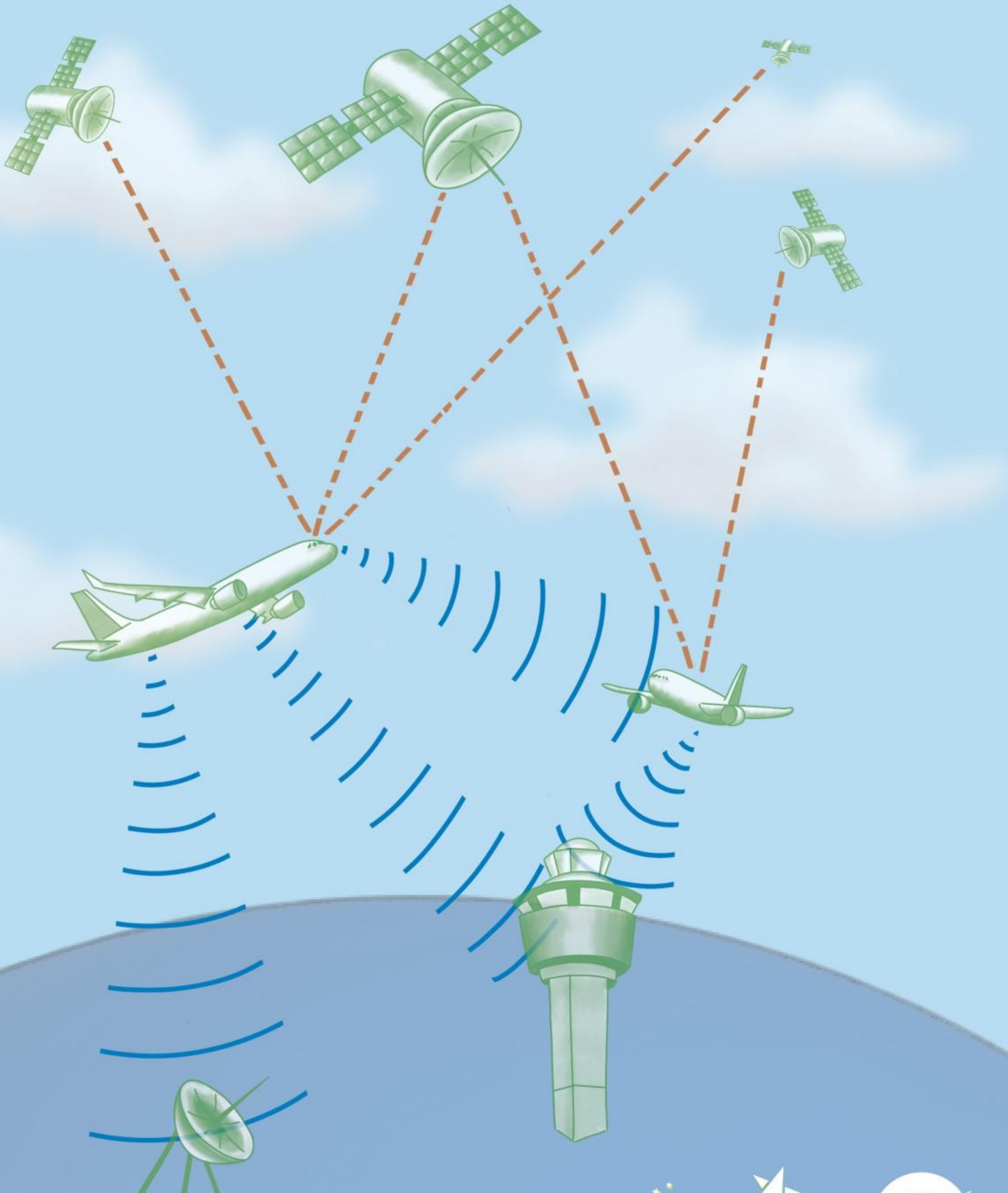
ADS-B Ground Implementation and Best Practices

based on ANSP interviews



SESAR DEPLOYMENT MANAGER

EUROCONTROL

ADS-B Ground Implementation and Best Practices based on ANSP interviews

Control

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1. Introduction

On request by the European Commission, SESAR Deployment Manager, with the support of EUROCONTROL, has coordinated and monitored the planning and implementation of ADS-B in EU since 2018. Following an intensive implementation campaign undertaken by air operators, by spring 2021 the fitment rate reached 85%.

In order to safeguard harmonized and coordinated deployment, in 2021 SESAR Deployment Manager oriented the monitoring focus on the ANS provider domain, in the form of a series of targeted virtual visits and interviews with a number of ANSP that showed to have accomplished substantive progress in the implementation of ADS-B as an ATC surveillance technology.

This document presents the consolidated findings of these virtual visits and is made available for the benefit of service providers, air operators and other stakeholders. It provides an overview of the main lessons gathered and the best practices encountered with the aim of further stimulate a broader adoption of ADS-B and foster a deeper and broader collaboration among ANS providers in this important endeavour.

SESAR Deployment Manager expresses its appreciation and gratitude to the ANS providers who collaborated on the production of this document, in spite of the hardships and resourcing shortages due to the COVID- 19 pandemic crisis on the entire aviation sector throughout 2020 and 2021. As part of the campaign, an assessment of the effect of the crisis on the concerned providers has been performed and the results report that despite the lasting effects of the crisis, the commitment among ANSPs to implement ADS-B remains strong.

1.1. Air Navigation Service Providers interviewed

SDM limited the scope of this exercise to the following six ANSPs, selected based on their known status from previous surveys and their ability to support the interviews.

- Austro Control GmbH is the Austrian Air Navigation Service Provider. Austro Control provides ANS services in controlled airspace over most of Austria, including approach and tower ATS.
- Avinor Air Navigation Services AS provides air traffic services in Norwegian airspace including aerodrome control and approach control services at airports. The Norwegian airspace includes two FIRs: ENOR – Polaris in ICAO EUR and ENOB - Bodø in ICAO NAT.
- Deutsche Flugsicherung GmbH (DFS) is the German Air Navigation Service Provider. DFS provides ANS services in controlled airspace over most of Germany, including approach and tower ATS.
- ENAIRE, a public enterprise under the Spanish Ministry of Transport, Mobility and the Urban Agenda, is the principal air navigation services provider in Spain. ENAIRE provides ANS services in controlled en-route airspace, approach and most of the tower ATS in Spain.
- Malta Air Traffic Services (MATS) is the Air Navigation Service Provider for the Maltese islands and Malta’s FIR (LMMM). LMMM is 600NM long and 130 NM wide, and with the exception for the Maltese islands, the FIR is entirely over the sea.
- NAV Portugal provides ATC services in Lisboa FIR under ICAO EUR including the Madeira archipelago and its connecting corridor, and in the ICAO NAT oceanic FIR of Santa Maria over Azores in the middle of the Atlantic Ocean.

2. Drivers and approach

The following chapters are based on exchanges with six EU-based ANSPs who have pioneered the implementation of ADS-B in their airspace.

2.1. Drivers for ADS-B use

ANSPs were asked what the main drivers were for them to implement ADS-B. The following reasoning was recorded:

- Surveillance performance
  - Improved robustness of surveillance service (single radar environment)
  - Reduction of RF environment load / passive target acquisition
  - Additional surveillance layer, featuring higher update rate and accuracy for aircraft position tracking, where it is operationally required, such as NTZ in parallel runway approaches (in addition to WAM and/or radar)
- Economic benefits
  - CAPEX lower infrastructure cost for extended coverage or avoidance of replacement of end-of-life radars
  - Reduced OPEX thanks to less complex surveillance systems (hardware, maintenance)
- Extend surveillance coverage
  - Coverage in areas difficult to be covered by radar (low altitude areas, remote/oceanic airspace, terrain-complex areas)
  - Better surveillance beyond AOR
  - Reduce dependencies from other surveillance data providers
- Improve services: Air Traffic Control service, Flight Information Service, and Search And Rescue
  - Increased capacity, robustness (leading into less reroutes/interventions)
  - Radar-like surveillance for specific applications (such as low-level helicopter ops)
  - Availability of on-board data (e.g. Selected Altitude/FSSA)

An additional ADS-B implementation benefit reported was that ADS-B enhances the situational awareness of both AFIS personnel and of pilots, if equipped with ADS-B In, translating into benefits in terms of safety and quality of the flight information service.

