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THE NAM/CAR/SAM AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST (ADS-B) OPERATIONAL CONCEPT

Development by Surveillance ICAO Task Force

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Contents

1. – INTRODUCTION

Installing and maintaining ground-based aviation infrastructure in remote areas can be challenging and costly. This concept of operations considers the use of Automatic Dependent Surveillance - Broadcast (ADS-B) data from aircraft to expand surveillance coverage into remote areas, to augment current cooperative surveillance coverage, or to replace existing cooperative surveillance assets. Currently, some Air Traffic Service (ATS) providers depend upon ground-based infrastructure to receive ADS-B data from aircraft. This concept of operations also considers the possible use of orbiting satellites to receive and relay ADS-B data from aircraft.

The CAR/SAM Region is working on the commissioning of ground-based ADS-B stations and space-based ADS-B services in its Flight Information Regions (FIR). The supporting safety analyses, testing and monitoring for these implementations provides the foundation for expansion of ATS surveillance services based on ADS-B.

The reduction of longitudinal separation between aircraft is an operational benefit that can be realized by implementing an appropriate surveillance and communication infrastructure.

Document Overview

The purpose of this document is to facilitate coordination between stakeholders who will be involved in, or affected by, the implementation of services using ADS-B. This concept of operations was developed to assist ICAO CAR/SAM region States considering the use of ADS-B as part of an ATS Surveillance System as defined in ICAO's Procedures for Air Navigation Services - Air Traffic Management (PANS-ATM, Doc 4444). Individual CAR/SAM region States may develop complementary implementation documents as needed to reflect their unique operating environments.

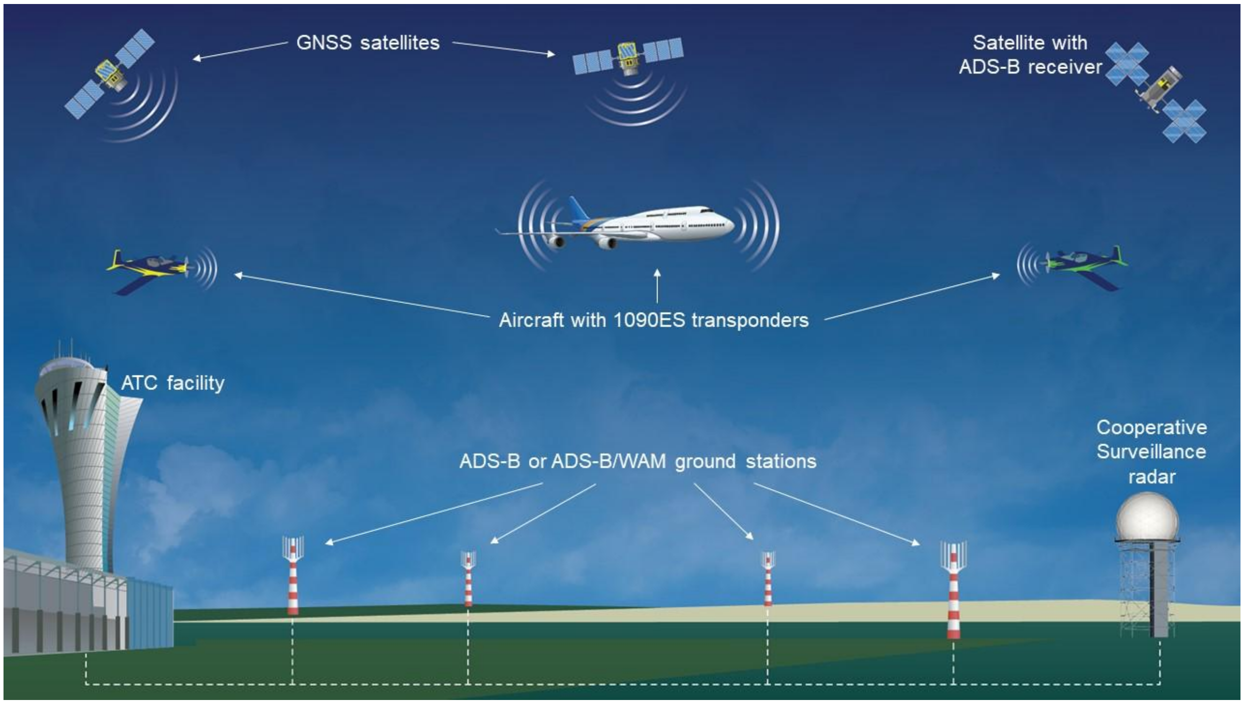
As developments occur, this Concept of Operations may need to be updated.

