCP/RSP types

Identify possible gaps and limitations and assess if / when they can be addressed

Objectives of EXE-2: IPS-OSI Interoperability over Inmarsat SATCOM

Validate that an aircraft equipped with ATN/OSI over SATCOM capability can interoperate with the IPS-based FCI ground segment.

Validate that an aircraft equipped with IPS over SATCOM capability can interoperate with the existing ATN/OSI ground segment.

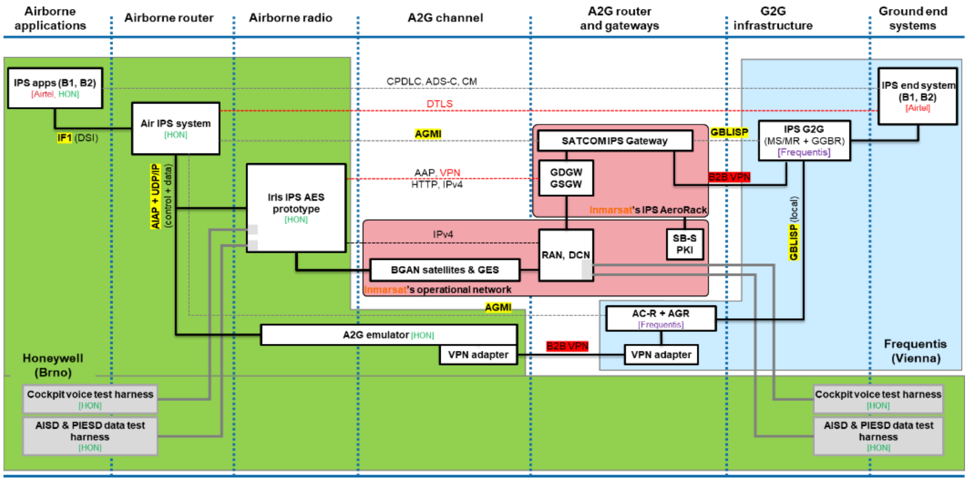


Figure 16. EXE-1: E2E IPS/SAT Integration & test setup

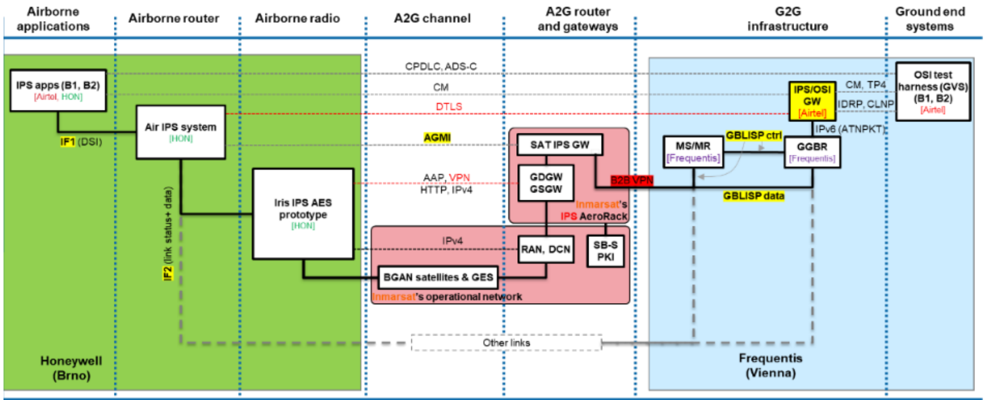


Figure 17. EXE-2a: IPS Aircraft to OSI ground

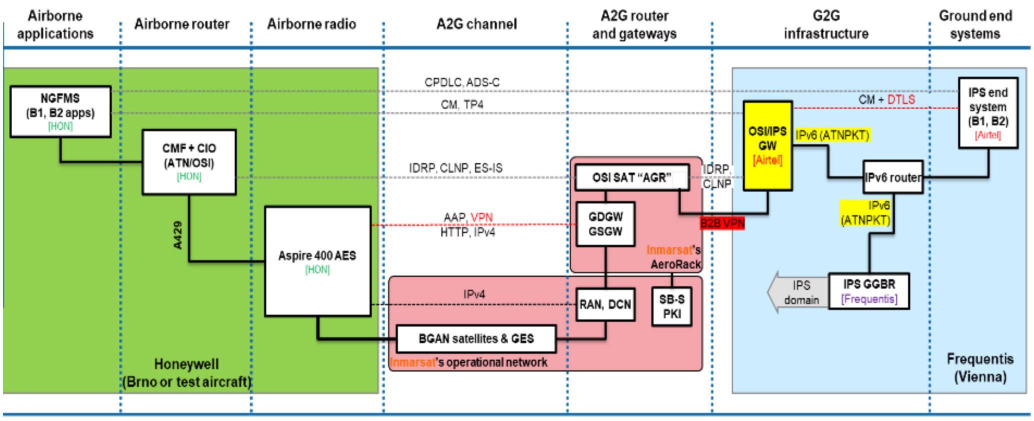


Figure 18. EXE-2b: OSI aircraft to IPS ground

The EXE-1 and EXE-2 test procedures were completed jointly with PJ.14-W2-77 "FCI Services" with successful integration of the SATCOM link in the FCI test bed for Multilink validation and in coordination with ESA-Inmarsat-Iris for the provision of the SATCOM data link and SATCOM IPS Ground Segment.

The purpose of the validation exercises was to demonstrate that the SATCOM technology can be used as a valid constituent of the Future Communications Infrastructure (FCI) based on IPS Multilink.

The following results can be summarized:

***EXE-1: IPS over SB-S**:* This exercise validated the delivery of IPS traffic over the SATCOM network between the airborne and ground IPS end systems. Within this end-to-end IPS connectivity SATCOM provided an air-ground link between the Airborne IPS System and the SATCOM ground IPS gateway (also referred as Air-Ground Router or AGR), through the encapsulation of IPv6 packets into the existing Inmarsat SB-S datalink.

***EXE-2: OSI-IPS interoperability**:* This exercise validated the interoperability between the IPS and ATN/OSI network technologies using the live Inmarsat SB-S network. Both sub-exercises defined in the [TVALP] were successfully completed with no adverse findings.

With the results obtained from these validation exercises and with the methods in which they were conducted (Realistic avionics, operational satellite system and realistic FCI ground segment) it was possible to define the TRL of the solution as *TRL6 On-going* (TRL 5 with initial steps towards TRL 6), but also identifying future steps to actually achieve TRL 6.

In addition, during the activity important results were obtained on:

- Link management, performance monitoring and control in IPS;
- The development of the voice on SATCOM;
- Cost Benefit Analysis - and SATCOM Benefits, reported above;
- Contribution to the standardization of the solution with contributions to SATCOM standards such as ICAO PT-Sat, ICAO Mobility sub-group, EUROCAE WG-82, AEEC IPS and AEEC AGCS.

With the results obtained in Sol 107, in synergy with the ESA Iris program, it was possible to consolidate the "SATCOM Long Term requirements" with the formalization of the Final TS/IRS (Technical Specification/Interface Requirements Specification); In particular, following categories of requirements have been consolidated:

- Functional

- Interface
- Interoperability
- Performance
- Safety
- Security

PJ.14-W2-107 Standardization

Deliverable D6.2.300 “PJ.14-W2-107 TRL6 ongoing - Standardization, Dissemination and Harmonization Activities Report Final” summarises the activities performed in standardisation aspects. Solution representatives have actively contributed to the following SATCOM standards groups:

ICAO PT-Sat: Updated SARPs for SATCOM Class B (completed in May 2022, endorsed by the ANC in September 2022), updated SATCOM Manual - Doc 9925 (estimated to be completed in 2023).

ICAO Mobility sub-group: Support of specifications for air/ground interface supporting mobility and Multilink.

EUROCAE WG-82: update of ED-242C (MASPS) and ED-243C (MOPS) to include IPS items such as supported service stacks (including dual ACARS/IPS and OSI/IPS stacks), priority, precedence and pre-emption, satellite subnetwork data protocol, user data interfaces, and equipment performance verification procedures for IPS

AEEC IPS: Support the specification of Internet Protocol Suite (IPS) Part 3, Common IPS Radio Interface (CIRI) protocol, intended for data transfer and radio status exchanged between radio modems operating in an airborne IPS network

AEEC AGCS: Develop an APIM to add IPS Radio Interface to the ARINC 771 and 781, and add performance requirements for switching between dissimilar SATCOM systems

PJ.14-W2-107 Recommendation & Future steps

The following recommendations have been drawn by the solution:

The **IPS data differentiation** and prioritization within the SATCOM system boundaries should be implemented and validated. This is now planned under ESA Iris Global.

The region-specific and flight-phase specific constraints need to be defined and implemented in **IPS Multilink policies** to efficiently use SATCOM and other air/ground links.

No showstoppers for **space-based VHF** have been identified, but further research is needed and recommended.

The **standardization** of IPS over SATCOM needs to continue. This is now ongoing under RTCA SC-222 / EUROCAE WG-82 for MOPS and MASPS and related activity has been launched under AEEC for ARINC 781 and 771 standards.

The **investigation and quantification of the data traffic** needs for AOC data, and on the future ATS needs, is also recommended for future works, in order to guarantee that all the future capacity needs are actually taken into account.

The support of **flexibility and scalability** capabilities, to cope with eventual increased capacity demand (on a per user or on a geographic basis) and possible accommodation of future new datalink services is recommended for future works (being addressed under the ESA Iris Global project).

Next steps identified in PJ.14-W2-107

IPS SATCOM service

The next step to achieve full TRL 6 is to **flight tests** the IPS SATCOM service, reusing the infrastructure used in this Sol.107/77 validation

For SB-S this is now planned under the **ESA Iris Global project**

Synergy with other programs is needed to enable combination with other Air/Ground links such as LDACS or VDLM2

The **standardization** of IPS over SATCOM will continue under the related standardization groups (RTCA SC-222 / EUROCAE WG-82 for MOPS and MASPS and related activity has been launched under AEEC for ARINC 781 and 771 standards)

Demonstration of **IPS Multilink policies** and investigation of improvements will continue in several projects

ESA Iris

The **EASA certification of the Iris IOC** (Initial Operational Capability) SATCOM service and service provider has started at the end of 2022, led by the technical Iris Service Provider. The target is an **initial certification in March 2023 and a final one by June 2023**

Commercial Inmarsat aero safety service already at TRL 9

Iris FOC (Full Operational Capability) is the candidate SATCOM Long Term solution, being designed under the ESA Iris Programme (Iris Global) to meet SATCOM evolution needs.

4.2.1.3. LDACS

Introduction to LDACS:

L-band Digital Aeronautical Communications System (LDACS) is a terrestrial-based radio access technology designed for aeronautical air-to-ground communication, which supports high-rate data communications and digital voice communications. It enables the introduction of important future applications which will bring benefits to airlines, Air Navigation Service Providers (ANSPs) and Communication Service Providers (CSPs). This secure broadband Air/Ground communications system for aviation addresses the limitations of existing technology and provides an invaluable opportunity for modernisation and future-proof aeronautical communication networks. Technologies such as LDACS allow for the integration of new CNS services, which will facilitate the introduction of future ATM modernisation applications leading to more efficient air travel. LDACS is a promising solution that can ensure that CSPs and ANSPs networks are prepared for the upcoming demands. Benefits are coming from high-throughput datalinks, priority management, protected aeronautical spectrum, resilience to cyber-security risks, native IP capability, and conformance with aviation standards.

LDACS allows IP-based data and voice communication between the cockpit and the ground. The IP-based (IPv6) data and voice communications are standardised by ICAO, EUROCAE and AEEC and are expected to be the basis for future air-to-ground data communication (digital voice is considered as complement for data communications and could complement/replace analogue voice communications in the future). It will provide efficient, secure, and high-bandwidth communication capability (voice and data), with embedded navigation capability.

Note: It is anticipated that LDACS digital voice communications will be used for voice communications in the long term. Analogue VHF voice communications should run in parallel and it should be supplemented by an LDACS digital voice service.

In addition to data and digital voice communication, LDACS can also be used for ranging. The LDACS ranging capability may provide input to the alternative positioning and timing (APNT) solution.

LDACS will be deployed in the aeronautical L-band (960 to 1164 MHz), sharing the spectrum with the legacy navigation and surveillance systems operating in this band. LDACS is a cellular communications system, which uses a coordinated multiple-access scheme, ensuring collision-free channel access with guaranteed low latency. LDACS is highly spectrum-efficient and is designed to be placed within those parts of the L-band where no other service could be allocated.

LDACS technology is based on an open standard, which can be used by any CSP or ANSP to provide a corresponding datalink service. In addition, it allows the use of the same radio in the aircraft for all LDACS service providers, i.e., no new radio has to be installed in the aircraft for any new service provider; LDACS guarantees interoperability between different Manufacturers.

Since the communication technologies used in LDACS are based on LTE/4G mobile radio technologies, LDACS is considered a proven, future-proof technology. It enables high-throughput, low-latency datalink communications well beyond the scope of current and proposed VHF communications. Covering ATN/B1 and ATS/B2, LDACS is also expected to accommodate ATS/B3 as well as additional future services, including full 4D trajectory-based operations (TBO) and flight-centric air traffic management (ATM).

With significantly greater bandwidth and throughput than VDLM2, LDACS will offer much-needed headroom for aeronautical communications and remove barriers to innovation. The technology will also include prioritisation, allowing users to reliably transfer large amounts of essential operational data (such as engine and maintenance data, graphical weather) without delaying time-sensitive ATC data traffic. The ability to share this operational data during flights will help airlines to support better fleet management and reduce aircraft turnaround times.

The security concept of LDACS requires all entities in an LDACS network to authenticate each another in order to ensure that only trusted participants can use the air-to-ground communications system. The trust infrastructure (PKI) provided for this purpose offers mutual authentication between the aircraft and the LDACS access network during the login procedure. For logged-in users, LDACS provides protection of user and control data in the radio link layer, independent of higher-layer security mechanisms.

State of LDACS in SESAR:

Background:

SESAR started its LDACS activities in 2010 in the framework of the SESAR1 Programme (Project P15.02.04): LDACS Transmitter (TX) demonstrators were developed, that were used to demonstrate the spectrum compatibility of LDACS with the existing systems operated in the L-band, as well as to show that LDACS meets the performance requirements.

Subsequently, in SESAR2020 Wave 1 Programme (Solution PJ.14-02-01, started in 2017 and closed in 2019) a series of activities and technical validations were executed on LDACS devices from different manufacturers, allowing to increase the Maturity for enabler CTE-C02e (“New Air/Ground datalink using ATN/IPS over L-band - LDACS”). Exercises were executed to validate physical layer requirements and to integrate

LDACS Access Network with ATN/IPS Networks and in Multilink environment. The scope of PJ.14-02-01 was to identify the target architecture supporting the LDACS technology and to successfully execute the different Technical Validation Exercises.

In SESAR2020 Wave 2 Programme (started in 2020, closing in Q2 2023), PJ.14-W2-60 Solution follows-up the work undertaken by Solution PJ.14-02-01, together with PJ.33-W3-02. Details are reported in the following Chapters.

PJ.14-W2-60 Solution: “FCI Terrestrial Data Link (LDACS)”

PJ.14-W2-60 Solution has the following main objectives:

Finalize and validate LDACS Air/Ground Specification and Technical Requirements, including Security, Performance and Safety Requirements

Verify interoperability of LDACS radios developed by different LDACS manufacturers (see Note below)

Integrate and verify the LDACS Data Link with ATN services in a relevant end-to-end environment.

Validate LDACS mobility aspects in a realistic environment (through Laboratory Tests and Flight Trial)15

Develop a Technological Cost-Benefit Assessment for LDACS in the Future Communication Infrastructure (FCI)

Support the activities of the relevant Standardization Bodies

Note: LDACS Ground Stations configured to behave as Airborne Stations were used in all of the PJ.14-W2-60 and PJ.33-W3-02 Exercises. This represents a gap that will be solved by future activities (see 0).

The PJ.14-W2-60 activities aim to increase the Maturity Level of the following Technical Enablers from TRL4 to TRL6 (TRL=Technological Readiness Level):

CTE-C02e: “Ground Technology for New Air/Ground datalink using ATN/IPS over L-band”

Aircraft-98: “Avionic Technology for New Air/Ground datalink using ATN/IPS over L-band”

TRL6 means “technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)”

PJ.14-W2-60 will be closed in Q2 2023, with a Maturity Gate on April 27th.

Below a quick report on the Technical Validations outcomes.

[15] A LDACS Flight Trial has been performed in SESAR Wave 3 Solution PJ.33-W3-02 “Complements to LDACS Activities”, strictly coordinated with PJ.14-W2-60

Exercise #1

Exercise #1 has successfully validated (in a laboratory environment) the interoperability between two different LDACS Radio Manufacturers (Leonardo and Frequentis), and provided results needed to progress with the LDACS standardization activities.

In particular, two scenarios have been validated:

- Leonardo Ground Station vs. Frequentis Airborne Station
- Frequentis Ground Station vs. Leonardo Airborne Station

In both scenarios, the following sets of qualitative tests were performed:

Complete interoperability involving PHY/MAC/DLS layers, with the execution of Airborne Station Cell Entry

Exchange of FL/RL user data messages between LDACS AS and GS

Exercise #2

Exercise #2 successfully validated (in a laboratory environment) the exchange of ATN-B1 and ATS-B2 data through a network composed of the prototype LDACS RX/TX equipment produced by Frequentis and ATN Routing devices provided by Airtel.

In addition, this Exercise also measured some QoS and performances provided by LDACS, like the Latency, demonstrating that this Data Link fully supports RCTP performances requested by Safety-critical Applications in relevant Standards and Regulations.

Exercise #3

This Exercise was divided in two distinct Technical Validations:

Exercise #3.1 has successfully technologically validated (in a laboratory environment) the Mobility features of Seamless Handover and Cell re-selection, and provided results needed to progress with the LDACS standardization activities. In addition, EXE3.1 confirmed that LDACS performance (user data rate throughput) is appropriate to support future high throughput demanding Services.

Exercise #3.2 has successfully validated Security Requirements derived from the Security Risk Assessment; validated requirements concern topics of Mutual Authentication and Key establishment (MAKE), LDACS Secure Ground Handover Procedure (LSGHP), and User Data Protection Measures.

Exercise #4[16]

[16] This Exercise (LDACS Flight Trial) has been performed in SESAR Wave 3 Solution PJ.33-W3-02 "LDACS Complement", strictly coordinated with PJ.14-W2-60

Exercise #4 carried-out tests for technological validation of information exchange between aeronautical applications over the air interface using LDACS radios and the ATN/IPS technology and demonstrated that the flying aircraft can switch the connection from one LDACS ground station to another.

Exercise #4 successfully demonstrated the technical feasibility of the LDACS data link. In Exercise #4three LDACS radios were involved: two LDACS ground station radios and one LDACS radio configured as LDACS airborne station.

LDACS AS and GSs prototypes were developed by Frequentis, Honeywell provided the Airborne Router and the Airborne End-System, and AIRTEL contributed to the validations through provision of the Ground End System. These main contributions were integrated into the validation platform at DLR premises in Oberpfaffenhofen and into DLR's test aircraft as shown in Figure 19 and Figure 20.

Figure 19. DLR test aircraft

Figure 20. Antenna installation of LDACS ground station installed in Oberpfaffenhofen

Standardization

PJ.14-W2-60 supports ICAO and EUROCAE with the development of the following Standards.

ICAO COM Panel will publish LDACS SARPs (amendment to Annex 10) as well as an LDACS Manual.

Note: SARPs have been developed and submitted to ICAO in October May 2022.LDACS Manual from ICAO shall be developed by June 2023.

EUROCAE MOPS for L-band Digital Aeronautical Communications System (LDACS) for Data and Voice Communications, in order to cover the equipment functionality. Publication by WG-82 is planned within November 2024.

EUROCAE MASPS for L-band Digital Aeronautical Communications System (LDACS) for Data and Voice Communications, in order to cover the overall system aspects including performance. Publication by WG-82 is planned within November 2024. ETSI will start working on LDACS in Q3 2023 with the development of European standardisation deliverables addressing PHL and MAC sub-layers. Technical characteristics and methods of measurements will be considered. These deliverables will be the baseline for the future development of Harmonised Standards under the Radio Equipment Directive which applies to aeronautical ground-based equipment.

In addition, LDACS provides comprehensive state-of-the-art cybersecurity measures aligned with the work of the AEEC and the ICAO WG-I Security SG..

In addition, LDACS provides comprehensive state-of-the-art cybersecurity measures aligned with the work of the AEEC and the ICAO WG-I Security SG.

PJ.33-W3-02 Solution: "LDACS Complement"

This is a Wave 3 Solution, whose activities were completed in Q4 2022. The Solution framework was divided into two sub-tasks (called Threads):

Thread 1 carried-out complementary activities to remove the risks of the maturity expectations at the end of Wave 2 on COM aspects of LDACS under PJ.14-W2-60, thanks to the arrangement and execution of the Flight Trial described in 0.

Thread 2 covered the development of LDACS digital voice. Digital voice is foreseen to replace VHF radio completely in the long term in all continental operational environments: en-route (flight-centric or with geographic sectors, continental high and low density), Terminal Manoeuvring Area (TMA) and Tower (TWR), including ground and platform control.

Thread 2 has successfully technologically validated digital voice support of the prototype LDACS RX/TX equipment produced by Frequentis with Voice Communication Systems provided by different vendors (INDRA and FREQUENTIS) and the LDACS Digital Voice capability reached TRL4 maturity.

PJ14-W2-81 Solution: "Alternative Position, Navigation and Timing"

Alternative Position, Navigation, and Timing (APNT) is a technological enabler of continued operation of airspace in the case of corrupted, degraded, or unavailable GNSS. One aspect of APNT is the introduction of ground and airborne systems that can support current airspace requirements, while also providing a backup infrastructure with the required level of performance to continue enabling PBN and other CNS operations.

This Solution has provided an Analysis investigating LDACS as a complementary system to the current navigation infrastructure, and identifying impacts of A-PNT both on the LDACS Ground Network and on the LDACS Avionics.

Future SESAR3 activities

In the context of the new "Future Connectivity and Digital Infrastructure" project, the solution " LDACS End-to-End integration" will be focused on research activities to solve the gap related to the lack of real LDACS Avionic Prototypes in PJ.14-W2-60 solution.

The new solution will address by the following elements to allow for an LDACS decision point in 2026:

LDACS End-to-End integration to TRL6

The Solution aims to fill the gap left in SESAR W2 integrating current Legacy ATN Systems with LDACS Systems containing real avionic prototypes in representative environment

LDACS Avionics component development to TRL5 (and tentatively TRL6 if linked to flight Trials) for both ATN-IPS and ATN-OSI environment capability

Capability to ATM system to integrate Military datalink RF Spectrum compatibility and LDACS interoperability for military avionics FCI technologies

Link to AOC systems

LDACS Ground Components already TRL6 revisit to ensure ongoing compatibility with new avionics components

Standardisation and Regulation finalisation of MASPS and MOPS in 2024

The consortium consists of an impressive number of participants (LDACS Ground Manufacturers, LDACS Avionic Manufacturers (Research & Innovation, Honeywell, Collins), ANSPs, CSP and ATN Network Providers), with very high geographical coverage. The capacity and role of each participant and the extent to which the consortium as a whole brings together the necessary expertise ensures that the level of maturity required for deployment can be reached from 2026 onwards.

4.2.1.4. Off the shelf technologies/Hyperconnected

The solution 61, named "Hyper Connected ATM" has studied the feasibility and benefits of the use of public non-safety commercial communication systems (such as broadband Ka or Ku satellite systems, and 4G or 5G International Mobile Telecommunications airport or air-ground systems) as a component of aircraft safety or mission critical communications. As Aircrafts are increasingly equipped with such in-flight connectivity systems, which give broadband communications access to the cabin for entertainment and communication of passengers, and as it is observed that the quality of service of these systems is continuously improving, it looks attractive and opportunistic to leverage this available and expanding infrastructure for offloading and complementing the safety links.

The baseline Hyper Connected ATM solution is based on a hybrid approach, whereby public links/networks are used in combination with a qualified safety network (e.g. VDLM2) which remains selectable as a fall-back in the event of service interruptions or degradations on the public links. The solution comprises mechanisms to detect loss or degradation of the connectivity through the public links/networks and to automatically and promptly failover traffic over the available safety link(s) when needed. If a public link ceases to be available or experiences degradations, the concerned aircraft can stay connected for safety communications through the "fall-back" safety link. This hybrid strategy leverages public links infrastructure where and when possible, as it exists, along a "best effort" approach, and can revert to using the safety infrastructure where and when necessary. The solution is designed to be deployed over available public link(s), without any changes to be made in their constituting elements (airborne and ground radios, satellites, etc.).

This solution 61 has defined the overall Hyper Connected ATM concept, including the identifications of benefits/justifications, the primary use cases, the assessment of the different challenges and potential show stoppers, and the description of the technical mechanisms that could be envisaged.

The maturity of the solution 61 is currently set at TRL2. However, the solution is composed of a mix of very mature elements (the already deployed COTS infrastructure, already used for Passengers' and for AOC communications) and of some new (but proportionally small) additional mechanisms which are those at TRL2. Hence, when considering the balance between the mature components and the low TRL components, and their respective weights in the extent of the overall infrastructure, it could be considered that the maturity barycentre for the commercial link is relatively close to a high TRL.

