SESAR DEPLOYMENT MANAGER

Assumptions for a synchronised deployment towards Initial Trajectory Information Sharing

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Control

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Executive summary

The new ATM systems envisaged in SESAR and NextGen promote efficiency gains by enabling accurate Trajectory-Based Operations (TBO) associated with a trajectory exchange.

The TBO aims at creating an environment where air and ground stakeholders share a common view of flight information, including trajectory, so that the flight can be managed as closely as possible to the Aircraft Operator's ideal profile, while optimising the flow of air traffic. The goal of TBO is, therefore, the exchange, maintenance and use of consistent aircraft trajectory and flight information for collaborative decision-making during the flight, with minimal deviations from the user requested flight trajectory.

According to the ATM Master plan 2020, the TBO represents an Essential Operational Change (EOC) - including a wide set of SESAR solutions and concepts - whose full technical implementation and operational use on the ground will be achieved by 2030. Considering the different level of maturity of SESAR solutions and the related interdependencies and complexity, the need to define a stepwise approach for TBO deployment in Europe becomes obvious.

One of the key enablers for TBO consists of making use of the Extended Projected Profile (EPP), which is the predicted trajectory of the aircraft that can be downlinked via ADS-C application or equivalent systems.

This four-dimensional trajectory reflects the aircraft's intended flight path taking into account constraints known by the airborne system and other operational factors. This enabler is part of the European Regulation EU IR No. 716/2014 (PCP), which describes the initial Trajectory Based Operations ATM Functionality and for the purpose of this document the Initial Trajectory Information Sharing (AF#6).

Moreover, this regulation (PCP) mandates the SDM to develop a strategy, which shall include incentives, to ensure that an adequate number of aircraft flying in Europe are equipped with the ADS-C/EPP capability (20 % of the aircraft operating within the airspace of European Civil Aviation Conference (ECAC) countries in the ICAO EUR region corresponding to at least 45 % of flights operating in those countries). It has to be noted that the PCP is going to be updated and replaced by a new EU regulation early 2021. The current proposal is called Common Project 1 (CP). It has received a positive opinion from the Single Sky Committee in November 2020 and is expected to be adopted by the European Commission in February 2021. Therefore, this document also anticipates the evolution in scope and requirements of AF6 in line with the CP1.

To address the SDM mandate, the present document has been developed with the main objective of providing an integrated roadmap for the timely implementation of the ADS-C/EPP, including potential financial incentives to achieve the IR requirement in a consistent manner. To do this, the SDM has engaged all the relevant and impacted stakeholders, with a specific focus on the operational stakeholders and manufacturing industries, collecting their inputs and/or deployment plans. The AF6 deployment approach, therefore, covers all the ATM chain, from the airborne to the ground domain, and takes into consideration also complementary communication technologies as well as the multilink concept.

The overarching roadmap, stemming from the integration of a number of ongoing activities under R&D and implementation plans in the different domains, has been analysed highlighting potential issues and/or impacts on the TBO implementation.

It has to be noted that although EU-USA long-term communication plans may converge by the next decade with ATN/IPS protocol, the short/medium-term plans are not fully aligned. It is therefore very likely that Europe (ATS B2) and North America (FANS ADS-C/EPP) will adopt different approaches for TBO in a first step. Nonetheless, the SDM and FAA are working for the future convergence of their DLS deployment plans and it is recommended to harmonise and synchronise TBO implementation in both sides of the Atlantic. It is also worthwhile mentioning that this harmonisation should be addressed at ICAO level.

Based on the technical analysis performed, combined with potential financial mechanisms and operational benefits, a list of recommended actions has been identified. These recommendations are based on a detailed assessment of the current situation regarding ADS-C/EPP implementation plans (air and ground), complementary technologies to alleviate the current DL system based on VDL M2 (SatCOM, LDACS and others) and the multilink concept under development. A synchronised deployment on ground and airborne domains is key to ensure operational benefits, justifying future investments and preventing potential fragmentation as occurred during ATN B1 services deployment. However, it has to be noted that new technologies need to be mature and must have an associated business case with a clear CBA before proposing its implementation.

Full details can be found along the document and lead to an initial list of recommendations in Chapter 8, summarised as follows:

- Trajectory Based Operations is a key concept of the ATM system modernisation, however COVID -19 crisis is having a huge impact on stakeholders' investments priorities that could jeopardise the start of deployment. The crisis should be closely monitored, and stakeholders supported;
- A strong European Programme Management is needed to ensure synchronised and harmonised deployment, with clear functions and responsibilities;
- It is recommended to EC to put in place financial support for the implementation of the needed elements to implement TBO (for example, Airborne systems, ground infrastructure and ADS-C/EPP Common Service, complementary technologies, etc.);
- Regarding the current DL System based on VDL M2 technology, it is recommended to timely introduce mature complementary technologies, like SatCOM, LDACS, AeroMACS, 4G/5G (which can be used for AOC only, not for ATS), etc. in order to alleviate/prevent congestion;
- Regarding the multilink concept, it is recommended to produce CONOPS for AUs and ANSPs, to be integrated in the already defined multilink concept;
- Regarding the ground/ground communications segment, it is recommended to facilitate the establishment of the Common European ATN Backbone (CEAB) and to monitor the R&D activities related to the infrastructure of the ADS-C/EPP Common Service. Those two infrastructure elements (CEAB and ADS-C/EPP Common Service) will both contribute to the collection of ADS-C/EPP (ATN) data from the aircraft as well as to the distribution of data among the users;
- The use of the EPP data by NM systems and its potential upgrades must go through a full validation activity.

1. Introduction

According to the European ATM Master Plan, modernisation of the ATM infrastructure will be needed to accommodate the expected air traffic increase in the coming years. However, due to COVID-19 crisis impact, the growth is expected to be much slower in the short and medium term, although the challenges on capacity and environmental needs will surely return. Even if traffic levels as before the crisis will probably be reached within the next four or five years, modernisation needs to keep moving in a sustainable and digital way.

Trajectory Based Operations is a key concept of the ATM system modernisation enabling consistent performance-based 4D trajectory management by sharing and managing trajectory information. TBO will enhance planning and execution of efficient flight profiles by reducing potential conflicts and resolving upcoming network and system demand/capacity imbalances early. Specifically, the expected benefits deriving from a full Trajectory-Based Operations implementation, are:

- flexibility and efficiency using continuous climb and continuous descent operations concepts (CCO/CDO) based on aircraft profile data;
- improved operations through enhanced predictability;
- increased effectiveness of ground-based safety nets;
- improved traffic flow management through more reliable data processing by using sequencing tools (AMAN/DMAN);
- enhanced ATCO's situational awareness and overall safety by generating alerts in case aircraft behaviour or aircraft intent deviates from flight intent computed in ground system.

One important step to achieve this concept is making use of ADS-C applications to download the Extended Projected Profile (EPP) data. This document, which has been widely consulted with the operational stakeholders, is the evolution of the initial "*Note on a synchronised deployment approach towards AF6*" that SDM delivered to EC in July 2020.

In this context, airborne systems are expected to be upgraded in order to downlink ADS-C/EPP data. This data will be used by ATM ground systems to improve the ground Trajectory Prediction (TP) and the air traffic controller's conflict detection and resolution tools with more accurate parameters coming from the airborne systems.

Furthermore, ground systems will share consistent and up-to-date flight trajectories once the enhanced ground TP, building on FF-ICE (the ICAO Flight and Flow Information for Collaborative Environment) and SWIM (System Wide Information Management) will be available[1].

To achieve this, a stepwise and synchronised approach for both ground and airborne domains, has been considered.

1.1 Deployment approach

The purpose of this document is to present an initial integrated roadmap to implement ATM functions improved by the use of ADS-C/EPP information, considering ground and airborne domains.

From the airborne perspective, aircrafts need to be equipped with new avionics technology to provide ADS-C/EPP data.

From the ground perspective, manufacturing industries and ANSPs should continue investigating the possibility of creating a common European service architecture, in line with SJU research and development activities. Hence, ADS-C/EPP data required by multiple ground stakeholders will only be downlinked from

[1] It has to be noted nonetheless that flight trajectory information on the ground is already exchanged and synchronised, but without the EPP data. The addition of the EPP information (aircraft intended trajectory) will therefore enhance the ground trajectory prediction.

the aircraft once, thus reducing demand on the data-link communications network bandwidth/capacity and reducing associated costs (the details related to the air/ground segment are available in section 2.1).

Once downlinked, end users should have the capability to access to ADS-C/EPP Common Service and integrate ADS-C/EPP data into their own systems.

The implementation of this integrated roadmap and strategy will allow more efficient operations and, as far as possible, provide operational benefits for equipped aircraft. In addition, proposals for incentives to achieve the expected targets as required in due time have to be considered.

The proposed deployment approach includes not only airborne and ground plans but also provides an enhanced complete picture with complementary technologies and the multilink concept.

The full integration of ADS-C/EPP data into the FDPs and the consideration of other ATS-B2 services are not in the scope of this document. The R&D work to process and make complete use of the ADS-C/EPP data by the ground systems is still ongoing. What has been validated so far, is the downlink of EPP data from the aircraft (using ADS-C application) to improve trajectory information on the ground and the display of EPP trajectory data on a controller working position. However, the EPP data integration into the ground systems (FDPs) and the use of EPP data by NM is still not mature enough for deployment. Some additional ATS-B2 services (e.g. DCL, D-ATIS) are under consideration of EASA's rule making task force (RMT 0524).

Furthermore, the approach depicted in this document aims to support European Commission and stakeholders in moving towards TBO in a synchronised way, avoiding the problems faced during the DLS IR (EU) 29/2009 (and its amendments) implementation.

From the legislative framework, the EU Regulation No 716/2014 (PCP) mandates the SDM to *"develop a strategy, which shall include incentives, to ensure that at least 20 % of the aircraft operating within the airspace of European Civil Aviation Conference (ECAC) countries in the ICAO EUR region corresponding to at least 45 % of flights operating in those countries, are equipped with the capability to downlink aircraft trajectory using ADS-C/ EPP as from 1 January 2026."*

After the revision of the PCP and the elaboration of the Common Project 1 (CP1), the mandate to down-link trajectory information using ADS-C/EPP is likely to be kept but the due date may be extended until 2027 (pending endorsement and adoption of CP1 by EC), where the CP1 proposal includes a forward fit mandate from 2028 onwards. A maturity gate (December 2023) has been included in the CP1 proposal to check the readiness of all elements before to start the full deployment. The main requirements of PCP and CP1 are outlined in the following paragraphs.

1.1.1 PCP requirements

System requirements related to ADS-C/EPP outlined in the PCP are the following:

- *"Equipped aircraft shall down-link trajectory information using ADS-C Extended Projected Profile (EPP) as part of the ATN B2 services; The trajectory data shall be automatically down-linked from the airborne system shall update the ATM system according to the contract terms;*
- *Data link communications ground systems shall support ADS-C (downlink of aircraft trajectory using EPP) as part of the ATN B2 services;*
- *Flight data processing systems, controller working positions and Network Manager systems shall make use of downlinked trajectories"*

Geographical scope: *"Initial Trajectory Information Sharing shall be deployed in all ATS units providing air traffic services within the airspace for which the Member States are responsible in the ICAO EUR region."*

1.1.2 CP1[2] proposed scope and requirements

Following the PCP revision, the proposed Common Project 1 (CP1) includes the following system requirements:

- **Regarding the Initial air-ground trajectory information sharing:**
    - *Aircraft must be equipped with the capability to automatically downlink trajectory information using ADS-C EPP as part of the ATS B2 services. The trajectory data automatically down-linked from the airborne system must update the ATM system in accordance with the terms of the contract.*
    - *Data link communications ground systems must support ADS-C (downlink of aircraft trajectory using EPP) as part of the ATS B2 services while keeping compatibility with controller - pilot data link communications ('CPDLC') services as required by Commission Regulation (EC) No 29/2009, including provision of service to flights equipped only with the Aeronautical Telecommunication Network Baseline 1 ('ATN-B1').*
    - *All ATS providers referred to in point 6.3[3] and the related ATC systems must be able to receive and process trajectory information from equipped aircraft.*
    - *The ATC systems must enable controllers to display the route of the downlinked trajectory.*
    - *ATC systems must provide a warning to controllers in case of a discrepancy between the downlinked aircraft trajectory and the ground system trajectory elaborated using the filed flight plan route.*

- **Regarding network manager trajectory information enhancement**
    - *The Network Manager systems must use elements of the downlinked trajectories to enhance their information of trajectories flown by aircrafts.*

- **Regarding initial trajectory information sharing ground distribution**
    - *Ground systems must ensure that trajectory data downlinked from the aircraft is distributed between ATS units and between ATS units and the Network Manager systems.*
    - *The data link capability referred to in Regulation (EC) No 29/2009 is an essential prerequisite for the AF6.*
    - *A reliable, fast and efficient air/ground communication infrastructure must support initial trajectory information sharing*

The following stakeholders are required to implement these functionalities with the related implementation dates:

- ATS providers and the Network Manager must ensure that they enable initial trajectory information sharing above flight level 285 by the implementation target date of 31st December 2027.
- For the Initial air-ground trajectory information sharing, all flights operating as general air traffic in accordance with instrument flight rules within the airspace above flight level 285 within the Single European Sky airspace as defined in Article 3(33) of Regulation (EU) 2018/1139. Aircraft operators must ensure that aircraft operating flights with an individual certificate of airworthiness first issued on or after 31st December 2027 are equipped with ADS-C/EPP as part of ATS B2 capability, in accordance with the applicable standards in order to downlink aircraft trajectory.