The interviews also revealed that the ATC competency for procedural control has been largely phased out of ANSPs training manuals; this resulted in a measurable net benefit in terms of staff and training costs.

2.2. Implementation Approach

ADS-B integration in ANSP's surveillance chains is a complex undertaking due to the specificities of the technology, the existing surveillance infrastructure, the operational service and the local environment. To address the complexity and mitigate implementation risks, all interviewed ANSPs approached their ADS-B implementation in iterative steps, taking into account the availability of the different kinds of operational benefits. The detailed approaches per ANSP interviewed are further described in the respective annex.

Some observed high-level integration aspects are reflected in this section.

It is common that the ANSPs deploy ADS-B in separate parts of their Area Of Responsibility in regional clusters with independent or sequential roll-out timelines. Resulting in phased implementation, where smaller operational implementations are upscaled and/or expanded as experience grows. For example:

- small-scale FIS in a few isolated areas, at low altitudes and specific traffic operations, followed by upgrade to ATC service, then extension to more areas with specific operations and finally ATC provision in full FIR including en-route.
- En-route implementation using existing ADS-B capable sensors in complementarity to conventional surveillance, deriving some immediate benefits while gathering operational experience with ADS-B specifics, afterwards expansion of ADS-B en-route coverage constituting a contiguous layer and finally extension of ADS-B coverage downwards into all controlled airspace.

Thorough validation before large scale operational deployment performed in one or several steps. For example:

- A thorough technical evaluation campaign, investigating all and any facets and particularities before finalising the integration plan, potentially supported by defined benefit mechanisms but not crucial to the provision of the ATC service at this given point. The intention seems to be to ensure that ADS-B stands out as a reliable alternative to conventional surveillance, considering both its strengths and limitations, in support of key decisions with regards to the national surveillance strategy.
- Particular attention is being paid to the assurance of CNS service provision responsibility which with GPS dependency no longer reside fully under the control of the ANSP. It was observed that this discussion is often elevated at a national level and some ANSPs reported to be awaiting a specific authorization from the national authority to use ADS-B for ATC surveillance.

3. Operational considerations

3.1. Operational environments and use-cases

In terms of the operating environment in which ANSPs deploy ADS-B for surveillance, a number of distinct operational contexts emerged during the visits.

- **High-density continental En-route airspace and TMAs** characterised by typical 3 or 5 NM separation minima, robust and independent CNS (including full independent cooperative surveillance) and dominated by commercial operations with a high ADS-B V2 equipage rate
- **Low-density continental En-route airspace** characterised by typical 5 or 10 NM separation minima, CNS with lower redundancy, dominated by commercial operations with a high ADS-B V2 equipage rate and military operations present
- **Low-density low-altitude and Terminal airspace** (e.g. TMA, TIA) characterized by partial dependence on procedural control due to lacking surveillance and/or adequate communications, presenting a mix of commercial operations with a high ADS-B V2 equipage rate and General Aviation aircraft with lower ADS-B equipage rate1
- **Oceanic airspace** characterised by the use of procedural control based on FANS 1/A (ADS-C and CPDLC) or voice reports for positioning and dominated by commercial operations with a high ADS-B V2 equipage rate

In terms of how ANSPs intend to use ADS-B, it was found that ANSPs tend to pursue multiple benefit mechanisms simultaneously

- Some visited ANSPs use ADS-B operationally in several different ways depending on the part of the airspace. Example of operational implementations include:
  - ADS-B as the sole means for ATC service (including separation provision) in some low altitude areas with specific traffic operations
  - ADS-B as a complement surveillance layer (in addition to WAM and/or radar) for ATC service. ADS-B fulfils the role of a third layer in most of the FIR and a second layer in some remote areas of the FIR
  - ADS-B for the provision of FIS in low altitude uncontrolled airspace and in oceanic FIR
  - Complementing surveillance infrastructure as an additional layer to provide ATC service in continental airspace and improving the surveillance service
  - Provision of ATC service (including separation provision) where no radar or WAM coverage is feasible in remote areas
  - Implementing ADS-B-based surveillance service to enhance or replace ADS-C and voice based procedures towards a reduction of separation minima (ASEPS)

- For use in ATC Separation, ADS-B is required to meet at least the same performance level as existing cooperative independent surveillance systems. Where the performances of ADS-B are not met, due to e.g. potential lower quality parameters or lower probability of update in far distance of the sensor, then ADS-B is considered for services other than ATC such as FIS, SAR or situational awareness.

3.2. Use of Aircraft Derived Data available from ADS-B

[1] Very low V2 equipage rate + some V0 equipped aircraft

Apart from aircraft identity and 3D position information, ADS-B transmits certain onboard parameters also called Aircraft Derived Data (ADD) to ATC. When asked whether they have investigated this data source, some ANSPs reported the use or intent to use ADD provided by ADS-B (in particular FSSA), in which case it is important to ensure that the sensor system is capable to output ADS-B based ADDs

Note that although Version 2 of the ADS-B transponder has the required capability, it will not automatically output all the parameters which are otherwise provided by Mode S EHS. For instance, Indicated Airspeed/Mach Number is only transmitted in non-nominal cases when substituted for an unavailable Airborne Ground speed. Track and Roll Angle cannot be provided by ADS-B V2.

3.3. Depiction of aircraft ADS-B capability in the CWP

The question of whether ADS-B capability should be conveyed to the ATCO was one that made a frequent appearance in the visits. The reported drivers were:

- Informing the ATCO that the aircraft will/will not remain displayed when transiting from multi sensor coverage into ADS-B only coverage, and consequently different procedures may need to be applied
- Building operational experience with ADS-B as a new dependent source of surveillance data. When sufficient experience has been gained, the distinction of ADS-B aircraft could be reassessed.
- Allowing the ATCO to assess situations where ADS-B target reports result in incorrect tracking behaviour (track at incorrect position due to bad position reports).

To achieve this objective, two methods were reported by ANSPs:

- Symbol convention (applying different symbols based on the origin of the track)
- Surveillance capability information as per Item 10b of the filed flight plan

Note: Flight planned information should be used with caution as the experience shows that the field 10b is not always properly filled. Moreover, the current flight plan indications do not support identification of ADS-B version, for which enhancements are in progress.

4. Technical considerations

4.1. Cooperation with neighbour States

Extensive FAB and other cross-border cooperation on ADS-B was identified, in some cases even bridging into non-EU territory. Some concrete examples were:

- Cross-border sharing of surveillance data
- Using a neighbour state site to install an own sensor
- Cooperation on the deployment of a sensor with a neighbour state ANSP
- Cooperation on technical issues and solutions
- In some cases, the national authorities have a FAB-level agreement on audit procedures

Note: The 2020/587 amendment of SPI IR simplified the data sharing agreement template. It was noted that many local cooperative agreements anticipated this development.

4.2. Sensor selection

Terrestrial ADS-B sensors are generally deployed either as standalone ADS-B stations, integrated with multilateration/WAM systems or integrated – to a variable degree – with a Mode S secondary radar. Here are the key features that set the sensor forms apart in the ANSPs decisions:

- ADS-B provided by WAM accounts for the largest number of ADS-B sensors in the EU continental context; this sensor type offers two surveillance techniques simultaneously, enabling an additional surveillance layer, and if specified accordingly, the WAM central processor will usually act as an ADS-B server.