As part of reaching TRL2, the hyper connected ATM concepts have been validated with laboratory exercises involving physical prototypes. Validation was also done through "Expert analysis", which comprised Safety Assessment, Security Assessment, and other transverse considerations notably addressing the justifications and benefits, the use cases, the required performance, the spectrum regulation, and the certification.

It is envisaged that the standardisation of the Hyper Connected ATM concepts could start in 2023. The standardisation activity should first be engaged at ICAO level, notably with the objective to integrate the concepts within the ATN/IPS standards. Also, the ICAO Doc 9718 – Handbook on Radio Frequency Spectrum Requirements for Civil Aviation may need to be updated to formally state the legitimacy of the use of public spectrum bands for safety communications under some conditions. The standardisation of the solution at EUROCAE/RTCA and AEEC should start soon (e.g. one year) after activities have been started at ICAO level. The key role of ETSI in the standardisation of commercial technologies such as 4G/5G and satelite systems should also be taken into account. It has been assessed in [RefDoc 04] "FUTURE CONNECTIVITY FOR AVIATION EU/US task force White Paper - Dated 09/11/2022, Issue 1" that standardisation of Hyper Connected ATM could be completed in 2027, on the road for ground and airborne deployment of the resulting certified system components within year 2032, in sync with the start of the full transition to ATN/IPS communications.

The standardisation of Hyper Connected ATM mechanisms in the ATN/IPS standardisation framework may enable the implementation of these (or equivalent) mechanisms within the legacy ACARS and ATN/OSI networks. For these environments, the update of the associated legacy standards may be more challenging, because the standardisation groups can be dormant or disbanded; in that case, implementations may rather be based on dedicated documents produced by and at the initiative of some fewer collaborating stakeholders interested by a shorter term "precursor" deployment of the Hyper Connected ATM concept.

4.2.1.5. ATN/OSI – IPS Transition Task Force

Architecture study objective

This part of the Multilink roadmap study has the following objectives:

- Reviewing existing alternatives for the ATN OSI/IPS architecture transition
- Studying pros/cons of alternatives
- Recommending a way ahead for the architecture transition

1. Existing concepts

In SESAR, the FCI has been developed since the early tasks of SESAR 1, then through SESAR1, SESAR2020 waves 1 and 2. In parallel, ICAO WGI has been developing the relevant standardization documents, now joined by EUROCAE, RTCA and AEEC, 'ATN/OSI – IPS Transition Task force' ref. (3), (4), (6).

The latest relevant reference documents developed in solution 77 of SESAR2020 wave 2 are (2), section 5.5, and (1). Indeed 'ATN/OSI – IPS Transition Task force' ref. (1) has already developed ATN/OSI to ATN/IPS transition concepts in some detail and is a strong basis for current further developments.

In Europe, several ANSPs are joining in a common contract for air/ground communication: the ATS Common Datalink Services (ACDLS), 'ATN/OSI – IPS Transition Task force' ref. (5), that defines a common procurement governance proposal having consequences on the most practical architecture, i.e. to which degree some components needed for the transition should be part of this contractual arrangement, based also on lessons learned from ATN B1 implementation in Europe.

As mentioned in 'ATN/OSI – IPS Transition Task force' refs. (7) and (1), the Common European ATN Backbone (CEAB), a performance optimized 'ATN Backbone', is intended to ease connectivity toward additional CSPs , like ATN /OSI Satcom or via Gateways to IPS based Services.

Additionally, although Europe has been so far the sole implementer of ICAO ATN/OSI, the final state towards full ATN/IPS implementation shall include other ICAO regions as well, where the strategy has been based on non-ICAO standards, i.e. FANS 1/A.

The inclusion of AOC communication capabilities in the strategy is due to the fact that the data links may arguably continue being used operationally for both AOC and ATS.

2. Architecture evolution

- Initial state: ATN/OSI

The initial state of the transition, corresponding to the currently deployed architecture in Europe, is based on an ATN/OSI Network connecting three different VDLM2 routing domains. This configuration has its limitations17 and must be optimized targeting performance, stability and throughput with VDLM2 for the radio link, augmented with SATCOM as shown below.

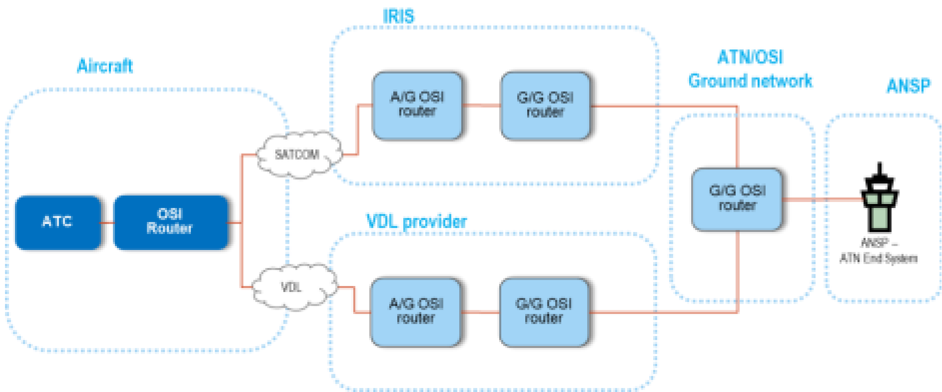


Figure 21. ATN/OSI/VDLM2-SATCOM IRIS Dual Link, 'ATN/OSI – IPS Transition Task force' ref. (10)

Having ATN/OSI based on VDLM2 and SATCOM links has the following functionalities:

- Off-loading the VDLM2 channel,
- Adding bandwidth for increasing AOC and ATS data traffic,
- Supporting resilience mechanisms.

- End state – global IPS

The desired end state is based on IPS. SESAR 2020 PJ14 is the latest step in the detailed developments in that respect. The Figure 21 illustrates the interconnection of new IPS-native data link subnetworks (LDACS, SATCOM, AeroMACS) via an ATN/IPS ground backbone, both for AOC and ATS end systems. The figure does not include the COTS subnetworks due to the lower TRL of this option, at the time of writing, but does include the possible option of VDLM2 over IPS as proposed in some groups.

---

[17] The EUROCONTROL Datalink Support Group is documenting, quantifying, and addressing these issues.

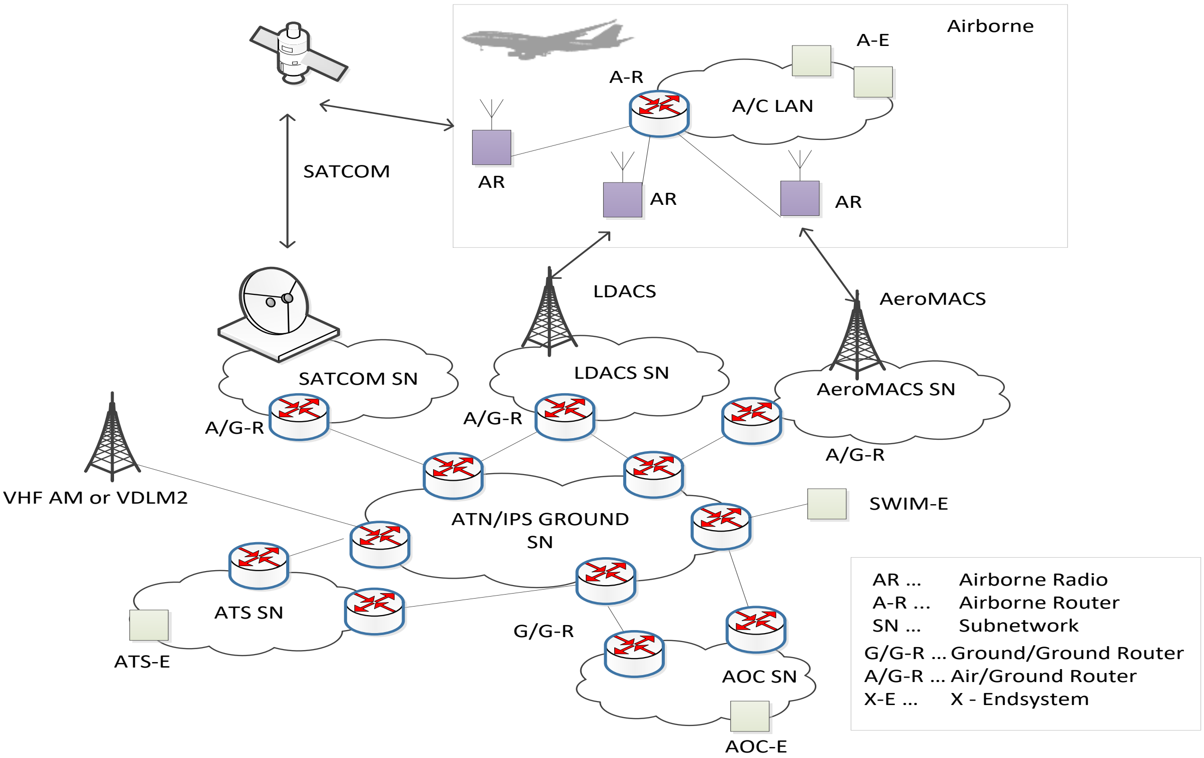


Figure 22. ATN/IPS scope (EUROPE) of SESAR2020 PJ14

NOTE: **IPS over VDLM2** as shown in the figure is under discussion in EUROPE at the time of writing. 'ATN/OSI – IPS Transition Task force' ref (1) section 2.3.3 addresses details. This VDLM2/ATN/IPS solution has been tested on flying aircraft and is being standardised as part of ATN/IPS SARPS.

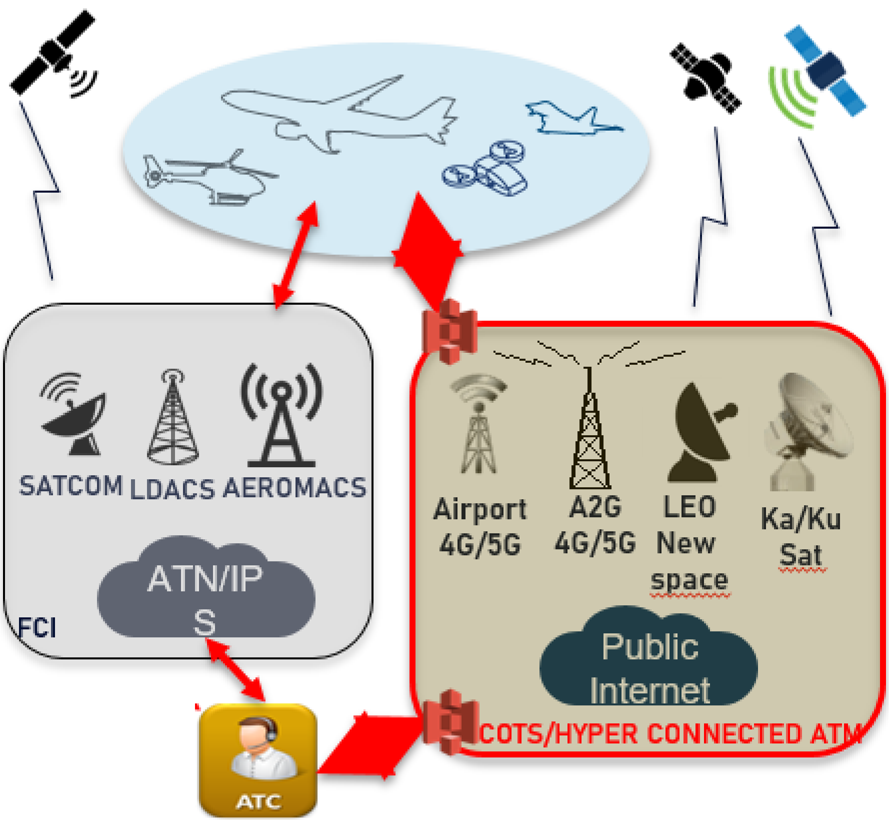


Figure 23. COTS or 'Hyper Connected' ATM

Additionally, the use of IP-based Commercial-Off-The-Shelf (COTS) is represented above, also called 'Hyper-connected ATM', which was initially developed to TRL2 in Solution 61 of SESAR2020 Wave 2. The highlighted components on the right of the figure show the possible inclusion of non-ATS specific technologies in the FCI (i.e. COTS), interconnected over public IP networks (using suitable technologies such as VPNs etc. if required but not detailed above). The overall infrastructure of the FCI with this configuration is referred to Hyper-Connected ATM.

3. Possible intermediate steps and pros/cons

Evolving from today's Dual-Link ATN/OSI situation to a ML IPS architecture requires a transition period whiting a mixed environment, in possible scenarios noted in the table below from 'ATN/OSI – IPS Transition Task force' ref. (1).

<table>
<tr><th colspan="2"></th><th colspan="3">Aircraft</th></tr>
<tr><th colspan="2"></th><th>None IPS Ready</th><th>Some IPS Ready</th><th>All IPS Ready</th></tr>
<tr><th rowspan="3">ANSPs/Ground Users/CSPs</th><th>None IPS Ready</th><td>Current situation: Starting point.</td><td>It may happen that airlines crossing between different ICAO regions equip IPS in new aircraft and cross regions where the ANSPs and/or CSPs are not ready for IPS yet.</td><td>Very unlikely to happen that all aircraft are IPS equipped and no ground user/CSP supports IPS. Airlines will not invest until confirmation of use. Scenario to be avoided for airlines cost efficiency.

Scenario discarded</td></tr>
<tr><th>Some IPS Ready</th><td>Possible deployment case as first step: ANSPs, ground users and CSPs start deployment while no aircraft is IPS-equipped yet.

Identified scenario 1</td><td>Very likely to happen. ANSP/users/CSPs and airlines start deploying and supporting IPS. There are areas with IPS support and other areas without it, while in all areas both IPS and non-IPS aircraft are flying.

Identified scenario 2</td><td>Unlikely to happen due to the long periods to replace the fleets and/or retrofit aircraft to support IPS. Not realistic that all aircraft support IPS while not all ground users/actors support IPS.

Scenario discarded</td></tr>
<tr><th>All IPS Ready</th><td>Unlikely to happen and situation to be avoided for ANSP, ground users and CSPs cost efficiency.

Scenario discarded</td><td>Likely to happen: assumed that airlines deployment takes longer than on ground.

Identified scenario 3</td><td>This is the final scenario.</td></tr>
</table>

Table 2.'ATN/OSI – IPS Transition Task force' ref. (1)

The corresponding combinations of aircraft and ground system OSI / IPS types is shown in the table below from 'ATN/OSI – IPS Transition Task force' ref. (1).

		Aircraft	
		OSI capable	**IPS capable**
Ground Users (ANSPs and others)	**OSI only**	Initial Stage	Need OSI/IPS GWs
	Dual Stack OSI/IPS	OK	OK
	IPS only	Need OSI/IPS GWs	OK

Table 3. 'ATN/OSI – IPS Transition Task force' ref. (1)

4. Discussion

It is quite likely that, in the coming years, ANSPs will have to deal with a mixed fleet of both ATN/OSI and ATN/IPS capable aircraft. Hence, ATN/OSI ANSPs will have to accommodate IPS aircraft, whilst ANSPs which will have migrated their ATM system to IPS will have to accommodate legacy ATN/OSI aircraft.

As such, an OSI/IPS Gateway (GW) shall be capable of accomplishing both accommodations (OSI to IPS and IPS to OSI).

An important architectural decision is on the position of this OSI-IPS gateway function.

In the current FANS accommodation configuration in ATN OSI B1, the gateway resided as a double stack at each ANSP electing to accept FANS 1/A aircraft. Since the latter are exempted from the ATN B1 DLS regulation in Europe, this was an individual ANSP decision and did not justify the creation of a centralized facility.

As mentioned above, the situation is different in the OSI/IPS transition in that all ANSPs will be confronted with a dual population of aircraft during the transition

As illustrated below, the GW may thus be part of the ANSP or the DSP/CSP/ACSP domain.

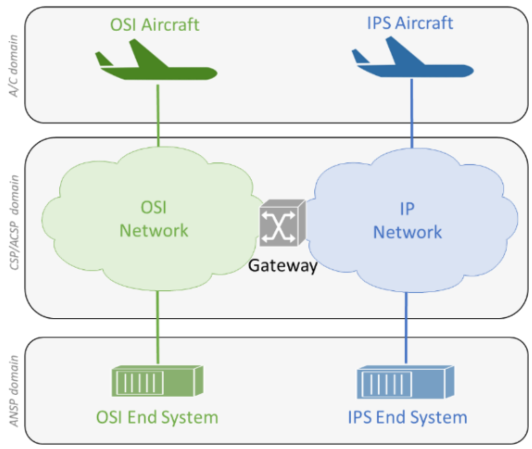


Figure 24. GW not at ANSP

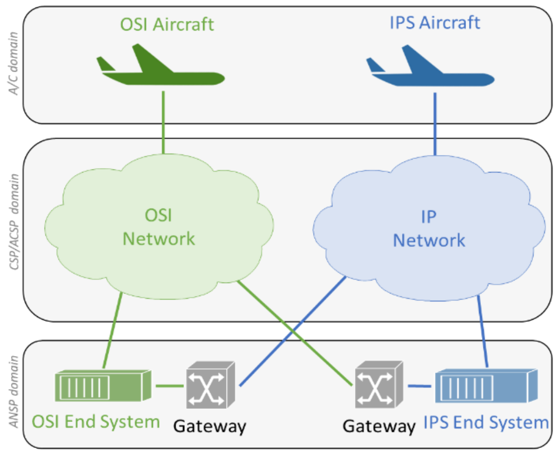


Figure 25. GW at ANSP

In 'ATN/OSI – IPS Transition Task force' ref. (1) it is argued that the best option (for cost efficiency and implementation time) is that CSPs/DSP implement the Gateway function, though allowing that individual ANSPs decide to implement their own.

5. Recommendations

The following recommendations are proposed:

- From an Airspace User perspective it is desirable to have more choices for air/ground links which need to be harmonised in a global manner, meaning the long term goal is to have a variety of IPS air/ground links to choose from. This will enable simpler Avionics architecture, ease addition of security measures, ease a harmonized introduction of new service requirements.
- **ATN/OSI - IPS Gateways**
    - Add an IPS/OSI gateway service in the DSP specifications
    - This gateway service will also be made available to the CSPs, allowing a full transparency (OSI/IPS) during the transition.
    - This gateway should be a common service under the remit of ACDLS
    - It is recommended to implement this service before 2030.
- **ACARS/IPS gateway**
    - Gateways must include the capability of FANS/1A exchange
    - This should also be a common service to avoid fragmentation
    - The GW should also hold high availability common functions for the FCI-Multilink in Europe:
        - IPS Mobility server function

- LISP and Security server function
- Management of Multilink policies
  - which will be defined will be defined in SESAR 3 FCDI project WP4

6. Reference documents

(1) SESAR 2020 PJ.14-W2-77 'TRL6 Deployment and Transition Strategy FCI Services', D5.1.800, Aug. 2022, ed. 01.00.00

(2) SESAR 2020 PJ.14-W2-77 'TRL6 Overall Concept of Operation FCI Services', D5.1.610, Sept. 2022, ed. 01.00.00

(3) 'EUROCAE Study: ATN/OSI and ATN/IPS comparison', EASA.2016.FC19 SC.003, Nov. 2018, ed. 01.00.00

(4) "Mobility Solution Proposal – Ground Based LISP mobility solutions for ATN/IPS", presented by Frequentis, Dec. 4, 2020, ICAO DCIWG (CP), WG-I Mobility SG-7 – see also 'The Locator Identifier Separation Protocol' in CISCO Internet Journal, vol. 11/1, 03/2008

(5) 'The ATS Common Datalink Services (ACDLS) Governance, presented by DSNA/DEB chair at COMSG21, 20 Oct. 2022

(6) EUROCAE/RTCA - Draft ATN/IPS MASPS, Private communication, Feb. 2023

(7) SDM 'Report on DLS Architecture and Deployment Strategy', Dec. 2019

(8) FCI Business Case, V18, 21 April 2022, presented at JCSP7 (May 2022) [updated by SESAR20202 PJ14 Solution 77, deliverable D5.1.500, Nov. 2022]

(9) 'FUTURE CONNECTIVITY FOR AVIATION' – EU/US Task Force White Paper - 9/11/2022, Ed. 1

(10) SDM 'CONOPS for multilink operations', V1.0, 20 Oct. 2021

Change log

V number	Date	Authors	Description
V1-V2	10 Feb. 2023	ECTL	Initial versions on MSTeams - internal
V3	21 Feb. 2023	ECTL	Comments JP Distributed to SDM and Archi TF
V4-V5-V6	21 March 2023	ECTL, SDM + Archi TF members/ comments	
V7	10 May 2023	ECTL, SDM, Archi TF members	○ Take into account: SCP comments 5 May 2023 (see replies in XL sheet) ○ Comments from TF members in original text before SCP consultation

Figure 26. Change log

4.2.1.6. Need for VDL Lifetime Extension - Offload scenarios

The SDM datalink capacity study has demonstrated that the increase of air traffic and the introduction of the ADS-C EPP downlink will, within a few years, lead to severe congestion of VDLM2 making the datalink useless for the time-critical ATS-B2 services where they are needed most, i.e. in the core ECAC area. On top of that, the usage of the EFB for an increasing number of AOC applications and the rapid increase of airborne downlinking engine performance data in particular with newer aircraft types, make the need to resolve this congestion only more urgent.

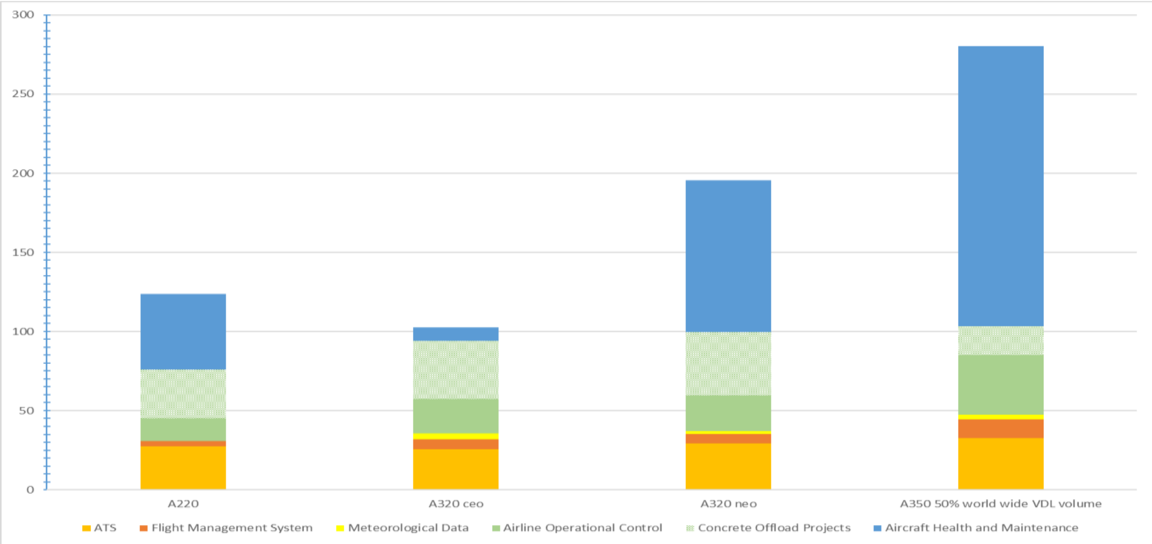


Figure 27. SDM datalink capacity study

The FCI Multilink capability allows for a smooth integration of new A/G datalink technologies, as they become available. However, from the new technologies assessed in the previous section, only SATCOM class B is expected to be certified by EASA this year. Regarding the other technologies, standardisation and validation is ongoing, with a target date for LDACS to reach TRL6 by the end of 2026, and for the use of open public network (HYPERCONNECTED) to reach TRL6 by the end of this decade. For both technologies, after reaching TRL6 some more time is to be taken into account for industrialisation and certification before deployment can start.

Looking at the timelines of forecasted VDLm2 congestions, versus availability of new technologies there are basically two paths that can be taken to avoid operational damage.

Option 1: Immediately after certification, rapidly increase the deployment of SATCOM over multilink, and transition to SATCOM as soon as possible. When prioritising investments, a distinction should be made between forward fit and retrofit.

Option 2: Apply a balanced mix of mitigating measures (all resulting in offloading VDLm2) to push the expected VDLm2 congestion back a few years, buying time to ensure more A/G datalink technologies will be available before heavily investing in new technologies. The following mitigation measures have been proposed for consideration:

1. **Offload measure 1:** It is in particular the rapid increase of **aircraft health and maintenance** data of newer aircraft types, that speed up the congestion process.

    a) The periodically downlinked reports contain a significant amount of data that currently still contain many empty place holders that unnecessarily increase the message size. To avoid this, either reformatting report or message compression could be applied. This would require industry involvement.

    b) Removing defaults might contribute to message size reduction.

    c)The frequency of periodic downlinks might be reduced.

    d) Change timing of downloading data (e.g. to after landing). Note that this could only work for some of the engine performance data: Retain trend reports until after landing, but keep the exceedance reports real time as they may require immediate action.

Such optimisation has been applied in the past on many AOC application, but has not yet been done for the aircraft health and maintenance data.