The industrialisation target date for these functionalities is 31st December 2023. This means that the necessary enablers, concept of operations and system requirements are ready for implementation by that date.

Regarding the geographical scope, initial trajectory information sharing must be deployed in all ATS units providing air traffic services within the airspace for which the Member States are responsible in the ICAO EUR region.

[2] CP1 as per positive opinion received by SSC/77 in November 2020

[3] Referenced point in CP1, as the text is copied exactly from there

2. ADS-C/EPP Implementation plans

ADS-C/EPP is part of the ATS B2 standard as defined in EUROCAE ED-228A document. It specifies Data Link Services for continental, oceanic and surface operational environments including CM, CPDLC and ADS applications. The standard outlines the Uplink and Downlink messages in order to support DLS operations. Only ADS-C/EPP and 4DTRAD, as part of ATS B2, is expected to be deployed in Europe in the medium term in addition to ATN B1 services.

As described in the ATM Master Plan edition 2019, Trajectory Based Operations is an Essential Operational Change that encompasses a wide range of SESAR solutions and concepts with different levels of maturity.

All of them, when combined and deployed, will allow full gate to gate TBO from planning to execution.

In that regard, ATM MP roadmap is mentioning that this would be achieved from 2030 onwards.

From a deployment perspective, this clearly shows the necessity to proceed through a stepwise approach by considering the level of maturity of each solution and building a deployment plan accordingly.

As of today, the ADS-C/EPP downlink functionality required by PCP ATM functionality 6 (AF6) "Initial Trajectory Information Sharing" is ready for deployment on the airborne side. However, the operational use of the EPP data on the ground systems is still under validation (R&D work).

2.1 Airborne Domain

Avionics upgrades related to ADS-C/EPP implementation, together with TBO capabilities e.g. ATS B2 as well as CTA/O and TTA/O, are included in the following packages from the major manufacturers:

- FANS C for Airbus;
- FANS 3 for Boeing.

Both introduce required functionalities at FMS and airborne communication router (ATSU, ACR, CMU, CMF) levels allowing ADS-C/EPP downlink, auto load of route clearances into the FMS as well as basic CPDLC functions.

FANS C package is already certified on A320 and A330 family and should be certified on A350 by 2025-2026.

Airbus A220 family is certified for FANS 1/A as well ATN B1 services. Regarding ATS B2/FANS C capability development and certification, Airbus is working out the plan to develop and certify ADS-C/EPP capability on A220 aircraft in order to allow customers/operators to be in compliance with the mandate by 1st January 2028 onwards.

Boeing has not provided any plan regarding ADS-C/EPP implementation before 2030. Further details are provided in the Boeing paragraph below. However, upcoming CP1 mandate, as described in chapter 1.2 hereinabove, will force Boeing to develop and certify ADS-C/EPP capability on Boeing aircraft in order to allow customers/operators to be compliant with the mandate by 1st January 2028 onwards.

Additionally, it has to be noted that there is not yet a clear roadmap available for Embraer E2 jets fleet. However, upcoming CP1 mandate, as described in chapter 1.2 hereinabove, will force Embraer to develop and certify ADS-C/EPP capability on Embraer aircraft in order to allow customers/operators to be compliant with the mandate by 1st January 2028 onwards.

After discussions with both Airbus and Boeing, it was noted that although long-term COM plans may converge by the next decade with ATN/IPS protocol, their short/medium-term plans are unaligned. It is therefore very likely that Europe (ATS B2) and North America (FANS ADS-C/EPP) will adopt different approaches for TBO in a first step (the SDM and FAA are working for the future convergence of their DLS deployment plans). However, as described hereinabove, FANS C/3 packages offered by Airbus and Boeing could allow medium term (in the time window of CP1 proposal) harmonised and coordinated service provision between EU and US. Regarding longer term, and especially deployment of ATN/IPS COM protocol, it is highly recommended that EU and US roadmaps are aligned in order to avoid inefficiencies and huge extra costs to airlines. To that extent, regular DCOM meetings between FAA and SDM do allow further alignment of development as well as deployment roadmaps between EU and US.

Airbus' plans to forward fit A320 family aircraft with FANS C / B2 capability from 2021 until end of 2026 (production rates include COVID-19 impact as assessed in June 2020) are the following:

Hypothesis A320 family:

- FANS C product option for European customers from 2021 (replacing FANS B+);
- Between 80 and 100 aircraft have been delivered or upgraded for SESAR VLDs (2019-2020);
- 40 deliveries per month (2021–2023) and 60 deliveries per month (2024-2026);
- 25% for European (ECAC) market;
- 25% additional aircraft of ECAC fleet number, not ECAC registered, but flying in ECAC airspace and that need to be equipped.

Therefore, by end 2026, there would be between 1.100 and 1.300 aircraft of A320 family equipped with FANS C / B2 capability.

Hypothesis A330 family:

- A330 NEO is fitted with FANS C capability since early 2021;
- 2 deliveries per month (2021-2024) and 4 deliveries per month (2025-2026);
- 60% flying in ECAC airspace.

Therefore, by end 2026, there would be around 115 aircraft of A330 family equipped with FANS C / B2 capability.

Hypothesis A350 family:

- A350 will be delivered with FANS C capability as of 2025;
- Around 12 deliveries per month (2025-2026);
- 60% flying in ECAC airspace.

Therefore, by end 2026, there would be around 170 aircraft of A350 family equipped with FANS C / B2 capability.

Hypothesis A220:

A220 is compliant with both FANS 1/A (for Oceanic routes) and ATN B1 (European DLS IR). Airbus plan is under development for being ready to deliver the new A220 "ATS B2 capable" from 2027.

Hypothesis A400:

A400M is compliant with both FANS 1/A (for Oceanic routes) and ATN B1 (European DLS IR). For the time being, AIRBUS does not have plans to implement the ATS B2 capability on A400M.

Airbus Summary:

As a result, according to these plans, the total number of AIRBUS' aircraft equipped with FANS C / B2 capability by end of 2026 would be around 1.400.

Boeing equipage plans, as expected before publication of CP1 mandate

Boeing product equivalent to Airbus FANS C is called FANS 3 which should include ATS B2 (US version[4]) and most likely EPP. During the consultation activity in July 2020, Boeing has outlined the following position: Boeing's intent for ATS B2 is to develop a single globally harmonized B2 (FANS-3) implementation that includes all B2 applications (CM, CPDLC and ADS-C including EPP). At present, Boeing expects to potentially deploy B2 avionics on some Boeing airplane models no earlier than 2030. That timing depends on several factors, namely:

- a positive business case for Boeing, aircraft customers, and ANSPs;
- firm commitments for widespread and synchronised B2 ground deployment;
- B2 services harmonisation between the US and Europe.

As already mentioned, CP1 mandate would force Boeing to revise their plans in order to be in accordance with forward fit equipage mandate from 1st January 2028 onwards.

Business Aviation equipage plans

Business aviation equipage will not be considered in the first version of this document; however, it should be noted that the equipage of Business Aviation Aircraft will facilitate the overall performance of the ATM system.

The number of flights (per aircraft type) is rather low; i.e. Business Aviation flights will not deliver a considerable contribution to the percentage of flights providing ADS-C/EPP data.

Airborne Domain outlook

This section aims at providing the overall airborne equipage plans based on the different manufacturer's information. In this version of the document (August 2020), only Airbus has solid plans and therefore the figures presented below are based on Airbus' plans.

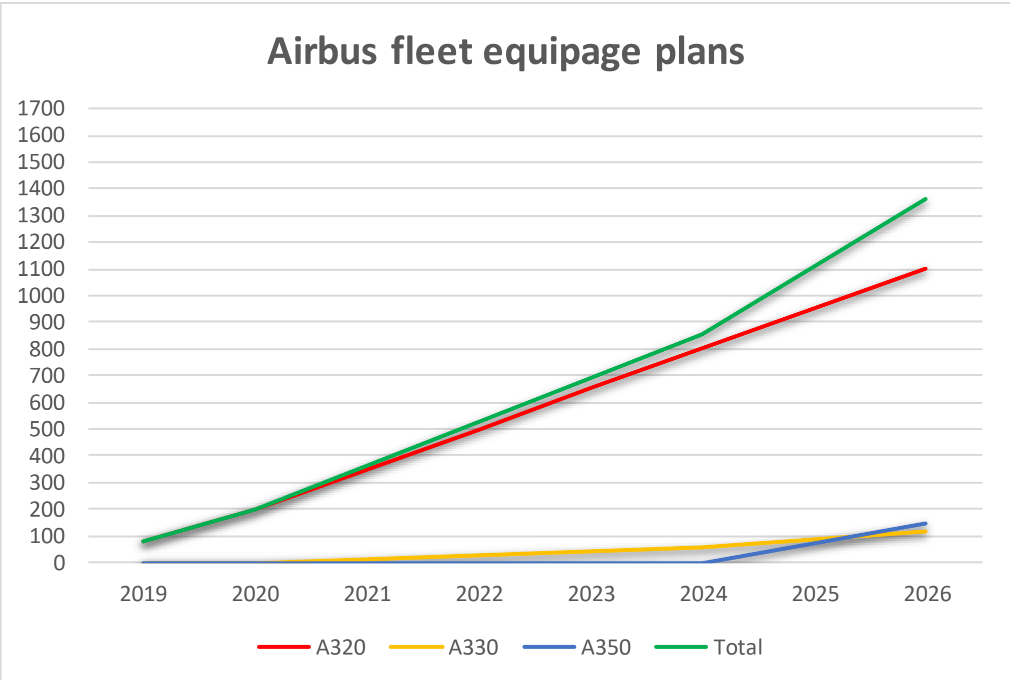

Figure 1 – ADS-C/EPP Airbus fleet equipage plans until 2026

[4] US Version is based on FANS

Although Airbus fleet equipage ramp up could be considered promising, it has to be noted that there are still uncertainties regarding ATS B2 development and certification timeframe for other A/C manufacturers as of now until 2027.

Initial target figures of 20 % of aircraft / 45% of flights should be reconsidered and increased in regards of usual critical mass figures expected by ATM in order to reach an acceptable level of efficiency for ADS-C/EPP usage and further TBO concepts deployment ECAC wide.

As a result, it would be recommended to set-up incentive mechanisms, being financial and/or operational, in order to foster retrofit on fleets and development, certification and fleet equipage (forward and retrofit) for all airspace users; providing also airspace users with a better context to invest than the previous one when deploying ATN B1 in Europe.

2.2 Ground Domain

This section provides an overview on how ground implementation and operational use of ADS-C/EPP could evolve over time. It covers the A/G communication segment and the G/G communication segment focused on the requirement of the PCP, namely Data Link communications ground systems to support ADS-C/EPP. There is also a description of the Common European ATN Backbone (CEAB) and a Common European distributed ADS-C/EPP Service because those two infrastructures will both contribute to the collection of ADS-C/EPP (ATN) data from the aircraft and then the distribution of data among the users.

In order to obtain the strategic benefit of reducing the fragmentation and facilitating a seamless integration of complementary communication technologies, all ANSPs should be connected to the Common European ATN Backbone (CEAB). It is expected that all ATN data, including ADS-C/EPP data, will be provided to ANSPs via the CEAB.

- Beyond what is strictly required as per CP1 proposal (e.g. receiving and displaying ADS-C/EPP data and providing warnings to ATCOs by comparing trajectories), ADS-C/EPP information applied to the trajectories could further support: Enhanced Conflict Detection thanks to a more accurate and reliable Trajectory Prediction;
- Enhanced Conflict Resolution based on a better estimate of possible flight behaviour ("what-if" scenarios);
- Conformance Monitoring improved by more accurate knowledge of the aircraft intent;
- Capability to load ground clearances in the aircraft FMS improving the alignment of aircraft predicted trajectories and the ground clearances;
- Sequencing automated tools, for AMAN or Extended-AMAN, for instance by using estimated time window (ETA [min, max]) that can be sent by the aircraft via ADS-C application (on top of EPP).

This list is not exhaustive, and the relevance of implementing one ATC function or the other is a local decision based on operational needs.

From the deployment perspective, in order to ensure synchronisation of ANSP and manufacturer plans, industrialisation and implementation on a broader basis throughout Europe require further coordination. A synchronised deployment in ground and airborne domains is key to ensure benefits, otherwise operational implementation costs could hardly be justified.