- Standalone ADS-B sensor systems are a cost and spectrum efficient option especially where siting options are scarce, e.g. due terrain. Directional antennas may be used where there is a need to further improve the range in a specific direction.

- The ADS-B station may be collocated and functionally, to a varying degree, integrated with a Mode S secondary radar. ANSPs who are experimenting with this setup reported that the technology was evolving asymmetrically due the lack of specification. This issue will be solved with the new EUROCONTROL Specification for Mode S stations (EMS) edition 4.0 released in 2021, that includes a full integration of the ADS-B technology for several uses as the passive acquisition (function that allows to decrease the Mode S all-call interrogations and therefore improve the use of the 1030/1090 MHz frequency band). Prior to this specification, some pioneering ANSPs were experimenting with a proto passive acquisition function and some were planning as well to utilize some of the ADD parameters from the ADS-B data stream to avoid the Mode S long call interrogations for the respective equivalent registers. Both these functions will help to reduce the spectrum use.

4.3. Surveillance Tracker

All visited ANSPs employ surveillance trackers in their surveillance chains. The primary purpose of a tracker is to collate the various inputs coming from individual sensor types and sites and use them to build an unambiguous, contiguous and consistent track for each target. The recent emergence of ADS-B among tracker inputs revealed new behaviours and risks; some of the ANSPs visited are investing substantial resources into adapting the tracker specifications and developing local parameter settings to make the best use of this new technology. Some of the key findings are reported below:

- The tracker will perceive ADS-B differently from the radar; the ADS-B (1090ES) sensor may be configured to output a much higher rate of update with both position and velocity reports coming in each at approximately 1s intervals; this compares to a position measurement each 4-8s from the typical radar.

  Consequently, ADS-B allows the tracker to discover a change of vector, such as turn or climb/descent, much faster than the radar would.

- The high update rate may cause ADS-B to dominate the track in an environment with multiple sensor types, and the tracker may need to apply different rules (balancing, weighting or delaying/timing) to the ADS-B data in different regions/airspaces. The potential large amount of data from ADS-B should also be considered in relation to the tracker performance and computational power.

- A method to filter out duplicate reports coming from multiple overlapping ADS-B sites is needed, either in the form of an ADS-B server placed between the sites and the tracker, or as a native tracker function.

- At the same time, the selected network architecture should be sufficiently robust, so that the failure of such an ADS-B server does not preclude sites from contributing data downstream.

- To safeguard contingency and robustness of the ATC service, ANSPs tend to operate two independent tracker chains, one primary and one fall-back. The ADS-B integration aspects will also have to be considered in the fall-back tracker, particularly for what concerns the ability of the tracker to apply different rules to the ADS-B data in different regions/airspaces.

- Trackers are often used to filter out low quality target reports/tracks; this is further explored in Section 4.5.

4.4. Space-based ADS-B

In the recent years, Space Based ADS-B (SBA) has established itself as an alternative or complement to ground-based surveillance. When asked to elaborate on their perception of Space Based ADS-B and contrast it with conventional terrestrial ADS-B, the ANSPs responded as follows:

- SBA changes the role of the ANSP from owning and operating an ADS-B system as an ATM/CNS provider, to instead purchasing an ADS-B data service from another CNS provider.

- ANSPs generally consider Space Based ADS-B a gap filler in remote or oceanic airspace as well as non-covered regions. Where there is adequate terrestrial coverage, Space Based ADS-B does not seem to attract interest.

- The visited ANSPs who opted for a cost-benefit assessment, reported that the business case is in many cases not positive, but that could change with recovering air traffic.

- Some ANSPs have Space Based ADS-B contracts for specific regions in place to support other services provided, such as FIS and SAR.

- None of the interviewed ANSPs had at the time been able to complete a pre-operational performance assessment with regards to their airspace.

4.5. Filtering of unreliable or incorrect ADS-B position data

Despite the substantial improvement in data quality obtained from the ADS-B Version 2 onboard transponder compared to earlier versions, ANSPs reported that some form of checking will need to be applied to the ADS-B data stream. In the conversations with ANSPs, two principal operational requirements emerged:

- ADS-B report with low or zero quality indicators
  - In ADS-B, surveillance performance is continually evaluated by the airborne position sensor and expressed for each individual report by means of so-called quality indicators, e.g. NIC for integrity, NAC for accuracy, for use by the downstream systems.
  - The use of ADS-B for ATC surveillance is a safety critical application and each ANSP will define their threshold values for the quality indicators in dependence to the service being provided; as a consequence, ADS-B reports not meeting that threshold will be filtered out and not be part of the track shown to the ATCO. In consequence, in an ADS-B only environment, no track would be shown.
  - The handling of this case depends on the intended use of the data and the local safety assessment. Multiple resolutions are possible at the sensor/pre-processor server/tracker level.

- ADS-B report coming from an aircraft with a known installation issue or suspected equipment failure
  - The majority of interviewed ANSPs reported to have plans to filter out such data based on the EUROCONTROL NPAL (Non-Performing ADS-B Aircraft List), which is coordinated with other similar mechanisms worldwide. Procedures to manage the integration of NPAL data into the tracker systems as well as reporting non-performing aircraft to EUROCONTROL are undergoing implementation by ANSPs. EUROCONTROL hosts regular NPAL meetings to discuss aircraft system issues among interested ANSPs.

Furthermore, ongoing work on tracker design considers ADS-B reports with acceptable quality indicators but position diverging from independent surveillance. If the sensors continue to diverge beyond a suitably chosen time limit, a detection and resolution of the ensuing divergence event is needed.

4.6. GNSS RFI monitoring and detection

All ANSPs expressed some degree of experience with GNSS signal interference, and in several cases, substantive effort has been invested by the ANSP and national authorities to establish an effective toolset of countermeasures. On the other hand, ANSPs reported no experience with intentional GNSS or ADS-B spoofing.

- There is a marked difference in the types of interference, depending on the identity of the interfering actor:
  - Low altitude interference is usually caused inadvertently by individuals utilizing GPS-jammers as Personal Privacy Devices – PPDs. This interference is usually – but not always – geographically limited to a zone spanning several kilometres at best, has limited reach height-wise and is transient in nature to the ATC.
  - High altitude interference is usually caused by a well provisioned entity with the explicit objective to disrupt or deny the use of GNSS in the area. This type of

interference is geographically vast – hundreds of kilometres in radius, persistent – can persist for weeks, months or even longer.

- Recently, counter-drone operations, including by law enforcement authorities, were observed to unintentionally affect ADS-B.

- Some ANSPs have developed advanced means to detect and mitigate RFI:
  - Example 1: The ANSP developed and implemented a complex technical solution to pick up, classify and alert an ongoing interference event; a system to detect and localize GNSS interference in a major TMA, based on simultaneous GPS SIS monitoring at multiple sites, and a nationwide network of receivers and interference detectors.
  - Example 2: The ANSP jointly with the national aviation authority and the frequency management authority, established a national coordination centre that provides an instantaneous SIS health picture to users. The ANSP conducted own field tests to evaluate the impact of RFI, and is further developing detection and classification methods jointly with national research institutes.
  - Both these ANSPs have made extensive use of ADS-B quality flags (NIC, NAC, NUC) to detect and classify an ongoing interference.
  - Example 3: The ANSP operates GNSS monitoring stations at airports and has engaged with the national authorities to promulgate a legal reform aimed at sales controls, ownership and operation of PPDs. The state will sponsor the reform at the ITU with the view of a global implementation.

ANSPs should aim to mitigate interference occurrences to the extent practicable, and duly report occurrences to own national authority.

Note: Of particular importance to ANSPs in this context is CIR 2020/469 of 14 February 2020 amending 2017/373, and specifically the following requirement:

ATS.OR.525 Information on the operational status of navigation services

(a)An air traffic services provider shall ensure that air traffic services units are kept currently and timely informed of the operational status of radio navigation services and visual aids essential for take-off, departure, approach and landing procedures within their area of responsibility, and of those radio navigation services and visual aids essential for surface movement.