2. **Offload measure 2:** Use existing alternate links whenever available by changing the AOC datalink selection policy parameters within the AOC multilink capability. Although this could apply to all long-range aircraft as they are already equipped with SATCOM capability (20-30% of the total amount of aircraft in Europe), the expected relief will be significantly less than 20-30%, noting that long range AC usually have only one or two flights per day, while single aisle aircraft can potentially conduct up to 6-7 flights per day. Of sub-measure of this could be to limit the switch to SATCOM to the core-area only (as this is where the VDLm2 congestion will appear first).

3. **Offload measure 3:** Mandatory compression of EFB data, when connected over VDLm2, might lead to a slight reduction of AOC data traffic. Note also that compression is already available on some installations, but not on all aircraft. Note that the application of compression does not always lead to smaller message. For example, for a weather grid, there is not much benefit in compression. Obviously, this measure would not not needed when the EFB is connected to 4G or cabin connectivity.

4. Offload measure 4: ACARS over IP[18]. Note that this solution is already commercially available and it is merely a matter of implementing (3-5 years).

[18] ACARS over IP is the term for tunnelling ARINC 618 (ACARS) protocol through commercial IP links like 4G/5G.

5. **Offload measure 5:** Use complementing alternate links by moving applications to e.g. the EFB, which should then be connected to cabin connectivity or 4G at the airport. The savings on VDLm2 data usage are expected to be substantial, in particular for single aisle aircraft.

An important factor in all these offloading scenarios, is that the AC that contributes to offloading to SATCOM, is not the one benefiting from the relief of VDLm2 (which is substantially cheaper than SATCOM) which the AC is still paying for through the route charges. Financial compensation for aircraft (avionics) modification as well as higher communication costs, should be considered.

4.2.2. Manufacturing industry view

4.2.2.1 Ground equipment Manufacturer

4.2.2.1.1. Frequentis

ATN/OSI dual link:

The ATN/OSI duallink is a logical extension to mitigate VDLM2 Air/Ground data link overload in Europe. It allows the introduction of SATCOM Inmarsat SB-S into the Air/Ground communication infrastructure. Due to the lack of mobility and Multilink functionality, it allows only a limited, rather static distribution of traffic between the available Air/Ground data links (Primary/Secondary link). The lack of end-to-end security and the limited throughput, detection performance and security of VDLM2 should limit the use of this technology for future applications

IPS Multilink:

ATN/IPS is the technology that is gradually replacing ACARS and ATN/OSI worldwide. It will bring improvements, particularly in the area of security and availability, and will enable a migration path to future native IP security applications. Ground IPS gateways are key to the adoption of IPS technologies, as gateways enable the transition from current technologies.

In Europe, ATN/IPS has been developed and validated as Future Communication Infrastructure (FCI) in many SESAR projects. Many of the solutions standardized at ICAO and EUROCAE/RTCA originate from these projects. The status of development and standardization would allow an initial deployment of ATN/IPS around 2028. The multi-link management functions (such as AGMI) used in ATN/IPS enable an improvement of the link management on the aircraft side and allow a high-performance and dynamic distribution of the data traffic, which on the one hand increases the availability of the entire FCI and on the other hand optimizes the parallel transmission of AOC traffic.

This functionality, together with new Air/Ground data link technologies allows to fully comply to the ATS-B2 Safety & Performance requirements of EUROCAE ED-228A (RCP/RSP).

The FCI solution validated in SESAR is an open platform and provides mobility, Multilink, safety and management features that enable all future data link technologies to work in an integrated and interoperable architecture.

The FCI ground infrastructure is largely based on COTS components and the mobility and Multilink solution proposed based on GB-LISP is the recommended and validated solution in ICAO Doc 9896 Edition 3 and the only solution with TRL6 maturity, ready for deployment in a Digital Sky Demonstrator.

LDACS:

LDACS is a terrestrial-based radio access technology designed for aeronautical air-to-ground communication, i.e., optimized for aviation needs. It provides a native mobility solution and the LDACS ground subsystem was developed for optimal integration into the ANT/IPS Mobility and Multilink solution currently standardized by ICAO. In the aircraft, LDACS already supports the Common IP Radio Interface (CIRI) discussed at AEEC, which enables a simple connection to an airborne ATN/IPS system.

LDACS allows a fast and deterministic symmetrical link loss detection, which is the prerequisite for a high-performance ATN/IPS Multilink system.

It also meets all the security and mobility expectations of an Air/Ground access network integrated into a Multilink ATN/IPS.

LDACS provides the throughput and latency performances required to meet the ATS-B2 Safety requirements (ED-228A RCP/RSP).

It addresses the limitations of existing technology and provides modern, secure broadband communications with more than 200 times the data throughput of the current system.

LDACS is the logical successor to VDLM2 and should be used for the transition to ATN/IPS communications as a ground-based Air/Ground datalink technology. This facilitates the transition to ATN/IPS

In our view, VDLM2 should not be used for ATN/IPS, because there are strong doubts whether VDLM2 can provide the required throughput and performance required to meet the ATS-B2 Safety requirements using secure end-to-end communication via DTLS.

LDACS operates in a different frequency band to the existing VDLM2 data link, so it can be deployed at existing VDLM2/VHF radio sites without the risk of interference. This protects the large investments in building, telecommunication, and energy infrastructure, as well as avoiding the considerable time and expense involved in finding and developing new sites.

As a distributed system with no central single point of failure, LDACS is very resilient. It also provides a maintenance approach that allows coverage from another site during repairs, further reducing downtime.

LDACS can be deployed step-by-step, starting in high-density areas with the greatest need for secure broadband communications. As a cell-based ground system, LDACS is highly scalable, which means it can be easily adapted to the required capacity needs.

LDACS is highly spectrum-efficient, so it can work within the aeronautical spectrum without interfering with existing systems. The compatibility verification of LDACS with legacy Surveillance and Navigation systems at ICAO is not yet completed, because on the one hand the standards of the existing systems in the aeronautical L-band are not ready for an efficient spectrum management, and on the other hand the standardization process at ICAO is not set up for the introduction of an integrated CNS system.

In the discussions with the corresponding working groups of the NSP and SP, it is largely agreed that nothing will change in the LDACS SARPS, but the legacy system standards must be adapted, and an intermediate step is required, which allows the deployment of LDACS.

Global aviation is very heterogeneous and different regions have temporally misaligned and partly different requirements. This also applies to CNS systems. As in the past with VHF 8.33KHz, ADS-B, 1090 ES, MLAT, etc., also in the future new systems will be needed at different times, depending on regional needs.

For the Air/Ground data link communication infrastructure, Europe and the USA will certainly be the first to require IP-based communication, i.e., the ATN/IPS standard currently being developed at ICAO will most likely be deployed there first. In addition, Europe has a need for a high-performance ground-based Air/Ground data link. LDACS is currently the only ground-based system that is being standardised at ICAO, that meets all the requirements for a safety-critical Air/Ground data link.

Just because there is currently only a need for such a system in Europe, one cannot consider it to be a purely European system - this is also not the case with ATN/IPS.

In addition, no global interoperability problems are expected since no other system is currently being standardized.

SATCOM:

Today, the two Aeronautical Mobile Satellite Service SATCOM Class B systems support oceanic data links. Both systems are currently being upgraded to be integrated into an ATN/IPS Multilink system and meet the requirements for required communications performance (RCP) and surveillance performance (RSP).

For safety services in the continental area, these L-band SATCOM systems are the perfect complement to a high-performance ground-based Air/Ground data link such as LDACS.

Hyperconnected ATM:

The "Hyperconnected ATM" concept has currently reached a TRL2 maturity and is a good idea as a complementary addition to a high-performance ATN/IPS system. The prerequisite, however, is a future communication infrastructure that is capable of transmitting the safety-relevant data with the required performance even without a "hyperconnected connection". This does not seem to be the case with VDLM2 as the ground-based part of the ATN/IPS Multilink solution. In addition, the Hyperconnected solution is based on many assumptions regarding standardization, availability, etc., which currently cannot be evaluated and thus result in an increased risk for the future communication infrastructure. The conclusion that the hyperconnected idea can replace a high-performance ground-based Air/Ground data link solution creates an increased dependency on service providers and equipment manufacturers of commercial communication systems, with the risk of having in a few years the same capacity bottleneck as today.

White Paper " Future Connectivity in aviation":

The white paper is an attempt to create a harmonized roadmap for global safety-critical data communications in aviation. Unfortunately, many stakeholders were not involved, the global roadmap of the ICAO was not considered, and the current state of research and development - especially that from Europe - was ignored. The SWOT analysis in the white paper contains many deficiencies and sometimes comes to opposite conclusions than those reached by the experts in the European aviation industry after years of research, development, and validation in SESAR.

Finally, it is not transparent or comprehensible how the final proposals for the roadmap are derived from the SWOT analysis.

4.2.2.1.2. Rohde & Schwarz

Rohde & Schwarz is a German company, a supplier of VHF/UHF radios and voice communication switches for ATC ground installations.

Rohde & Schwarz is actively supporting the development of LDACS since 2012, participating in different research projects of the German Aviation research program LUFO.

In the framework of these projects, Rohde & Schwarz has realized LDACS transceiver demonstrators, which were used first for laboratory LDACS principle validations and later for the first LDACS flight tests within the German research project MICONAV in March 2019.

Rohde & Schwarz is supporting the LDACS standardization at ICAO within CP/PT-T. Rohde & Schwarz is also contributing to the standardization activities within EUROCAE WG82. R&S also contributed significantly to the development of the LDACS security standards.

R&S will provide complete LDACS communication system (Radios and communication infrastructure).

LDACS can complement existing VDLM2 communication channels with increased bandwidth thanks to LDACS high bandwidth capabilities. For this ATN IPS is not necessarily required.

R&S supports to have an early transition phase based on ATN/OSI until the IPS-based FCI Multilink infrastructure is ready. With this approach (see Figure 28) the benefits of LDACS (enhancing the data capacity of VDLM2) can be achieved in much shorter time frame.

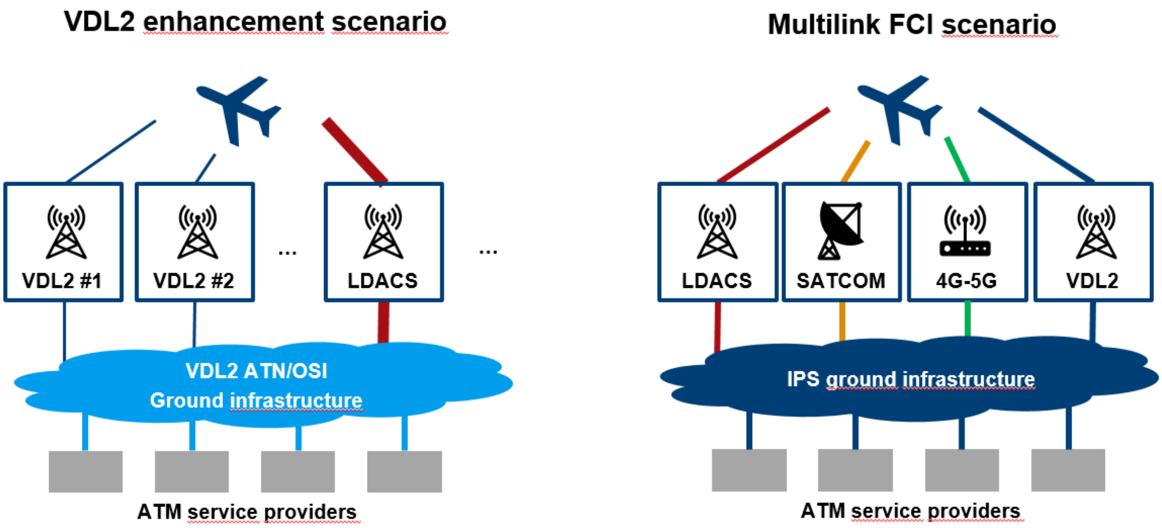


Figure 28. Approach LDACS benefits

R&S is involved in several European and national research programs with the goal to increase the TRL level of LDACS. The SESAR3 research programs FCDI and MIAR represent the next natural step to validate the integration of the LDACS in an already operational environment and enhancing TRL level to TRL6. Therefore Rohde & Schwarz intends to actively participate there, providing the experience gained in previous similar programs.

Rohde & Schwarz intends to provide LDACS demonstration transceiver in the size of an avionic radio form factor ARINC750, to be used both for the avionic and ground side. Rohde & Schwarz intends also to support any activity related to ensure compatibility with any existing civil or military communication system.

4.2.2.2. Avionics Manufacturer

4.2.2.2.1. Collins & Honeywell

ATN/OSI dual link: ATN/OSI over SATCOM has been implemented in the AES products (Cobham, Honeywell) and is expected to be ready for entry into service in 2023. The dual link (SATCOM + VDLM2) support in the airborne routers (ATSU, CMU, CMF) is being certified by Airbus and Collins. It has also been prototyped and flight tested in Honeywell's CMU and CMF products, nevertheless certification on other than Airbus aircraft has not been confirmed.

ACARS over IP (AoIP): The Aircraft Interface Devices (AID) are already available on many aircraft (Airbus FOMAX, Teledyne WGL, Honeywell Aircraft Data Gateway…). The ACARS over IP feature allows to relieve VDL and SATCOM (safety services) of some of the AOC, maintenance, and other non-safety traffic by sending the traffic through the links provided by the AID (Ku/Ka, Gatelink…). AoIP solutions are already in service on Airbus and Boeing aircraft.

In aircraft such as the Airbus A350, the AoIP concept is extended up to a messaging server able to send traffic over safety and IP links enabling the MIAM technology for improving large messages transmissions (compression/segmentation/flow control).

IPS: The Airborne IPS System technology is being developed by at least two avionics manufacturers (Collins, Honeywell). The product development programs are yet to be launched, but first certified products could be ready for entry into service in 2028 timeframe to enable the use of IPS as an alternative enabler for the European CP1 mandate and to start ramping up the IPS equipage and transitioning away from ATN/OSI. The IPS-capable links available for this entry into service should include at least Inmarsat SB-Safety (IPS capability being developed under ESA Iris program) and VDLM2 (standards being elaborated). For "hyperconnectivity" and LDACS see further below.

It is worth noting that, from an avionics implementation perspective, certification of the avionics systems has a lead time of few years after the standards are publicly available and called by the expected regulations (TSO/ETSO, Advisory Circulars…).

IPS is also designed to support enhanced multi-link management features that would improve the link management on the aircraft side and will optimize the transmission by the aircraft of the ATS traffic but also for the AOC traffic (supported by IPS).

Hyperconnectivity: The hyperconnected ATM concept, led by Airbus in the frame of FCI, describes the capability to convey safety traffic via the AISD and PIESD links, leveraging for example cabin SATCOMs in flight and Cellular/Wi-Fi connectivity on ground. The concept is under definition and validation and would allow to maximize the use of all existing links embedded in the aircraft. The concept will be supported by IPS, but it's not a prerequisite for IPS entry into service and may be introduced as an incremental upgrade later on. The possibility to apply the same concept to ATN/OSI and ACARS in a near to mid-term future is also being investigated, nevertheless the added value and commercial viability of such interim step needs to be evaluated.

Note: optimizing the use of the existing commercial air-ground links is a way to minimize the need for additional radios inside the aircraft.

LDACS: LDACS avionics prototypes have been developed by Frequentis and Rohde & Schwarz. The avionics suppliers are following carefully the development of the LDACS standards even though the development of LDACS certified radios cannot be done before complete validation of the performance/benefits and compatibility with the other aircraft safety systems using L-Band spectrum.

The following table provides the view of the avionics manufacturers on the use of the air-ground links for the different types of traffic:

Applications	ATS			AOC in ACD		AOC on EFB ***
Network Supported links	ATN/OSI	ACARS	ATNIPS	ACARS	IPS	“Public” IP
HF datalink	No	Yes	No	Yes	No	No
VHF datalink (VDLM2)	Europe only	Yes	Yes [future]	Yes	Yes [future]	No
Inmarsat L-band (SBB/SB-S)	Yes	Yes	Yes [future]	Yes	Yes [future]	Yes [Inmarsat SBB]
Iridium L-band (Certus)	Unlikely	Yes	Yes [future]	Yes	Yes [future]	No
Broadband cabin systems (GXA, EAN, Starlink…)	TBD*	TBD*	Yes [future]*	AoIP**	Yes [future]	Yes
Commercial 4G/5G	TBD*	TBD*	Yes [future]*	AoIP**	Yes [future]	Yes
LDACS	YES	TBD	Yes [future]	TBD	Yes [future]	No
Future aviation safety	TBD	TBD	Yes [future]	TBD	Yes [future]	No

Air/Ground links (5G…?)						

Table 4. Avionics manufacturers view on the use of Air/Ground links

* The use of non-safety public links is expected to be enabled by the hyperconnectivity mechanisms, where the non-safety links are overlaid by secured and monitored tunnels and integrated within the ACARS, ATN/OSI or ATN/IPS network infrastructure as alternative data paths with specific QoS limitations. The capability is expected to be implemented in the future ATN/IPS avionics and the viability of introducing it also as an upgrade for ACARS and ATN/OSI is proposed to be investigated under SESAR 3.

** AoIP stands for "ACARS over IPS" which is available or being implemented in different products. Principles are similar to "Hyperconnectivity", but it's only used for non-safety applications.

*** Some EFB implementations support air/ground communication over ACARS

4.2.2.2.2. Rohde & Schwarz

Rohde & Schwarz is a German company and a supplier of both ground station VHF/UHF radios, but as well a provider of avionic radios both for civil and military applications. The development of LDACS radios is a major goal for the next product portfolio.

R&S will support both forward-fit and retrofit with LDACS radios (e.g. this may imply double avionic interfaces like parallel ARINC429 and AFDX interfaces, and integration of VDLM2 and LDACS into a single radio).

Rohde & Schwarz is supporting the LDACS standardization at ICAO where it is leading the Avionic Architecture Task Force (AATF) for LDACS to evaluate the required steps for bringing LDACS onboard of aircrafts.

R&S plans to have in the portfolio measurements and qualification equipment for LDACS radios and systems as well.

4.2.2.3. Airframe Manufacturer

4.2.2.3.1. Airbus

VDLM2 improvements:

Even if delivering limited bandwidth, VDLM2 is a mature and widely deployed (worldwide in domestic areas) technology. It can provide the aircraft with both ACARS and ATN data link connectivity (OSI today and potentially IPS in the future depending on standardization and validation results). Today it is the primary link used to support safety data link transmissions in domestic airspaces, such as CPDLC or ADS-C (FANS 1/A, ATN B1 or B2), as well as AOC traffic.

New areas of improvement are currently explored to improve performance and extend its lifetime, like in particular the "Super VGS[19]" concept (under field validation). In-service issues are carefully addressed including by the relevant Standardisation bodies, to also continuously improve it.

This is why:

- "Super VGS" concept should be deployed as soon as practicable, knowing that it does not impact Airborne systems
- Deployment of multi-frequency capability, where not already done, should accelerate (ground and airborne capacity), with if possible deployment of additional frequenciesIt is necessary to continue to fix last issues discovered in current avionics and ground systems
- Solutions to reduce overhead of ACARS and OSI traffic on VDLM2 (in particular non-use of IDRP) are mature already to be deployed as soon as practicable. They are already standardised and provisions are provided and the latest avionics software.
- The adoption of solutions to offload non-safety traffic from VDL (e.g. AOC when possible) shall be encouraged. The following solutions are already available:
- ACARS over IP (via a specific ATSU software version and a dedicated option to be activated on FOMAX). This capability is available on A320/A330 Aircraft families.
- AMEX/MIAM over IP option, which allows sending a significant volume of AOC traffic towards IP Cellular or Cabin SATCOM links. This capability is available on A350.
- The FOMAX system, with Cellular connectivity and access to SATCOM L-band non-safety or Cabin SATCOM links can offer direct broadband connectivity to AOC applications not hosted in the avionics (e.g. on EFB).

It is expected that with solutions almost all AOC traffic should move to commercial links in the short term.

Leverage on SATCOM class B performance

Two Aeronautical Mobile Satellite (Route) Service (AMS(R)S) systems are supporting today oceanic data link and voice safety services – Inmarsat and Iridium. Both systems are enhanced to also support continental Required Communication Performance (RCP) and Required Surveillance Performance (RSP) requirements

[19] "Super VGS" concept is explained in SITA contribution (4.2.4.2).

(i.e., RCP-130 / RSP-160), and therefore evolve to offer so-called SATCOM class B services.

This new generation L-band SATCOM is the most promising complement to VDLM2 for safety services in domestic areas, while being the only safety spectrum SATCOM based solution for oceanic and remote areas.

SATCOM Inmarsat SB-S products are already available (in particular LCS Light Cockpit SATCOM form factor for the SDU avionics equipment). It is expected that Iridium Certus products will also be available in the short term with exactly the same form factor for an easy installation on Aircraft.

L-band SATCOM is basic on all Airbus Long Range Aircraft, and take rate is increasing on Single Aisle families thanks to this smaller form factor (LCS concept).

A version of LCS to support IRIS Very Large Scale demonstration is already available (ATN/OSI over SATCOM).

Iridium Certus LCS is not launched yet, until more elements are provided to make a decision (positive business case, demonstration of Iridium Certus performance)

Dual SATCOM (SBB - Iridium) is under study at standardisation level, as a possible solution for LRCS Long Range Communication System configuration (in replacement to HF), where needed for specific operations.

LDACS

LDACS is primarily aimed at being a solution to replace VDLM2 in highly congested continental areas, notably in Europe core area. Although it is standardised at ICAO, there is no worldwide consensus that LDACS will be the only and preferred successor to VDLM2. Regions where VDLM2 is not expected to be congested before long, have not closed the door to other solutions that could be proposed in the future. For instance, FAA stated in an LDACS Webinar , that ”when and if additional service is needed it will consider the use of LDACS along with potentially other Commercially available systems”.

China and Japan are supporting LDACS validation activities within ICAO.

Future evolution:

China, although being involved in the validation of LDACS SARPS, has also openly communicated on an aeronautical communication systems roadmap leveraging China’s 5G communication technology competences, and is conducting 5G-based A2G trials. In Europe, while communication experts of core European countries are supportive of LDACS, navigation and surveillance experts of the same countries have also raised some concerns about the compatibility of LDACS with other systems. And there is also a concern about the risk that LDACS could become and stay a European-specific system (in a way quite similar to the deployment of the ATN/OSI technology).

Airbus is also concerned about the risk that LDACS could become a European-only radio system. Airbus aircraft are flying worldwide, not only intra-regional but often in between two or more regions. The use of region-specific systems leads to aircraft equipped with multiple different solutions, which has disadvantages in terms of weight, volume/space, costs and complexity of the architecture. The development of region-specific systems is amortised over a smaller customers' base, which lead to more expensive equipment. There is also a risk that the system be replaced relatively quickly by other systems finally selected in other regions, which brings concerns on the perennity of the investments.

With LDACS, the difficulties to settle a positive business case might be exacerbated by the following additional concerns:

- The LDACS radio is not as simple as a VDR: It is a next generation radio, with up-to-date (4G-like) modulation techniques, working at higher frequencies, so with higher computing resources requirements, with new interfaces to provide increased bandwidth, comprising cryptographic software for security, and intended to be attached to two different domains in the aircraft (the Aircraft Control Domain, and the Airline Information System Domain) leading to a need for security partitions inside the equipment. The complexity of the equipment is hence a priori similar to that of a Class B L-band SATCOM system.
- The LDACS radio is destined to evolve to become also a continental voice system, which means that provisions will certainly have to be taken from the start to develop the system at DAL C and with the capability for dual airborne radios installations.
- The LDACS technology has the potential to be extensible to support air-air voice and data communications and navigation and surveillance services. While this looks very attractive at first sight with the potential, at some point, to replace other older technologies with one single multi-purpose equipment, this also gives the vision of a system that will be prone to frequent evolutions at the heart of the CNS aircraft functions, and to be maintained in parallel with configurations where LDACS is not used, for one, several, or all of the CNS functions.
- Past experience with VDLM2 has shown that obtaining a good maturity of a terrestrial-based communication system is a long process, which may require numerous iterations in the update and re-certification of the airborne radio(s), and costly test campaigns.
- There are uncertainties on if, where and when the LDACS ground networks will be deployed, and if it will be mandated.
- As the time passes, It is increasingly likely that LDACS will only be associated with an ATN/IPS infrastructure, which makes the step to transition to LDACS

even more challenging, because LDACS will have to be validated in parallel to other new (potentially not fully mature) technologies, and of the accumulation of the investments to be made .

- The installation of an LDACS equipment on Aircraft will be an option (at least on Single Aisle aircraft) for the operators to choose if they want to fly the aircraft in a region where LDACS is deployed. The operators will select (or not) this option depending on the incentives or mandating policies that will be decided by States, and which are unknown today.

Regarding airborne implementation of LDACS, no standard exists for the time being. SESAR and the ICAO « Avionics Architecture Task Force » (AATF – under ICAO/CP/DCIWG/PT-T) have been exploring the idea of the deployment of multi-modes VDR+LDACS radio (an « all-in-one LRU » that could replace the VDR3), and that would be coupled with a dual band antenna (VHF + L-Band) with the same footprint as current VHF3 antenna. Although this approach has good merits, notably by minimising impacts on the current aircraft systems installation, it has also a number of notable downsides:

- The development costs (Non-Recurring Costs) of a dual LDACS and VDR multi-modes radio are expected to be higher than those that would be needed for a standalone LDACS radio, due to the extra cost of the VDR part (re-) development and (re-)certification. Furthermore, as the extra-cost of the development of this "VDR part" might be amortised on the European market only, with one single instance per aircraft, there is a risk that these development costs are transposed into recurring costs for the VDR part that are higher than the cost of a legacy standalone VDR.