In this context, a Common Data Link Service (DLS) Governance for Europe is paramount.

The following Ground Domain segments need to be considered:

- A/G communication segment;
- G/G communication segment;
- ATM segment (ANSPs and NM systems).

1. A/G communication segment

The current air/ground communication segment for ATN B1 services is using VDL M2 technology. VDL M2 will be used also to support the ADS-C/EPP data downloading. Considering that ADS-C/EPP will be more demanding in terms of bandwidth, a DLS Capacity Assessment Study (CAs)[5] was launched in 2018 to identify the time horizon by which the VDL M2 system will reach its operational limits. Based on the CAs results, the SDM recommended in its Report on DLS Architecture and Deployment Strategy (PSA SGA5 D11.1.1) to introduce complementary communication technologies as early as possible to offload the VDL M2 data traffic.

2. G/G communication segment

Common European ATN Backbone (CEAB):

The Ground/Ground network (G/G) is the link between ATM system components. It also connects the ATM system components to the Air/Ground network (A/G) which provides connectivity to the airborne systems. The existing ATN G/G network suffers from fragmentation (three current networks and potentially more in the future with the A/G ATN routers proliferation) and does not provide optimum performance as was studied and concluded in the definition of Architecture 1 and Architecture 2 proposals (Path II / WP2 deliverable).

To improve the current fragmented approach in Europe, SDM is proposing, as part of its DLS deployment strategy provided in the PSA SGA5 D11.1.1 – *"Report on architecture and deployment strategy",* a transition towards the Common European ATN Backbone (CEAB). The successfully closed CEF 2017 Project IP1 describes the required architecture and functions for this performance driven G/G network, whilst the transition scenarios are available from CEF 2016 Path2 Project.

In order to obtain the strategic benefit of reducing the fragmentation and facilitating a seamless integration of complementary communication technologies, all ANSPs should be connected to the Common European ATN Backbone (CEAB).

The transition toward the Common European ATN Backbone is encompassing also the setup of a European DLS Governance, which will decide on the selection of a Data Link Service Provider (DSP) to implement and operate the CEAB. The "Common DLS Governance for Europe (CoDE)" Project, which started in 2020 with the support of SDM, is covering this activity. In order to get the most benefit of the CEAB, it is necessary connect all ANSPs, CSPs and complementary technologies to the CEAB.

As the CEAB is per definition the Common European ATN Backbone, the complementary technologies will need to be connected to the CEAB using an ATN/OSI gateway as an interface, if needed.

The physical transport connection used for CEAB connections is an IP-based network service. A good candidate to provide the required connectivity could be New Pan European Network Service (NewPENS), which has the advantage of being already used by of the ANSPs.

SatCOM should be most likely the first candidate to provide an additional connection from aircraft to ANSP's ATM-Systems from 2022 onwards. This first operational use of Multilink connectivity must be accompanied by a robust Concept of Operations (CONOPS).

The proposal of a timeline for Ground/Ground network deployment derived from the SDM DLS strategy is presented below:

[5] The DLS Capacity Assessment study (CAs) has been performed by the University of Salzburg and contained in the following deliverable: *"VDL M2 Capacity and Performance Analysis"*

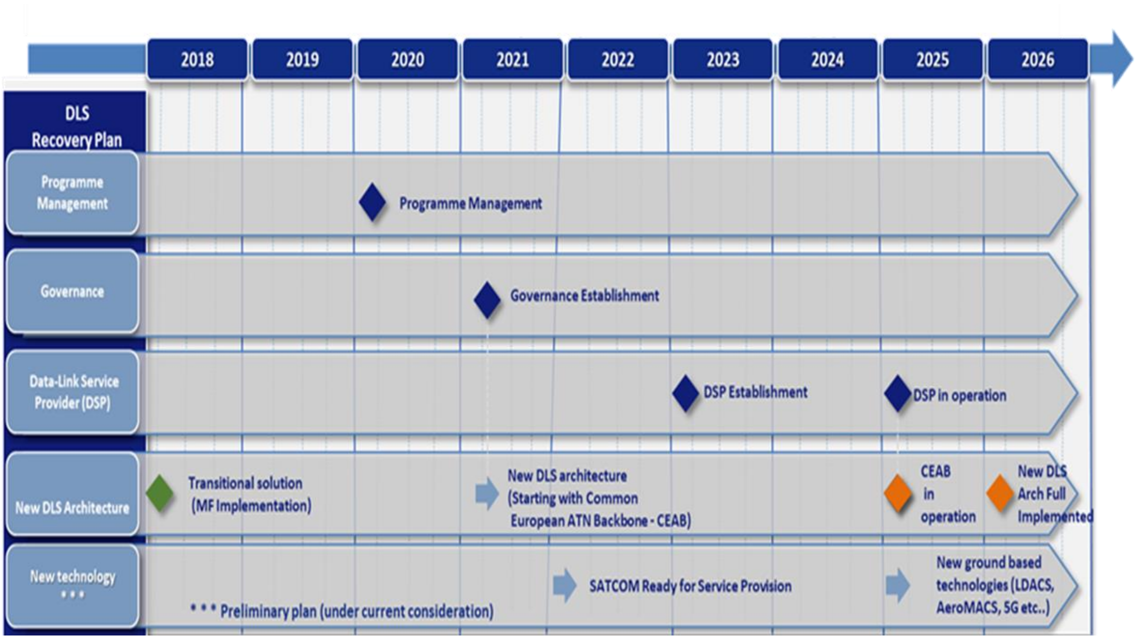

Figure 2 – SDM DLS deployment strategy

<u>Common European ADS-C/EPP Service:</u>

Distributed ADS-C/EPP Service provision over Europe per ACC has the disadvantage of fragmentation and is consuming rare radio bandwidth. A commonly planned, installed and operated ADS-C/EPP Service is expected to bring significant benefits in terms of improved service performance, reduced cost and resources to the ADS-C/EPP users. Such an approach should be considered from a European perspective and aligned among users.

The proposed SJU SESAR2020 Wave 3 PJ.38 has the goal to demonstrate the feasibility of an efficient European common management of ADS-C contracts with aircraft and the distribution of the received ADS-C/EPP data to multiple ground users. This will support the Service Oriented Architecture vision in the ATM Master Plan (MP). A major benefit is that ADS-C/EPP data required by multiple ground users will only be downlinked from the aircraft once, reducing demand on the data-link communications network bandwidth/capacity and associated costs.

The expected advantage is to provide a Pan European Service for all ANSPs which could be managed by the DSP under the DLS Governance to prevent fragmentation. The implementation is based on a sequenced approach (see generic timeline for ADS-C/EPP Service in Figure 7).

The distribution of EPP data could be done through the ADS-C common service. PJ38 will start working on the validation of the ADS-C/EPP common service from 2021 until December 2022, when the project is expected to be completed. Therefore, there is a risk that the architecture and the system requirements are not completely defined in time vis-à-vis AF6 maturity gate defined in the CP1 proposal (December 2023).

If the validation of PJ38 reaches the AF6 maturity gate, then the identified programme manager should define a clear deployment approach to establish the ADS-C/EPP common service.

3. <u>ATM Segment (ANSPs and NM systems)</u>

This section is focused on three key requirements to implement ADS-C application on the ground systems: *receiving ADS-C/EPP data, displaying ADS-C/EPP data and providing warning to ATCOs in case of inconsistencies between ground and airborne trajectories* (one calculated by ATM system and the other provided by aircraft through ADS-C/EPP data downloading).

The Network Manager (NM) systems may receive the EPP data and may use the elements of EPP data for updating and improving post-departure trajectories with more accurate predictions. This is subject to further validation in SESAR 3 (Strategic Research and Innovation Agenda 2020 proposal). The display of EPP - data and warnings - is not needed by NM, as those are pure ATC functions.

Implementation of the ADS-C application affects numerous ATM-System components like Human Machine Interface (HMI), Flight Data Processor (FDP) and may affect Network Manager Trajectory Prediction module and others. With the insights from SJU (SESAR2020 Wave 1 PJ.18 and PJ.31), it is recommended to use a sequenced implementation approach in order to minimize efforts for installation, testing and training. It is worth to be noted that NM interface for EPP has never been validated as it was not part of SESAR wave 1.

The current DLS implementing rules require a proper exchange of flight data information between ATM systems. ADS-C/EPP service introduction, as part of ATS B2, will be facilitated by the proper exchange of information that will include also the processing of B2 logon and the distribution of LOF messages on the ground. The introduction of the newest OLDI 5.0 and ADEXP 3.3 data format will facilitate LOF exchanges in mixed mode environments. The upgrade of FDP OLDI interfaces is recommended in order to prevent fragmentation on ground implementation.

The upgrade for ATM-systems will cover receiving and processing of ADS-C/EPP data sent by aircraft (ADS-C reports), including the HMI upgrade (displaying the EPP trajectory at the controller working position (CWP)) and warnings to ATCOs about discrepancies with the FDP trajectory. Furthermore, Network Manager systems could be upgraded after the full validation of EPP data handling by NM is completed. In the future, SWIM Blue Profile[6] and Flight Object (FO) could be (pending validation) considered a possible mechanism for ATM data sharing, including ADS-C/EPP, which is currently under consideration.

Below, the ATM-System Functions Upgrade timeline is shown (Figure 3). It is worth nothing that, although for some future functionalities (e.g. the conflict detection and resolution (CD&R) with EPP, the SWIM blue profile and some future enhancement for AMAN, etc.) the validation phase has not started or concluded yet, the timeline below includes indications on their potential implementation in order to provide a complete picture of the ATM system upgrades which will utilise the ADS-C/EPP data.

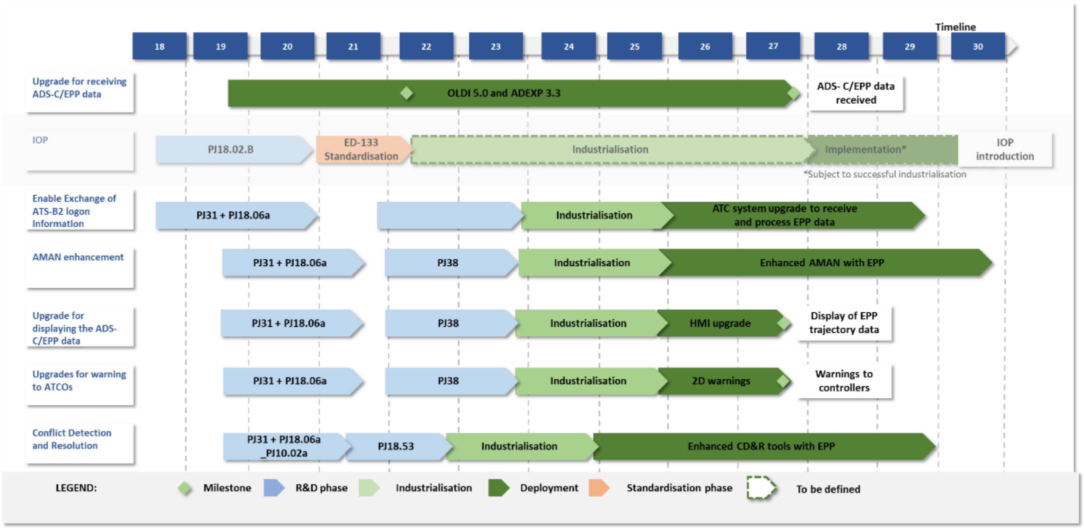

Figure 3 – ATM system upgrades timeline

With the PCP revision, in the Common Project 1 (CP1) proposal, the mandate to use trajectory information has been also planned for the NM systems with the introduction of a dedicated sub AF (6.1.2).

In more detail, the trajectory information in the NM systems, according to the new CP1 proposal, should be enhanced using elements of air-ground trajectory data exchanges. A further step for the deployment of Initial Trajectory Information Sharing consists of processing this data by NM.