(b)An air traffic services provider shall establish appropriate arrangements in accordance with point ATM/ANS.OR.B.005(f) of Annex III to ensure that information in point (a) of this point with regard to the GNSS services is provided.';

5. Other considerations

- Concerning operational approval, ANSPs looking to implement ADS-B should ensure that ADS-B is explicitly stated as part of their CNS certificate according to EU IR 2017/373 Appendix 1.

- Concerning military operations, it should be recognized that ADS-B in some cases may be in conflict with the military requirements on operational secrecy and security, and conversely the SPI IR mandate only covers a minor portion of military operations. On the basis of the information gathered during the visits, it is recommended that the military is consulted and as far as possible, involved in the implementation of ADS-B.

- Concerning general aviation, it was noted that all European ANSPs who participated in this survey, are concerned with the limited scope of the mandate, which effectively leaves out large portions of general aviation even when operating under IFR. As there is no visibility of a potential future mandate that would close the gap, ANSPs are encouraged to promote voluntary fitment locally, on the basis of the related benefits. It still remains an option for the state, in coordination with the ANSP, to issue a local mandate, as was observed during at least one of the visits.

- In discussion of expanding equipage to the unequipped light weight segment not ordinarily using ATS services, such as gliders, , it was noted that that there is a need to evaluate the impact from the additional RF load to be expected.

- Concerning the different generations of ADS-B MOPS editions/ADS-B Versions, and the respective population of transponders in operation:

    - V0 being the original legacy generation, V1 the interim update by RTCA, the currently mandated V2 which is intended as the mainstay version for the EU airspace, and the recently released new generation V3.

    - Several ANSPs were observed to not differentiate between ADS-B Versions. Others did however explicitly require V2, or made a definite statement that V2 is considered the baseline equipment.

    - V0 equipage level has reduced sharply over the recent few years and is now approaching 10% figure.

    - V3 is the most recent generation; regulatory material is being updated to permit approval and voluntary operation of the transponder in the European airspace. Efforts are currently ongoing to accommodate the voluntary introduction of V3 and safeguard compatibility in the end-to-end SUR systems.

- ADS-B opens parts of oceanic or remote airspace for non-FANS 1/A (incl. ADS-C position reporting) equipped airframes, provided that the aircraft is equipped with long range communication systems (HF or SATCOM) or VHF Comm coverage is available on the selected route as per the applicable AIP.
  A recent evolution emerged among the ANSPs who are responsible for oceanic or remote airspace. ADS-B enables much improved surveillance, allowing for the application of reduced separation minima. A recent update of ICAO Doc 4444 PANS-ATM with the outcomes of ASEPS trials offers a proven path down to 14/15 NM; further reduction, potentially down to the en-route continental standard, would be contingent upon adequate COM performance.

6. Conclusions and recommendations

On the basis of the ANSP visits, it can be concluded that:

- Several EU based ANSP have made substantial effort in implementing ADS-B in operations. Of the six visited, four are using ADS-B in operations to provide ATC Separation service at the time of drafting of this document. This should be contrasted with the magnitude of investment that was required of the air operators, and the resulting expectation that the investment could be leveraged.

- Most of the visited ANSPs have developed internal rationalization plans for their SUR infrastructures and have initiated their implementation. SDM is confident that all rationalization potential observed during the visits, was duly reflected in the ANSPs plans.

- The largest obstacles to wider implementation of ADS-B are the lack of a European mandate on the light aircraft segment, and the threat of radio frequency interference, primarily targeted at GNSS. As a result, the interviewed ANSP declared that they are not in position to provide large-scale surveillance based solely on ADS-B, rather the continued presence of at least one independent layer of surveillance will be necessary in the EU continental context. ADS-B sole means is occurring locally in less complex airspace; in more demanding environments, ADS-B sole means is not supported by the existing standard and so it cannot be expected to become the main scenario for European ANS provision in the foreseeable future.

- Similar progress on implementation of ADS-B has been noted elsewhere in EU and outside of the six ANSPs visited. In SDM experience, such efforts and their results tend to pass largely unbeknownst to the broader ATM community, especially the airspace users.

- All ANSPs ADS-B plans have been affected by the COVID crisis but no severe delays were encountered, compared to the impact status reported by SDM in the ADS-B Implementation Plan Edition 2020.

Furthermore, it is recommended that:

- Support and monitor the ground domain to ensure that the deployment momentum is sustained and continued.
- Efforts to communicate status and progress openly to airspace users and the broader ATM community are undertaken.
- Voluntary equipage in the light aircraft segment (<5.7t) operating in controlled airspace are promoted.
- ANSPs involve their military authorities in their deployment plans and activities.
- Once ADS-B operations have been implemented, ANSPs should evaluate any potential to optimize their surveillance infrastructure, in close coordination with the national authorities and the military.
- ANSPs and states should continue their efforts in mitigation of GNSS RFI vulnerabilities, and states should coordinate their approach at ITU level.

List of Acronyms

Acronym	Meaning
1090ES	1090 MHz Extended Squitter
A4E	Airlines for Europe
ADD	Aircraft Derived Data
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-C	Automatic Dependent Surveillance – Contract
AENA	Spanish Airport Operator
AFIS	Aerodrome Flight Information Service
ANS	Air Navigation Service
ANSP	Air Navigation Service Provider
AOR	Area Or Responsibility
ARINC	Aeronautical Radio, Incorporated
ASEPS	Advanced Surveillance- Enhanced Procedural Separation minima
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Services
CAPEX	Capital Expenditure
CIR	Commission Implementing Regulation
CNS	Communication, Navigation, Surveillance
COM	Communication
CPDLC	Controller Pilot Data-Link Communication
CWP	Controller Working Position
DFS	German ANSP (Deutsche Flugsicherung GmbH)
EDUU	Karlsruhe UAC
ENAIRE	Spanish ANSP
ENOB	Bodø FIR
ENOR	Polaris FIR
ESA	European Space Agency
EU	European Union
EUR	ICAO Europe Region
EUROCAE	European Aviation for Civil Aviation Equipment
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAB	Functional Airspace Block
FANS	Future Air Navigation System
FIR	Flight Information Region
FIS	Flight Information Service
FL	Flight Level
FSSA	Final State Selected Altitude
GA	General Aviation
GNSS	Global Navigation Satellite System

GPS	Global Positioning System
GS	Ground Station
HCAA	Greek ANSP (Helenic Civil Aviation Authority)
HF	High Frequency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IR	Implementing Rule
ITU	International Telecommunication Union
LMML	Malta International Airport
LMMM	Malta FIR
LSSIP	Local Single Sky ImPlementation
MATS	Maltese ANSP (Malta Air Traffic Services)
MLAT	Multilateration
Mode S EHS	Mode S Enhanced Surveillance
MOPS	Minimum Operational Performance Standards
MUAC	Maastricht Upper Airspace Center
NAC	Navigation Accuracy Category
NAT	ICAO North Atlantic Region
NAV	Navigation Accuracy Velocity
NIC	Navigation Integrity Category
NKOM	Norwegian Communications Authority
NM	Nautical Mile
NPAL	Non-Performing ADS-B Aircraft List
NTZ	Non-Transgression Zone
NUC	Navigation Uncertainty Category
OPEX	Operational Expenditure
RF	Radio Frequency
RFI	Radio Frequency Interference
RTCA	Radio Technical Commission for Aeronautics
SAR	Search And Rescue
SASS-C	Surveillance Analysis Support System for ATC-Centre
SBA	Space-Based ADS-B
SDM	SESAR Deployment Manager
SDP	SESAR Deployment Programme
SESAR	Single European Sky ATM Research
SIS	Signal In Space
SPI IR	Surveillance Performance and Interoperability Implementing Rule
SUR	Surveillance
TIA	Traffic Information Area
TMA	Terminal Control Area
UAC	Upper Area Control
VHF	Very High Frequency
WAM	Wide Area Multilateration

ANNEX

AUSTRIA/AUSTRO CONTROL

Austro Control GmbH is the Austrian Air Navigation Service Provider. Austro Control provides ANS services in controlled airspace over most of Austria, including approach and tower ATS.