- Some Airbus aircraft are now fitted with 2 MVDRs (dual channels) instead of 3 standalone VDR (A350, and an increasing proportion of A320/A330). The approach of a combined LDACS+VDR radio is not well suited for aircraft equipped with those « 2x MVDRs » configurations because a « 2 VHF channels » MVDR cannot be replaced by a « single VHF + single LDACS channels » multi-modes VDR+LDACS radio

- This approach would introduce another VDR product line (additional to the existing ones), to be managed and maintained over time

The LDACS system is targeting operations in the L- band. This band is heavily utilised by navigation and surveillance aviation systems. The spectrum compatibility analysis is critical for LDACS and has to work in both directions: first not to hinder the operation of existing systems, but also to be able to operate in the presence of existing systems. While it has been noted that a significant amount of testing has been performed in the lab as well as in the field, it cannot be overstressed how important it is to prove unquestionably that the LDACS will not interfere with the other systems which currently support safety of flight operations.

It is understood that the mitigation of interferences of LDACS with other L-band systems will largely rely on the separation of the aircraft LDACS antenna from other antennas and on exhaustive co-site interference tests campaigns on every targeted aircraft model. This can be a costly exercise, notably when constraints with the aircraft physiognomy (e.g. short aircraft) may sometimes imply that the installation has to be done with minimum antenna separation margins, and with keeping a risk that interference issues might exceptionally be observed, and recurrently trigger dedicated problem solving plans.

Given the above considerations, Airbus has not taken any decision regarding the implementation of LDACS, and has no LDACS implementation plan for the moment. Airbus monitors the progress of the LDACS standardisation, and if concrete ground implementation plans are initiated.

Airbus anticipates that 5 years of development would be needed to develop and certify an LDACS radio for datalink communications after a decision is taken.

AeroMACS

AeroMACS (Aeronautical Mobile Airport Communication System) is an ICAO standardised data link system aiming to support the ATS and AOC data communication exchanges on ground, at airports. It is defined to operate in the C-band especially in the 5091 to 5150 MHz band internationally, and extensions to this band may be granted by local administrations. AeroMACS is currently based on a relatively modern 4G wireless technology (WIMAX IEEE 802.16e). However, an initiative is starting at ICAO to update the AeroMACS standards, so that to make them more agnostic of the supporting Wireless technology, and enable future implementations of Aeromacs to be based on latest 3GPP standards, such as 4G-LTE, or 5G, and even 6G over the next decade.

The deployment of AeroMACS has been relatively limited until now, to few Airports in the USA, In Portugal, In Japan and in China, where AeroMACS is mainly used for ground-ground communications between fixed points for use cases interested in avoiding the costs of pulling wires throughout the airport. There are no revenue aircraft equipped with AeroMACS today, and no Airborne AeroMACS equipment has been developed and certified yet.

For Airbus, the deployment of AeroMACS on Aircraft is hindered by the following points:

- In a way similar to LDACS, the airborne AeroMACS radio is an equipment that is not necessarily simple and inexpensive to develop. Even it is based on a public 4G (or 5G/6G in the future) standard and can potentially leverage the availability of COTS chipsets, there remains safety-domains-related specificities that are significant related cost drivers: operation in the C-band, compliance to MOPS/MASPS, compliance to development assurance standards (DAL D at software/hardware level), Equipment at the boundary of 2 aircraft domains (ACD and AISD) with robust partitioning required and strong security assurance levels. Here again, the complexity of the equipment looks a priori similar to that of a Class B L-band SATCOM system.

- Because of the above point, the AeroMACS may not be a cost effective and competitive solution for AOC communications at airports, compared to the use of public cellular IMT solutions (3G+/4G/5G/..) which are:
    - Easier to developed, and certify (no MOPS, DAL E, directly based COTS chipsets from the mobile phone market)
    - Cheaper to equip and possibly to use (communication costs)
    - Already available on the ground on a wide scale (most airports are already covered by public cellular systems - whereas AeroMACS availability will depend on Airport equipage)
    - Already available on aircraft (e.g. basic on A320/A330/A350 ,)
    - Not restricted (by spectrum regulations) to data exchanges for “regularity of flight” applications
    - Progressing along the public cellular technologies roadmap, with notable and regular improvements from one generation to the next one
- It remains that AeroMACS could be justified mainly to support ATC communications at airport surface on those airports that will be equipped with AeroMACS. However, as there are relatively few ATC datalink exchanges at airports, and few airports equipped with AeroMACS, a very low demand for airborne AeroMACS equipment can be expected from operators, which has negative impacts on the amortisation of the development costs, which generally increases the unit price, which is then worsening the whole business case.

Airbus sees a risk that the above points may still exist for the future version (agnostic) of the AeroMACS standard, while a strong use case has not been identified that could justify the need for a high-bandwidth safety air-ground communication system at airport.

Some other concerns, identified for the case of the LDACS equipment above, are also valid for AeroMACS: uncertainties on the ground deployment, likely worth to postpone until when or after ATN/IPS is deployed, no known incentives or mandates that could help building a business case.

Given the above considerations, Airbus has not taken any decision regarding the implementation of AeroMACS, and has no plan to implement AeroMACS for the moment.

Airbus anticipates that 5 years of development would be needed to develop and certify an AeroMACS radio after a decision is taken.

Mature and validate ATN/IPS for an Airborne system entry into service by 2032

ATN/IPS aims at being the convergent technology replacing progressively ACARS and ATN/OSI worldwide. It will provide upgrades, particularly in the areas of security, and also provide a migration path towards future native-IP safety applications (such as air-ground SWIM). IPS Gateways located on the ground are key to the introduction of IPS technologies, as the gateways will provide ways to enable transition from current technologies. Airbus does not plan to certify an airborne ATN/IPS capability until the technology is sufficiently deployed on ground.

ATN/IPS is currently covered by R&T activities (SESAR, NextGen…) with the objective to validate on-going standardisation activities and prepare the future deployment.

Target certification and entry into service is currently around 2032 (given sufficient elements are provided to make a development decision, like a positive business case, maturity of the standards, and ground deployment)

ATN/IPS should be designed to run over SATCOM and if feasible over VDLM2, and Hyperconnected ATM concept.

This 2032 target is consistent with the remaining work to be done until an ATN/IPS Airborne capability can be certified. The remaining challenges to overcome and next steps are:

- Even if suitable for the future, data security is still a key challenge (integration in the aircraft, security infrastructure deployment and operation / PKI…)
- Even if agreed convergence worldwide technology (single stack worldwide), difficult business case compared to already deployed ACARS and ATN/OSI.
- Airbus will deploy ATN/IPS only when sufficient ground ATN/IPS infrastructure is deployed. No interest to deploy ATN/IPS at airborne level only with ground gateways for accommodation with other technos ACARS or ATN/OSI.
- Ground infrastructure is expected to be very complex (mobility management, security, gateways,…)
- Current datalink systems (e.g. ATSU on 320/330) likely not able to host ATN/IPS (performance, hosting capability, segregation…): ATN/IPS is a hardware and software evolution (likely including dedicated hardware/software additional security bricks)

These challenges (technical, business case) justify the remaining time (around 10 years) for an ATN/IPS entry into service at Airbus aircraft level.

Hyperconnected ATM

Airbus sees the SESAR "Hyperconnected ATM" solution as a promising concept. It would allow leveraging the state of the art "at hand" commercial radio infrastructure already deployed and available on the ground, in space, and increasingly on aircraft to serve the growing needs of connectivity for passengers' satisfaction and for optimized aircraft and flights operations. Also, it has the potential to easily scale up to expand with any break-through public air/ground communications systems that may come in the future, such as the future IMT systems generations (6G, …) and "new space" LEO mega constellations.

Because available commercial radio infrastructures are reused, the "Hyper Connected ATM" solution has the potential to be deployed with relatively small impact on the baseline architecture and low risk on the invested capital. A preliminary step to this solution, only dealing with the transfer of AOC traffic on these public links, is anyway already engaged and being deployed, and should contribute to demonstrate and popularise partly the approach, starting with the transfer of an increasing (over time) proportion of the AOC traffic. Offloading the AOC traffic from legacy safety communication links can be seen as a first essential contribution of the approach, allowing mitigation of the VDLM2 capacity issues.

The Hyper Connected ATM solution is defined only as a complementary approach, and not as an alternative to other safety link technologies: it is not assumed or proposed that public links alone could be used to support ATS datalink services in the future. It is rather envisioned that public links could be coupled with another safety link to serve as an opportunistic "best effort" alternative to equipping the aircraft with a second safety link, when Multilink configurations become the most reasonable solution to go beyond the end-to-end datalink services availability, continuity and capacity obtained with one single safety link.

With Hyper Connected ATM, there is no guarantees of better end-to-end performance. There is only confidence that a "best effort" approach can "generally" bring improvements and a certitude that "it will not be worse". So, even if the hyper connected ATM solution does not bring the same level of determinism as what could be obtained with the deployment of a second/new safety link, there is high confidence that it will be better to complement a safety link with a public link, than to stay with that safety link alone. The lack of guarantees or determinism is a negative aspect of the solution; however, this limitation has to be balanced with the opportunity (or good confidence) to get extra flexibility and performance at reasonable costs and risks and with the fact that public networks are increasingly reliable and show impressive performance (high capacity, low latencies) within usual nominal conditions.

Regarding maturity, the Hyper Connected ATM solution is composed of a mix of very mature elements (the already deployed public links infrastructure, used for Passengers' communications) and of some new (but proportionally small) additional mechanisms at TRL2. Overall, it can be considered that the maturity barycentre is close to the high TRL.

Taking into account all the required next steps before adoption (R&T maturation, Standardisation, validation, ….) it is expected to be fully operational by 2032, in synchronisation with the ATN/IPS deployment.

4.2.3. Infrastructure Operator view

4.2.3.1. SATCOM Infrastructure and Readiness

Aeronautical Mobile Satellite En-Route Services – AMS(R)S are already being offered by Inmarsat and Iridium for Performance Class B SATCOM systems based on Inmarsat SwiftBroadband-Safety/Iris and Iridium Certus services respectively, while performance Class C SATCOM systems continue in operation after decades supporting voice and ATS datalink applications in oceanic airspace – based on Inmarsat Classic Aero and Iridium services, in use since the early 1990s.

Inmarsat SwiftBroadband-Safety/Iris relies on a constellation of GEO satellites, with 3 Inmarsat-4 series satellites[20] operating in three primary orbital slots to offer global coverage (Alphasat EMEA, I4-F1 Asia-Pacific and I4-F3 Americas) and 1 satellite providing regional coverage (I4-F2 MEAS). The ground network is fully redundant, with dual Satellite Access Stations in Europe, USA/Canada and China/New Zealand as shown Figure 29 below.

Alphasat serves the ECAC region with 16 narrow beams using Inmarsat Broadband Global Area Network – BGAN infrastructure, with capacity allocated to beams based on traffic demand. Each of these beams is assigned as many 200 kHz channels as needed to support traffic. Alphasat was launched in 2013, with a currently expected lifetime likely to be well in excess of its planned 15+ years.

[20] Alphasat 25°E, I4-F1 143.5°E, I4-F2 64°E , I4-F3 98°W.

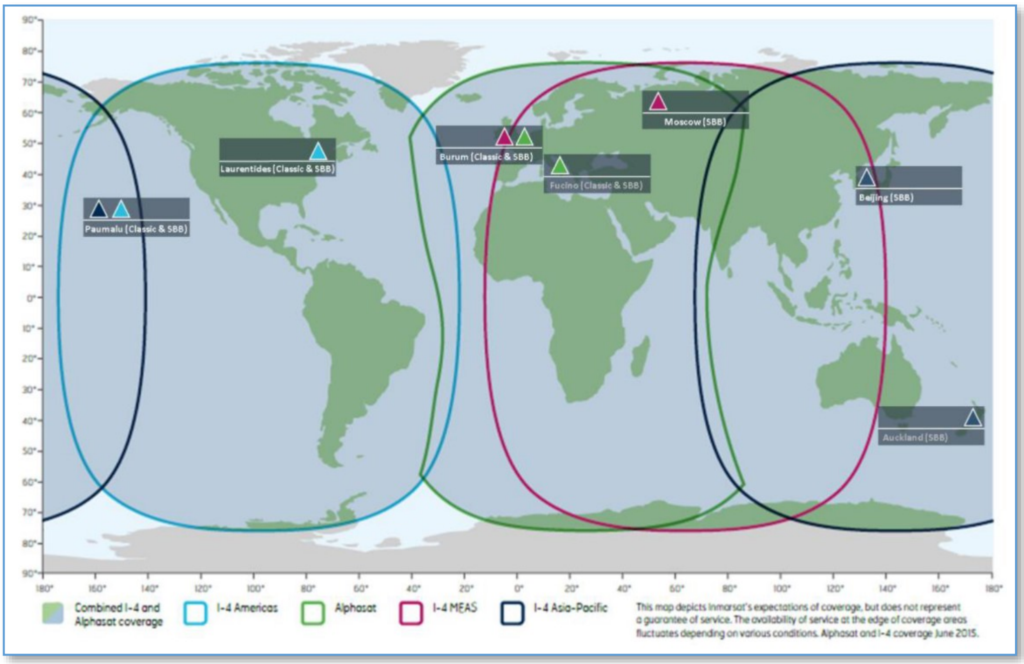


Figure 29. Inmarsat I4 and Alphasat coverage

To ensure future continuation of aviation safety services now supported by I4 up to 2040 and beyond, Inmarsat started deployment of the more sophisticated Inmarsat 6 series satellites, with I6 F1 launched in December 2021 to cover the Indian Ocean, and I6 F2 launch planned mid-February 2023 to serve the Atlantic region. I6 satellites convey hybrid payloads that feature both L-band and Ka-band services, with each I6 alone offering more L-band capacity than the entire I4 fleet. Seamless coverage over Europe of the aviation safety services will be supported via the I4, Alphasat and I6 satellites.

Current ATC and AOC Services – SwiftBroadband Safety

In 2018, the FAA approved SwiftBroadband Safety (SB-S) for the provision of FANS 1/A operations in airspace requiring RCP240 and RSP180 performance requirements. SB-S has been in use since then for conducting both ADS-C and CPDLC (FANS 1/A datalink) in oceanic airspace, compliant with ICAO PBCS (Doc 9868).

SwiftBroadband Safety also provides airlines with capabilities for both safety and non-safety AOC ACARS services, which are distributed via redundant ACARS Ground Gateways to the current Datalink Providers SITA and Collins.

Additional AISD AOC services that rely on IP communications, such as Electronic Flight Bag applications, are also natively supported by the BGAN network and offered as part of the Inmarsat portfolio of SwiftBroadband Safety services.

SB-S 2.0

SB-S supports air-ground communications using standard 3GPP protocols adapted for the satellite link, thus natively protecting stakeholders using the 3GPP feature set.

Enhanced cybersecurity has been introduced on top of these capabilities with SB-S 2.0, which offers since 2021 mutual authentication and integrity for safety AOC and ATC datalink communications based on a cutting-edge PKI security infrastructure.

New safety services - Iris

Iris is the satellite-based datalink technology providing Air Traffic Management communications in continental Europe compliant to RCP130 and RSP160 performance requirements.

Iris builds on Inmarsat infrastructure retaining legacy SB-S 2.0 capabilities for oceanic FANS1/A, SATVOICE and ACARS AOC, and introducing new capabilities to support continental ATN/OSI via SATCOM, including ATN B1 and ATS B2 services, and enabling i4D and TBO.

Iris also relies on the SB-S 2.0 cybersecurity infrastructure to offer mutual authentication and integrity for the exchange of trajectory data, in line with the CP1 requirement for secured datalink. The Iris ATN/OSI infrastructure consists of dual-redundant Air-Ground Routers located in the Burum and Paumalu AeroRacks (ground gateways), currently connected to the SITA ATN/OSI network, with the potential for future connection to other networks such as NewPENS.

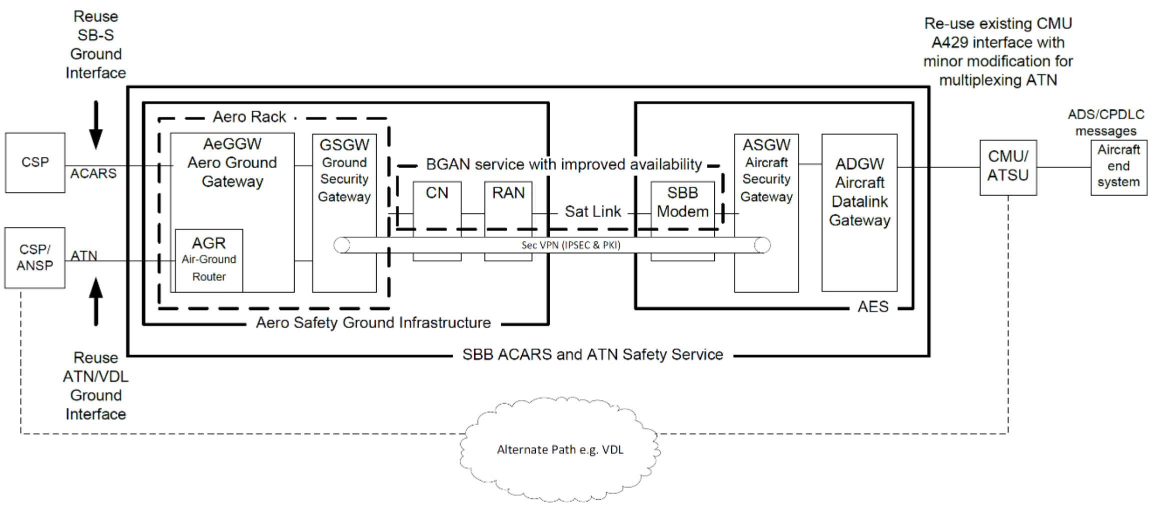


Figure 30. Iris System Architecture (omitting redundancy)

Iris implements the SESAR dual-link concept, with link preferences established by airlines on a per-aircraft basis and maintained throughout a flight. For aircraft equipped with both VDLM2 and SATCOM, dual-link allows switching to VDLM2 in the event of loss of the satellite link, automatically switching back to SATCOM once the link is restored, and vice-versa in the case of VDLM2 unavailability. Airbus' certified ATSU CSB/CLR 10.2 already incorporates dual-link capability following this mode of operation.

With its inherent enhanced air-ground data link capacity, Iris will start operating at pan-European level inQ2 2023, following approval from EASA and certification of the Iris Service Provider – ESSP in accordance with EU IR 29/2009 datalink regulation. Following EASA approval, easyJet and other airlines will evaluate the benefits of Iris operationally in a series of pre-commercial flights.

Transition to ATN/IPS

The European Union is moving towards implementation of the Single European Sky ATM Research (SESAR) project for implementing a new Air Traffic Management administrative, operational and technical concept. Satellite communications for Air/Ground communications (i.e., voice and data exchange between aircraft and flight control centres) have an important role to play in the future ATM infrastructure, both in Europe and in the rest of the world. In coordination with the EC, EUROCONTROL, ANSP's and the SESAR consortium, the ESA ARTES 10 Programme ("IRIS") intends to define and develop the use of SATCOM for ATM communications in the future ATM system defined by SESAR.

The main focus of IRIS to date has been to deliver a SATCOM service supporting the ATN/OSI protocol suite. However, there is also an intent to implement the ATN/IPS protocol suite in the future.

Standardisation activities at the ICAO level are currently under way to specify SARPs and supporting documents for the ATN/IPS. ICAO final documentation on IPS is a a necessary precondition before work can begin on the support of an ATN/IPS service by IRIS.

Development activities

Under the Iris programme, there have been several activities around the development and testing of ATN/IPS.

The work proposed within the Iris programme needs to be considered in the broader context of the preceding, overlapping and future projects such as SESAR 2020 (Sol 77 and Sol 107), and other partners such as Boeing, and FAA.

The system design activities with the programme are already underway in the Iris consortium.

The objective of these activities will be two-fold:

Define the final SB-S IPS service design and the planning, requirements and design documents for the ground segment and the AES.

Define the exact scope of the IPS Demo/validation/flights in support to IPS products and avionics and end to end system certification

Standards

The main ongoing standardisation activities for ATN/IPS are as follows:

ICAO Communications Panel (CP) Working Group I: Responsible for the update to ICAO SARPS in Doc 9896 (ATN/IPS Manual), which will contain the overall architectural concept and behaviour / protocol definition. ICAO is planning to issue Doc 9896 Ed 3 by end 2024.

RTCA SC-223: Currently developing Protocol Profiles based on IETF standards for input into the ICAO CP WG-I.

AEEC ATN/IPS Subcommittee. AEEC has already produced a work plan (AEEC PP658) which identifies ATN/IPS considerations from an avionics system design perspective and identifies all the areas that are required to be addressed for ATN/IPS standardisation both within AEEC and the other bodies. A new ARINC standard (ARINC 858) will be developed as a result of this work.

Within ICAO CP WG-I, a Mobility Subgroup has been established to address one of the most critical elements within ATN/IPS concerning mobility of aircraft within the future ATN network and the support for reliable communications through use of multiple air-to-ground radio links (Multilink). Sufficient work has now been completed to ensure that ICAO will be able to issue SARPs Edition 3 by 2024.

4.2.3.2. ATN/OSI Dual Link Architecture

ATN/OSI dual-link – context and infrastructure

The complex transition towards ATN/IPS Multilink encompasses multiple steps, including the evolution from ATN/OSI single link (VDLM2 only) to ATN/OSI dual link (VDLM2 and SATCOM). It is of paramount importance that such transition is managed carefully in order not to jeopardize the datalink capacity gains enabled by the introduction of complementary technologies.

Iris SATCOM

The Iris SATCOM project, developed with ESA' support has developed the first mature complementary link to VDLM2. The service is close to certification by the Iris Service Provider against EASA regulation. The Iris Service Provider will distribute the ARN service to ANSPs. This chapter develops how the dual link could be managed taking into account the various constraints from the ground and airborne side.

[ATN/OSI dual link : VDL-2 and SATCOM]

The terminology "Dual-link" refers to VDLM2 + SATCOM link management whereas the "Multilink" terminology refers to the management of multiple ATN links (i.e. potentially more than 2). Some initial guidelines regarding ATN/OSI dual link management have been produced under the framework of the "Task 6" of WP4 of PJ14 within the SESAR program, which outcome was subsequently updated as a result of the coordination activities involving Iris stakeholders21. These materials also provide guidance as to how link preference should be managed in an ATN/OSI environment.

On aircraft equipped with both technologies, an onboard parameter will specify which subnetwork is the preferred link to be used for ATC datalink communication. Aircraft manufacturer implemented an on-board mechanism in the ATSU specifying that the default setting will be SATCOM 1st and VDLM2 2nd. When in flight, should the preferred link become unavailable then the airborne system will automatically switch onto the alternative link without interrupting any ATN ongoing session and then switch back to the preferred link once it is available again. The mechanism will be transparent to ANSPs connected on the ATN backbone and will not require any change to their ATN infrastructure.

[The ATN traffic discrimination challenge]

When ATN traffic is exchanged over an ATN backbone, the route being used is totally transparent for ANSPs and based on the Aircraft preferred linked. In such configuration, no standard ATN/OSI mechanism exists today to allow to convey ATN traffic to/from an ANSP using a specific subnetwork (VDLM2 or SATCOM) selected by the ANSP. In a nutshell, dual equipped aircraft will have the capability to send downlink ATN traffic only to a specific subset of ANSPs but ANSPs will not have the capability to select which link shall be used to convey uplink ATN traffic to such aircraft.

For the Iris pre-commercial flights phase, no evolution will be brought to the ATN backbone to enable ANSP discrimination or route selection. For the subsequent commercial phase, in case the ANSP discrimination becomes necessary, two solutions have been identified:

- Implementation of a direct link over NewPENS between the Iris Network and participating ANSPs.
- Deployment of dedicated ground routers on the ATN backbone specifically used to convey SATCOM ATN traffic.

However, such workarounds can only be envisaged for a transition period and the DLS community will have to jointly define the technical solution and ATN network architecture for a fully integrated dual-link. SATCOM deployment and usage by ANSPs will consolidate over a period of time, hence the need to agree on the most appropriate mechanism to manage dual link during an initial phase.

[21] In the form of a whitepaper "Multilink aspects in the Iris deployment - version 6.1 - Iris IOC"

4.2.4. Communication Service Provider

4.2.4.1. Collins

As a Communications Service Provider (CSP) our mission is to provide air/ground connectivity between aircraft and ground systems/users. This includes offering alternative communications technologies that meet customer's technical, operational and business requirements.

Multilink as a concept has already been successfully implemented by the industry in the ACARS environment for AOC and ATS communications starting in the 1990s. The initial deployment of VHF service (POA) has been complemented by VDL (AOA), L-band SATCOM (Inmarsat and Iridium) and HFDL. More recently IP-based media have emerged as further link options for ACARS (AoIP).

In the ATS ATN environment, VDL (VDLM2) has been the only available operational media so far. With the emergence of new technologies designed to support ATN this is now expected to gradually evolve into a Multilink ATN environment.