Operational use

The operational use of ADS-B can be realized in five areas:

a. Enroute
b. Terminal
c. Search and Rescue
d. Oceanic Areas
e. Aircraft Tracking

1.1 – System Overview



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[2] Space Based ADS-B Surveillance in Oceanic Airspace Concept of Operations Draft 0.2 dated February 1, 2012.

[3] ICAO Document 9854 "Global Air Traffic Management Operational Concept:" First Edition 2005

[4] DOC 4444, "Procedures for Air Navigation Services, Air Traffic Management", ICAO, Tenth six edition 2016

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[6] Annex 4 to the Convention on International Civil Aviation, "Aeronautical Charts", ICAO, July 2009.

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2. OPERATIONAL NEED:

The use of ADS-B technology is needed to help ensure the optimization of airspace through improved surveillance capability, reliability and accuracy, which should result in reduced separation minima while reducing the cost of providing surveillance services. In addition, the reduction of separation minima provides an improvement to CO2 emissions.

2.1. Current Environment

A variety of surveillance equipment is used within the region (e.g. PSR, SSR, MLAT). Both Procedural Separation Standards and Cooperative Surveillance Radar standards are used within the region.

3. SYSTEM JUSTIFICATION

3.1. Description of Desired Change

To use ADS-B surveillance information (airborne and airport surface) for air traffic control operations (including improved automation system safety functions and traffic flow management), or for other services including situational awareness or search and rescue.

Other authorized facilities (ramp control, airline operations center, etc.) may use ADS-B surveillance information to track flight activities and optimize operations. ADS-B provides more information at a faster update rate and with improved accuracy as compared with existing SSR systems. This enables service providers and users to achieve improvements in safety, capacity, and efficiency. Additionally, ADS-B data is inherently easier to share among adjoining States as the data broadcasted from the aircraft is in the longitude and latitude coordinate system.

3.2. Potential Benefit of new or Modified System

The following ADS-B surveillance capabilities will contribute to improved safety, capacity and efficiency:

Safety

- Provides aircraft-to-aircraft traffic surveillance capability
- Provides ATC and pilots (in the cockpit) with airport surface traffic surveillance

- Provides surveillance in areas currently not served by ground-based surveillance systems
- Improves or supplements existing ground-based surveillance information
- Improves ATC automation performance and safety features (e.g., target accuracy, alerting functions)

Capacity

- Enables the use of radar-like separation procedures in remote or non-radar areas
- Supports a common separation standard in select domains and airspace classifications
- Supports a potential reduction in existing separation standards in all domains and airspace classifications
- Supports increased airspace capacity through select user-executed airborne spacing and operations

Efficiency

- Provides a lifecycle cost reduction relative to cooperative surveillance radars
- Provides new information, allowing for enhanced sector & airport-derived predictions
- Provides improved information for traffic flow management, collaborative decision making, fleet management, and management by trajectory functions
- Provides a rapidly deployable, mobile surveillance sensor for contingency operations
- Provides precision surveillance and flight parameter information for unique operating areas

4. OPERATIONAL DESCRIPTION:

ADS-B is a surveillance tool in which, like radar, aircraft transmit identity and altitude information to the ATS unit. The position (and quality of this position), as determined by the aircraft sensors, is also broadcasted, along with track vector information. Like a Mode S transponder, certain alert conditions are broadcasted when selected by the flight crew. ADS-B messages are transmitted at regular intervals and any receiver may receive and process the data.

Some of the information transmitted by the aircraft can also be derived from radar data (speed, position and vertical rate) however, since ADS-B relies on high quality reports, under nominal conditions, it is more accurate than radar.
ADS-B is implemented in a Mode S transponder and uses the aeronautical protected frequency of 1090 MHz.