Target scenarios identified

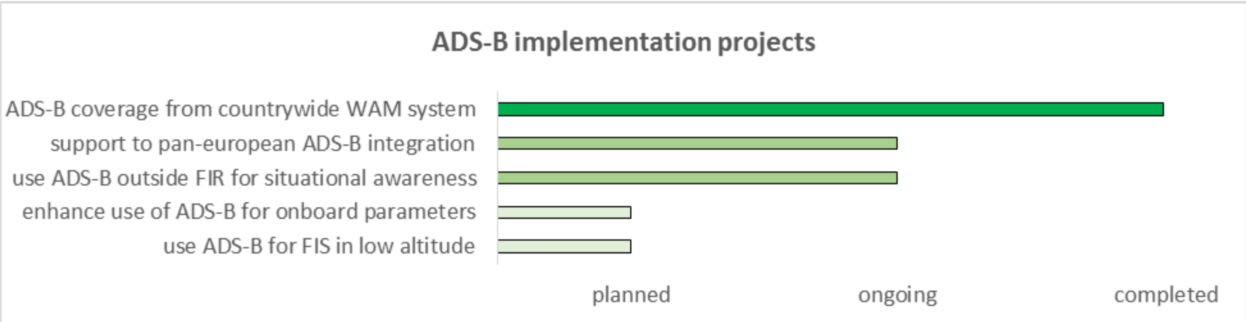
As there is sufficient WAM and Radar coverage, there is no urgency to use ADS-B for ATC separation. Nevertheless, Austro Control is pursuing **ADS-B related benefits**, such as:

1. Additional coverage outside FIR to improve situational awareness (implementation in progress).
2. Additional coverage in valleys of the Alps for FIS provision and situational awareness.
3. Use Final State Selected Altitude (FSSA) via ADS-B.
4. ADS-B improving track position accuracy of equipped aircraft in En-Route airspace (under exploration) and situational awareness.

Current status and projects

A Countrywide WAM system with ADS-B capabilities is deployed, which has enabled the decommissioning of two radars. The countrywide WAM system is further augmented by coverage from eight Mode S radars (four radars from neighbouring ANS, one from the military, two co-located with primary radar), four Mode A/C radars (one from a neighbouring ANSP, three co-located with primary radar).

One Mode A/C radar is being upgraded to Mode S. Another Mode S radar is replaced by a Primary/Mode S Radar, which will allow to switch off one Primary/A/C radar.



Austro Control has a number of activities ongoing or planned to integrate ADS-B:

Extensive technical validation campaign with contribution to pan-european specifications for surveillance systems, primarily data handling and distribution architectures and trackers.
Use of ADS-B for surveillance beyond Area of Responsibility, which could generate benefits in diverse areas such as flow management, arrival management, coordination and transfer.
Use of FSSA from ADS-B, pending WAM/ADS-B system upgrade to unlock the capability.
Implementation of ADS-B for surveillance in Alpine valleys, where the terrain conditions yield poor coverages with legacy infrastructure.

Challenges encountered

Austro Control concludes that existing ADS-B equipage limitations, paired with the limited scope of the SPI IR, present an obstacle to ADS-B being considered a full additional surveillance layer. Consequently, no further rationalization of radars is planned at this point.

Technical: Austro Control evaluated an early implementation of an ADS-B capable Mode-S radar and concluded it not sufficiently mature.

A need for an ADS-B Server functionality was identified, when considering multiple ADS-B data streams to be processed in the future.

A potential performance impact with regards to tracker system capacity amid growing traffic numbers in post-COVID recovery was hypothesized.

Good existing independent coverage but intensive efforts to achieve complete end to end technical integration of ADS-B in the surveillance system.

GNSS RFI: Notable legislative effort was exerted to mitigate GNSS RFI weakness, including collaboration at national and ITU level.

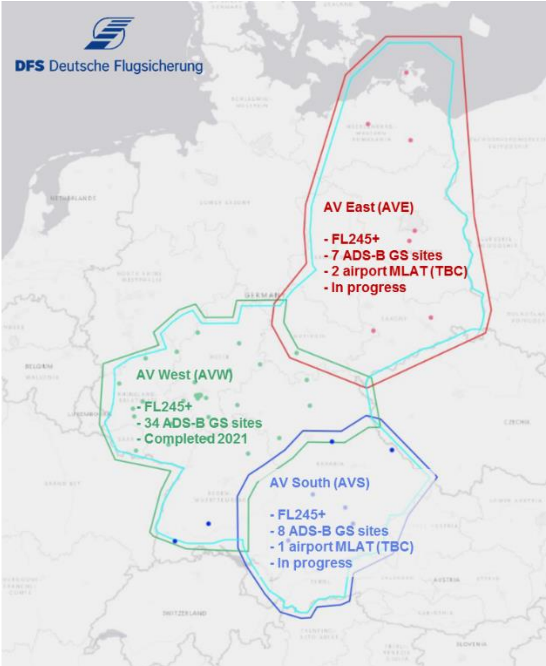
COVID: Austro Control assessed the impact of the crisis on ADS-B work as mild to substantial; activities were reprioritized. Reduced traffic levels further attenuated any benefit potential.

GERMANY/DFS

Deutsche Flugsicherung GmbH (DFS) is the German Air Navigation Service Provider. DFS provides ANS services in controlled airspace over most of Germany, including approach and tower ATS.

Target scenario

DFS aims to establish **a minimum SUR coverage of two cooperative independent and one ADS-B layer**; the ADS-B layer (V2) will replace end of life radar systems and improve extraterritorial coverage into North Sea and Vosges to improve flow management and coordination. **In terms of SUR rationalization, DFS has identified at least four sites** and is currently exploring the existing dependencies, also with regard to the military needs.

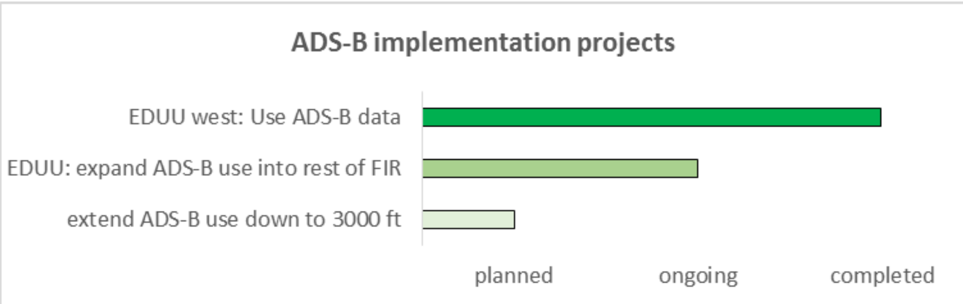


DFS project phase 1b, figure provided by DFS

Current status and projects

DFS SUR infra builds on several layers of independent surveillance to provide 3NM horizontal separation.

The German ADS-B project is divided into 3 phases. Phase 1 considers the upper airspace and phases 2 and 3 the lower. Phase 1 has been further divided into 2 sub-phases. Phase 1a, which covers the western and central airspace of Karlsruhe UAC using the PAM-FRA System with 34 sensors, is already in operational use. Phase 1b covers the remaining upper airspace (see figure).