[6] SWIM Blue Profile has not been included in the CP1 technical annex

Based on the industrialisation target date proposed by CP1 for 2023, SDM has elaborated the following hypothesis for the deployment of the Sub-AF related to NM systems, as shown in the picture below:

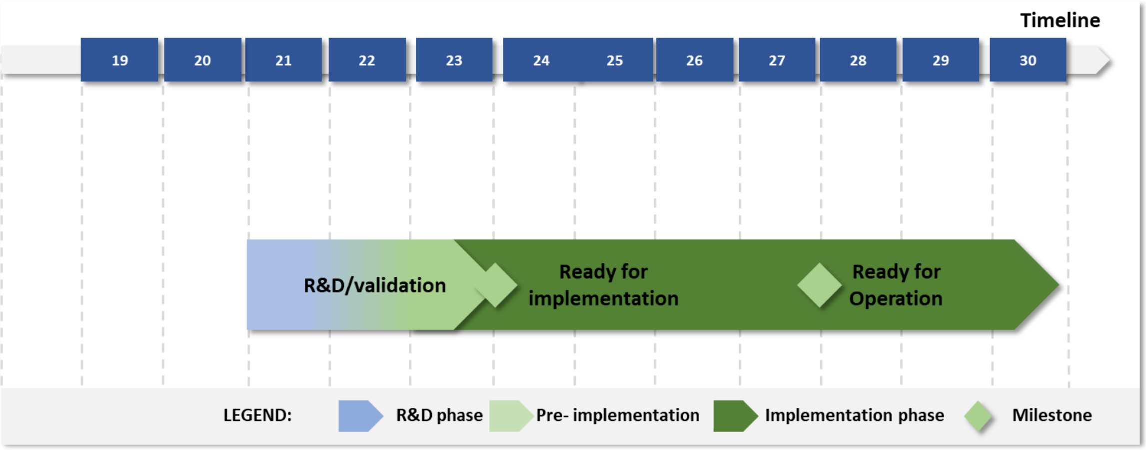

Figure 4 – NM trajectory information enhancement

It has to be noted that in order to start deployment, both NM systems requirements and the use of EPP data should be validated. This gap is not covered yet.

The expected compliance of ATM requirements to implementing rule IR No. 716/2014 (PCP), in particular ATM Functionality 6, is depicted in the maps on the following pages, obtained through SDM consultation with relevant stakeholders.

The first deployment of ADS-C/EPP in ATM systems is expected to start with the early movers shown in Figure 5. This is expected to be the ANSPs which contributed already actively to the SJU PJ31 project and future PJ38: DFS, ENAV, MUAC, DSNA and NATS.

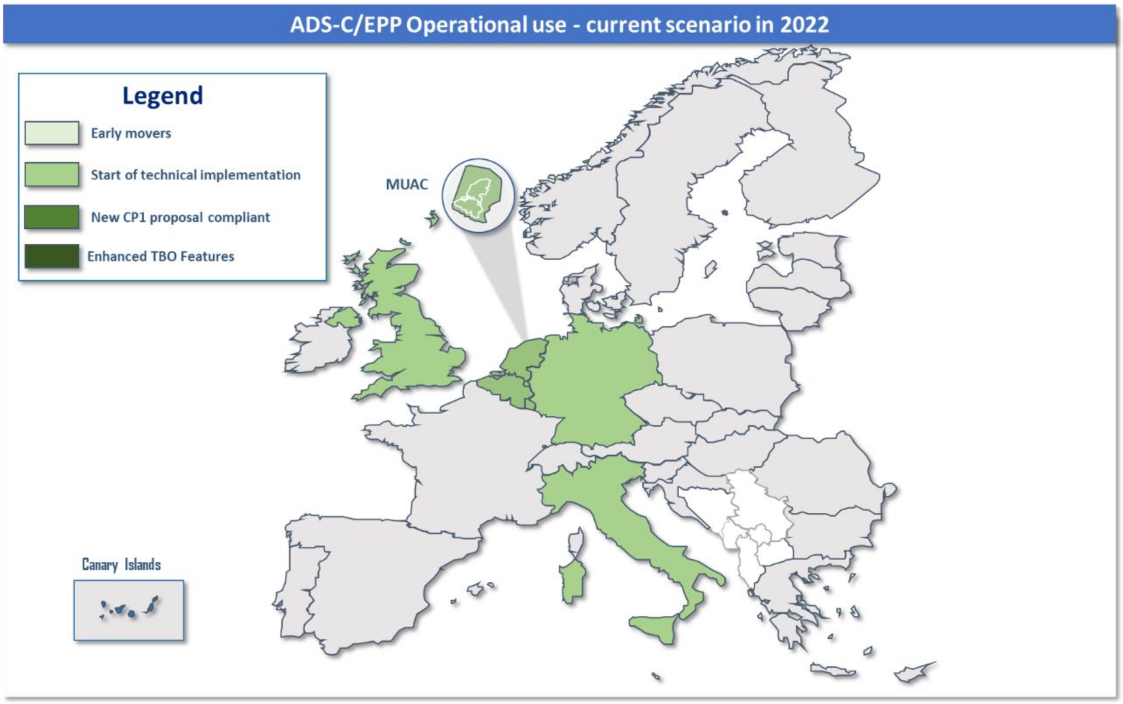

Figure 5 – ADS-C/EPP Operational use current scenario in 2022

Further deployment on the ground will very likely follow the roadmaps of ATM-System vendors and the corresponding ANSP alliances (e.g. COFLIGHT, COOPANS or iTEC). However, the sequence of deployment is still subject to individual planning and coordination among the respective ATM stakeholders. A more predictable scenario of ground deployment can be achieved by introducing a common coordinated deployment plan for ATS-systems. It is assumed that in 2025 the implementation of the three key requirements by the early movers could start, as shown in Figure 6.

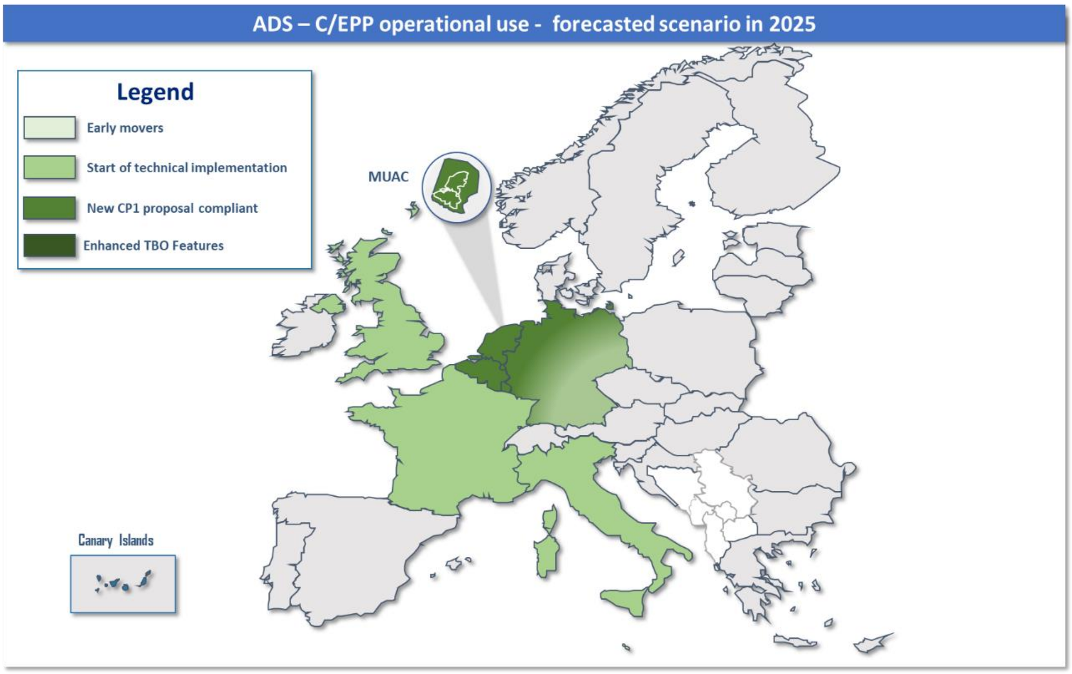

Figure 6 – ADS-C/EPP Operational use forecasted scenario in 2025

The full deployment of ADS-C/EPP over Europe is planned to be operational in 2027. The implementation of ADS-C/EPP data distribution is expected to be in line with the CP1 proposal.

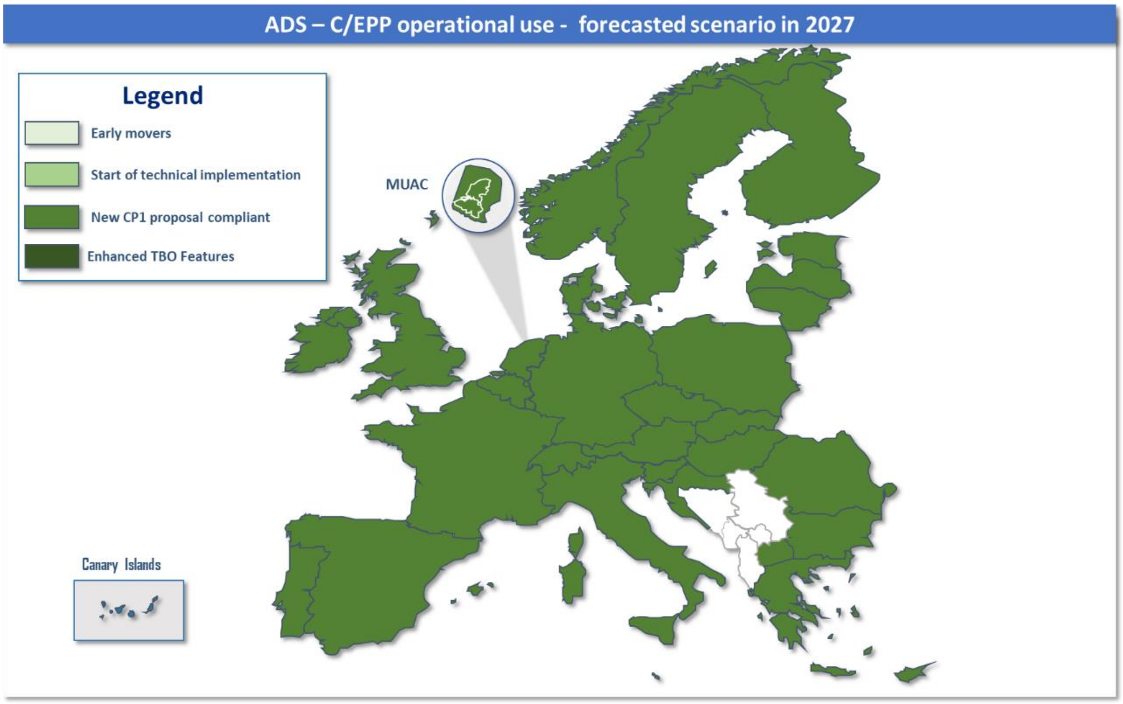

Figure 7 – ADS-C/EPP Operational use forecasted scenario in 2027

The implementation of further enhancements in ATM Systems is expected between 2027 and 2030 and highly dependent on progress made in R&D activities.

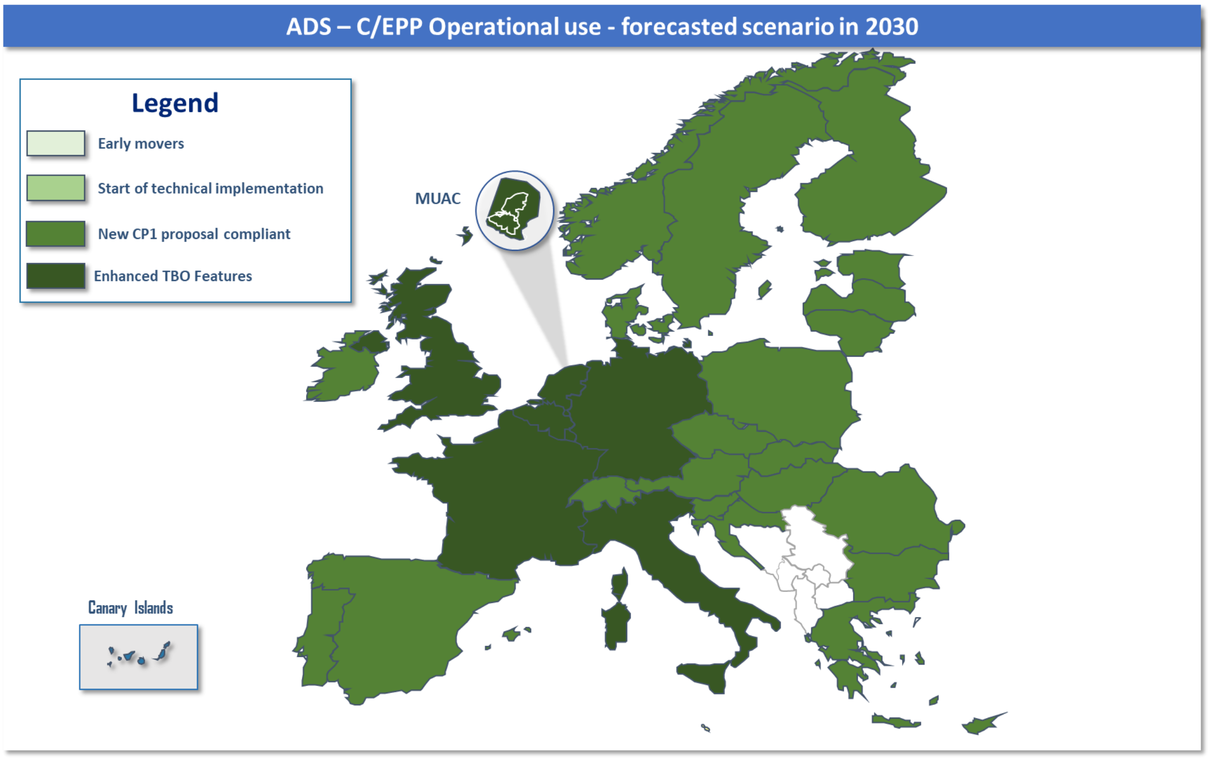

Figure 8 – ADS-C/EPP Operational use forecasted scenario in 2030

Conclusions for Ground Domain:

Based on SDM consultation with relevant stakeholders and the experience obtained through previous projects, SDM recommends building the "CEAB" as first priority and then adding new services. This makes sure that the expected data load can be handled properly. A synchronised implementation of ground and airborne systems in a stepwise approach combined with European-wide coordination is the most likely scenario for achieving the expected benefits for all users.