However, Collins expects VDL to remain the dominating media for mission-critical ATS and AOC datalink well into the 2030s while complementary air/ground media are gradually being deployed in parallel. Collins continues to invest in the VDL service in Europe for the foreseeable future. This includes near term deployment of a 3rd alternate regional VDL frequency in 2023 onwards, adding additional sites and upgrading existing ground stations as required to optimize capacity and coverage as required. In addition to the above, a deployment of local TRM/GND frequencies at selected airports is an option that would allow further optimization of available regionally cleared frequencies for enroute use only in the core area.

Collins supports the migration of less-critical ACARS AOC traffic off VDL to alternative IP-based media (AoIP) where the airspace users/end users of the data consider this acceptable and economically justifiable. This includes using COTS services e.g. cellular networks and satellite broadband solutions. There is a potential to migrate a significant percentage of the current AOC VDL traffic volume typically generated by airline operated aircraft.

Collins also supports industry initiatives and activities aiming at using the VDL spectrum more efficiently. This includes enhancements to the VDL and ATN standards and protocol to improve the efficiency and resiliency of VDL.

Collis supports IRIS as a complementary satellite media for ATN/OSI communications, with Pre-Commercial Flights due to take place in 2023. The number of commercial aircraft entering service in the years ahead (ca 2025-2035) and being equipped with IRIS-enabled avionics will depend on the business rationale for the aircraft operators to do so. Therefore, the actual impact IRIS is going to have on complementing VDL for overall ATN traffic growth in the same period remains uncertain for the time being.

Regarding LDACS, from a technological point of view, Collins believes it might be possible to implement such service as a complement to existing deployed VDL infrastructure. The focus would initially be on the core high-traffic area and gradually expand to the peripheral EU area as required. The coverage of an LDACS radio is approximately the same as the one of a VDL RGS. From the point of readiness for industrialization, a coverage in the core area could possibly be achieved within 5 years from a decision to start deployment. The CSP's business case for deploying LDACS ground infrastructure is contingent on availability of mature LDACS-enabled avionics and ground radios, decisions by OEMs to offer this equipment and business decisions by operators to equip a significant number of aircraft in the years ahead (2030-2040?). Like with IRIS the potential impact on complementing VDL for ATN traffic is therefore difficult to forecast at present.

Before a decision to deploy an LDACS service there is a need for industry consensus to avoid fragmented, regional implementation. Airlines and other operators strongly advocate globally adopted solutions for reasons of interoperability and cost. In addition to this there are currently some technical concerns with LDACS (L-band interference) that remain to be addressed.

Collins monitors industry initiatives related to space based VDL services on LEO satellite networks. Initial concerns include capacity and interoperability with terrestrially deployed VDL networks and frequencies.

Collins monitors industry proposals related to the use of commercial non-safety links for provision of safety ATM/ATN communications ("HyperConnected ATM" concept).

In summary, Collins supports Multilink as a way forward while VDL is expected to remain a major media for critical ATS and AOC communications into the 2030s and quite possibly beyond. Less critical AOC traffic will be migrated to other media where there is a business case for operators to do so. New avionics are expected to become available in growing numbers capable of ATN/OSI and later ATN/IPS over complementary media thus gradually complementing VDL and supporting overall predicted traffic growth.

4.2.4.2. SITA

A CSP view on Multi-Link

Airspace Users operate in an increasingly complex environment and face a number of challenges, including growing air traffic volumes, changing regulatory environments, disparate aircraft fleets, volume growth within a limited airspace, this combined with the increased focus on improving airline and passenger safety, as well as optimizing operational efficiency, are SITA customers' challenges that we strive to address through our communications service offering; where the Multi-Link concept is a well-established principal in how communication services are delivered to Airlines, Airspace users and Air Navigation Service Providers , the evolution of this concept creates an interesting principle that could enable enhanced services to be to these users, leveraging the use of multiple physical and logical links to accommodate the diversity of performance and reliability (QoS) requirements that our customer's communications have.

Communications Service Providers enable wireless communication between the Airspace Users' aircraft and their ground systems, as well as third parties operating on the ground (such as air traffic control). A Communications Services Providers offering is typically comprised of two main elements:

- The "core/backbone" ground network, ground systems, processing, management and distribution and;
- The access networks to which the Airspace Users connect to, enabling air-to-ground communications and linking back to the "core/backbone" ground network, through a highly diversified and integrated network, spanning across multiple technologies, operated together by the CSP in order to provide its Users with a seamless, unified and versatile, communication service.

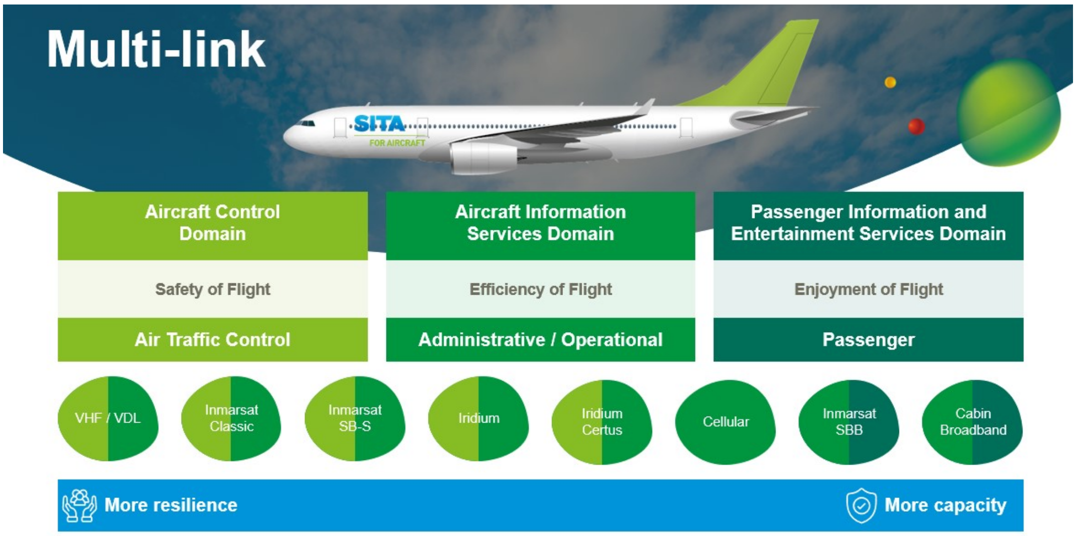


Figure 31. Multilink benefits

Multi-link communications services connect aircraft for safety, sustainability and operational efficiency by enabling the seamless flow of communications for air traffic control and aircraft operations to support mission critical process. To date, Air Traffic Control (or Aircraft Control Domain) communication is in only provided over approved and dedicated communication networks. These systems operate in dedicated and protected aeronautical frequency bands and include High Frequency radio, Very High Frequency radio, as well as L-Band satellite networks (e.g., Inmarsat and Iridium).

A CSP view on preparing the future

Preparation of the future from a CSP point of view comes in 3 different timespan that overlap to provide an evolution path for our users.

Improvement of existing systems and technologies to increase their offered capacity

Introduction of new systems and technologies, extending towards implementation of the multi-link concept

Extension of the multi-link concept towards the inclusion of non-safety links for improved diversity and better management of the wide range of quality of service requirements of end users' applications

Amongst new technologies, the following sections outline the principles underlying steps 1 and 2 above:

1.Maximising the capabilities of existing technologies

In addition to preparing the future for the arrival of new networks, given the time that new technologies will take to come to market, it is essential we maximize the capabilities and the life of the existing network. SITA is engaged in several initiatives to improve the performance of our VDLM2 network.

One such initiative is the Super VGS (VHF Ground Stations) which optimizes Air-to-Ground aircraft communication by deploying a cluster of stations, where all ground stations operate as one from the aircraft perspective.

Today, by-design, the aircraft establishes point-to-point communication between each individual ground station. The aircraft keeps track of the different stations in the vicinity and ranks the best station by the Radio Frequency (RF) signal strength using an indicator called Signal Quality Parameter (SQP)). The aircraft then selects the best station based on the signal strength and establishes a "virtual link" with the selected station.

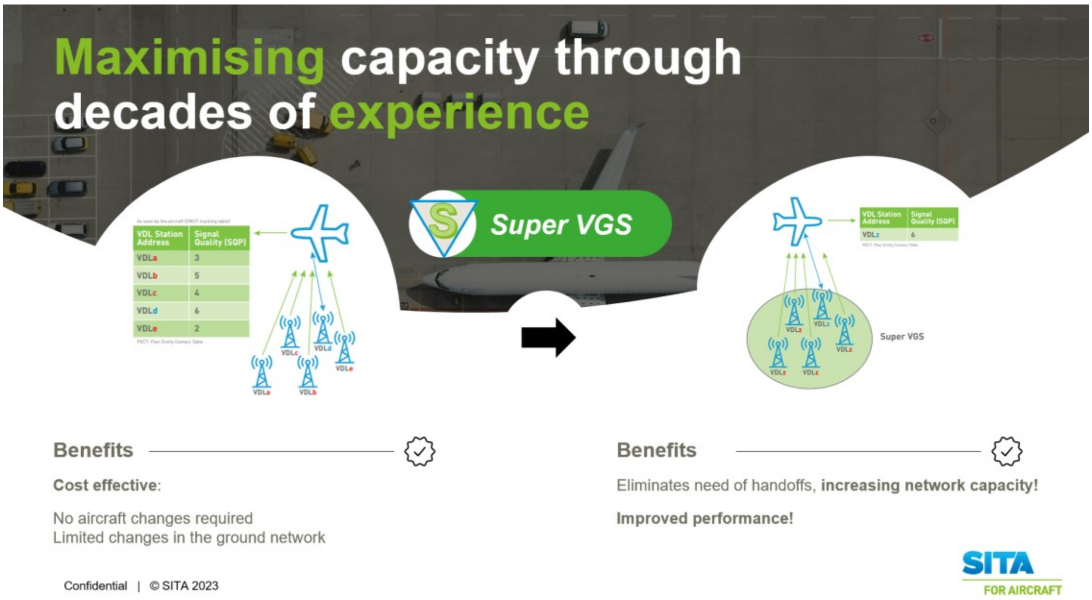


Figure 32. Maximising capacity through decades of experience

Super VGS operates by making all VHF Ground Stations run as one from the perspective of the aircraft. This is achieved by the implementation of a cluster controller. This controller then becomes responsible for selecting the optimum station to communicate with each aircraft. By bringing the control of the communication to the ground system, Super VGS also eliminates the need of handoffs. From the aircraft's perspective it is always in communication with the same ground station. With fewer handoffs, more aircraft can communicate over the same channel and the aggregate throughput is maximised.

This concept is currently being testing in our operational network. If successful, AEEC standards will be updated and the Super VGS will be rolled out across the SITA VDL network.

2. Introduction of new systems and technologies towards the multi-link concept implementation

- Using protected spectrum of for ATC/aircraft operational/Urban Air Mobility (UAM) communications

Examples could include:

- Next generation terrestrial networks
- L-band digital aeronautical communications system (LDACS)
- New generation satellite networks

Space-based VHF

Dedicated VHF payload on LEO satellite constellations

No new technology can successfully be brought to fruition by a single entity. Industry consensus and coordination is paramount to building and executing a long-term technology roadmap.

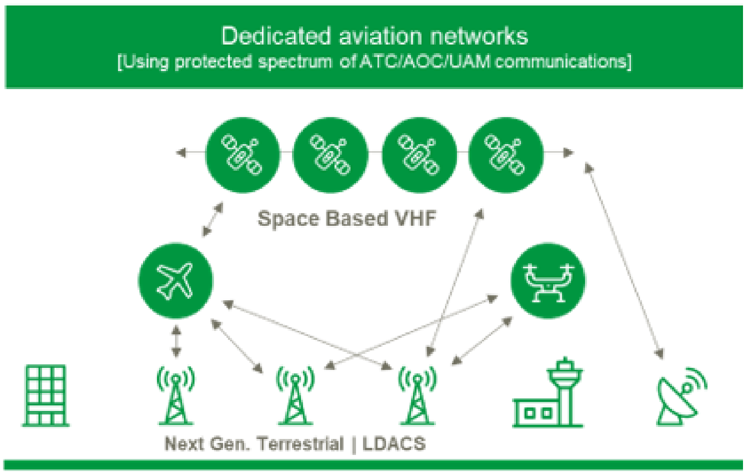


Figure 33. Dedicated Networks

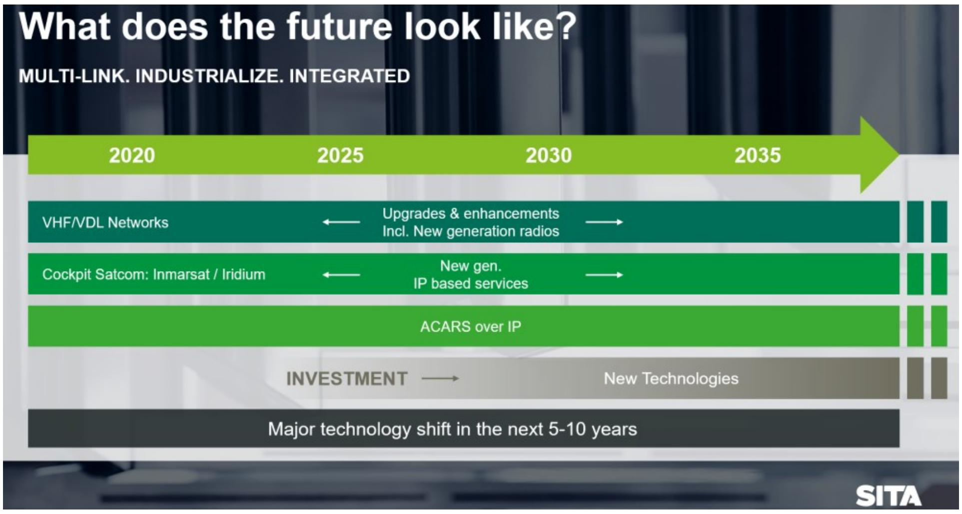


Figure 34. New technology

New Technology Readiness and Roadmap

Dedicated aviation networks

<u>L-band digital aeronautical communications system (LDACS)</u>

Note: this technology is the focus of research activities in the frame of SESAR Future Communication Infrastructure (FCI)

Maturity: Low. Avionics and radios to be developed

Pros: Can reuse existing VDL network infra (locations / ground networks). High bandwidth. High performance. Support Voice, Data & Tracking. Open standard. Supports multi-CSP model. Lower cost, compared to some other technologies, e.g., SATCOM

Cons: Avionics and Air Framer consensus. Needs global endorsement, Euro-centric technology / network less likely to gain traction

Industry consensus: Low. Avionics and Air Framers key stakeholders need to be brought onboard

Timeline to deploy estimate: Fast to deploy ground network once radios are available, Euro network approximately 2 years. Linefit avionics availability +5 years following Air Framer 'go' decision.

Estimate operational readiness, could be as soon as 2030-2035 but dependent on the adoption of the technology by the airspace users and OEMs.

<u>New generation satellite networks (SwiftBroadband-Safety)</u>

Maturity: Mature. SB-S widely available for FANS and AoC ACARS. ATN pre-commercial trials due to commence in Q2 2023 (IRIS)

Pros: Proven satellite network.

Cons: High cost for aircraft operators to equip. Slow ramp of SB-S capable aircraft, particularly IRIS. Small number of equipped aircraft results in low benefit to ANSPs[22].

Industry consensus: High. ANSP adoption to be established. Airline willingness to equip to be seen.

Timeline to deploy: Deployed.

<u>Space-Based VHF</u>

Note: this technology is the focus of research activities in the frame of SESAR Future Communication Infrastructure (FCI)

Maturity: Low. Research and Proof of concept.

Pros: Global VHF/VDL service (Voice and Data). No avionics changes required.

Cons: Global coverage requires payloads on global satellite network.

Industry consensus: Low. Benefits from less industry stakeholder involvement, due to not new avionics or aircraft modifications

Timeline to deploy: Communications Service Provider timeline is short, refuse of existing infrastructure. Payload and satellite network availability, longer term.

Estimated operational readiness: 2030+

3. An outlook to the very long term research around multi-link

In a much longer time horizon than the one presented in the approaches described in the previous paragraphs. The concept of HyperConnected ATM, further generalizes the multi-link to include non-safety links among the possibilities for a CSP to build his service offering on. In such context, the concepts established and demonstrated in the frame of the multi-link implementations will be further extended to include the use of links that do not present the guarantees of the aviation dedicated links nor operate in frequency bands dedicated to aviation and protected from harmful interference by external systems under the ITU Radio Regulations article 4.10.

Although interesting as a concept and the range of possibilities its implementation could offer, the advent of the so called “HyperConnected ATM” is currently hard to place in time as research is barely starting to emerge on the concept and its implementation has yet to be studied.

[22] Note : the ramp-up of LCS is progressing quickly with 7 EU airlines having selected SATCOM at the time of writing. Linefit will be preferred as more cost effective.

4.2.4.3. ESSP

The Iris service is a satellite-based air–ground data communication service for Air Traffic Control (ATC) services in continental en-route airspace. It is tailored and compliant in particular with the aviation requirements for ATN/OSI-based data communications as specified in the relevant European Regulation such as the DLS IR, ICAO SARPS and EUROCAE specifications. In particular, the Iris service enables:

The Data Link services mandated in the Regulation (EC) 29/2009, as specified in the ED-120 with the corresponding RCP specification (i.e. ATN Baseline 1) and in the ED228A with the RCP130/A1 specification (ATS Baseline 2): Data Link Initiation (DLIC), ATC Communications Management (ACM), ATC Microphone Check (AMC);

The Data Link ATS Baseline 2 Service specified in the ED228A with the RCP130/A1 specification (ATS Baseline 2) others than those mandated by the Regulation (EC) 29/2009: Clearance Request and Delivery (CRD), Data Link Taxi (D-TAXI);

The Data Link ATS Baseline 2 Service specified in the ED228A with the RCP130/A1 and RSP160/A1 specifications (ATS Baseline 2): 4-Dimensional Trajectory Data Link (4DTRAD), Information Exchange and Reporting (IER), Interval Management (IM).

The Iris service will be provided as a pan-European certified Communication Service provider of Aeronautical Mobile Satellite (Route) Service (AMS(R)S) oversight by the European Union Aviation Safety Agency (EASA). In this regard, the European Satellite Services Provider (ESSP) SAS ESSP has been tasked with developing the necessary elements to create the Iris Service Provider (ISP) prior to the start of the Pre-commercial Flights (PCFs) in the second Quarter of 2023.

The Pre-commercial Flights will have a duration of 6 months, consisting of up to 11 EasyJET aircraft to be equipped with Iris and ATS-B2 capable avionics (backwards compatible with ATN-B1 functionality). These aircraft will then be integrated into airline schedules and conduct revenue flights making use of these capabilities. EasyJET signed its participation in in June'22, while there are on-going discussions with other airlines for their inclusion in the PCFs. In relation to the ANSPs, as of today more than 15 ANSPs are expected already to be involved in the PCFs.

Once the certification is granted, the ESSP will hold the ATM/ATN Service Provider Organisational Approval for the provision of AMS(R)S service in the EU continental airspace, within the European Civil Aviation Conference (ECAC) region. Thus the ESSP will be the Iris Service Provider not only for the PCFs but during the subsequent years in which Iris become a commercial service at European level.

The ISP role will act as the focal point for the service, and will include the relevant Service Provider activities such as monitoring and reporting functionalities. To this end, the ISP will be fully responsible for the end-to-end provision of Iris service up to the Air Traffic Service Providers (ATSPs) facilities, and in compliance the regulation and associated standards towards the ATSPs as will be described in the Iris Service Definition Document (Iris SDD).

The Iris system comprises two main segments:

SSP Air-Ground segment (INM): is composed of the Space segment and Ground sub-segment that covers from the Aircraft boundary (i.e. AES which is out of the scope of the ISP service) down to the Inmarsat air-ground network which interfaces with the CNP Ground/Ground segment through the Meet Me Points (MMPs), and vice versa.

CNP Ground-Ground segment: Two options are possible:

Option 1 – connection via the current ATN Backbone through the ATN Ground/Ground routers operated by SITA/Collins which route the CLNP (Connection-Less Network Protocol which supports ATN/OSI service) traffic all the way up to the ANSP ground network.

Option 2 – connection via IP network operated by NewPENS which conveys the CLNP traffic encapsulated in IP packets all the way through to ANSP ground network.

On top of the above segments, it is the defined the ISP service segment: providing the overall service provision and in compliance with the standards.

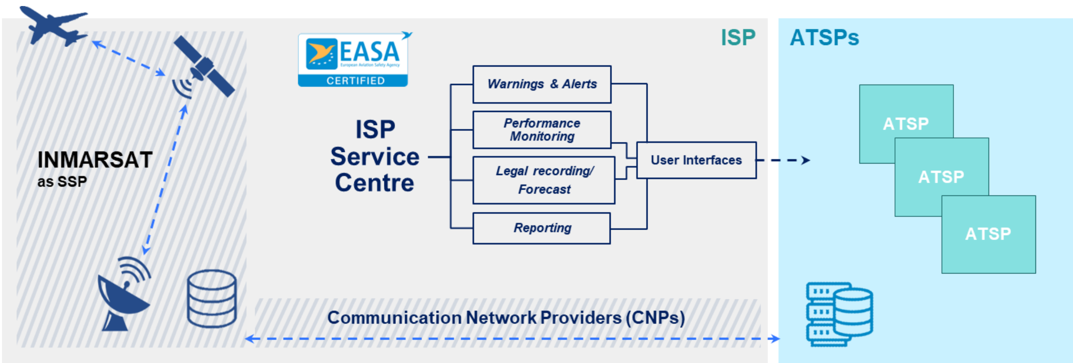


Figure 35. Iris Service Context

The ATSPs will rely on the ISP certificate for their provision of ATC Data Link Services. No re-certification of this communication service will be required to the ATSPs who want to use the Iris service in the airspace under their control. Neither oversight over the ISP nor over the SSP / CNPs will be required from the ATSPs since the overall scope of Iris service will be under EASA oversight.

To enable the use of the Iris service by the Airspace Users in the corresponding airspace, each ATSP needs to sign a contractual Working Agreement with the ISP. This contractual aspect is required by the SES regulation and formalises the relationship between the ATSPs and the ISP in order to establish the service provision framework and the corresponding perimeter of responsibility of each certified Entity in accordance with their certificates. The Iris Working Agreement (IWA) will rely in the Iris SDD and will comprehend the corresponding SLA in accordance to the defined requirements. The service provision framework will establish the liabilities, service commitments, service specifications, interfaces / coordination actions between the ATSP and the ISP, setting the service base for the Working Agreement.

As the ISP is ultimately responsible of the end-to-end data provision to ATSPs, it will monitor the overall behavior of the Iris service and functional system. In particular the ISP will monitor the RCTP / RSTP performance parameters specified for the aforementioned services.

As a consequence, and taking into account the information gained during the PCFs, the Iris service will follow a continuous improvement process to evolve in a Multilink functional framework within Europe.

The Iris service will be available for use starting with the Pre-Commercial Flights (PCFs) at the second quarter of 2023. Once the AOA Certificate is granted by EASA to the ESSP, which will assume the role of the Iris Service Provider through Europe, and the ANSPs agree on its use through corresponding Working Agreements, the Iris SATCOM Flights will start to fly across the continental airspace. The following figure shows the timeline:

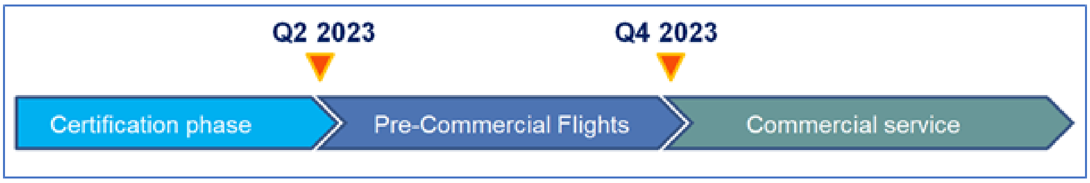


Figure 36. Timeline Iris service

5. Consolidated Implementation Roadmap

The contribution from stakeholders provided in chapter 4 have led to the identification of communication links and infrastructure solutions to be part of the consolidated implementation roadmap. For the sake of readability, the consolidated implementation roadmap is represented in three parts, an overall roadmap, a ground and an airborne related roadmap.

5.1. Summary of chapter 4 technologies

Table 5, adapted from the FCI Business Case, [RefDoc 01] "FCI Business Case, V18, 21 April 2022, presented at JCSP7 (May 2022) [updated by SESAR20202 PJ14 Solution 77, deliverable D5.1.500, Nov. 2022", shows a qualitative comparison between the new technologies identified. Depending on this information, including the relative Technical Readiness Levels (TRL), see ANNEX I. Technical readiness Level (TRL) defined by EC for description, the roadmaps assume different deployment dates.

The baseline is the current ATN-OSI-**VDLM2** infrastructure deployed in Europe in support of European Commission Regulation (EC) 29/2009 and its amendments.