DFS has a number of activities ongoing or planned to extend ADS-B service:

Implement additional 15 sites plus 3 airport MLAT systems to **cover the full EDUU upper airspace (>FL245)**, ongoing and expected completed by 2024/2025
Implement additional ADS-B infrastructure to **extend the vertical coverage downwards from FL245 to 3000'** first in southern Germany followed by the rest of the territory.

Challenges encountered

DFS is involved in industrialization, technical integration of ADS-B and regulatory issues concerning among others, suitability and security. Many issues were encountered and resolved; DFS draws particular attention to the following:

Surveillance System: All components need to be adapted in order to process ADS-B data: e.g. sensor performance optimization in high radio load environments, ADS B specific tracking (time, error characteristics), additional network connections and capacity in distribution systems. It has to be ensured, that main and fall-back tracking system implement consistent ADS-B data handling. A national Type Certificate is required for the Ground Stations in Germany.

Data Integrity: The validation of the data integrity is a prerequisite to use ADS B as Mode S equivalent layer in a high-density radar controlled airspace. In principle this could be achieved within sensors or tracking systems (additional functionality not always available and/or achievable). An optimized solution to ensure data integrity is to establish a dedicated ADS B validation (currently not available as product on the surveillance market).

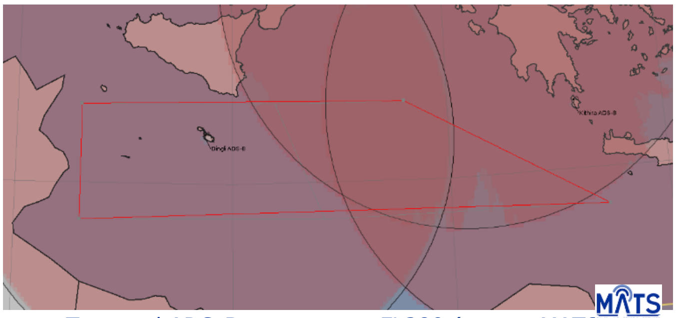
COVID: According to DFS assessment, the COVID crisis caused a delay of one year in the procurement of equipment for ADS-B implementation.

MALTA/MALTA ATS

Malta Air Traffic Services (MATS) is the Air Navigation Service Provider for the Maltese islands and Malta's FIR (LMMM). LMMM is 600NM long and 130 NM wide, and with the exception for the Maltese islands, the FIR is entirely over the sea.

Target scenario

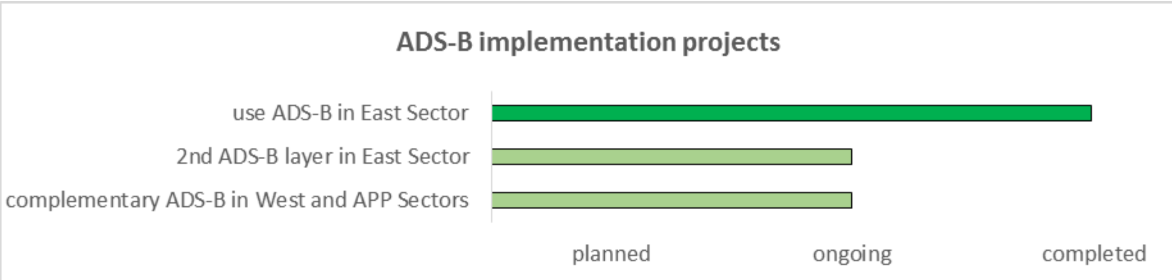
MATS objective is to have a **full ADS-B coverage of the upper airspace and the TMA of Malta International Airport (LMML)**. The East Sector will be covered by a Ground Station (GS) owned by MATS and installed on a Greek island (Lefkas radar site) and by ADS-B data received from HCAA (the Greek ANSP) from an ADS-B GS owned by HCAA (Kithira site). The West and Approach Sectors will be covered by an ADS-B GS in Malta (Fawwara radar site). One of the objectives is **to avoid airspace closure in the East sector in case of loss of radar surveillance**.



Targeted ADS-B coverage at FL380 (source MATS)
Red lines delineate LMMM

Current status and projects

MATS SUR infrastructure builds on four secondary radars and two primary radars installed in Malta, plus one combined radar in Italy shared with ENAV and on the use of data from two secondary radars and one ADS-B GS located in Greece and provided by HCAA (for the East Sector). **In case of loss of the radar data from HCAA (e.g. maintenance), the same service continues to be provided to ADS-B equipped aircraft** (10NM separation) and MATS coordinate with Athens ATC to reroute non-ADS-B aircraft. In case of loss of both radar and ADS-B data from HCAA, the East Sector is closed. The installation of a second GS in Greece will minimise this risk.



MATS has activities on-going or planned to extend ADS-B service:

- Deployment of an ADS-B GS on the Greek island of Lefkas to add second layer of ADS-B in the East Sector.
- Implementation of an ADS-B GS in Malta to cover the West and Approach Sectors.
- Currently a 5NM separation minimum is used in the West and Approach Sectors. The feasibility to reduce the minimum to 3NM will be assessed, and with it the feasibility of allowing any ADS-B Version Number, as is the contemporary practice in the East sector (10 NM minimum).

Challenges encountered

International cooperation: MATS is involved in an extensive international collaboration regarding ADS-B. With HCAA, it includes the sharing of data and also the possibility for MATS to install an ADS-B GS at a site in Greece. MATS considers that international co-operation is key for the optimisation of infrastructure.

Rationalization: Considering the existing topography and the large airspace over the sea to cover with surveillance, there is no radar rationalization potential to be considered with ADS-B. Rather, ADS-B allows to improve the surveillance coverage and performance and thus to provide an enhanced service to the ADS-B equipped aircraft.

GNSS RFI: MATS has experience with GNSS interference, but a reduction in GPS jamming has been noticed since the beginning of the Covid crisis.

Implementation Monitoring: Concerning monitoring of ADS-B implementation in the ground domain, MATS requested to streamline and simplify the monitoring process.

COVID: The COVID crisis has had a severe impact on the progress of MATS ADS-B activities, namely in terms of the travel restrictions and staffing.

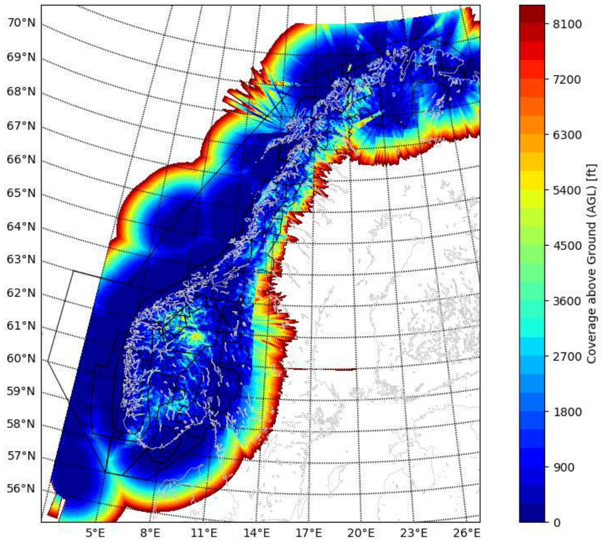
NORWAY/AVINOR

Avinor Air Navigation Services AS provides air traffic services in Norwegian airspace including aerodrome control and approach control services at airports. The Norwegian airspace includes two FIRs: ENOR – Polaris in ICAO EUR and ENOB - Bodø in ICAO NAT.

Target scenario

In Polaris FIR, Avinor is aiming at using three almost countrywide surveillance layers: radar first, WAM second (used to be radar too) and ADS-B third. In a few remote areas, ADS-B will be used as the second layer. **In all airspace, ADS-B data will be used to provide separation in complement to independent surveillance data.** The use of ADS-B only data for separation provision over mainland will be assessed.

In Bodø Oceanic FIR, Avinor is investigating the feasibility to use Space-based ADS-B to provide Air Traffic Control Service for low level offshore helicopter operations, and in the future including separation provision.