ADS-C Ground Domain Evolution Roadmap covering G/G network, ATM-system upgrades and the common European ADS-C/EPP Common Service is depicted below:

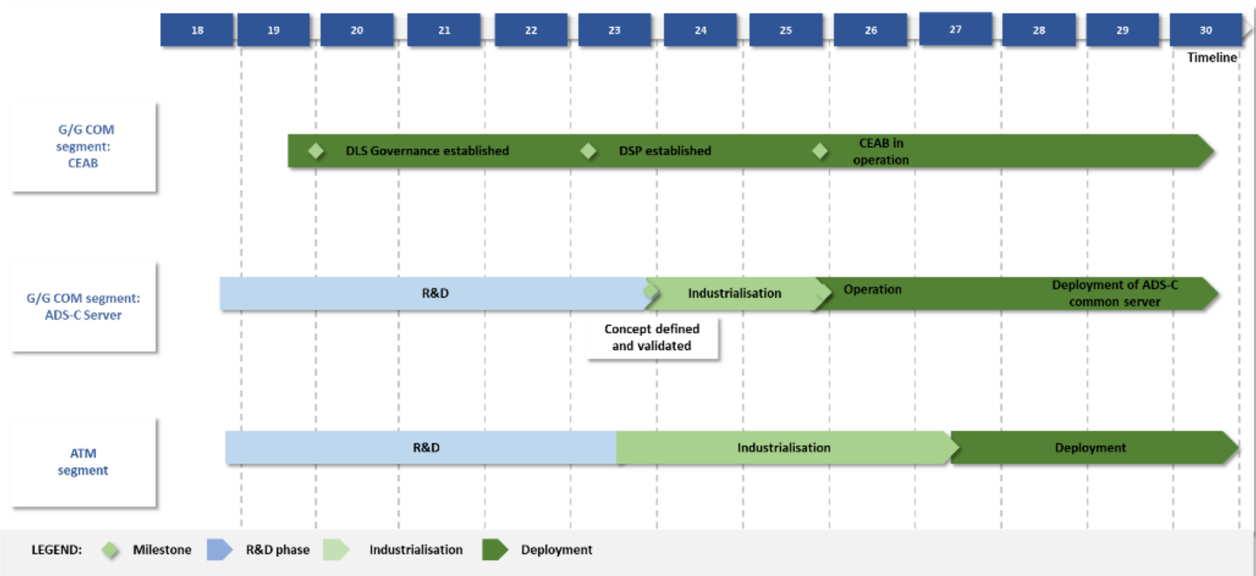

Figure 9 – Ground evolution plans

3. Complementary technologies

VDL M2 is the main pillar of Air/Ground communication today. However, the VDL M2 technology brings a number of limitations and the VHF band is expected to potentially get congested (again) from 2027 onwards considering the Architecture 2 implementation and the hypothesis made in IP1 project. In the long term, VDL M2 is not expected to provide sufficient headroom to cope with the ever-growing demand for data volume induced by new ATS and AOC applications. However, some studies/activities are ongoing in order to improve the VDL M2 lifetime (e.g. advanced VDL M2, more frequencies, etc.). These studies/activities could affect the timeline of the complementary technologies' implementation.

Additional loading of VDL M2 radio links can be expected from increased use, the deployment of new air-ground applications and the need for cybersecurity measures. It becomes therefore obvious that for the establishment of the "European Digital Sky" VDL M2 has to be complemented by modern communication technologies as soon as possible and could be replaced by these much more capable and secure technologies in the long term. This chapter will provide the status and an outlook on the most promising Air/Ground Technologies considered to complement the legacy VDL M2 system.

In addition, it needs to be considered that equipping a significant share of the fleet with complementary technologies will take a minimum of 10-15 years. The deployment of complementary technologies (e.g. SatCOM) should start as soon as possible (ideally in 2023) in order to minimize the overall cost of deployment for users, before the VDL M2 cannot cope with DLS requirements anymore.

However, it is worth to note, that none of the complementary technologies described hereafter is finally accepted or even agreed by the stakeholders at this point in time. It has been identified that <u>all</u> technologies listed need to provide a positive business case and a full validation and need to be certified before they can be considered for deployment.

Moreover, also the future transition from OSI to IPS will have to be considered because it will influence the COM technologies deployment.

3.1. SatCOM

At present, the most mature complementary A/G datalink technology is Satellite Communication (SatCOM) that could alleviate VDL M2 in the short term.

Avionic upgrades related to the implementation of ATN over SatCOM would typically include installation of the new state-of-the-art SatCOM user terminal avionics (also referred as Aircraft Earth Station – AES) and software modification of the existing airborne routers. For retrofit installations, existing SatCOM antennas may be reused in some cases. Also, aircraft that get equipped in the near term with the selected new AES products for FANS 1/A capability (i.e. typically aircraft operating in oceanic and remote airspace) could seamlessly be upgraded to ATN over SatCOM through software upgrades of the AES and the airborne router. Future transition from OSI to IPS will also require new airborne router hardware in many cases.

So far, Cobham and Honeywell are about to offer SatCOM products supporting ATN for A/C (certification for the Airbus family (SA, LR) is planned in 2022). The Honeywell product to be used for other aircraft types is still to be confirmed.

Regarding the costs, as mentioned above, ATN over SatCOM will typically require new SatCOM avionics installation plus software upgrades of the exiting routers. This is the reason why SatCOM installation cost, being on forward fit or retrofit, should be carefully considered. Nonetheless the costs have not been quantified in this document, further work will be needed in the future to address this point.

The most advanced SatCOM product is developed by Inmarsat, called "IRIS". "IRIS" is a SatCOM System funded and promoted by the European Space Agency (ESA). It is based on consolidated Inmarsat Swift Broadband Safety technology already certified for oceanic use, expanded and enhanced in order to be used also in continental airspace for the provision of current and future demanded Data Link services (ATN B1 / ATS B2), as well as advanced Airline Operational Communications (AOC).

In addition, it is worth mentioning that EUROCAE standards covering SatCOM emerging technologies are available. Revisions of these standards are currently under development at EUROCAE.

Another SatCOM product that should be considered for the future, is developed by Iridium and it is called "Iridium Certus".

This is a LEO network for global coverage (pole to pole) for voice and data connectivity.

It is expected that Iridium Certus devices, IP based, can be used for AMS(R)S Services, ATS Safety Voice, FANS Data Services and ATN Services covering the Performance-Based Communication and Surveillance (PBCS) defined by ICAO (RCP400 voice and RCP130/RSP160 data).

Iridium Certus is not available yet but it could become a reality because Iridium manufacturing partners have been developing their products and are working to obtain on-air testing in the next years.

In addition, Iridium has been supporting the industry developments of future ATN IPS service.

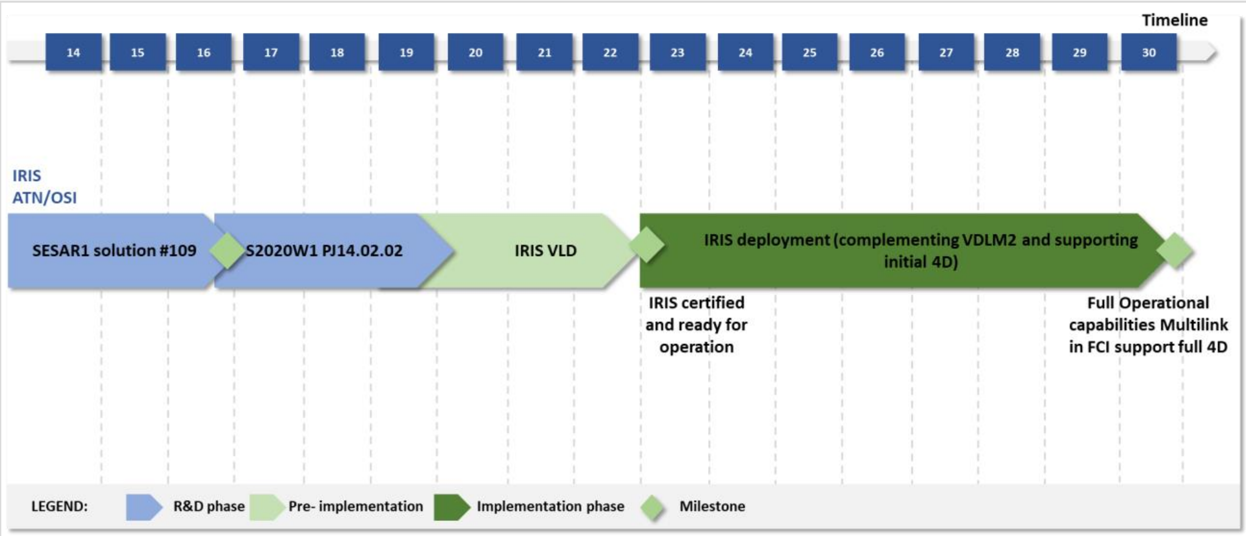

Figure 10 – SatCOM roadmap – based on "IRIS"

3.2. LDACS

Action Plan 17, undertaken jointly by the FAA and EUROCONTROL, determined that the L-band is the most suitable band to support future terrestrial Air-Ground communication needs. This finding led to the development of the "L-Band Digital Aeronautical Communication System" (LDACS) technology to meet the requirements of the Future Communication Infrastructure (FCI). It is, however, worth to be noted, that there is not yet a firm commitment by the stakeholders to implement LDACS in Europe or in other parts of the world. Such a decision is expected not before 2022/23 when the current SESAR activities will be about to deliver.

LDACS is a scalable Air/Ground Data Link technology in the aeronautical L-Band between 960 MHz and 1164 MHz that allows a step-by-step deployment along with already fielded systems with very low risk. LDACS will initially be fielded to complement existing infrastructure and provide the possibility to replace legacy VHF Data Links. Standard IP interfaces will allow easy integration into the existing communications infrastructure and the emerging multilink environment. LDACS could be introduced locally, where most needed, to supplement VHF Data Links with the high-capacity broadband LDACS Data Link with the same communication service range as the legacy VHF link. LDACS is designed as a cellular system. Thus, the well-known co-channel interference problems of VDL M2 (Hidden Transmitter issue) are avoided by assigning different frequencies to neighbouring LDACS cells.

To support future Air/Ground Communication needs, LDACS can provide data throughput from 550 Kbit/s up to 2.6 Mbit/s depending on the chosen adaptive coding and modulation scheme. This is 50 to 200 times higher than the throughput of the currently operated VDL M2 system. LDACS also manages service priorities and, thus, guarantees bandwidth, low latency and high continuity of service for safety-critical applications, while also accommodating airline AOC services. Additionally, LDACS can provide secured private communications for aircraft operators and ANSPs (Air Navigation Service Providers) and is therefore also suited to support the Command & Control link (C2) for Remotely Piloted Air Systems (RPAS).

In addition to the communications capability, LDACS also offers a navigation capability. Ranging data, similar to DME (Distance Measuring Equipment), is extracted from the LDACS communication links between aircraft and LDACS ground stations. This results in LDACS providing an APNT (Alternative Position, Navigation and Timing) capability to supplement the existing on-board GNSS (Global Navigation Satellite System) without the need for additional bandwidth. LDACS provides secured and increased throughput capacity paving the way for future navigation applications, such as curved precision approaches and full 4-D trajectory operations.

Spectrum is a scarce and valuable resource especially within the aeronautical L-band where already many services of high importance are allocated. LDACS is highly spectrum efficient because it is designed to be placed within those parts of the L-Band where no other service could be allocated until now. This valuable feature was achieved by designing LDACS in a way that it can be co-located with DME navigation aids in the L-Band.

LDACS was investigated in SJU#PJ.14-02-01 and it is currently followed by SJU PJ.14-W2-60 with a target maturity of TRL6 by end of 2022 whilst the standardisation at ICAO level started in 2016. ICAO draft SARPS have been agreed in 2018 and it is expected to publish the final SARPS not later than 2024.