4.1 Surveillance

ATC will use ADS-B surveillance information in the same manner as current cooperative surveillance system information is used, for example, to assist aircraft with navigation, to separate aircraft, and to issue safety alerts and traffic advisories. ADS-B surveillance may be used to replace radar-based surveillance or to enhance the quality of existing radar-based surveillance information for ATC automation system functions, for example, aircraft tracking, Minimum Safe Altitude Warnings (MSAW), Conflict Alert, and Mode-C Intruder Alert. The possible implementation areas include surface, terminal, en-route, offshore, and oceanic domains. ADS-B surveillance will allow ATC to provide separation services between ADS-B-to-ADS-B, ADS-B-to-radar and fused (ADS-B/radar) targets. ADS-B can support a reduction in separation minima in current non-radar environments.

4.2 ADS-B Applications

4.2.1 Surface movements

The primary ADS-B surface application is airport surface traffic situation awareness in support of surface movement guidance and control. Any increase in ground surveillance can serve to reduce the incidence of runway incursions.

4.2.2 Terminal airspace

The airspace immediately surrounding an aerodrome is considered the Terminal Management Area (TMA). This is where aircraft on approach (instrument and visual), aircraft departing and those operating in the vicinity of aerodromes are in close proximity to terrain. Since this is the area of initial climb and final descent, aircraft would be crossing the levels of other aircraft.

In TMAs where the terrain restricts Secondary Surveillance Radar (SSR), ADS-B can be used to provide surveillance. The deployment of several ADS-B antennae would be a cost effective way to provide surveillance where it would not be possible via single SSR. The cost difference between radar and ADS-B installation makes it feasible to install several ADS-B antennae to provide overlapping coverage.

In terminal airspace, when ADS-B equals or exceeds the accuracy of SSR (see ICAO Circular 326), the minimum established radar separation in PANS-ATM (Doc 4444) sections 6.7.3.2.4; 6.7.3.2.5; 6.7.3.4.2, 6.7.3.5.1, as well as Chapter 8 may be applied without any further safety assessment requirement.

ADS-B increases situational awareness in the cockpit and at the controller work position. Aircraft equipped with ADS-B IN will receive information about other ADS-B equipped aircraft in the vicinity based on their transmitted positions. Minor adjustments in speed and heading could be used to adjust spacing in the TMA where there is a high concentration of aircraft. For controllers, having an accurate picture of traffic in the TMA would result in heightened situational awareness and improvements in safety.

ADS-B surveillance can be used to reduce separation and an increase in terminal airspace capacity. An increase in airspace capacity can then allow for increases in flight schedule flexibility, increases in flight path efficiency and reductions in delays or flight disruptions.

ADS-B integration supports safety nets such as MSAW for aircraft flying close to terrain and reduce the occurrence of Controlled Flight Into Terrain (CFIT). In radar airspace, ADS-B would provide redundant surveillance to enhance safety.

4.2.3 En-route airspace

The rapid update of information received from aircraft through ADS-B would increase the situational awareness of the controller since it would allow for a more accurate depiction of the aircraft's current track on the controller work position. This would improve the prediction of trajectories, increasing the effectiveness of ATM system conflict detection.

The coverage range of an ADS-B receiver is line-of-sight and can be two hundred and fifty (250) nautical miles at high altitude. If sufficient ADS-B receiving stations are used, complete coverage can be achieved despite the presence of mountainous terrain or tall structures.

The data obtained from adjacent FIRs could be shared across borders as long as there are compatible data formats. Compatibility considerations for ADS-B data sharing include: availability of different data fields if different ADS-B version(s) are supported; interoperability of different ASTERIX CAT021 editions; and handling of ADS-B data received from different ground stations in regions where coverage overlaps.

In a procedural environment, it is difficult for a controller to know if an aircraft is in an abnormal situation. In many cases, this only becomes clear after position reports have been omitted or an emergency (or urgency) report was sent by the pilot. In a surveillance area however, emergency reports are received instantaneously. This allows controllers and emergency professionals to see the aircraft's flight path and accurately locate its last position. A situation that significantly increases the likelihood of a favorable outcome.