Table 5 is **presenting these different technologies** identified in the Future Communication Infrastructure Business Case. The "Multilink cooperative mode" column presents their combination into a **Multilink environment** (VDL is not presented in the table but an essential part of the roadmap) which is the **target scenario for Europe**. Although OSI was not part of the SESAR FCI Multilink environment the consolidated roadmap considers a transition Multilink Environment where ATN/OSI and ATN/IPS exist in parallel. This is considered in the table. The TRLs are presenting the situation at the time of writing the document. It is recalled that the Multilink Environment over time will be composed of:

- the ATN/OSI/VDLM2 and/or ATN/IPS/VDLM2 and
- for the airborne side: at least one additional certified complementary air/ground link for the ground side: the implementation of all related technology services that are composing the Multilink including the gateway services

In the Multilink environment, the technical solutions shall support the parallel use of different links by different applications and seamless switching between links (confirmed for IPS, pending for OSI switching finetuning).It is to be noted that all FCI technologies are based on ICAO Standards And Recommended Practices (SARPS).

Criteria	LDACS	COMMERCIAL OFF-THE-SHELF ('Hyperconnected')	SATCOM NG	Multilink
Maturity Level:				
Technological Readiness Level (TRL) expected at the end of SESAR Wave 2 (i.e., end of 2022)	TRL-6 * LDACS voice TRL4	TRL2 (for overlay and security mechanisms)	TRL6 for ATN/IPS TRL9 for ATN/OSI	Based on TRL for each technology supported
Infrastructure status	ATN/IPS depends on the availability of the IP infrastructure ATN/OSI (2025) Over LDACS	Available today for AOC only	Service provided for ATN/OSI as from 2023. ATN/IPS tested in 2022 (prototype) for migration to an operational system in 2024. SATCOM Class B	Prototype
Validation status	Validation to TRL6 (ground) and TRL 6 ongoing (Avionics) at the end of Wave 2. Test flights in Wave 3 Project PJ.33 solution 2 Thread 1 . Test flights also out of SESAR in Germany project MICONAV.	Validated and available today for AOC only. New mechanisms for ATS communications validated to TRL2 at the end of Wave 2 .	Several ATN flight campaigns (NLR, Airbus, Honeywell). Next Airbus ATN test flights with 3 ANSPs in March 2022. Only for SATCOM Class B.	Validation ongoing
Service distribution status	None	Available today for AOC only.	The satellite infrastructure is already connected to the GND ATN Network infrastructure EASA certification planned Q2 2023.	None

Criteria	LDACS	COMMERCIAL OFF-THE-SHELF ('Hyperconnected')	SATCOM NG	Multilink
Early-implementation flights	Germany test flights in MICONAV project.	None for ATS In use for AOC.	Pre-commercial flights phase to start in June 2023 with 2 European airlines (EZY, ITA) and 15 participating ANSPs only for SATCOM Class B.	None
Supported Protocols	IPS & OSI/	IPS & OSI	IPS &OSI	IPS & OSI
Standard(ICAO)/Certification (ATS)	YES	Based on mature COTS standards Sol 61 overlay and security mechanisms to be standardised, planned for 2026.	YES	YES
Safety compliance required (with SESAR requirements)	YES	YES	YES	YES
Security (compliance with SESAR requirements)	YES	YES	YES	YES
Compatibility with aviation systems	ICAO standard available (applicability: 2024) EUROCAE standard (applicability 2024).	No ICAO/ EUROCAE standard yet; ARINC and COTS standards available (for AOC part).	ICAO standard available end 2024 EUROCAE ED-228A (OSI) ED-228B (IPS).	Based on each technology standard available Standard IPS available end 2024.
Potential complementing fuctions	Digital voice, complementing VHF communications, Navigation, Surveillance.	Air-ground voice, air-air data and voice.	Voice, Global IoT. Easy expansion to global service with ATN/IPS.	IP mobility architectures.

Criteria	LDACS	COMMERCIAL OFF-THE-SHELF ('Hyperconnected')	SATCOM NG	Multilink
Ease of deployment	It can be deployed at existing radio sites without risk of interference Protects current investments in infrastructure Scalable for high-density areas Distributed, avoids single point of failure. *Note: currently potential interference issues with LDACS and neighbouring frequencies in the SUR domain are discussed on ICAO level and need to be sorted out, see also recommendation R.9 in chapter 6*	Ground infrastructure and service is available for commercial services Additional standardisation and certification for ground and air systems.	Global coverage from day 1. No ground investment required for ATC service provision Service distribution already in place.	Incremental network infrastructure (gateway and airborne router), no additional radio compared with scenarios 1-3 Additional end-user training Management of link selection policies by stakeholders and regulators.

Table 5. Table of FCI technologies and Maturity levels

Technical readiness levels (TRL) of Air/Ground Links today and their assumed evolution until 2035 are depicted in the figure below shows the TRL roadmap. It is derived from Table 5 above.

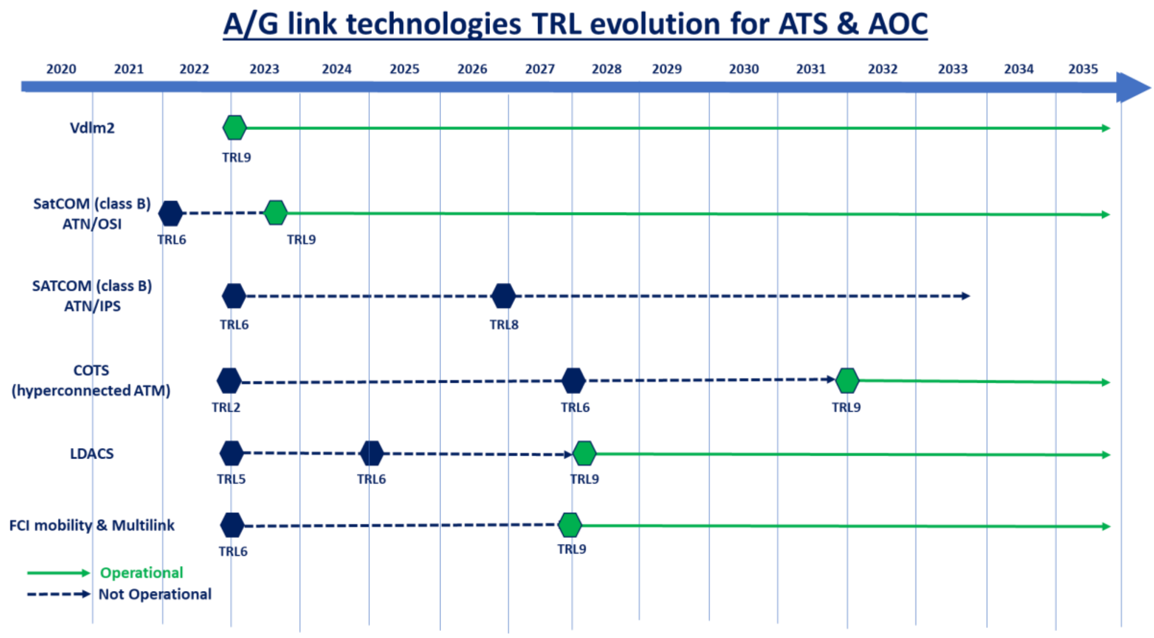


Figure 37. Evolution of technical readiness level for Air/Ground links until 2035

5.2. Scenarios that have been considered

Four scenarios (Sc) coming from the FCI Business Case and on top of the "Do nothing scenario (Baseline)" have been considered for the roadmap development, see *Table 6*:

Sc4 is the Multilink environment supporting the use of all available links (Sc1 thru Sc3). The working group identified scenario Sc4 as the preferred scenario for Europe.

Future technologies, like new generation satellite systems, not in the market today, may emerge rapidly, in a short future, and offer valuable Communication opportunities for the community. They should be considered in the scope of Multilink, although their deployment roadmap is not known at the time this document is written.

For sake of clarity of this document, they are included in the "hyperconnected ATM" solution.

Though as far as "Hyperconnected ATM" scenarios are concerned, it is considered that ground architecture is able to accommodate current systems (3G/4G, KaKu, etc.) but also any emerging technology meeting specifications.

Baseline	Do nothing option * (VDLM2 capacity crunch identified from 2027-2032), VDLM2 for both AOC + ATS (ATN/OSI) Note – AOC may be considered for partial removal from VDLM2 if alternative links are available that are suitable. *nothing on top of VDL optimization
Scenario 1	VDLM2 for both AOC + ATS (ATN) + LDACS (ATN)
Scenario 2	VDLM2 for both AOC + ATS (ATN) + COTS (Hyperconnected)
Scenario 3	VDLM2 for both AOC + ATS (ATN) + IRIS SATCOM Class B for both AOC + ATS for all European ANSPs (ATN/OSI, ATN/IPS)
Scenario 4	**Target Multilink environment for Roadmap consideration:** VDLM2 for both AOC + ATS (ATN)), Plus **Airborne:** at least one complementary link in the future, freedom of choice LDACS, Hyperconnected ATM or SATCOM (IRIS), depending on AUs operational needs for the individual aircraft, e.g SATCOM for Long Range and LDACS for Single Aisle aircraft. Ground: Accommodate VDLM2 and complementary links as necessary

Table 6. Baseline plus 4 scenarios from FCI Business Case

Table 7 depicts the assessment of the different scenarios Sc1 to Sc4 in the FCI Business case document. Cost indications have been extracted from the FCI-BC (2022).

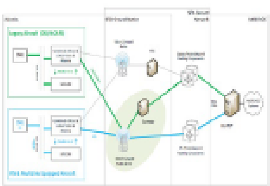
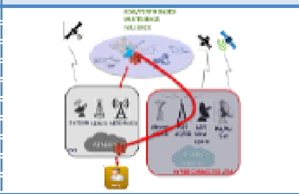
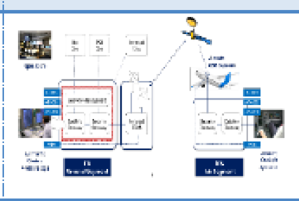
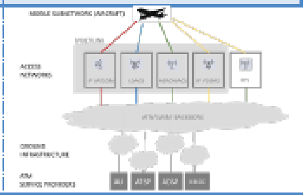
Scenario 1 LDACS	Scenario 2 OFF-THE-SHELF	Scenario 3 SATCOM NG	Scenario 4 MULTILINK/ MULTIMODE
			
Advantages: • Aviation technology • Integrated CNS • ATN/OSI and IPS • Competition	*Advantages:* • Competition, global service • Expandable to new COTS • Saving investments • Performance	*Advantages:* • Maturity: Standards and services available • + oceanic • 100% of airspace at start • Global service • Energy-efficient	*Advantages:* • Competition – evolution • Immediate start of deployment • + oceanic • Performance • Resilience
Risks: • Global endorsement • Spectrum (frequency criteria) • Avionics not yet mature	*Risks:* • Maturity • Paradigm change • Interoperability • Security	*Risks:* • Compatibility between SATCOM operators	*Risks:* • Maturity • + complexity (ground)
Maturity: Medium	*Maturity :* Low (ATC) High (AOC)	*Maturity:* High	*Maturity:* Technology-dependent
AUs CAPEX (ATC + AOC) • EUR 481 million (all new a/c by 2039) • **EUR 284 million** (59% fleet equipage by 2039)	**AUs CAPEX** (ATC + AOC) • EUR 300 million (all new a/c by 2039) • **EUR 70 million** (23% fleet equipage by 2039)	**AUs CAPEX (ATC + AOC)** • EUR 856 million (all new a/c by 2039) • **EUR 513 million** (60% fleet equipage by 2039)	**AUs CAPEX** (ATC + AOC) • EUR 769 million (all new a/c by 2039) • **EUR 422 million** (59% fleet equipage by 2039)
ANSPs OPEX (ATC only) • EUR 209 million (2025 -> 2039) • **EUR 15 million** (2039)	**ANSPs OPEX (ATC only)** • EUR 24 million (2027 -> 2039) • **EUR 8 million** (2039)	**ANSPs OPEX (ATC only)** • EUR 352 million + ? (2023 -> 2039) • **EUR 25 million + ?** (2039)	**ANSPs OPEX (ATC only)** • EUR 578 million + ? (2023 -> 2039) • **EUR 43 million + ?** (2039)

Table 7. FCI Business Case

The airline view sees the need to continue the research and development activities on the non-mature links from the FCI business case to allow complementing air/ground communication infrastructure by time. There is a strong request to support other links beyond VDL plus IRIS for various reasons.

It must be noted that the business aviation view because of their different choice of communication links sees the priority on Hyperconnected ATM in complement to VDLM2 (see scenario 2 below).

The Multilink Scenario (FCI Multilink scenario 4) was selected because it meets both requirements and is the only one allowing competition while reducing the technology risk (cf. FCI Business Case).

Further the below table lists advantages and risks identified in chapter 4.1 complementing table 7.:

Scenario	Advantages	Risks
Baseline	Supported by current avionics infrastructure	Link capacity not sufficient for future AOC and ATC applications Link performance not supporting full TBO Costly AOC offload measures needed
Scenario 1 LDACS	Supports multi provider infrastructure Mitigates risks stemming from foreign ownership	Costs for ground infrastructure high
Scenario 2 OFF THE SHELF	Some links already in use for AOC	Adaption to ATC comm at low maturity level
Scenario 3 SATCOM NG	Installation in modern Long Range equipment supports FANS applications	Risk of discontinued service based on commercial or political decisions Stakeholders won't accept the price for the SATCOM
Scenario 4 MULTILINK/MULTIMODE	Allows fitment and use of the most optimum link for the specific role of the aircraft	Stakeholders won't accept the price for the Multilink

Table 8. Identified advantages and risks on top of FCI BC

The evolution toward IPS only based Multilink environment in terms of connectivity and possible link usage is depicted in the figure below. It is visible that different links will be used in the aircraft and there is need on the ground to accommodate aircraft connectivity demands. This variation in Air/Ground links, related technologies and used data protocols over time can be seen as "Mixed Environment" which dominate operational use of Air/Ground links over years.

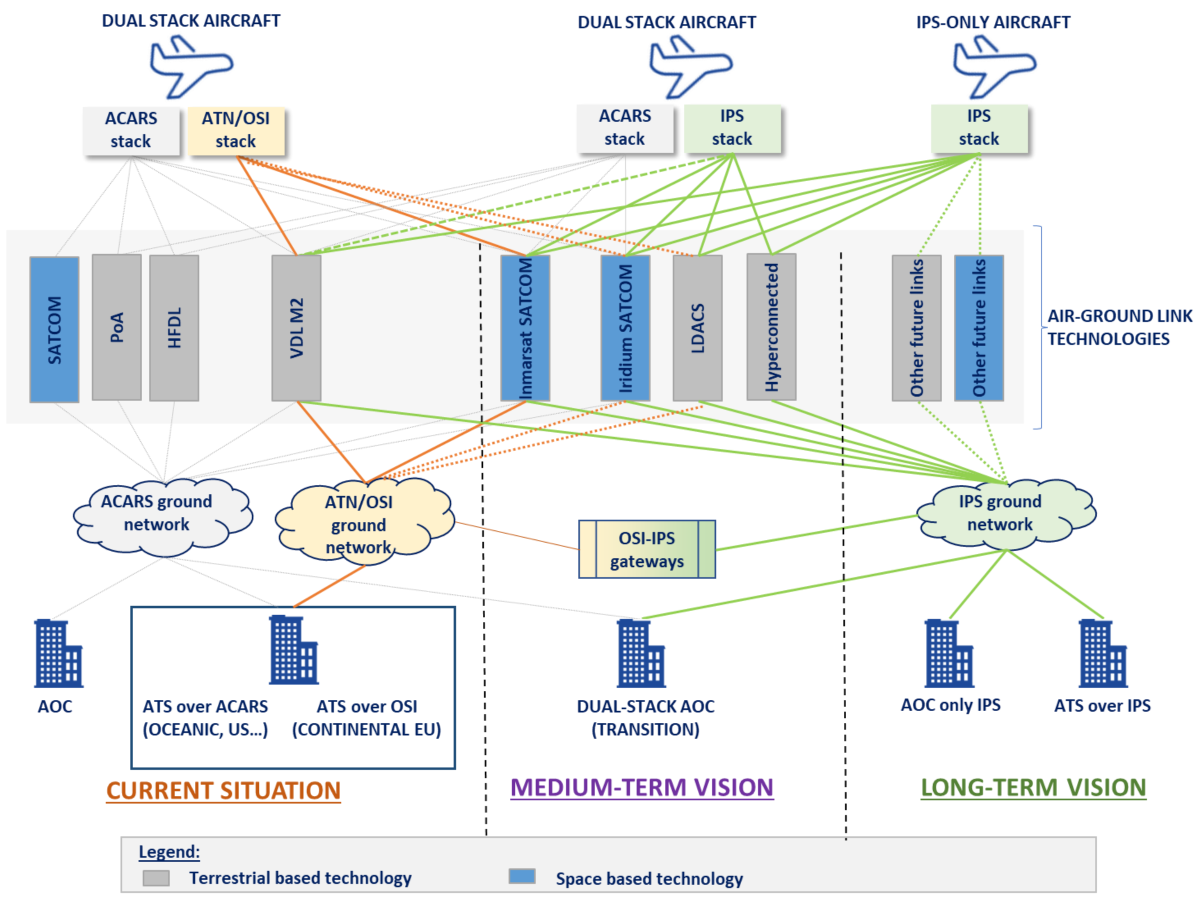


Figure 38. Mixed environment: expected Datalink evolution and transition

5.3. Assumptions for building the Roadmap

The following assumptions for creating the Multilink implementation Roadmap have been considered:

- The Airborne side is forward fit equipped with the ATN applications (CPDLC and ADS-C) and VDLM2 radio as a baseline due to the European mandates (DLS CIR (EU) 29/2009; CP1 CIR (EU) 2021/116).
- Deployment of links solely for ATS is assumed to be too costly, therefore AOC is important to consider as the data links will be shared between ATS and AOC.
- In Europe [RefDoc 01] “FCI Business Case, V18, 21 April 2022, presented at JCSP7 (May 2022) [updated by SESAR20202 PJ14 Solution 77, deliverable D5.1.500, Nov. 2022”.
- The expected VDLM2 capacity crunch in core Europe is the main cause of the need for early decisions and evolution given in the roadmaps below. The baseline Scenario, ‘do nothing and keep VDLM2 only’ is not seen as an option. Even with AOC offload campaigns VDL will not fulfil performance needs in a VDLM2 full TBO environment.

- Baseline scenario can be viable for a period depending on the geographic location of ANSPs and traffic evolution but will prevent modernisation with more automation.
- Scenario 4 is the target scenario with demand and performance driven implementation of complementary links (1 to n) together with VDLM2.The adoption of a new Air/Ground technology in support of ATC services, should be co-ordinated between ground ANSPs and airspace users'.
- The AUs will have the choice to equip the best fitting technologies for the individual aircrat from a set of 'possible' technologies[23].
- Ground Gateways will be needed for accommodation of a mixed airborne environment avoiding equipping aircraft with several technologies
- From the ground side in Europe, a possible simplification/rationalisation of the ANSPs infrastructure is the intended implementation of one common DL service (the common ADS-C Service, Logon Service, gateway services) via the ACDLS project.[24]

Costing:

The roadmap addresses solutions and decision points on operational and technical means. Actual decisions will require additional discussions and decisions on other aspects such as regulation and especially financing and incentives.

To offer the airlines the possibility to equip with different technologies to maintain competition, the ground will have to provide different services that will be sponsored by all the airspace users, hence airlines may have to pay for services that they may not use. Competition can be obtained at this price.

The recovering of the ground cost of the FCI infrastructure has been discussed and the group cannot come to an agreement.

The following positions were noted:

- ANSPs are considering that, in accordance with the current ATC charging scheme, all costs related to the ATC Communication services have to be recovered via the route charges. It means that if airline can choose the communication services, the ANSPs have to provide all the services and the

[23] A positive market expectation for avionics- and airframe-manufacturers as well as CSPs and ANSPs is a prerequisite

[24] This can simplify a proposed charging scheme for the services, but doesn't simplify the cost-benefit challenge for each ANSP user - that needs to be further discussed in the appropriate groups (e.g. DEB).

related costs shall be recovered with the current mechanism of the route charges, i.e. at present throughout all the airspace users.

- The airlines, part in the Multilink working group, support the ANSPs' position expressed in the bullet above.

- IATA considers that:

  Competition means that the customer pays for what they use, and the communication services providers compete for gaining more customers. There will not be competition if communication services providers are getting paid, regardless the number of customers actually using their services/system/technology.

  IATA interpretation is that this can become extraordinarily expensive when potential new actors, currently foreseen or not, enter the market expecting contracts with ANSPs regardless of their number of users. Such yearly income based solely on availability of a system for potential use, being transferred into the current ANS charging scheme through ANSPs, would not be truly fostering competition, nor would it incentivize customers through pricing. It would also transfer the risk of infrastructure deployment to the airlines, who will be paying for more non-self-sustainable services than they are individually receiving. Therefore, we believe that other more sustainable charging options deserve exploration, which are more consistent with the pay per use principle.

  If ANSPs are providing datalink services through procurement contracts, when the user equips with one technology and chooses an AOC provider, they are implicitly choosing a procurer. Paying for all the costs linked to all the procurements when only using one choice is not a competitive market scenario and it is not sustainable as the potential number of choices grows.

5.4. ROADMAP – Overview

The roadmap depicts:

- decision milestones required for the development or the implementation of a technology based on foreseen maturity and availability of standards and products.
- and implementation phases starting with milestones representing the earliest Initial Operational Capability of a technology.

These decisions concern specifically SATCOM NG, LDACS, Hyperconnected ATM (COTS ATS) and IPS. The COTS AOC alternative is already largely present and technologically ready, therefore no decision milestone is associated

As depicted in the roadmap, Research & Innovation is still needed for the LDACS and Hyperconnected ATM: for LDACS in relation to compatibility in the L-Band (NAV, SUR and MIL systems), for Hyperconnected ATM to develop aviation-specific components and certification material.

As it is considered very important to observe the independence of ATN/OSI & ATN/IPS development streams, a dedicated roadmap (see Figure 39. ATN/OSI & ATN/IPS technologies development Implementation Roadmap Overview) is depicting related milestones.

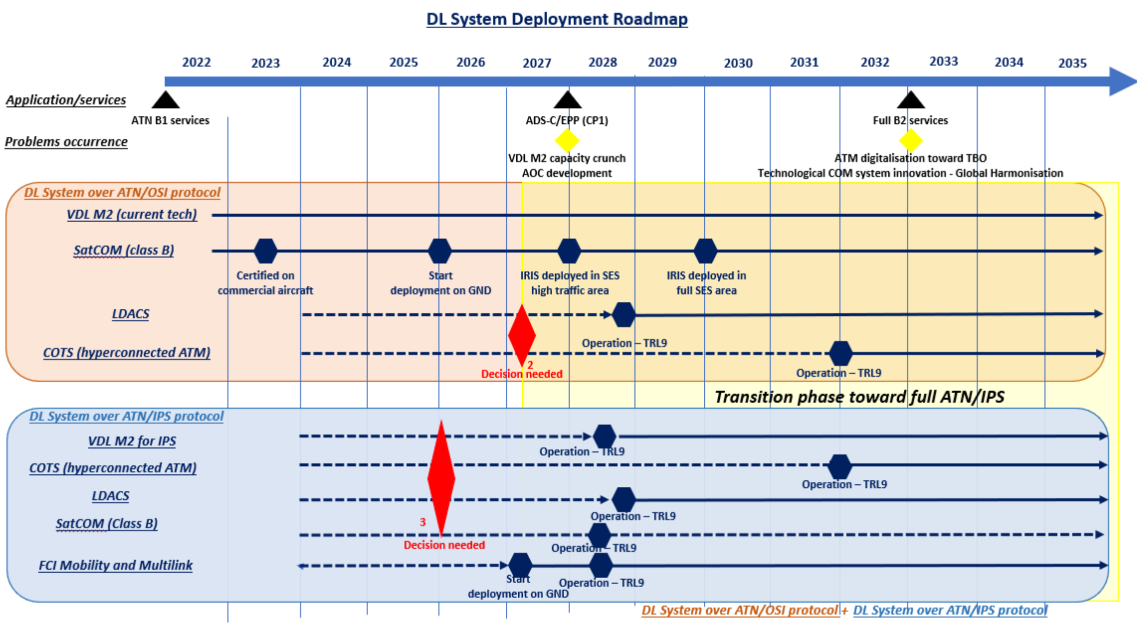


Figure 39. ATN/OSI & ATN/IPS technologies development Implementation Roadmap Overview

The roadmap shall identify decision points for deployment synchronised with reaching the right maturity (TRL6).

The integration of IPS into the communication infrastructure requires a number of prerequisites further elaborated in the ANNEX III. Integration prerequisites for IPS.

Decision criteria:

Implementing decisions for the individual link subsets of the multilink concept have to be taken at individual points in time, after a number of prerequisites have been reached and criteria are demonstrated:

- A sufficient Technical Readiness Level is reached, TRL6 is to be seen as minimum
- A positive business case for the individual link is identified
- The cost distribution & charging scheme is agreed
- Sufficient stakeholder support is identified for the individual link subset to achieve expected and required equipage rates OR Sufficient stakeholder support is identified for the desired link to be implemented
- The capability to support the envisaged services has been demonstrated for the individual link technology OR Very large Demonstrator proofed performance of services and applications

Decision Milestones have been identified reflecting the expected date for meeting the above criteria. Those milestones are depicted in the roadmaps in yellow circles for the individual technologies. Following positive decision, the estimated follow-up activities and start of operation is shown in individual lines, for the ease of reading one roadmap is shown for each view:

- Overall – with general decision
- Airborne – showing the technological evolution of airborne equipment and availability of products for airspace users
- Ground – depicting development and deployment related to ground based infrastructure

Each milestone is described in the respective milestone table and detailed planning after taking a decision is key for implementation.