In March 2019, an LDACS flight test campaign was conducted. Several flights were performed at different altitudes up to FL 350. During these flights, all the major capabilities of LDACS were successfully validated in real practical scenarios by using industrial LDACS demonstration equipment in the aircraft and in four LDACS ground stations. Capabilities demonstrated included high-rate, low-latency data transmission secured by post-quantum cryptography, authenticated GBAS broadcast (secure GBAS) and handovers between LDACS ground stations. The results of the flight campaign proved that LDACS is a mature technology for aeronautical communication and potentially also for navigation. This makes LDACS the first truly integrated CNS system recognized by ICAO. It should be noted that another LDACS flight test is planned as part of SJU PJ.33-W3 in 2022, to further support achievement of TRL6 maturity level as communications system. The flight trials will technically validate LDACS support of different potential applications (ATN-B1, ATN-B2, AOC) by involving prototypes both for avionics and ground systems. In addition, it is worth mentioning that EUROCAE Activities on LDACS have not yet been activated. Below a potential implementation roadmap for LDACS based on all the ongoing R&D and ICAO activities assuming that support from the stakeholders can be achieved as soon as the maturity gate will be reached in 2022/23.

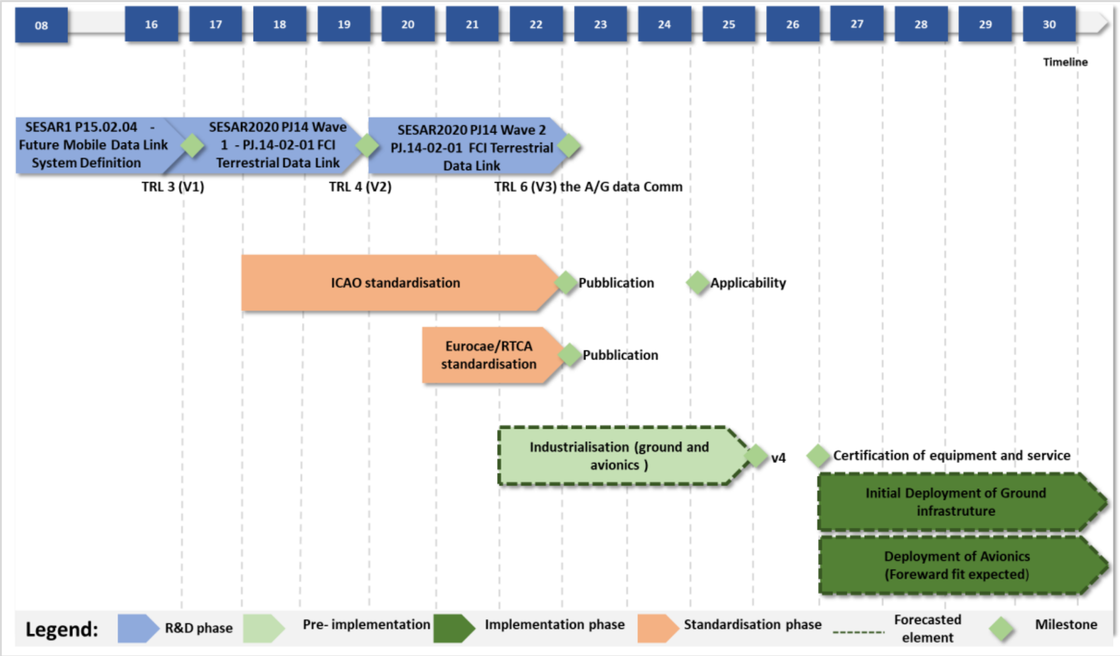

Figure 11 – LDACS roadmap

3.3. Data communication with Aircraft on Ground

A significant volume of data is exchanged with aircraft on ground, i.e. while the aircraft is parked or taxiing at an airport. Today, most of this data traffic is transported by the same technologies that also serve the aircraft in flight, loading the Air/Ground communication channels required to serve the aircraft when airborne. Communication infrastructures required to provide services to aircraft in flight are in general more expensive than (short-range) communication technologies that can provide communication services only while the aircraft is on ground.

Dedicated ground communication services could not be used for ADS-C/EPP and TBO, however using these communication technologies will unload the communication media capable to serve the flight phase and thus extend the lifetime of the Air/Ground communication technologies.

There are some communication technologies available to serve aircraft on the ground, which are deployed at European airports and installed onboard of aircraft. However, these solutions are often aircraft-type specific, not standardized, and require heavy investments, both on board (retrofit), and on ground (IT security, dedicated ground tools from manufacturers). Different solutions are deployed, based on individual airline initiatives.

3.3.1 AeroMACS

AeroMACS is standardised by ICAO and operates in a protected Aeronautical (C-)Band. AeroMACS is therefore suited to transport ATS and AOC communications. Standards (EUROCAE associated standards) and ground products are available for several years already, meaning that the technology is mature. However, there are no certified avionics supporting the AeroMACS communication standard yet, hence the existing AeroMACS implementations in Europe are limited to communication between fixed and mobile airport infrastructure. Besides, as it is an airport-based solution, the AeroMACS solution is hardly manageable for airlines (too many service providers, airport coverage, IT security, etc.).

3.3.2 3G/4G/5G – public Cellular Networks

3G/4G/5G public cellular networks are not approved by ICAO for safety critical communications with aircraft. Their use is therefore restricted to AOC communication only, as ATS messages cannot be transmitted. These solutions are often aircraft-type related, not standardized and require heavy investments, both on board (retrofit) and on ground (IT security, dedicated ground tools from manufacturers). Different solutions are deployed, based on individual airline initiatives, and some issues are regularly experienced, such as coverage (congested airport environment, Faraday problem for antenna inside aircraft, etc.), involving unacceptable quality of service.

However, aircraft operators seem to favour the use of public cellular networks over AeroMACS as 3G/4G networks are available at European airports in general and might be enhanced by the emerging 5G networks in the near future. Some avionics manufacturers offer 3G/4G communication equipment that is certified for aircraft installation (e.g. FOMAX from Collins) and ACSP offers an integration of these communication into the legacy AOC communication infrastructure for non-safety critical services. Other service providers offer cellular Gatelink capabilities that allow (non-safety critical) IP based communication on ground between A/C LAN and airline LAN. In addition, it is worth mentioning that the use of such cellular networks for AOC traffic while aircraft are on the ground could also alleviate potential congestion of aviation protected spectrum.

3.3.3 WiFi Networks

Some Aircraft Operators use WiFi connections to transport AOC data at certain Airports (Wi-Fi Gatelink) the same way as described above for 3G/4G/5G. However, because this is a proprietary solution, it is not widespread. Providing radio coverage at an airport beyond the gates is much more difficult than with AeroMACS or 3G/4G/5G public cellular networks and it will most likely be complemented or replaced by 3G/4G/5G in the future.

4. Operational Multilink Concept

For the Air/Ground (A/G) communication segment, the VDL M2 has been considered the prime technology for ADS-C/EPP data downlink and, the following technologies have been considered to complement it, alleviating its future capacity crunch:

- SatCOM;
- Communication at Airport surface (e.g. AeroMACS);
- LDACS (continental airspace).

The VDL M2 and the above-mentioned complementary technologies will constitute four independent radio subnetworks that, once deployed in the same operational area, will be able to work simultaneously. This scenario implies the need to manage the multilink operations and this management has still to be fully defined. In this framework, in the short term the operational multilink concept has to be developed for ATN/OSI, while, in the long term, it is expected to be addressed for ATN/IPS. In any case, the principles, which lay down the basis for this multilink operational concept should be very close to each other independently from the chosen protocol.

In fact, some relevant R&D activities (e.g. SESAR2020 PJ14.2.2) have been already focused on this need and, in details, the following points have been considered:

- To provide seamless transition from single to multilink operation area and vice versa, interfacing and integrating the available complementary air-ground technologies into existing ATN/OSI systems on board and on the ground;
- To satisfy technical, commercial and political needs and constraints which may impose different link selection policies depending on the geographical location of the aircraft as well as on the ground end system to which the aircraft connects;
- To properly apportion the performance requirements and liability to the operators of the different air-ground links and the shared ground infrastructure.

Even if the three above mentioned points have been addressed, additional work is still needed in order to define an appropriate Concept of Operations (CONOPS), intended as “rules” for AUs & ANSPs, that are still missing so far. The CONOPS, in fact, could prevent future operational and technical issues operating in a multilink environment. For this reason, the CONOPS shall be facilitated by the programme manager and defined in close collaboration with AUs and ANSPs as final DLS users, before going in operation.

Additionally, considering that CONOPS will likely influence the multilink technical implementation, it should also be considered in the validation phase of the multilink operational use (first it is needed to know, how to use the system (CONOPS), and only then it will be possible to finalise a proper system design). It is expected that the CONOPS and system design may iterate.

For this reason, the CONOPS shall be defined by the stakeholders, with the support of the programme manager, before going in operation with multilink in order to have a clear rule on how the link will be selected and how the available ones will be used (for example, only one will be used per flight while, a second one will be used in case of failure). For instance, the CONOPS will be also useful to clarify how a complementary technology (e.g. SatCOM) could temporary cover the VDL M2 gaps or vice versa. The CONOPS definition will take into account the PJ38 and PJ14 material, once it is available. In particular, the Programme Manager will need to build upon the results of PJ14 to consider the VDL M2 radio link and ATN/OSI datalink services.

In this sense, the following timeline is expected for the multilink full definition:

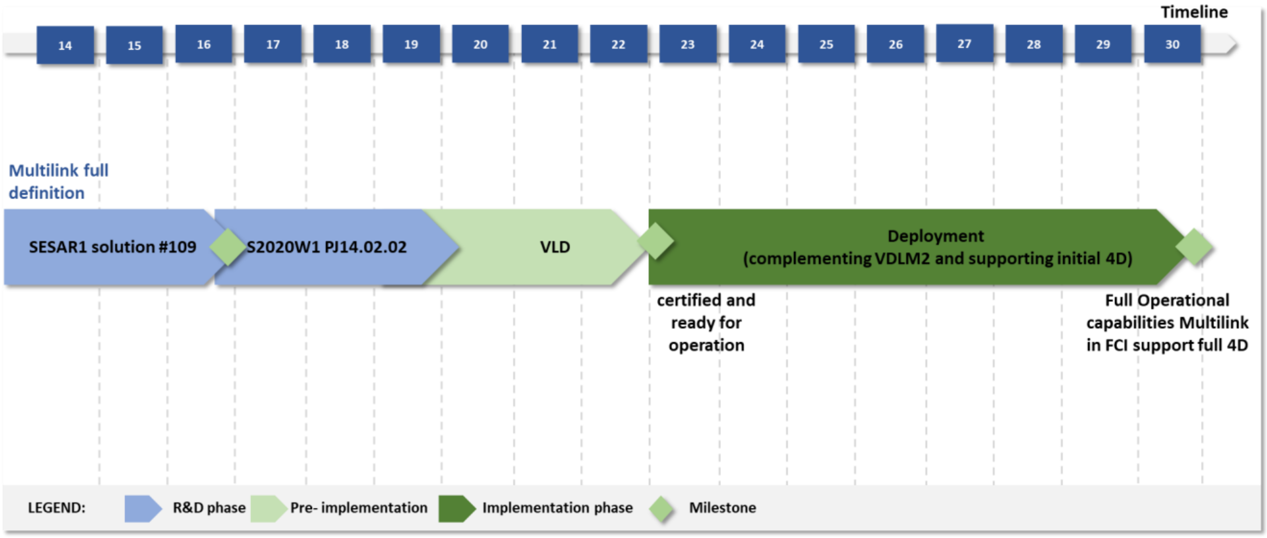

Figure 12 – Multilink full definition

5. Incentives

This chapter provides an overview of the financial, operational and industrialisation mechanisms that can be adopted for both ground and airborne implementation domains.

The following sections are focused on the **airborne domain**, while for the **ground domain** deployment, it is worth mentioning that the existing financial/incentive mechanisms could be adopted as already successfully done in the past (e.g. CEF Framework).

5.1. Financial mechanisms

Considering that by end of 2026 there will be approximately 8.000 aircraft, 1.600 aircraft will have to be equipped with FANS C / B2 technology to reach the 20% as requested by IR 716/2014.

As explained before, according to Airbus' plans and EU composition fleet provided by NM, by end of 2026, 2.155 new aircraft flying in EU would be equipped (forward fit). In order to reach a higher percentage of aircraft equipped, financial mechanisms should be envisaged. Per Article 7 of the CEF Regulation (EU) 1316/2013 of 11th December 2013, ADS-C is eligible for support through EU financial assistance.

This support can be provided in the form of grants or other financial instruments, but it is clear that grants are expected to be the primary source of funding and financial instruments will only be a complementary source and are not expected to substitute the grants. As highlighted under Article 14.2, the Union contribution to the financial instruments "shall not exceed 10% of the overall envelope of the CEF". Article 15.4 also indicates that "financial instruments may be combined with grants funded by the European Union".

On the basis of such financial assistance made available for ADS-C under the current (and supposedly future) CEF Regulation, airlines retro-fitting their fleet could apply for future grants launched by INEA. To prevent the inconvenience that the late movers would become recipients of the grants, a specific funding scheme should be worked out in advance to allow first movers to finance their investment.