ADS-B can provide redundant coverage for areas already served by SSR.

In non-radar airspace, cockpit workload could also be reduced through the implementation of ADS-B. Accurate position reporting in non-radar airspace can create a significant amount of workload for a pilot. A pilot's priorities during flight is to aviate, navigate and communicate. If less time is required to communicate position reports then there would be more time for aviating and navigating.

4.2.3.1 Upper airspace

The characteristics of an aircraft in the Upper Airspace (at or above Flight Level 180) would be level flying or change of cruising level by only one or a few thousand feet (Flight Levels). Lateral changes to a flight path would be due to weather deviations or to avoid separation violations where aircraft tracks cross each other.

In procedural (non-surveillance) upper airspace, ADS-B could provide surveillance coverage and reduce the required separation therein, to that defined by ICAO PANS-ATM (Doc 4444) 8.7.3 provided:

- Identification of ADS-B equipped aircraft is established and maintained;
- The accuracy and integrity measures of ABS-B messages are adequate to support the separation minima;
- There is no requirement for detection of aircraft not transmitting ADS-B; and
- There is no requirement for determination of aircraft position independent of the aircraft navigation system.

The surveillance provided by ADS-B can improve efficiency by facilitating more direct flight paths in the en-route phase of flight. More direct flight paths have a positive impact on fuel and greenhouse gas emissions.

4.2.3.2 Lower en-route airspace

The lower airspace (below Flight Level 180) is characterized by a mix of aircraft types with varying performance characteristics. There are significant changes in altitude (several thousand feet) for some aircraft while others would be operating at their cruise levels. There is also a high concentration of aircraft arriving and departing airports.

The speed, rate of climb and descent and general maneuverability vary widely for aircraft in the lower airspace. Commercial aircraft, general aviation and military operators all share the lower airspace. Different classes of aircraft have different performance characteristics and ADS-B can increase situational awareness for controllers. This leads to safer operations, especially in areas of high traffic density.

For aircraft with ADS-B IN, improved situational awareness would also be extended to the cockpit.

In areas of low traffic density, where the volume of traffic does not justify the installation of a radar, ADS-B offers a cheaper way to monitor a variety of aircraft.

4.2.4 Oceanic and Remote airspace

The objective of using ADS-B on aircraft operating in oceanic and remote airspace is to enable more frequent approval of flight level change requests through the use of a reduced separation standard. Such an application would improve flight efficiency and safety. Flight crews request flight level changes to improve flight efficiency and safety by optimizing fuel burn, accessing better wind conditions and by avoiding turbulence. In procedural oceanic and remote airspace, only ADS-B-IN equipped aircraft can use In-Trail-Procedures (ITP) to execute flight level change maneuvers. ITP allows ATC to approve these flight level change requests between properly equipped aircraft using reduced separation minima during the maneuver.

4.3 Proposed environment

In the short term, ADS-B will continue to support conventional ATC surveillance systems. Due to its high update rate and the accuracy of its position reports, ADS-B is as reliable as SSR systems, and through its use, the same separation minima could be applied for a particular airspace as if it were monitored with a conventional SSR system. By using both SSR and ADS-B together, the accuracy of composite tracks is improved. For aircraft with ADS-B IN, pilots have increased situational awareness.

Radars will continue to be surveillance sources until the existing systems reach the end of their life cycle, at which time they could be replaced by ADS-B. ADS-B systems could be installed in anticipation of certain radars becoming obsolete to give sufficient lead-time for their acceptance as radar replacement. The cost-to-benefit ratio and small footprint of ADS-B infrastructure is an enabling factor for early deployment.

Terrestrial ADS-B coverage can vary depending on altitude and terrain. A range of two hundred and fifty (250) Nautical Miles is possible at high altitudes. This range is reduced at lower altitudes and in mountainous terrain. Existing modeling tools can determine the expected coverage based on these factors and should be considered when deciding where to place a ground-based antennae. The availability of additional infrastructure such as power, communications and security should also be considered when choosing a site. As space-based ADS-B develops and is proven to be as effective as terrestrial installations, these factors may be less restrictive.