For the ease of reading the roadmap is composed of three different views: **overall, airborne and ground** and includes the following lines:

1. **The application line**: providing an overview of the application that are or will be implemented within the next 15 years. The CPDLC V1 is already in operation. ATS-B2 applications (CPDLC V2, ADS-C V1) in support of initial Trajectory Based Operations (**TBO**) will be fully deployed before 2028 including EPP over OSI, and from 2030 onwards over IPS. Complex clearances should be expected from 2030/32 onwards at European level, some pioneer implementation could happen earlier

Applications are agnostic to the protocol stack (OSI or IPS). The GND and the AIR Systems need to support the same underlying protocol stack. The accommodation of both protocols, OSI and IPS, will be ensured through ground gateway functions because the individual aircraft is expected to support either OSI or IPS.

2. **The protocol OSI** line shows basically the expected lifetime of the OSI protocol

3. **The protocol IPS line** provides a view of the expected development and implementation of the IPS related solutions. A date for an earlier deployment of ground ATN/OSI-IPS Gateways still needs to be identified to accommodate ATN/IPS aircraft potentially flying in from other regions (e.g. US).

4. **VLD-2 line** shows the lifecycle and technical adaptions to the VDLM2 communication link, including opportunities for performance and cost optimisation of ground infrastructure.

5. The roadmap also includes the Datalink Service Provider (**DSP**) service[25] that should be operated from 2025 onwards in Europe, providing the communication service to most if not all the EUR ANSPs.

6. The **SATCOM Class B[26]/LDACS/Hyperconnected ATM** lines provides a view of the expected development and implementation of each corresponding technology

.

[25] Currently anticipated as the ACDLS initiative

[26] IRIS commercial service for ATN/OSI will be ready 2024. For ATN/IPS, SATCOM IRIS should be ready by 2024 (TRL6), operational services are expected by 2026 at the earliest, subject to one region to deploy ATN/IPS and FANS/IPS.

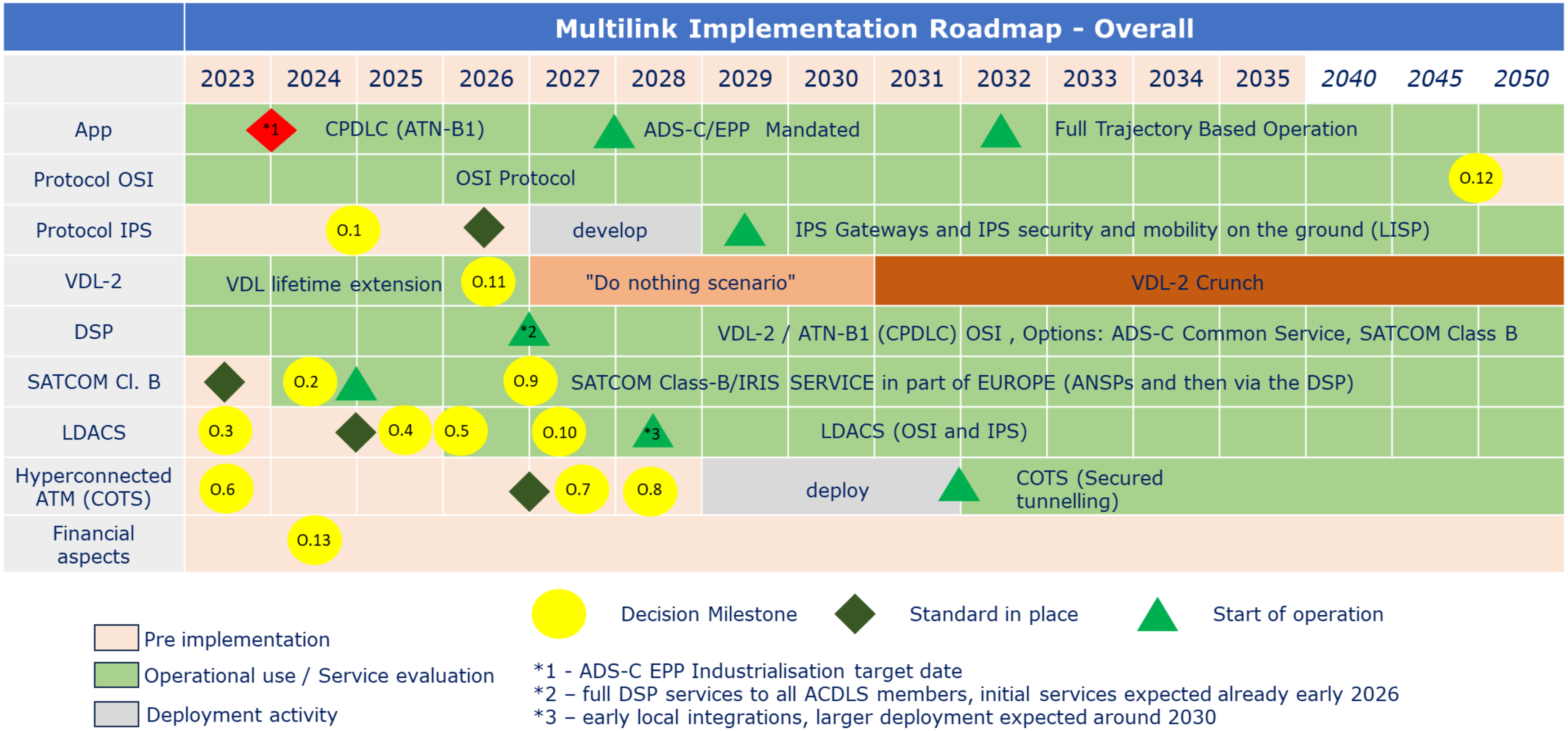


Figure 40. Multilink Implementation Roadmap Overall

Below is the table of decision milestones identified in the Overall roadmap.

ID		Overall Decision Milestones	Decision Bodies
O.1	IPS 2025: Research & Innovation decision	**Topics:** **launch activities** to enhance support for IPS System TRL8, … **Prerequisite: N.A.** **Follow up activities:** follow progress of TRL evolution **Next step:** Confirm Standards in Place ("green Diamond")	S3JU, Industries
O.2	IRIS 2024: financial and operational Incentives	**Topics:** Decide on funding & operational incentives to foster the operational use of IRIS SATCOM **Prerequisite:** standards and certification **Follow up actions:** AUs & ANSPs to create detailed implementation plan **Next step:** N.A.	EC/CINEA (for financial support)

ID		Overall Decision Milestones	Decision Bodies
O.3	LDACS 2023: Research & Innovation decision	**Topics:** launch activities to enhance support for LDACS Research & Innovation to reach TRL8, solve spectrum issues **Prerequisite:** N.A. **Follow up activities:** follow progress of TRL evolution in particular on airborne side **Next step:** Confirm Standards in Place ("green Diamond")	S3JU, Industries
O.4	LDACS 2025: Deployment decision	**Topics:** Assess LDAC deployment readiness **Prerequisites:** LDACS standards available/finalised, frequency planning agreed, VLD successfully completed **Follow Up activities:** develop Deployment Plan for GND (Radio & Connections) & Air **Next Step:** assign service operator, evaluate funding opportunities	NDTECH/Relevant Consultation Processes

ID		Overall Decision Milestones	Decision Bodies
O.5	LDACS 2025: financial and operational Incentive	**Topics:** Decide on funding & operational incentives to foster the operational use of LDACS **Prerequisite:** standards and certification **Follow up actions:** AUs & ANSPs to create detailed implementation plan implementation **Next step:** N.A.	EC/CINEA
O.6	Hyperconnected ATM(COTS) 2023: Research & Innovation decision	**Topics:** enhance support for Hyperconnected ATM activities to reach TRL8 **Prerequisite: N.A.** **Follow up activities:** follow progress of TRL evolution **Next step:** Confirm Standards in Place ("green Diamond")	S3JU, Industries

ID		Overall Decision Milestones	Decision Bodies
O.7	Hyperconnected ATM(COTS) 2027: Deployment decision	**Topics:** assess COTS (Hyperconnected ATM): deployment readiness **Prerequisites:** standards available/finalised, VLD successfully completed **Follow Up activities:** develop Deployment Programme **Next Step:** identify & publish performance guidelines, evaluate funding opportunities	NDTECH//Relevant Consultation Processes,
O.8	Hyperconnected ATM(COTS) 2027: financial and operational Incentives	**Topics:** Decide on funding & operational incentives to foster the operational use of Hyperconnected ATM **Prerequisite:** standards and certification **Follow up actions:** AUs & ANSPs to create detailed implementation plan implementation **Next step:** N.A.	EC/CINEA

ID		Overall Decision Milestones	Decision Bodies
O.9	IRIS IP 2026 Deployment decision Make Links IPS ready	**Topics:** Deployment Decision to make IRIS IPS ready **Prerequisite:** standards [and certification] **Follow up actions:** N.A **Next step:** N.A.	NDTECH//Relevant Consultation Processes
O.10	LDACS IPS 2026 Deployment decision Make Links IPS ready	**Topics:** Deployment Decision to make LDACS IPS ready **Prerequisite:** standards [and certification] **Follow up actions:** N.A **Next step:** N.A.	NDTECH//Relevant Consultation Processes
O.11	VDL IPS 2026 Deployment decision Make VDL IPS ready	**Topics:** Deployment Decision to make VDL IPS ready Note: US strategy, in Europe not yet agreed **Prerequisite:** standards [and certification], products available **Follow up actions:** N.A **Next step: N.A.**	NDTECH//Relevant Consultation Processes

Table 9. Overall Decision Milestones

ID		Overall Decision Milestones	Decision Bodies
O.12	OSI 2040 Decommissioning Decision on OSI	**Topics:** Decision on the discontinuation of the OSI protocol **Prerequisite:** Number of OSI equipped airplanes very low **Follow up actions:** N.A **Next step:** N.A.	NDTECH//Relevant Consultation Processes
O.13	Financial 2024	**Topics:** Decide on how to treat financial challenges for AUs & ANSPs linked to Multilink operation. Identified topics to be addressed: • "Elaborate Charging Scheme" and defined financial support **Rationale:** Additional communication services/providers increase provisioning charges, their distribution needs to be negotiated. **Prerequisite:** Solid ML related Business & service cost indication **Follow up actions:** Organize dedicated workgroup(s) Set deadlines **Next step:** N.A. **NOTE:** This decision milestone is derived from recommendations R.4 ; R.10	Dedicated Expert Group

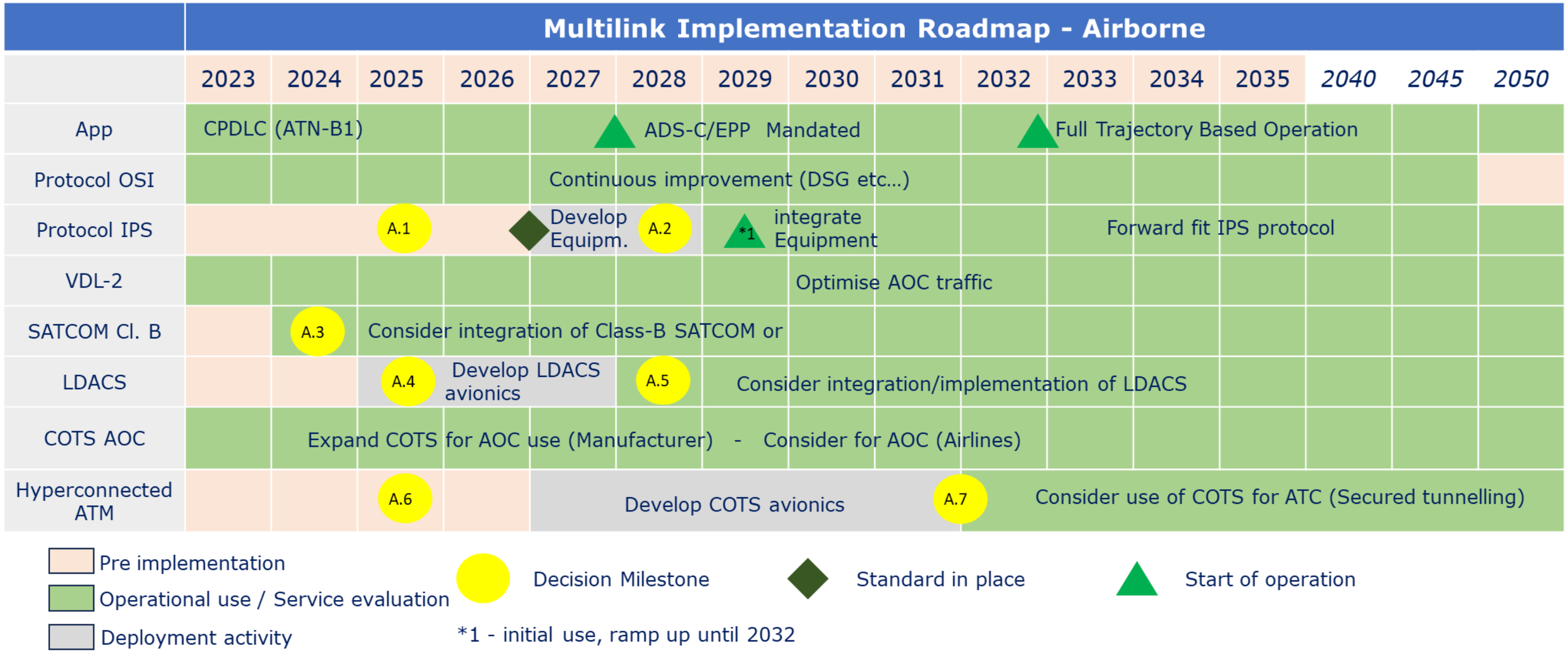


Figure 41. Airborne Implementation Roadmap

Below is the table of decision milestones in the Airborne roadmap that identify decisions and starting points for the development and the implementation phases for aircraft/avionic manufacturers and aircraft operators.

Note:

ID		Airborne Decision Milestones	Decision Bodies
A.1	IPS 2025: Industrialisation decision	**Topics:** launch product development activities **Prerequisite:** standards published, commitment from Infrastructure providers and CSPs. **Follow up activities:** entry into service **Next step:** incremental enhancements	Manufacturing Industry
A.2	IPS 2028+ fitment decisions within timeframe starting at 2028	**Topics:** decide on IPS avionics fitment if ready for operational use y/n for individual sub-fleet **Prerequisite:** Products are available, Ground is ready **Follow up actions:** n/a **Next step:** n/a	Individual airspace users

ID		Airborne Decision Milestones	Decision Bodies
A.3	IRIS 2024+ fitment decisions within timeframe starting at 2024	**Topics:** decide on IRIS SATCOM solution if ready for operational use y/n for individual sub-fleet **Prerequisite:** standards in place (completed), certification **Follow up actions:** Contract AOC **Next step:** evaluate funding opportunities, start implementation according to plan, coordinate with DSP	Individual airspace users
A.4	LDACS 2025: Industrialisation decision	**Topics:** deployment LDACS avionics as a product **Prerequisites:** LDACS standards available/finalised, Spectrum assigned, VLD successfully completed **Follow Up activities:** develop Deployment Plan for Airborne system with AUs **Next Step:** evaluate funding opportunities	Manufacturing Industry

ID		Airborne Decision Milestones	Decision Bodies
A.5	LDACS 2028+ fitment decisions within timeframe starting at 2028	Individual airline: implementation decision for individual sub-fleet **Topics:** select & implement LDACS avionics as a product **Prerequisites:** forward fit/retrofit option available, need to have GND Systems deployed **Follow Up activities:** integrate into airline communication infrastructure **Next Step:** evaluate funding opportunities	Individual Airspace Users
A.6	Hyperconnected ATM(COTS)2025: Industrialisation decision	**Topics:** Development COTS capable ATS avionics as a product **Prerequisite:** standards in stable draft **Follow up activities:** develop Deployment Plan for Airborne system with AUs **Next step:** evaluate funding opportunities	Manufacturing Industry

ID		Airborne Decision Milestones	Decision Bodies
A.7	Hyperconnected ATM[27](COTS)2032+ fitment decisions within timeframe starting 2032	Individual airline: implementation G/NG decision, for individual sub-fleet **Topics:** select & implement Hyperconnected ATM supporting avionics as a product **Prerequisite:** Specification and products available **Follow up activities:** N.A. **Next step:** TBD	Individual Airspace Users

Table 10. Airborne Decision Milestones

[27] Concerning Hyperconnected/COTS for AOC, there is no milestone as it is already In use and continuously expanded

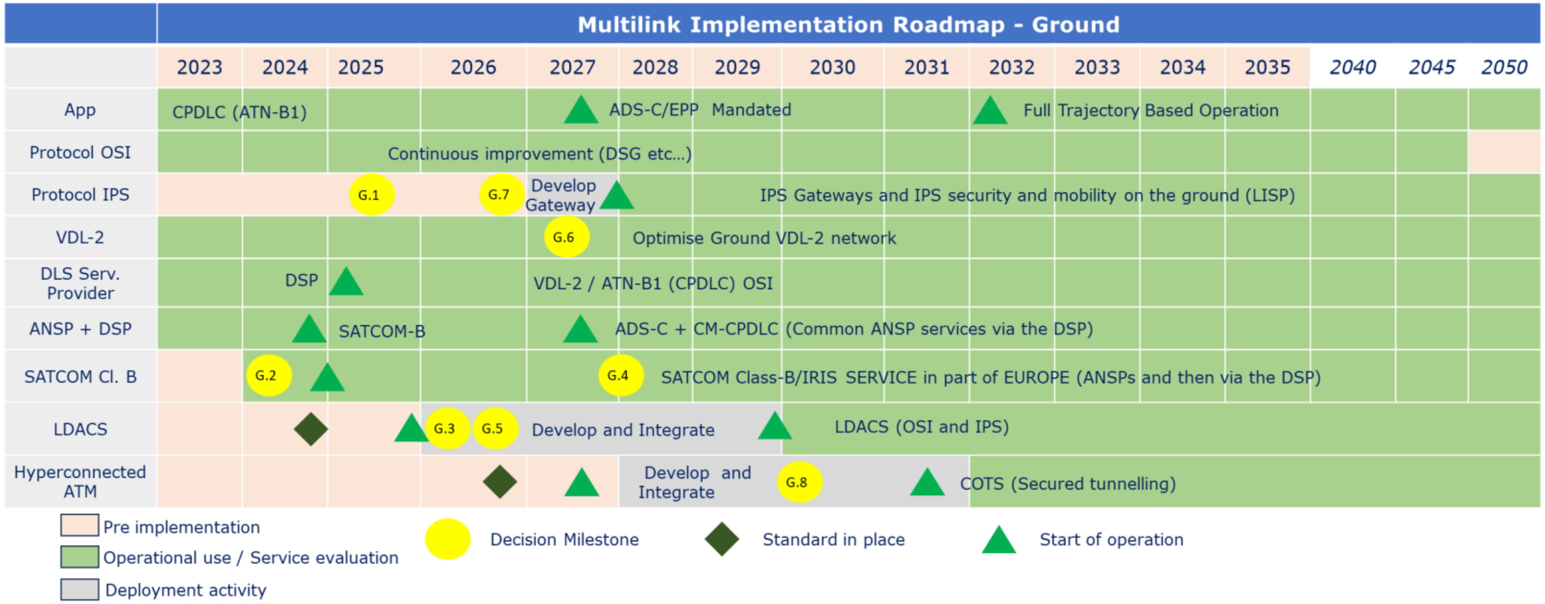


Figure 42. Ground Implementation Roadmap

Below is the table of decision milestones in the Ground roadmap that identify decisions and starting points for the development and the implementation phases for ANSPs / ACDLS, CSPs and ground equipment manufacturers.

ID		Ground Decision Milestones	Decision Bodies
G.1	IPS 2025: Industrialisation decision	**Topics:** launch product development activities **Prerequisite:** IPS capable Air/Ground access network prototype/demonstrator available, standards published, commitment from Infrastructure providers and CSPs. **Follow up activities:** entry into service **Next step:** incremental enhancements	Manufacturing Industries, CSPs and operators of ground network
G.2	IRIS 2024: Deployment decision	**Topics:** implementation plan for ground deployment; decide on IRIS SATCOM solution if ready for operational use y/n. **Prerequisite:** standards in place (completed), certification, … **Follow up actions:** create plan for implementation on Air & GND **Next step:** evaluate funding opportunities, start implementation according to plan, coordinate with DSP ….	Individual ANSPS ACDLS

ID		Airborne Decision Milestones	Decision Bodies
G.3	LDACS 2026: CSP deploy LDACS GND infrastructure:	**Topics:** implementation plan for ground deployment; based on operational needs (e.g. start from core area) **Prerequisite:** standards in place (completed), certification, … **Follow up actions:** Evaluate expansion of coverage **Next step:** N.A.	CSPs
G.4	IRIS 2028: Make GND IPS ready	**Topics:** Implement changes to make IRIS IPS ready **Prerequisite:** standards [and certification] **Follow up actions:** N.A **Next step:** N.A.	CSP Manufacturing Industries
G.5	LDACS 2026: Enable GND IPS	**Topics:** Enhance LDACS ground Infrastructure to make it IPS ready **Prerequisite:** standards [and certification] **Follow up actions:** N.A **Next step:** N.A.	CSPs Manufacturing Industries

ID		Airborne Decision Milestones	Decision Bodies
G.6	VDLM2 2027: Make GND IPS ready	**Topics:** Implement changes to make VDLM2 ground infrastructure IPS ready **Prerequisite:** Agreement on operational use between AUs & ANSPs standards and certification **Follow up actions:** N.A **Next step:** N.A.	CSPs Manufacturing Industries
G.7	IPS 2027: Deploy GND ATN/OSI Gateways	**Topics:** Implement GND ATN/OSI Gateways to accommodate IPS capable aircraft **Prerequisite:** Standards, Products available **Follow up actions:** N.A **Next step:** N.A.	ACDLS ANSPs
G.8	Hyperconnected ATM 2030: Deploy GND COTS connectivity	**Topics:** Implement ATM connectivity to COTS service providers on ground **Prerequisite:** standards and certification, VLD successfully completed **Follow up actions:** service monitoring and improvement **Next step:** N.A.	ACDLS ANSPs

Table 11. Ground Decision& Deployment Milestones

6. Final Recommendations & Way Forward

This chapter provides a summary of recommendations identified while creating this Multilink Implementation Roadmap. It must be noted that this list is not exhaustive as numerous related activities (like Research & Innovation, Standardisation, etc.) are still ongoing and evolution maturity level is rather quick.

The Table of identified Recommendations is below.