Possible complementary financing schemes could be derived from the studies developed in 2017 when, in cooperation with the European Investment Bank (EIB), SDM investigated other mechanisms for complementing grants. This analysis suggested that several characteristics might encourage airlines to seek opportunities in financial mechanisms:

- Airborne components being eligible to a limited funding percentage (currently 20%, possibly 50% in the future CEF2), a complementary financing mechanism aiming at providing an overall 100% project financing would likely raise their interest.
- Airlines being subject to wait for ground investments to be achieved before getting benefits from airborne equipage, an innovative financing with postponed reimbursement profiles could do the bridge between investment and operational benefits (when ground investments are achieved).

Financial instruments, if properly designed, could deliver several advantages to airlines: lowest possible interest rates, 100% project financing (possibly off-balance sheet) and tailor-made reimbursement schemes that are critical for their operations.

Even with regard to the proposed CP1 forward fitting mandate, ADS-C equipage should also be supported by financial mechanisms to ensure a large proportion of the fleet is equipped within the shortest timeframe.

Because EIB's internal guidance currently limits individual loans to single borrowers to a minimum of €25M, covering 50% of the investment, with a preference for larger tickets, the minimum size would be reached when clustering projects into one single action for a total investment cost of approximately €50 M. This is one of the first challenge to be met. It requires to bundle many carriers with different credit ratings, each of them retrofitting enough aircraft to result into an investment in the range of €50M corresponding to around 500 aircraft.

The past schemes discussed with EIB, were promoting a straightforward structure, with EIB lending to an intermediary bank, which itself would be spreading the total loan across airlines:

- Up to 20% of the action through grants;
- Up to 50% of the action through a loan from EIB to a private bank, acting as an intermediary between EIB and the action's beneficiaries;
- Balance of around 30% private loan to complement financing of the action in order to reach 100% financing through the intermediary bank;
- Duration required to bridge the time gap between ground and airborne functionalities.

This scheme should later be adapted to the future CEF2 regulation where the funding rate for airborne equipage could possibly be increased from 20% to 50%.

In conclusion, this scheme could be worked out in anticipation of a future CEF Call, though it is subject to several challenges:

- Reaching a critical mass in time, requiring that a sufficient number of airlines demonstrate their interest early enough (past experience has shown that the interest from the airlines is not guaranteed);
- Working out the detailed contents of the financing schemes in time for the signature of agreements.

5.2. Operational Benefits and Proposed Incentives

Solutions supporting TBO as well as complementary COM technologies may be considered as pillars of a high performing and sustainable ATM.

Therefore, airlines investing and equipping their fleet with such new features should be considered as *Best Equipped*, and then could be eligible for a more efficient ATC service.

The respective immediate **operational benefits** resulting from the equipage itself, are the following:

- Optimised flight trajectories which result in a lower fuel consumption as well as less emissions;
- Less voice communication needed due to automated air-ground data exchange;
- Less and more precise tactical interventions by ATCOs (e.g. descent clearance aligned with aircraft's calculated TOD);
- Higher flight efficiency due to an optimized overall flow management including connection to extended AMAN systems.

Noteworthy, in this regard, is that the full operational potential will be reached once a major amount of aircraft is equipped with the ADS-C/EPP capability.

In order to catalyse this process, ATFM **operational incentives** for early movers should be seen under the best equipped, best served policy. In this regard ATFM operational incentives (access to particular routes, prioritisation), among others, can help to accelerate the equipage process by providing short-term benefits to early adopters. It shall be noted that the availability of ADS-C/EPP data opens a long list of options to further improve ATC and its systems/applications. The ones mentioned in this document explicitly are only considered to be the quick wins.

5.3. Industrialisation mechanisms

As described in the figure below, SESAR R&D and Deployment are a continuous process, involving all civil and military stakeholders, the manufacturing industry, which has a crucial role to play, as well as the standardisation organizations.

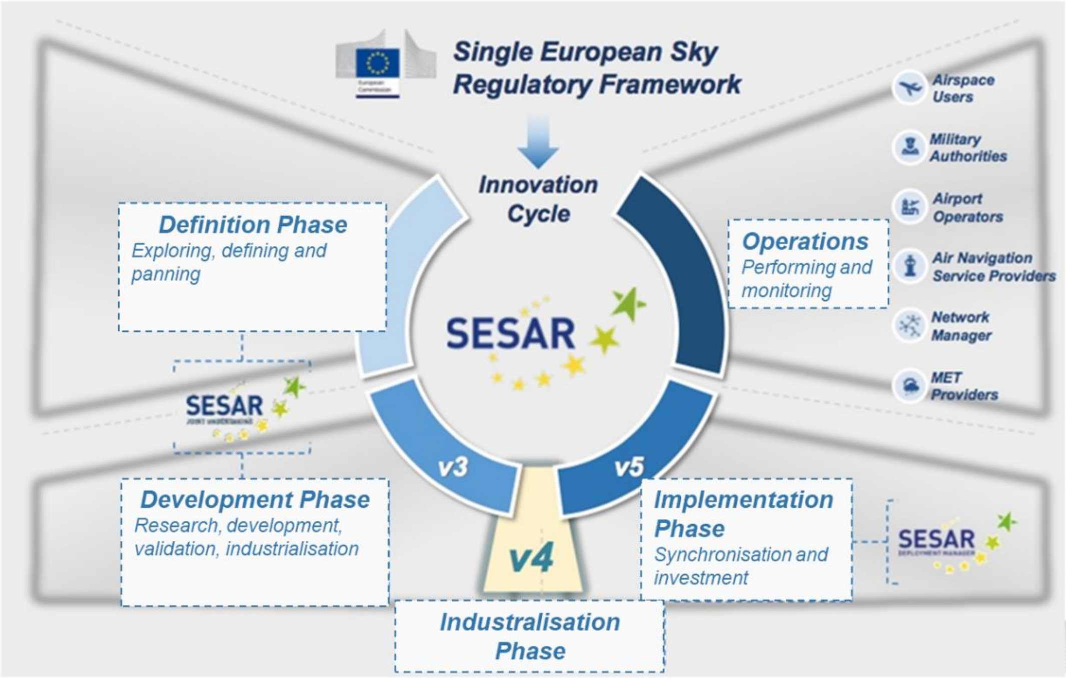

Figure 13 – R&D, Industrialisation and implementation phases overview

Assessing the maturity of technical solutions and the availability of standards is crucial, especially the ones necessary to support sub-functionalities of ADS-C implementation. To succeed at improving V4 and reducing potential gaps, it is essential to develop close synergies between R&D and Deployment in order to:

- Allow very large-scale demonstration (VLD) into operational environment;
- Stimulate industry buy-in;
- Facilitate standardisation;
- Provide an appropriate regulatory framework.

To achieve this, it is needed to:

- Establish a mechanism to support the manufacturing industry and interact with standardisation bodies within the European ATM Standardisation Coordination Group, which has released the rolling standardisation roadmap primarily involving EUROCAE, EUROCONTROL, ETSI and observers such as SDM;
- Implement a strong programme management taking on board the local development phases to better synchronise and to facilitate the deployment.

This strong programme management should take care of the implementation soon after R&D and VLD while considering also real system developments (pre-deployment) and not only prototypes.

6. Technical & operational integrated roadmap

This chapter aims at providing a general and integrated overview of all the technical and regulatory elements needed for the trajectory-based operation, in order to support the development of a modern and sustainable ATM system. In fact, the trajectory-based operation (TBO) is becoming crucial since its implementation will provide several benefits, like the increase of flight predictability, the reduction of time buffers among flights, the optimisation of overall ATM system capacity and resources.

In this context, considering the key elements described in the previous chapters, the following integrated roadmap includes the ADS-C/EPP implementation supporting TBO.

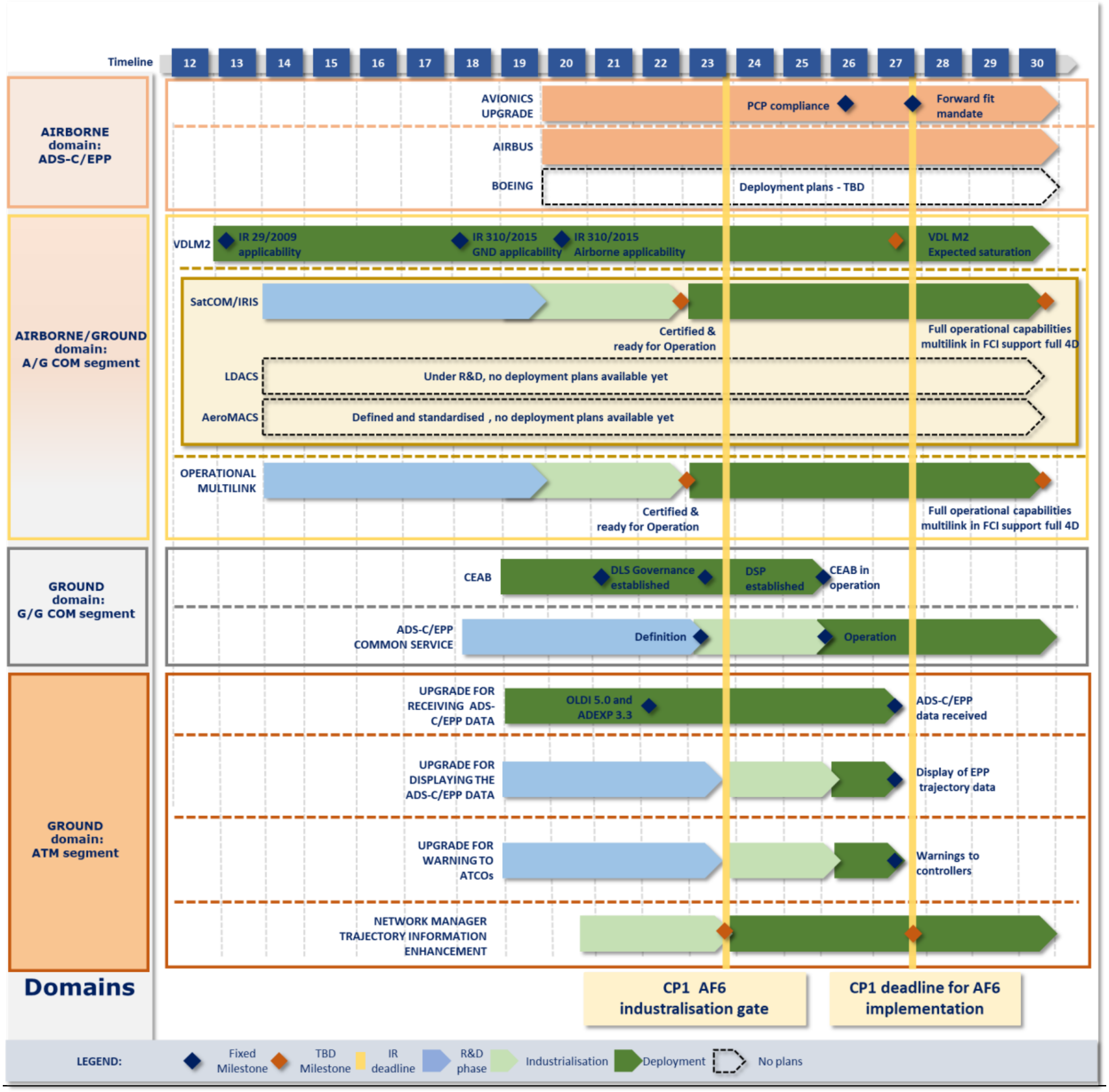

Figure 14 – Integrated roadmap

Considering the PCP and CP1 proposal deadlines, the integrated roadmap analysis has been focused on each domain as follows:

- The PCP envisages at least the 20% of equipped aircraft, corresponding to 45% of the equipped flights; compliance to the IR is expected by 2026 and the new CP1 proposal addresses all new aircraft with an individual certificate of airworthiness first issued on or after 31st December 2027;

- Currently only Airbus has provided plans for the deployment in most of their products. Boeing, the other major aircraft manufacturer, has not provided any plans for ADS-C/EPP deployment before 2030. This might limit the operational use of ADS-C/EPP data before that date.

AIRBORNE/GROUND domain: A/G COM segment

- Initially, the ADS-C/EPP service can be supported by the current DL system based on VDL M2 technology. However, the current VDL M2 system has several limitations that cannot be solved. At the moment, initial VDL M2 system capacity issues are expected to appear from 2027 onwards[7]. Thus, when the number of aircraft equipped with DLS (including ADS-C/EPP) is growing over the coming years, it will become necessary to support these limits with the following complementary technologies:
    - **SatCOM** is considered the most mature technology that could be implemented first, even if its validation process is expected to be completed by 2022. On the same date the deployment is expected to start.
    - **LDACs** is considered to be ready for deployment from 2027 onwards; i.e. it will contribute in the long term in view of the PCP or CP1 compliance.
    - **AeroMACs** is considered mature for implementation although the stakeholders have not shown a particular interest in its deployment until now.
- Regarding the use of the complementary technologies (multilink operation), currently a definition is needed by when the related CONOPS together with the validation and integration for AUs and ANSPs will be available. A lack of an agreed and available multilink operational concept might seriously limit the options to introduce the complementary technologies which are becoming essential as from around 2030.