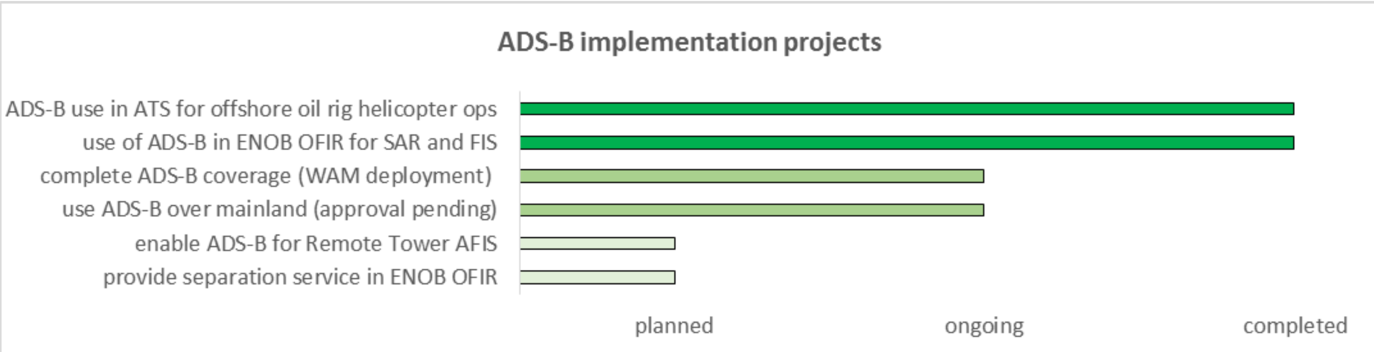


ADS-B coverage by end of 2022 (source Avinor)

Current status and projects

Avinor launched the first ADS-B implementation project in 2010 at the ADS-Area between Stavanger Airport Sola and Ekofisk offshore oil rig, following a long experience with an application of a modified ADS-C protocol (M-ADS) for the same purpose. ADS-B started to be **operationally used for helicopter operations** in 2013 for FIS and in 2015 for ATC service, **applying 5NM separation minimum**. ADS-B is now used as sole surveillance means for ATC service provision in all major offshore areas.

Avinor is also **using ADS-B data to provide FIS** in the part of Bodø Oceanic FIR covered by some ADS-B ground stations in the so-called Svalbard corridor.



Avinor is deploying a countrywide WAM system (NORWAM) which is the aggregation of local WAM systems covering some TMAs, CTAs, etc. These WAM systems provide a full ADS-B coverage of Polaris FIR (almost 200 receivers). Some dedicated ADS-B servers independent of the WAM systems are deployed to process the ADS-B data.

Even if an ADS-B coverage over large parts of Polaris FIR exists, the ADS-B data are not yet used pending clarification of the national regulatory status of use of ADS-B for surveillance over mainland. ATC service will be introduced once regulation is available.

In the meantime, introduction of ADS-B in Polaris FIR is planned in 2021 to enhance low-level coverage below controlled airspace for light aircraft with certified ADS-B and to enhance tracking and onboard data collection on the ground.

Besides, the ADS-B coverage will enable AFIS provided at airports from Remote Tower Centres.

In Bodø Oceanic FIR, Avinor is assessing the use of Space-based ADS-B as a back-up layer, in new CTAs and the feasibility to provide 5NM separation, in which case a potential limitation stems from communications due to poor VHF coverage.

Challenges encountered

Rationalization: After the countrywide WAM/ADS-B system becomes operational, six radars are planned to be decommissioned after 2023 (~ 40% rationalized). Avinor will consider the potential for further SUR rationalization depending on the outcomes of the planned assessment of separation provision based on ADS-B data only. One of the anticipated limitations is the lack of requirement for GA aircraft to be equipped with ADS-B. Avinor expressed their wish about an ADS-B mandate for GA aircraft.

GNSS dependencies: Historically, Avinor acquired extensive experience with GNSS based CNS in all domains; including its strengths and limitations. Outages of GNSS occur two to three times a year in the very North East part of Norway. Additionally in some cases, aircraft at low altitude experience GNSS RFI in several places in Norway. Norwegian Communications Authority (NKOM) has established a national coordination centre for synchronization and alert distribution between stakeholders. In cooperation with Norwegian Defence Research Establishment and Norwegian Space Centre, Avinor is ongoing work on using ADS B as a detector for GNSS RFI.

COVID: According to AVINOR assessment, the only real impact of the COVID crisis on the Avinor ADS-B implementation projects is that the traffic in Bodø Oceanic FIR was not sufficient to justify to add the cost of investment for Space-based ADS-B to enroute air traffic above FL100, and aim for funding the investment of Space-based ADS-B to the offshore industry to provide FIS and Alerting Service for offshore helicopter operations below FL100 only.

PORTUGAL/NAV PORTUGAL

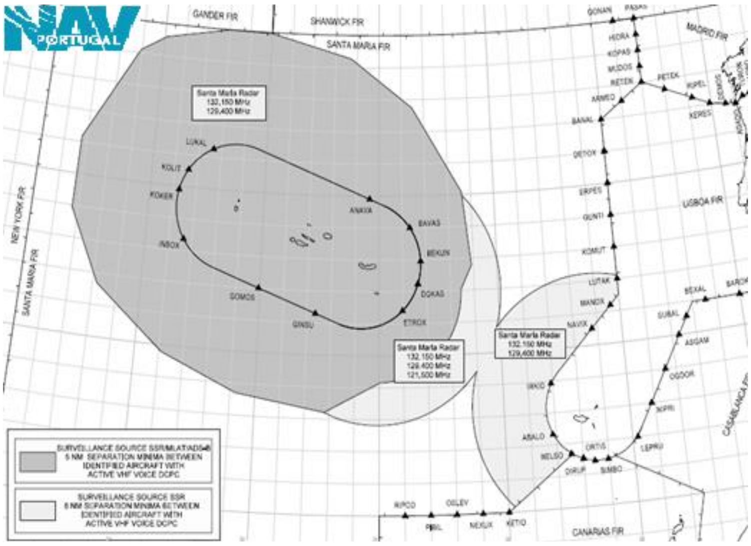
NAV Portugal provides ATC services in Lisboa FIR under ICAO EUR including the Madeira archipelago and its connecting corridor, and in the ICAO NAT oceanic FIR of Santa Maria over Azores in the middle of the Atlantic Ocean.

Target scenario

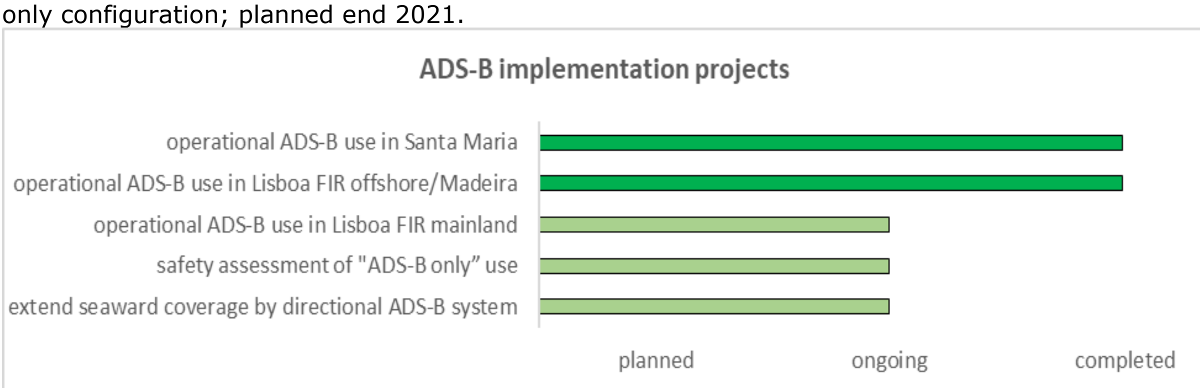
NAV Portugal aims to use ADS-B as **one of the two principal surveillance layers**; the other one being independent cooperative coverage provided by Mode S radar and WAM. **ADS-B as sole-means is a viable application locally** in areas where radar/WAM coverage is unfeasible to implement, such as remote offshore airspace in Santa Maria.