5. SYSTEM DESCRIPTION:

5.1. Surveillance Services System

The Surveillance Services system's functions (Aircraft/Vehicle, Data Link Processor, Broadcast Server, ATC Automation, and Traffic Flow Management Automation) provide the ADS-B services that support ADS-B applications. The ADS-B surveillance service is supported by Aircraft/Vehicle, Data Link Processor, and ATC Automation functions.

5.2 Functional Description

The purpose of each function of the Surveillance Services System, how they interoperate with each other, and how the Surveillance Services System fits into the Region are described below.

5.2.1 Aircraft/Vehicle

The Aircraft/Vehicle is the source of ADS-B information. The Aircraft/Vehicle gathers information including position data from a GNSS or other navigation source, crew input, barometric altitude, vertical speed and aircraft identification data. The Aircraft/Vehicle processes the gathered information and determines the associated integrity and accuracy indicators. The Aircraft/Vehicle encodes and broadcasts all the information in an ADS-B message. The ADS-B system will monitor information broadcasted by the aircraft avionics package. The quality of the data will be evaluated to ensure aircraft compliance with the mandated performance measurements and standards. If equipped with ADS-B IN, the Aircraft/Vehicle receives and decodes ADS-B messages transmitted by other Aircraft/Vehicles. The Aircraft/Vehicle may display ADS-B on a Cockpit Display of Traffic Information (CDTI).

5.2.2 Data Link Processor

The Data Link Processor receives ADS-B Messages broadcast by Aircraft/Vehicles over the 1090Extended Squitter (1090ES) data link, formats them into ADS-B reports, and sends the reports to an ATC automation system. The Data Link Processor generates status reports, containing information on alarms and events in the Data link Processor subsystems and sends them to the ATC automation system. The Data Link Processor will also generate internal test target messages and send the resulting ADS-B reports to the ATC automation system.

5.2.3 ATC Automation

ATC automation (systems) receives ADS-B reports and status reports from the Data Link Processor. ATC automation receives ADS-B reports in both an ADS-B-only environment as well as mixed surveillance (e.g., radar, ADS-B, and Wide Area Multilateration, WAM) environments. ATC automation performs MSAW and CA processing using the ADS-B data (and radar/WAM data if in a mixed surveillance environment). In mixed surveillance environments, radar/WAM data may be used to "validate" ADS-B data to mitigate ADS-B "spoofing" risk. ATC automation may be able to improve tracking and safety feature functions using the high accuracy and greater update rate of ADS-B reports. ADS-B reports may also feed targeted surface surveillance systems and support their alerting functions. ATC automation tracks and displays targets by using the information provided in the ADS-B reports.

5.2.4 Traffic Flow Management (TFM) Automation

TFM automation receives ADS-B reports as part of the surveillance data passed from an en route and/or terminal ATC Automation system. As the coverage areas increase, TFM decision support tools will incorporate the data to produce more accurate demand projections, operational response strategies, (such as Traffic Management Initiatives (TMIs)) for periods of excess demand relative to capacity and weather. Additionally, the resultant aggregate demand data provided to the ATM community will reflect the increased accuracy and support better informed collaborative decision-making through traffic management.

5.3 Modes of Operation

The Surveillance Services system is a system of systems, making the definition of modes of operation more complicated than those of a single system providing a single function. Applications are enabled by specific Surveillance Services. Under normal operating conditions, all functions are available and operational, thus all services and applications are supported. Degradation or loss of a system function leads to degradation or loss of the services supported by that function, and ultimately of the applications enabled by the service.

5.3.1 Normal Operations (All Services Available).

5.3.2 Aircraft/Vehicle Degradation or Loss

The Aircraft/Vehicle is required for all services and applications. The Aircraft/Vehicle could degrade such that transmit only, receive only, or both are lost. Additionally, this function can degrade or be lost on a per aircraft basis and also regionally. Each of these outages has a different impact.

5.3.2.1 Loss of Reception Capability (ADS-B air-to-ground available, ADS-B air-to air lost)

Degradation or failure of the reception functionality on the aircraft would result in loss of ADS-B traffic information in the cockpit applications on a given aircraft.