ID	Recommendations for Multilink Implementation	Addresses
R.1	Confirm that the FCI ATN/IPS mobility and multilink solution is the preferred solution and shall be deployed in Europe.	NDTECH//Relevant Consultation Processes ACDLS
R.2	Confirm that complementary links should be contracted and integrated through ACDLS	NDTECH//Relevant Consultation Processes ACDLS

ID	Recommendations for Multilink Implementation	Addresses
R.3	Setup the appropriate mechanism and forum to update and agree on the Multilink roadmap implementation strategy involving all relevant stakeholders: • To confirm and support that the chosen IPS Multilink scenario is the selected path for Europe • Liaise with appropriate ICAO working groups to make sure that the result of this work receives the buy-in from impacted stakeholders • Liaise with EUROCAE/RTCA, ETSI and any other relevant Standards Development Organizations (SDOs) to pave the way for a future standardization process • Ensure that LDACS & COTS are endorsed globally by ICAO • Coordinate with other ICAO regions on worldwide harmonised deployment (Note: in developing that strategy, a balance should be found between mandates for regulation and freedom of choice in a market driven environment. Any new DLS regulation should be based on a performance-based approach, allowing competition while ensuring the required Quality of Service)	S3JU ECTRL SDM CNS Programme manager
R.4	Urgent need for clarification where the business rules and logic for the implementation of Multilink will be discussed and agreed. This requires identifying appropriate bodies or the creation of a dedicated task force. (The benefit arguments need to be built up and agreed with all stakeholder, mainly the airlines and the ANSPs. Need for clarification about cost distribution and charging scheme refinement).	Designated Bodies/Task force

ID	Recommendations for Multilink Implementation	Addresses
R.5	Ensure that there shall always be interoperability with VDLM2 air/ground link, which is the baseline air/ground technology mandated in the current Datalink Regulation, i.e. (EC) 29/2009, as long as operational performance requirements are given.	ANSPs AUs Other potential impacted stakeholders
R.6	In the Multilink environment, seamless switching between links for aircraft with multiple links should be available. It should be ensured the parallel use of the different A/G technologies shall always be possible.	ANSPs AUs Other potential impacted stakeholders
R.7	There shall be no obligation to deploy, procure or contract, either on the ground or onboard for the aircraft, any specific complementary A/G technology or service that is considered part of the Multilink technologies, e.g., Satcom, LDACS or COTS/Hyperconnected ATM provided interoperability between air traffic services units and aircraft is maintained.	ANSPs ACDLS SDM EASA
R.8	The identified (CNS) Programme Manager shall organize the implementation of the European Multilink infrastructure considering the Multilink Implementation and Air/Ground Application (ADS-C/EPP) Roadmap 2023.	CNS Programme Manager
R.9	Complete the Research & Innovation process for LDACS & Hyperconnected ATM to bring the maturity up to TRL8 (LDACS 2027; Hyperconnected ATM 2031) and address the currently discussed potential LDACS interference issues with neighboring frequency bands e.g., the SUR domain.	S3JU

ID	Recommendations for Multilink Implementation	Addresses
R.10	Elaborate operational and financial incentives packages to foster discussion & conclusion at decision milestones Identified activities Setup CEF initiatives for Research & Innovation, Multilink deployment Setup OPS stakeholder expert group to submit “OPS incentive catalogue) Provide financial Support for deployment activities of Multilink and VDL Life Time extension e.g. via EC/CINEA funds as soon as technology is ready and agreed for deployment	EC ANSP AUs
R.11	Asses existing Charging Scheme(s) and adapt it to the Multilink requirement and organize the Transition from single link to Multilink Charging scheme	EC/RP4
R.12	Launch VDLM2 capacity crunch mitigation activities as soon as possible due to late availability of complementing links support - VDLM2. Accelerate deployment of new VDLM2 frequencies Promote optimization of AOC traffic over VDLM2, and offload options as a separate working thread outside the scope of the multilink roadmap.	AUs ANSPs Manufacturing Industry CSPs, DSP SDM
R.13	Assess the results of the IRIS precommercial flights for potential weaknesses of the current ATN/OSI dual link installation and implement technical adaptions.	Manufacturing Industry CSPs

ID	Recommendations for Multilink Implementation	Addresses
R.14	Setup, as soon as possible, the appropriate framework to tackle Multilink implementation challenges (note: ATN/OSI VDL / SATCOM dual-link deployment has already been initiated in 2023). And identify clear owner for the concept to maintain it	S3JU Identified (CNS) Programme Manager
R.15	Follow the timeline of Milestones as provided in Chapter5 with priorities on short term measures	
R.16	Consider IATA request to review the communication charging scheme and report to the appropriate governance.	IATA EC
R.17	Encourage the ACDLS DLS Executive Board (DEB) to include in the Datalink Service Provider (DSP) contract, at least an option for the procurement of IPS/OSI gateway services from 2030 onwards.	DEB

Table 12. Recommendation for Multilink Implementation

ID	Complementing recommendations identified	Addresses
CR.1	Reinforce the DPMG /DSG Rationale: As it is important to have European View on DLS performance And Foster VDLM2 traffic evolution follow-up through DPMG	ANSPs ECTRL AUs
CR.2	Encourage more ANSPs to join ACDLS to harmonize DLS deployment in Europe	ASNPs ECTRL CANSO SDM
CR.3	C2 link needs to be addressed in the midterm future Rationale: Not covered in ML implementation roadmap so far	NDTECH//Relevant Consultation Processes
CR.4	Endorsing common ADS-C and CM_logon Service Rationale: To optimize related Ground/Ground network and Air/Ground link load. Ease the implementation of ADS-C/EPP (ATS-B2) on airborne side.	NDTECH/Relevant Consultation Processes ACDLS DEB
CR.5	Elaborate on the need for regulatory measures to foster IPS deployment	EC EASA ECTRL
CR.6	accelerate Research & Innovation process for LDACS & Hyperconnected ATM to reach TRL9 maturity level,	EC/S3JU

ID	Complementing recommendations identified	Addresses
CR.7	Maintain a monitoring view of the progress of the recommendations and decision milestones addressed in this Multilink Roadmap document and provides regular updates[28].	SDM/S3JU/NM/Relevant Stakeholders
CR.8	Continue to steer the activities that would lead to stabilize the roadmap and foster the actual implementation of the European multilink environment[29]	NDTECH

Table 13. Complementing recommendations identified

[28] Recommendation agreed at NDTECH#10 on 13 June 2023 during step 2 of SDM Stakeholders Consultation Process

[29] Idem as [28]

7. Reference documentation

[01] FCI Business Case, V18, 21 April 2022, presented at JCSP7 (May 2022) [updated by SESAR20202 PJ14 Solution 77, deliverable D5.1.500, Nov. 2022

[02] D11.1.1_Report on DLS Architecture and Deployment Strategy after SCP and CA comments_v1.0

[03] D1.1 – CONOPS for Multilink Operation Version 1.2, 02 February 2022

[04] FUTURE CONNECTIVITY FOR AVIATION EU/US task force White Paper - Dated 09/11/2022, Issue 1

[05] Network and Information System (NIS) Directive (EU) 2022/2555 (known as NIS2)

[06] Doc 10045 IPS Security Risk Assessment (SRA)

[07] Doc 10095 Manual of Public Key Infrastructure (PKI) Policy for Aeronautical Communication

[08] Doc. 10090 Manual of Security Services for Aeronautical Communications

8. Acronyms

	Acronym	Description
A		
	A6	A6 Alliance (ANSP members of S3JU)
	A4E	Airlines for Europe
	AATF	Avionics Architecture Task Force
	AC	Aircraft
	ACARS	Airline Communications and Reporting System (Air Ground VHF Data Link legacy protocol)
	ACC	Area Control Centre
	ACD	Aircraft Control Domain
	ACL	ATC Clearance Message
	ACM	ATC Communication Management Service Message
	ADS	Automatic Dependent Surveillance
	ADS-C	Aircraft Dependent Surveillance - Contract
	ADS-C/EPP	Aircraft Dependent Surveillance – Contract Extended Projected Profile
	AEEC	Airlines Electronic Engineering Committee
	AERO H	Inmarsat Legacy SATCOM system
	AES	Airborne Earth Station
	AeroMACS	Aeronautical Mobile Airport Communication System (AeroMACS)
	AF6	ATM Functionality No.6
	AGCS	Air/Ground Communication System
	AGR	ATN Air-Ground Router
	AGMI	Air Ground Mobility Interface
	AID	Aircraft Interface Devices
	AIP	Aeronautical Information Publication
	AIRCOM®	SITA for Aircraft Communication Service
	AIS	Aeronautical Information Services
	AIS/MET	Aeronautical Information Services/Meteorological services for air navigation
	AMACS	AeroMACS Requirement
	AMC	ATC Microphone Check Service (CPDLC)
	AMDAR	Aircraft Meteorological Data Relay
	AMS(R)S	Aeronautical Mobile Satellite (Radio) Services
	ANS	Air Navigation Service
	ANS CR	Air Navigation Services of the Czech Republic
	ANSP	Air Navigation Service Provider
	AOA	ACARS over AVLC (ACARS over VDL Mode2)
	AOC	Airline Operating Communication
	AoIP	ACARS over IP

Acronym	Description
APC	Airline Passenger Communication
APNT	Alternative Positioning Navigation and Timing
ARINC	Aircraft Radio Incorporated
ASBU	Aviation System Block Upgrades
ASP	ATM Service Provider
ATC	Air Traffic Control
ATC/AOC	Air Traffic Control /Airline Operating Communication
ATSP	Air Traffic Service Provider
ATIS	Automated Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATN-B1	ATN-Baseline 1
ATN/IPS	Aeronautical Telecommunications Network Internet Protocol Suite
ATN/OSI	Aeronautical Telecommunications Network Open Systems Interconnection
ATS	Air Traffic Service
ATS/AIS	Air Traffic Service / Aeronautical Information Services
ATS-B2	Air Traffic Service Baseline 2
ATSU	Air Traffic Services Unit
AU	Airspace User
AVLC	Advanced VHF Link Communication (VDL Mode 2)
A/G	Air Ground
B	
BC	Business Case
C	
CAPEX	Capital Expenditure
CARATS	Collaborative Actions for Renovation of Air Traffic Systems
CBA	Cost Benefit Analysis
CDM	Collaborative Decision Making
CEAB	Common European ATN Backbone
CEF	Connecting Europe Facility (EU funding instrument)
CLNP	Connection Less Network Protocol
CM	Communication Management
CNS	Communication Navigation Surveillance
CLNP	(ATN) ConnectionLess Network Protocol
COM	Communications
CONOPS	CONcept Of OPerationS
CoS	Class of Service
COTS	Commercial Off The Shelf

Acronym	Description
CP	Communications Panel
CP1	Common Project No.1
CPDLC	Controller Pilot Data Link Communications
CPDLC v2/v3	Controller Pilot Data Link Communications mode2/mode3
CRD	Clearance Request and Delivery
CSB/CLR	(Airbus) Configuration Single aisle Body / Configuration Long Range
CSC	Common Signaling Channel
CSP	Communication Service Provider
D	
DCL	Departure Clearance
DFS	Deutsche Flugsicherung GmbH (ANSP Germany)
DLS	Data Link Service
DLFEP	Data Link FrontEnd Processor
DLIC	Data Link Initiation Capability
DLS	Data Link Services
DPMG	(Eurocontrol-)DLS Performance Monitoring Group
DSG	Data Link Support Group
DSNA	Direction des Services de la Navigation Aérienne (ANSP France)
DSP	Data Link Service Provider
E	
EASA	European Aviation Safety Agency
EBAA	European Business Aviation Association
ECAC	European Civil Aviation Conference
EEC	Eurocontrol Experimental Centre (Bretigny)
EFB	Electronics Flight Bags
eFPL	Extended Flight Plan
ENAIRE	ANSP Spain
ENAV	Ente Nazionale di Assistenza al Volo (ANSP Italy)
ENR	En route
EPP	Extended Projected Profile
ESSP	European Satellite Services Provider
ETA	Estimated Time of Arrival
ETOPS	Extended Range Twin Engined Operations
ETSI	European Telecommunications Standards Institute
ETSO	European Technical Standard Order
EU	European Union
EUROCAE	European Organization for Civil Aviation Electronics (standardization organization for aviation electronics)

	Acronym	Description
	EUROCONTROL	European Organization for the Safety of Air Navigation
F		
	FAA	Federal Aviation Association
	FAB	Functional Airspace Block
	FABEC	FAB Europe Central - Belgium, France, Germany, Luxembourg, Netherlands, Switzerland (including Eurocontrol UAC Maastricht)
	FANS	Future Air Navigation System
	FCI	Future Communication Infrastructure
	FCI-BC	Future Communication Infrastructure Business Case
	FF-ICE	Flight & Flow Information for a Collaborative Environment
	FMS	Flight Management Systems
	FOC	Flight Operations Control
	FPL	Filed Flight PLan
G		
	GEO	Geostationary Orbit
	GB-LISP	Ground Based List Processing
	G/G	Ground-Ground
	GANP	Global Air Navigation Plan
	GW	
H		
	HALO	High Altitude, Low Opening
I		
	IATA	International Air Transport Association
	ICAO	International Civil Aviation Organization
	ICAO FMG	International Civil Aviation Organization Flow Management Group
	IDRP	(ATN) Inter Domain Routing Protocol
	IER	Information Exchange and Reporting
	IN OPS	?
	IOC	Initial Operational Capability
	IPv4	Internet Protocol Version 4
	IPv6	Internet Protocol Version 6
	ISP	Iris Service Provider
	ITU	International Telecommunication Union
	IWA	Iris Working Agreement
K		
	KPI	Key Performance Indicator
L		
	LDACS	L-Band Digital Aeronautical Communication System

Acronym	Description
LEO	Low Earth Orbit
LISP	List Processing
LRU	Lowest Replacable Uni
LTE	Line Terminating Equipment
M	
M2	(VDL) Mode 2
MATS	Malta Air Traffic Services
METAR	Metereological Aerodrome or Aeronautical Report
MHz	Megahertz
MMPs	Meet Me Points
M&ML	Mobility and Multi Link
N	
NAT	Network Address Translation or North Atlantic Airspace
NAT HLA	Network Address Translation or North Atlantic Airspace High level Airspace
NATS	National Air Traffic Services (ANSP UK)
NDOP	Network Directors of operations
NDTECH	Network Directors of operations & technology
NM	Network Manager
O	
OOOI	Out Off On In
OPEX	Operational Expenditure
OPS	Operation/Operations
P	
PBCS	Performance Based Communication and Surveillance
PIAC	Peak Instantaneous Aircraft Count
POA	Plain Old ACARS (legacy VHF Datalink / VDL Mode 0)
Q	
QoS	Quality of Service
R	
RCP	Required Communication Performance
RCTP	Required Communication Technical Performance
REQ	Requirement
RFC	Request for Comment
ROMATSA	Romanian Air Traffic Services Administration (ANSP Romania)
RR	Receive Ready
RSTP	Required Surveillance Technical Performance
RTCA	Radio Technical Commission for Aeronautics (North American equivalent to *EUROCAE*)

	Acronym	Description
S		
	SARPS	(ICAO) Standards and Recommended Practices
	SATCOM	Satellite Communications
	SBB	Swift BroadBand
	SB-S	Swift Broadband-Safety
	SDD	Service Definition Document
	SDM	SESAR Deployment Manager
	SES	Single European Sky
	SESAR	Single European Sky ATM Research
	SIGMET	Significant Meteorological Information
	SITA	Société Internationale de Télécommunications Aéronautiques
	SLA	Service Level Agreement
	SPR	Safety and Performance Requirements
	SQP	Signal Quality Parameter
	Super VGS	VHF Ground Stations
	S3JU	SESAR3 Joint Undertaking
T		
	TAF	Terminal Area Forecast
	TBD	To Be Decided / Determined
	TBO	Trajectory Based Operations
	TCP	Transmission Control Protocol (IP)
	TMA	Terminal Maneuvering Area
	TOBT	Target Off-Block Time
	TRL	Technology Readiness Level
	TS/IRS	Technical Specifications/Interface Requirements Specifications
	TSO	Technical Standards Order
	TWR	Tower
P		
	PDC	Private Data Channel
	PKI	Public Key Infrastructure
U		
	UA	Unnumbered Acknowledgement
	UAS	Unmanned Aircraft System
	UL	UpLink
	UM	(ATN) User Message
	UTM	Unified Traffic Management
V		
	VDL	Very-High Frequency Data Link

	Acronym	Description
	VDLM2	VHF Data Link Mode 2
	VDR	Validation Data Repository
	VGS	VDL Ground Station
	VHF	Very High Frequency
	VPN	Virtual Private Network
W		
	WP	Work Package
X		
Y		
Z		

9. Table of participants

List of Participants
ACDLS
Air France
Airbus
Airtel ATN
Boeing
Bombardier
Collins
DFS
DSNA
DSNA/ACDLS Chair
EASA
easy jet
EBAA Consortium
EDA /MIL
Embraer
ENAIRE
ENAV
ESA
ESA
ESSP
EUROCONTROL
EUROCONTROL/MUAC
Frequentis
Honeywell
IATA
Indra
Inmarsat
JURG
Latvia/LGS
MATS
NATS
ROMATSA
S3JU
SDM
SITA
Thales (Avionics)

Table 14. Table of participants

10. ANNEX I. Technical readiness Level (TRL) defined by EC

Technology Readiness Levels (TRLs) are used in EC's Horizon Europe programmes as a measurement of the maturity level of particular technologies. This measurement system was introduced in Horizon2020 and provides a common understanding of technology status and addresses the entire innovation chain. The TRLs are defined as follows:

TRL 1 – basic principles observed

TRL 2 – technology concept formulated

TRL 3 – experimental proof of concept

TRL 4 – technology validated in lab

TRL 5 – technology validated in relevant environment

TRL 6 – technology demonstrated in relevant environment

TRL 7 – system prototype demonstration in operational environment

TRL 8 – system complete and qualified

TRL 9 – actual system proven in operational environment

11. ANNEX II. Conclusions from the FCI Business Case document

On the basis of the outcome of previous agreement (see ANC 2011) on the Future Communication Infrastructure and the discussions which took place with the stakeholders during the development of this business case, a certain number of common agreements can be reached:

The FCI will be used to support both AOC and ATC services in order to limit the amount of equipment that is required on board the aircraft, AOC communication constituting the major part of communication costs and bandwidth usage and ATC communication being more demanding with regard to safety and availability.

The Future Communication Infrastructure cannot be based on one technology only in order to mitigate the risk of global failure and maintain competition.

The FCI will be based on a global deployment and will avoid a regional solution/service.

The new technologies will support the ATN/IPS protocol identified as the only communication protocol that will remain in the future.

In the case of Multilink deployment, gateways and protocol conversion will be performed on the ground to avoid multiple stacks on board the aircraft. The infrastructure will be based on the hypothesis that a maximum of two stacks (dual stack) should be required on board the aircraft to support both AOC and ATC communications.

On the basis of the costs presented in chapter 9, the qualitative assessment of the various scenarios, and the requirements of both ANSPs and airspace users, the following can be concluded:

A decision on the Future Communication Infrastructure needs to be taken in 2022/2023 as the older technologies (VDLM2) cannot meet future ATC and AOC requirements. The FCI is identified as a main enabler to support ATM automation, and thereby reduce capacity congestion and related delays, the cost of which is estimated at between EUR 1 and 1.3 billion per year (based on 2019 traffic figures). Consequently, with an increase in operating costs that is below EUR 70 million per year (0.7% of the route charges), significant improvements in capacity can be anticipated. These improvements are dependent on the new ATC applications (ATN-B1/ATS-B2) that will be deployed, hence they are difficult to estimate. However, without an efficient data communication infrastructure, no improvements can be expected.

The four scenarios have different implementation costs, advantages and risks, which are summarised in the following table:

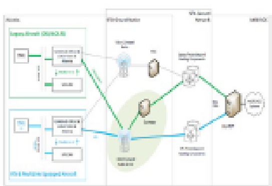
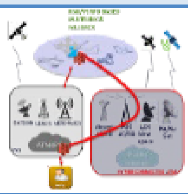
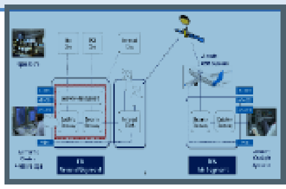
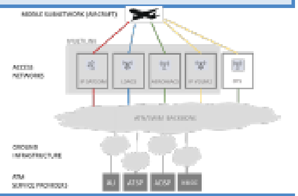
Scenario 1 LDACS	Scenario 2 OFF-THE-SHELF	Scenario 3 SATCOM NG	Scenario 4 MULTILINK/ MULTIMODE
			
Advantages: • Aviation technology • Integrated CNS • ATN/OSI and IPS • Competition	*Advantages:* • Competition, global service • Expandable to new COTS • Saving investments • Performance	*Advantages:* • Maturity: Standards and services available • + oceanic • 100% of airspace at start • Global service • Energy-efficient	*Advantages:* • Competition – evolution • Immediate start of deployment • + oceanic • Performance • Resilience
Risks: • Global endorsement • Spectrum (frequency criteria) • Avionics not yet mature	*Risks:* • Maturity • Paradigm change • Interoperability • Security	*Risks:* • Compatibility between SATCOM operators	*Risks:* • Maturity • + complexity (ground)
Maturity: Medium	*Maturity :* Low (ATC) High (AOC)	*Maturity:* High	*Maturity:* Technology-dependent
AUs CAPEX (ATC + AOC) • EUR 481 million (all new a/c by 2039) • **EUR 284 million** (59% fleet equipage by 2039)	AUs CAPEX (ATC + AOC) • EUR 300 million (all new a/c by 2039) • **EUR 70 million** (23% fleet equipage by 2039)	AUs CAPEX (ATC + AOC) • EUR 856 million (all new a/c by 2039) • **EUR 513 million** (60% fleet equipage by 2039)	AUs CAPEX (ATC + AOC) • EUR 769 million (all new a/c by 2039) • **EUR 422 million** (59% fleet equipage by 2039)
ANSPs OPEX (ATC only) • EUR 209 million (2025 -> 2039) • **EUR 15 million** (2039)	ANSPs OPEX (ATC only) • EUR 24 million (2027 -> 2039) • **EUR 8 million** (2039)	ANSPs OPEX (ATC only) • EUR 352 million + ? (2023 -> 2039) • **EUR 25 million + ?** (2039)	ANSPs OPEX (ATC only) • EUR 578 million + ? (2023 -> 2039) • **EUR 43 million + ?** (2039)

Table 15. FCI Business Case

Note: The question mark in scenario 3 means that we considered in this business case only one SATCOM NG service provider whereas at least two should normally be required.

Considering the results of the qualitative assessment, namely:

the need to avoid any monopolistic situation while having a maximum of two protocols on board aircraft (i.e., FANS/ATN/OSI or FANS/ATN/IPS);

the need to limit the number of different communication services on the ground to maintain interoperability while maintaining reasonable service costs;

the need to consider only global technologies;

the need to offload as soon as possible the VDLM2 with the AOC services that could be pushed to off-the-shelf technologies.

Considering the costs of the different scenarios compared with the gains which can be achieved through the deployment of the different technologies, it is concluded that Multilink/MULTIMODE is the scenario which reduces the overall technical risk whilst maintaining the competition for the Air/Ground services, for both ATC and AOC. Indeed, the Multilink/MULTIMODE scenario:

offers the benefits of all the scenarios (ramp-up, performance, etc.) whilst slightly increasing the overall costs, mainly for the ANSPs;

provides the appropriate resilience in order to maintain a high level of availability whilst avoiding single points of failure;

keeps the door opened for modernisation by offering the possibility to quickly implement new technologies that could potentially be less expensive;

allows for gradual implementation based on the maturity of the technologies and services, helping to reduce the load on the current VDLM2 infrastructure for both AOC and ATC services;

provides flexibility for airspace users to choose the technology they believe is the closest to their needs;

allows the various technologies with high and medium maturity levels for a timely deployment whilst mitigating the VDLM2 issues;

is compatible with a global approach where airspace users will not be mandated a specific technology but rather a performance target.

It is therefore proposed to initiate FCI implementation by taking the following steps:

Regroup under the Datalink Service Provider (DSP) services the management of the overall data communication infrastructure, i.e., establishing one contract on behalf of a large number of European ANSPs (if not all) for the procurement of the ATC services, the AOC services being provided by the CSPs.

Gradually implement the new agreed technologies whilst ensuring the interoperability via ground gateways.

The FCI-BC therefore concludes that:

Now is the time to implement new technologies for Air/Ground communication in order to prevent VDLM2 limitations and saturation that will jeopardise the modernisation of the infrastructure, which has an estimated cost of more than EUR 1 billion per year from 2027 onwards.

The Multilink/MULTIMODE scenario is the best approach for risk mitigation and capacity improvement. The MULTILINK/MULTIMODE scenario requires that the ground infrastructure architecture and services evolve towards European services for protocol conversion in order to avoid multitask/multiprotocol implementation on-board new aircraft.

Given that the Multilink/MULTIMODE scenario combines several technologies with different levels of maturity, it is proposed to develop a phased implementation, which could be based on the following main steps:

- Support the use of off-the-shelf technologies for AOC services in order to offload VDLM2, and start using SATCOM NG for ATC operations while the other technologies (LDACS, OFF-THE-SHELF) are not yet available for ATC services.
- Gain experience in the use of SATCOM in continental airspace, with the vision that the Multilink solution, including ATN/IPS, will be required in the long term.
- Take a go or no-go decision concerning LDACS based on the FCI-BC results, and mitigate the risk of LDACS remaining a European-only solution.
- Encourage and support the 'OFF-THE-SHELF' scenario initiative, e.g., for a short-term deployment for AOC, and medium-term deployment for ATC, in order initially to offload VDLM2 traffic while other technologies are maturing and being validated.
- Gain operational experience in and foster the maturation of the use of COTS (SATCOM Ku/Ka, 3-4G) as alternative links for safety, with the vision that a mixture of dedicated/public links could be beneficial in the long term.

12. ANNEX III. Integration prerequisites for IPS

1. To use an ATN/IPS compatible ground end system (ANSP or airline), i.e., to integrate it into the existing safety-critical Air/Ground communication infrastructure, an IPv6-capable ground infrastructure and a ground to air IPS/OSI gateway is required.

2. To use an aircraft with an ATN/IPS end system, for single link operation (i.e., only one Air/Ground data link active at a time, e.g., main/standby operation):

- Air/Ground technologies (e.g.,VDLM2, SATCOM) that can transmit IPv6 packets over the air interface.
- The corresponding airborne radios must have the functionality to communicate with the ATN/IPS airborne end system (e.g., support the Common IP Radio Interface - currently specified at AEEC in P858).
- The Air/Ground access network must meet the necessary security requirements.
- The Air/Ground access network must inform the IPv6 backbone network that the aircraft can be reached via this access network. (Mobility). A prerequisite for this is the Air/Ground mobility interface protocol (AGMI) between the aircraft and the access network, standardized by ICAO and needs to be supported by the Air/Ground access network.
- The ground infrastructure requires an air to ground IPS/OSI gateway to be able to communicate with legacy ATN/OSI end systems on the ground.
- The IPv6-capable ground infrastructure must support the security and mobility requirements (Global Mobility Solution) from the ICAO SARPS and Doc9896 document, as well as the requirements from the RTCA/EUROCAE IPS MASPS. I.e., it requires GB-LISP as a global mobility solution.

3. To use the standardized IPS Multilink concept on aircraft using more than one link, a ground infrastructure is required that supports multiple active Air/Ground links (routes) to the aircraft. (This is already the case with Gb-LISP). [30].

[30] If it is required in addition that aircraft specify the Air/Ground link for certain uplink data as an optional feature, then the ground infrastructure must be able to distribute and use the link preferences from the aircraft on the ground.