Current status and projects

ADS-B is in operational use. In Santa Maria, terrestrial ADS-B using any Transponder version and application of ICAO Doc 4444 provisions for Separation minima using ATS surveillance systems where VHF voice communications are not available (formerly known as "ASEPS"), enables **enhanced service** to the equipped operators by applying tighter separation and less tactical intervention. In the Madeira area of Lisbon FIR including the connecting corridor to mainland, ADS-B complements coverage of the legacy radars, allowing NAV PT to ensure ATC surveillance over the whole path. In the rest of Lisbon FIR, **ADS-B data will also be used as a complementary sensor** with WAM and radar and in some areas extend the coverage in ADS-B only configuration; planned end 2021.



ADS-B service area with reduced separation minima in Santa Maria FIR. Source: Portuguese AIP.



As the deployment status of NAV Portugal is fairly advanced, the ongoing activities focus on further enhancements and improvements of the service already provided.

A joint project with ENAIRE focusing on the deployment and data sharing of a coastal ADS-B site in Galicia, utilizing directional high-gain antennas. This is intended to provide longer range seawards at the expense of reduced sensitivity landwards where there already is sufficient coverage available. This project is co-financed by the European Commission and also includes the implementation of MLAT/ADS-B at Porto airport.

An ongoing safety case for the use of ADS-B as only sensor (*sole means*). Lisbon FIR features vast areas of ADS-B-only coverage, notably the western, overwater regions, and the application of 5NM by ADS-B will significantly improve airspace capacity. Anticipated introduction in operations by end 2021.

Challenges encountered

Oceanic experience: NAV Portugal made extensive use of the oceanic implementation of ADS-B and the resulting provision of ICAO separation minima resulting from ASEPS trials. Valuable expertise was accumulated with respect to the use of ADS-B (e.g. use of symbols and labels, management of mixed equipage also including FANS 1/A and its benefits, pair-wise application of dynamic separation minima).

GNSS RFI: NAV Portugal is participating in project titled *swair.ptech.io,* co-financed by ESA, to monitor in real time the quality of the GNSS signal, including space weather, jamming and spoofing. A station is installed at the Lisbon airport and another one is being commissioned in another airport in the Lisbon TMA.

COVID: NAV Portugal assessed the impact as mild, mainly thanks to the fact that by the time COVID hit, ADS-B was already largely implemented. COVID has however impacted plans to implement Space Based ADS-B in Santa Maria.

SPAIN/ENAIRE

ENAIRE, a public enterprise under the Spanish Ministry of Transport, Mobility and the Urban Agenda, is the principal air navigation services provider in Spain.

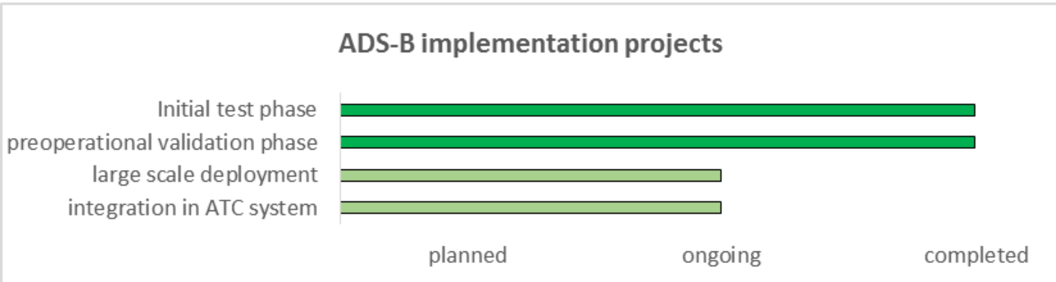
Target scenario

ENAIRE aims to implement ADS-B as **a complementary surveillance technology** to Mode S radar and WAM. **Initially** ADS-B will be used **to fill surveillance gaps** in oceanic areas, low altitude and on airport surfaces, to **reduce dependencies** on other providers and to develop tailored surveillance service solutions for AENA and other clients, and in the **long term, enable rationalization of conventional surveillance**. **ADS-B use for ATC separation** in continental Spain is **envisaged for 2022/2023.**

Current status and projects

ENAIRE started initial tests with ADS-B in 2015. A preoperational validation phase was completed in 2020, leading to a large deployment program involving 6 pilot ADS-B sites installed by mid of 2021: Madrid, Alicante, Granada, Menorca, Bilbao and Galicia, and an additional portable station. In December 2021, the Spanish regulator ASEA certified ENAIRE for the **provision of CNS using ADS-B.**

ADS-B deployment sites by 2023, ENAIRE



The detailed status of the large scale project is as follows:

Two sites completed July 2021: Yeste and Vejer de la Frontera.
Five sites for TMA and surface ADS-B are expected to be implemented by mid-2023 in the Cantabria sector: Vitoria, Burgos, San Sebastian, Pamplona and Bilbao.
Two en-route sites planned in the Canaries: El Hierro and El Roque de los Muchachos, beyond summer 2023.
Eight sites planned for TMA and airport surface; three in the south - Cordoba, Melilla and Almeria – and five integrated in the AENA Advanced Tower sites: Ibiza, Santiago, Vigo, Valencia and Sevilla, also planned beyond 2023.

A large number of additional sites, surface/TMA and/or en-route, has been identified for prospective deployment around 2025 and negotiations are currently ongoing involving the military authorities.

The large scale deployment program also caters to the rationalization potential that ADS-B deployment will unlock.

Simultaneously, ENAIRE is progressing on integrating ADS-B data in the surveillance chain and the ATC system (SACTA); the commissioning will be individual in each of the five en-route centers, anticipated to commence June 2022.

The ADS-B implementation plan at ENAIRE is co-funded by the European Union via CEF (Connecting Europe Facility - Transport) mechanisms.

Challenges encountered

Space-based ADS-B for oceanic airspace: oceanic airspace in the Canary Islands FIR is a perfect candidate to implement SBA. Coordination with the non-EU neighbouring countries is essential to ensure the benefits, as an implementation in the whole South Atlantic Corridor would be required.

International cooperation: ENAIRE is deeply integrated in pan-European efforts and activities to deploy and use ADS-B operationally and developed intensive cross border cooperation with neighbour states. This includes a sensor sharing project with NAV Portugal in Galicia, see preceding Annex chapter, utilizing a directional antenna for enhanced seaward coverage.

GNSS RFI and dependencies: GNSS interferences, jamming and potentially spoofing, have been encountered with increasing frequency, and described in great detail in terms of effect and impact since 2016. In response and in cooperation with national authorities, ENAIRE developed and deployed a detection and localization system around Madrid airport (DYLEMA), a Signal-In-Space monitoring suite (RECNET) deployed at a dozen sites countrywide, and an internal threat evaluation and classification tool (APRESTA) to enable the detection of GNSS interferences based on ADS-B data (quality indicators) to assess an ongoing event and deploy mitigations as appropriate. In terms of maximizing benefits of ADS-B, ENAIRE explored the matter of interdependencies with NAV, where GNSS is the primary position source, in great detail, and is active in further leveraging GNSS for CNS.

Standardisation evolution: To further foster pan-European deployment of ADS-B, ENAIRE highlights two areas of concern in particular: clarity and unambiguity in the standards for certification and evaluation material, and continued funding to the development and maintenance of the surveillance support tools such as SASS-C, in particular for what concerns surface surveillance.

COVID: The COVID crisis has had a mild impact on the progress of ADS-B activities at ENAIRE to date.