5.3.2.2 Loss of Transmit Capability (ADS-B ground-to-air lost)

Degradation or failure of the Aircraft/Vehicle transmit function would result in the loss of ADS-B information to the Data Link Processor and to other aircraft. ADS-B IN-equipped aircraft in the vicinity cannot perform cockpit-based applications involving the failed aircraft, however applications involving other full-functioning aircraft would continue.

5.3.2.3 Loss of ADS-B Surveillance Source

Due to the criticality of aircraft surveillance data, a backup plan must be in place. In areas covered by other surveillance sources, including radar and WAM systems, data from the other system would be used as backup surveillance in the ATC/TFM Automation system when this occurs. In non-radar areas, controllers would revert to procedural separation. The loss of the ADS-B surveillance source, GNSS, could result in regional loss of ADS-B services. This would result in the loss of the Aircraft/Vehicle‘s ability to transmit ADS-B state vector information.

The Aircraft/Vehicle receive functionality would not be impacted. ATC controllers would lose all ADS-B surveillance data on all aircraft. Pilots would lose surveillance information on other ADS-B equipped aircraft in the vicinity.

5.3.2.4 Loss of ADS-B Reception Capability (ADS-B air-to-ground lost)

Degradation or loss of the Data Link Processor reception would result in the loss of ADS-B, supporting core surveillance applications.

5.3.3 ATC Automation

Each ATC Automation system should have system-specific backup strategies that will apply regardless of the source of surveillance data.

6. ASSUMPTIONS, CONSTRAINTS, AND DEPENDENCIES

6.1 Organizational Impacts

6.1.1 Staffing

The introduction of ADS-B applications may require adjustments to current ATC facility staffing schemes to optimize facility operations. Technical support personnel adjustments may need to be made to support and maintain local and remotely deployed ADS-B equipment, in addition to the maintenance responsibilities for existing infrastructure equipment. An adequate number of field support facilities and personnel will be required to install, maintain, and certify ADS-B equipment (both ATC equipment and avionics).

6.1.2 Acquisition Management System (AMS)

Surveillance Services ground infrastructure will require certification by Technical support personnel. Organizations with acquisition and implementation responsibilities should complete necessary System management training requirements.

6.1.3 Safety Management System (SMS)

The Surveillance Services **s**ystem should conform to ICAO SMS processes. See Appendix B for representative hazards and commensurate risk assessments.

6.1.4 Regulation and Policy

Rules may be required and procedures will be necessary to support ADS-B enabled spacing and separation operations. States may need to develop policy and performance standards for aircraft and operators to support the ADS-B technology. Any changes to flight rules may require public comment and resolution.

Other actions, such as airspace redesigns, may be necessary to realize full operational benefits. Initial ADS-B IN applications are informational, providing pilots with an improved situational awareness to enhance safety, and probably do not require rule or procedural changes. The strategy initially depends on users voluntarily equipping with ADS-B IN capabilities. However, it is expected that over time more users will equip to gain the operational benefits. In line with the industry agreed policy of “Best-equipped, Best-served”, States may consider airspace rules or may designate areas to provide preferred service for users who are capable and equipped for ADS-B operations

6.1.5 Publication/Notices

Changes to current publications will be required to reflect operational and compliance changes. Development of new operational, procedural, and training documentation is required. Notices announcing changes to operational, procedural, and compliance requirements will need to be developed and distributed. Examples of documentation that may or may not be affected include, but are not limited to:

- International Agreements
- Advisory Circulars (AC)
- Technical Standard Orders (TSO)
- Facility Operations and Administration
- Aeronautical Information Publication (AIP)
- Terminal Instrument Approach Procedures
- Instrument Approach Procedure Charts (IAP)
- Standard Terminal Arrival Routes (STAR)
- Departure Procedures (DP)
- High/Low/Sectional Navigation Charts
- Letters of Agreement (LOA)