GROUND domain: G/G COM segment

- Regarding the CEAB is expected to be in operation in 2025, according to the PSA SGA5 "D11.1.1 - Report on DLS Architecture and Deployment Strategy".
- Regarding the ADS-C/EPP Common Service:
    - The system architecture is still under definition and a validation process is planned (SJU - PJ38), although there is a general consensus among ANSPs that the Common Service is the right way to deploy ADS-C/EPP at large scale. An overall European architecture shall be "endorsed" in due time in order to assess the AF6 maturity gate (December 2023).
    - It is needed to investigate the options to realise the ADS-C/EPP Common Service, via known service providers or a public tender, with a start of the industrialisation as soon as possible, after the validation completion, which is expected in 2022.
    - It is expected to be in operation in due time by 2025.

GROUND domain: ATM segment

Regarding the ATM segment (upgrade for receiving ADS-C/EPP data, upgrade for displaying the ADS-C/EPP data, upgrade for alerting the ATCOs when TP divert and NM trajectory information enhancement):

- The validation and industrialisation activities are still ongoing.
- The buffer time among operation phase and CP1 proposal compliance is very low.

[7] DLS Capacity Assessment study (CAs)

- Regarding the NM trajectory information enhancement, NM stated that the validation of EPP data for update of trajectory has not been done and it is rather difficult to contemplate any action especially from NM side. In addition, it should be clear that for NM, no roadmap can be developed until the full-scale validation is completed. Currently, NM cannot guess what elements of EPP can be used, what inputs have been taken when EPP is created (measures, restrictions, airspace availability) as some of these downloaded trajectories might not improve the NM trajectory data.

7. Way forward and recommendations

Based on the context and analysis described in the previous chapters, this summary contains a list of concrete actions being proposed from operational and strategical perspective, in order to ensure a synchronised and successful deployment of AF6 according to the PCP and its evolution.

A synchronised deployment on ground and airborne domains is key to ensure operational benefits, justifying future investments and preventing potential fragmentation as occurred during ATN B1 services deployment.

For clarity purpose, the recommendations have been structured into general recommendations and specific recommendations per domain (as defined in chapter 6).

The analysis performed in the current document, including the recommendations, have to be considered as first/main input for next steps of the ADS-C/EPP deployment, that should be managed according to project management rules. Within this framework, also the associated risks should be identified and mitigated.

GENERAL RECOMMENDATIONS TO EC

1. It is recommended to mandate a Body involving relevant civil and military stakeholders (Programme Manager) to be able to address effectively all datalink stakeholders and operational actors to ensure acceptable TBO operations, considering all relevant enablers such as EPP in a coherent manner.
2. It is recommended to establish financial support for the implementation of the related TBO elements (e.g. Airborne systems, CEAB, ADS-C/EPP Common Service, Complementary Technologies, etc.)
3. It is recommended to monitor the impact of the COVID-19 crisis in the overall roadmap through future editions of this document.

Specific recommendations per domain:

DOMAIN	RECOMMENDATIONS
AIRBORNE domain: ADS-C/EPP	**4.** It is recommended to accelerate the airborne implementation of ADS-C/EPP: **4.1** In order to achieve the original PCP requirements of 20% by 2026 of equipped aircraft, some AUs will have to retrofit aircraft. **4.2** The CP1 proposal includes a forward fit mandate from 2028 onwards which does not require retrofitting. However, it is recommended to AUs to retrofit aircraft in order to accelerate the benefits. **5.** To achieve the CP1 proposal forward fit mandate, it is recommended that the manufacturing industry moves towards an early development of avionics, in order to ensure that CP1 performance requirements are met by December 2027.
AIRBORNE/GROUND domain: A/G COM segment	**6.** It is recommended that the programme manager coordinates the timely introduction of mature complementary technologies as identified in the EU ATM Master Plan, supporting the aviation Spectrum Strategy to complement VDL M2 system when needed. More details can be found in the SDM D11.1.1 “Report on DLS Architecture and Deployment Strategy”’. **7.** Regarding SatCOM, it is recommended to the programme manager:

7.1. To monitor the current plans of the potential SatCOM options and follow their maturity.

7.2. To analyse the percentage of the SatCOM equipped aircraft required to alleviate the VDL M2 system.

7.3. To work on the Business Case to support SatCOM implementation in order to provide the necessary information to stakeholders.

7.4. To constantly monitor the deployment phase in order to ensure SatCOM will support offloading the VDL M2 system effectively.

8. It is recommended to the programme manager to follow LDACs evolution roadmap as the long-term A/G terrestrial datalink to support Data Link Services in general and ADS-C/EPP in particular, and start developing a deployment proposal for a harmonised approach for discussion with stakeholders.

9. Regarding data communication with Aircraft on Ground:

9.1. Regarding AeroMACs, which is already standardised and ready for implementation, it is recommended that the programme manager supports the stakeholders interested in its implementation, when required, given its capability to support safety-critical ATS communications.

9.2. Regarding 3G/4G/5G and WiFi networks[8], it is recommended to AUs to consider these technologies in order to relieve VDL M2 from non-safety critical communication load exchanged with aircraft while on ground.

10. Regarding the multilink concept:

10.1. It is recommended to the programme manager to monitor the ongoing work for multilink definition identifying the dependencies between the existing and the new communication technologies in order to prevent potential operational and technical issues when implemented.

10.2. It is recommended to the programme manager to produce multilink CONOPS for AUs and ANSPs, while considering the existing proposals and coordinating with all operational stakeholders.

GROUND domain: G/G COM segment

11. Regarding the Common European ATN Backbone (CEAB), it is recommended to the programme manager to monitor and facilitate its deployment process in line with the SDM D11.1.1 "Report on DLS Architecture and Deployment Strategy". This ensures seamless airborne ADS-C/EPP data exchange with ANSPs without adding additional equipment in ANSPs premises.

12. Regarding the ADS-C/EPP Common Service, it is recommended to the programme manager to monitor the ongoing R&D activities and the planned

[8] Regarding 3G/4G/5G and WiFi networks, AUs are already today investing into these technologies in order to relieve VDL M2 from non-safety critical communication load exchanged with aircraft while on ground. It is recommended to consider expanding the use of alternate links to further systems and data and to airlines and fleets where not widely used yet.

industrialisation phases, in order to assess the AF6 maturity gate of the CP1 proposal (December 2023).

GROUND domain: ATM segment

13. Regarding the ATM segment in line with the CP1 proposal (upgrade for receiving ADS-C/EPP data, upgrade for displaying ADS-C/EPP data, upgrade for alerting ATCOs when TP divert and NM trajectory information enhancement), it is recommended to:

13.1 The programme manager to monitor the validation and industrialisation phases that might impact the overall planning, considering the AF6 maturity gate (December 2023).

13.2 The programme manager to ensure the implementation of the AF6 based on the outcomes of SESAR2020 PJ31 & PJ38 closely following the conclusions of the dedicated VLDs.

13.3 SJU to accept and execute the validation proposal made by NM regarding the use of EPP, considering also the operational benefits. Finally, it is recommended that the programme manager monitors the validation process for the use of the EPP data by NM to enhance the trajectory information (Sub AF6.2) in order to assess the maturity gate (December 2023) of the CP1.

Glossary

Initial	Acronym	Description
3		
	3G	3rd Generation Cellular Networks Standard Technology
4		
	4D	Four-Dimensional, x, y, z and time
	4G	4th Generation Cellular Networks Standard Technology (LTE)
5		
	5G	5th Generation Cellular Networks Standard Technology
A		
	ACC	Area Control Centre
	ACR	Aircraft Server
	ACSP	Aeronautical Communication Service Provider
	ADEXP	ATS Data Exchange Presentation
	ADS	Automatic Dependent Surveillance
	ADSC	Automatic Dependent Surveillance Contract
	AES	Aircraft Earth Station
	AF	ATM Functionality
	AMAN	Arrival Manager
	ANSP	Air Navigation Service Provider
	AOC	Airline Operating Centre
	APNT	Alternative Position Navigation and Timing
	ATC	Air Traffic Control
	ATCO	Air Traffic Controllers
	ATFCM	Air Traffic Flow and Capacity Management
	ATM	Air Traffic Management
	ATN	Aeronautical Telecommunications Network
	ATS	Air Traffic Service
	ATS B2	ATN Services Baseline 2
	ATSU	Air Traffic Service Unit
	AU	Airspace User
B		
	B1	Baseline 1
	B2	Baseline 2
C		
	C2	Command & Control
	CA	Conflict Alert
	CCO	Continuous Climb Operation
	CD	Compact Disk
	CDO	Continuous Descent Operation
	CEAB	Common European ATN Backbone
	CEF	Connecting Europe Facility
	CM	Context Management
	CMF	Communications Management Function
	CMU	Communications Management Unit
	CNS	Communications, Navigation and Surveillance System
	COM	Communications
	COMM	Communications
	CONOPS	Concept of Operations
	COOPANS	European ANSP Cooperation Partnership
	COVID	Coronavirus Disease
	CP1	Common Project 1
	CPDLC	Controller Pilot Data Link Communications

Initial	Acronym	Description
	CTA	Calculated Time of Arrival
	CWP	Controller Working Position
D		
	D11	DLS Architecture and Deployment Strategy Document (11)
	DCB	Demand and Capacity Balance
	DCL	Departure Clearance
	DFS	Deutsche Flugsicherung GmbH
	DL	Data Link
	DLC	Data Link Communication
	DLS	Data Link Service
	DMAN	Departure Manager
	DME	Distance Measuring Equipment
	DSP	Data Link Service Provider
E		
	EASA	European Union Aviation Safety Agency
	EASCG	European ATM Standards Coordination Group
	EC	Executive Controller or European Commission/Community
	ECAC	European Civil Aviation Conference
	EIB	European Investment Bank
	ENAV	Società Nazionale per l'Assistenza al Volo (Italian ANSP)
	EPP	Extended Projected Profile
	ESA	European Space Agency
	ETA	Estimated Time of Arrival
	EU	European Union
	EUR	European Region
	EUROCAE	European Organization for Civil Aviation Electronics (regulatory agency for certifying aviation electronics in Europe)
	EUROCONTROL	European Organisation for the Safety of Air Navigation
F		
	FAA	Federal Aviation Authority
	FANS	Future Air Navigation System
	FCI	Future Communication Infrastructure
	FDP	Flight Data Processing
	FF	Flight and Flow
	FL	Flight Level
	FMS	Flight Management System
	FO	Flight Object
	FOMAX	Flight Operations and MAintenance eXchanger (Collins 3G/4G AOC product)
G		
	GBAS	Ground Based Augmentation System
	GNSS	Global Navigation Satellite System
H		
	HMI	Human Machine Interface
I		
	ICAO	International Civil Aviation Organisation
	ICE	Information for Collaborative Environment
	INEA	Innovation and Networks Executive Agency
	IOC	Initial Operational Capability
	IP	Internet Protocol
	IP1	Implementation Project 1
	IPS	Internet Protocol Suite
	IR	Implementing Rule

Initial	Acronym	Description
L		
	LAN	Local Area Network
	LDACS	L-Band Digital Aeronautical Communication System
	LOF	Logon Forward message (OLDI)
M		
	M2	Mode 2
	MHz	Megahertz
	MP	Measurement Plan
	MUAC	Maastricht Upper Area Control
N		
	NATS	National Air Traffic Services
	NM	Nautical Mile
O		
	OLDI	On-Line Data Interchange
	OSI	Open Systems Interconnection
P		
	PCP	Pilot Common Project
	PJ	Project
	PLN	Plan
R		
	RAD	Route Availability Data
	RPAS	Remotely Piloted Air Systems
S		
	SARPS	Standard and Recommended Practices (ICAO)
	SatCOM	Satellite Communication
	SDM	SESAR Deployment Manager
	SES	Single European Sky
	SESAR	Single European Sky Area Responsibility
	SJU	SESAR Joint Undertaking
	STAM	Short Term ATFCM Measures
	SWIM	System Wide Information Management
T		
	TBC	To Be Completed/Confirmed
	TBO	Trajectory Based Operations
	TMA	Terminal Manoeuvring Area
	TOD	Top of Descent
	TP	Trajectory Prediction
	TTA	Target Time of Arrival
U		
	US	United States
V		
	VDL	Very-High Frequency Digital Link
	VDL M2	Very-High Frequency Digital Link – Mode 2
	VHF	Very High Frequency
	VLD/VLSD	Very Large-Scale Demonstration