6.2 Operational Impacts

6.2.1 ATC Automation

For ATC surveillance application, Data Link Processors will provide ADS-B reports and status reports to ATC automation systems. ADS-B reports received by automation will include not only aircraft position/altitude and Mode 3A codes, but also additional surveillance related parameters such as, but not limited to, velocity, aircraft flight identification, and accuracy/integrity measures of ADS-B position reports. When ADS-B accuracy/integrity measures are inadequate for the service being provided, then either the corresponding ADS-B data should not be displayed to the controller, or the controller should be notified that the displayed data cannot be used. ADS-B ground stations will provide surveillance reports to automation at a higher update rate than radar. ADS-B reports will also be used by automation to improve aircraft tracking accuracy and safety functions such as CA and MSAW.

Because of the additional surveillance provided by ADS-B, ATS providers may desire to implement the use of fusion on ATC automation platforms. This capability fuses any available surveillance source (e.g., ADS-B, Radar, WAM) and displays a single tracked target to ATC. This allows automation to provide ATC with a faster synchronous display update and, when ADS-B surveillance is part of the fused target, a more accurate target position will be displayed to the controller.

6.2.2 TFM Automation

For TFM automation, ADS-B reports will be incorporated as elements of the already established provision of surveillance from en route and terminal ATC Automation systems. There are no anticipated significant operational impacts. The resolution of any asynchronous reporting/timing issues should be resolved within the ATC Automation systems prior to exchange with TFM. The use of the improved surveillance by TFM systems, processes and personnel will be as described above.

6.2.3 Radar-based Surveillance Systems

A communication interface method with existing primary and secondary radars or WAM systems and existing surface systems will be required to provide sensor measurements.

6.2.4 Service Provider and User Procedures

The introduction of ADS-B may require ATC procedural changes in order to optimize potential operational efficiency gains. New procedures should be designed to minimally impact current procedures. The goal is to minimize increases to cognitive workloads due to the implementation of ADS-B surveillance applications. New cockpit and ground automation capabilities provided by ADS-B give users the ability to achieve spacing and separation without fundamentally changing the overall responsibilities between pilots and controllers. Users may request or accept an ADS-B enabled operation, while service providers retain the authority to approve or apply a procedure depending on factors such as duty priorities and the operational situation at the time. However, procedures to clearly define the roles, responsibilities, and methods between users and service providers for initiating, executing, or terminating an ADS-B application will be required. Human factors analysis may be required to examine aircrew and controller workloads. Analysis may be required to develop rules and procedures defining all factors associated with the application or operations. Examples include, but are not limited to:

- ADS-B specific phraseology for application/operations;
- Modification of the symbology on ATC screens for the different sensors;
- Rules and procedures between pilot and controller for new operations;
- Designated areas, conditions, and types of ADS-B operations authorized;
- Service provider procedures for mixed operations (ADS-B participants versus non-participants) environments;

- Rules governing airborne spacing and separation operations;
- Backup, contingency, and transition procedures when ADS-B surveillance is lost.

6.2.5 ADS-B Separation Standards

Analysis may be required to determine separation standards between mixed equipage targets received from different surveillance systems including the transition boundaries between these surveillance areas. Once a service provider shows that ADS-B positioning accuracy and integrity is equivalent to or better than cooperative surveillance radar, then ICAO radar separation minima (PANS-ATM, Chapter 8) can be utilized. Where service providers wish to use ADS-B in En Route airspace to support separation of less than 5NM, additional analysis is required. The goal is a common, standardized separation minimum for service providers.

6.3 Service Provider and User Impacts

The equipage decision will vary for different users and consideration must be given on the effect ADS-B implementation and operations will have on those that do or do not equip. Each state will define and enforce avionics and navigation equipment standards through Technical Standard Orders (TSO), Advisory Circulars, Airworthiness Inspections, etc. but must be within the minimum standards specified by ICAO.
Each state will issue TSO's that prescribe minimum performance standards for navigation equipment used by the civil aviation community. ICAO issues standards and recommended practices for international civil aviation. The development of minimum performance standards for military users is the responsibility of the separate department services. These military standards must conform to civil airspace required navigation performance requirements, prevent violation of civil air traffic clearances, and ensure safe separation of military and civil air traffic.

6.3.1 User and Service Provider Training

Users and service providers will require training to understand the new technology’s capabilities, characteristics, and limitations. Users and service providers must have an understanding about one another’s use of ADS-B. Both service providers and users will require training on the operation of ADS-B equipment and knowledge of ADS-B-specific terms, phraseologies, and display symbology. Users and service providers will require training and certification/qualification on the use of ADS-B applications and operations. This will include, but not be limited to:

- Rules governing areas and conditions allowing an ADS-B application.
- Rules governing certified equipment levels and personnel qualifications.
- Rules and procedures for spacing and separation applications.

7. ADS-B IMPLEMENTATION

The ADS-B implementation, as any new technological solutions, must be based on a positive business case, maximizing existing aircraft capabilities, and only where operationally justified. The ADS-B implementation and related infrastructure should consider, among other aspects:

- Measurable safety and/or operational improvements as agreed by stakeholders.
- Follow an inclusive airline consultation process prior to investments being made.
- Be supported by coordinated cost-benefit analysis.
- Follow ICAO user charges principles.

In principle, ADS-B should not be implemented as a redundant surveillance capability, and, provided there is a positive business case, it should replace radar, or be used in non-radar airspace to improve ATS surveillance. Exceptions should be evaluated where there is a strong operational requirement (complexity and/or volume of traffic, for example) to keep both radar and ADS-B. Transition timelines need to be determined in consultation with airspace users.

Mandating ADS-B OUT avionics equipage should be considered only for airspace where ADS-B is planned to be the only surveillance capability. Once ADS-B ground stations become operational, ANSPs should, in consultation with airlines, publicly and transparently establish a timeline to decommission other surveillance infrastructure.

Performance requirements for ADS-B OUT should be consistent with ICAO Circular 326. Requiring unnecessarily high performance, without appropriate safety and/or cost benefit justification, should not be implemented. In this sense, States should specify the separation minima that could be used by applying the existing ADS-B avionics available onboard of the aircraft, using as guidance the information provided in the ICAO Circular 326.

ADS-B implementation should be part of an integrated planning, including, at least, communication, navigation, and ATM systems/procedures to implement concrete airspace user benefits such as enhanced air traffic flow management, optimized air traffic separation provision, Improved Operations through Enhanced en-route Trajectories - FRTO (e.g., User Preferred Routings – UPR, Strategic Direct Routing – SDR and Free Route Airspace – FRA). In this sense, in accordance with guidance provided by ICAO for planning/implementation of the Global Air Navigation Plan, States should use the Six Steps Method, provided in the ICAO Doc. 9883 to perform the mentioned integrated planning/implementation, applying its main principles:

- Strong focus on desired/required results;
- Reliance on facts and data for decision making; and
- Collaborative justified decision-making

7.1 ADS-B as enabler for ATM and Safety projects

7.1.1 Optimization of Longitudinal Separation Minima

Currently in several CAR/SAM regions FIRs boundaries, the longitudinal separation minima applied by ACCs is 80 NM or 10 minutes. Some initiatives in CAR/SAM Regions were taken to reduce such separation to 40NM, evolving to 20NM, in a non-radar environment, with application of GNSS distance and VHF communication, as provided in the ICAO Doc. 4444. However, there is still reluctancy on using this separation minima due to the lack of ATS Surveillance. ADS-B should be used to cover the existing gaps in the boundaries of the CAR/SAM FIRs to boost the reduction of longitudinal separation minima to 20 NM, evolving gradually to 5 NM, as provided in ICAO Doc. 4444. Special attention should be given by State for a possible need to cover gaps in VHF Communication to fulfil all requirements for such implementation.

7.1.2 Improved Operations through Enhanced en-route Trajectories - FRTO

The implementation of Improved Operations through Enhanced en-route Trajectories (FRTO), by the application of User Preferred Routings (UPR), Strategic Direct Routing (SDR) and Free Route Airspace (FRA), is one of the main initiatives to increase performance in the efficiency through the reduction of flight time and distance, improvement of vertical flight profile, focusing on fuel savings and CO2 emissions.
Some initiatives in some portions of the CAR/SAM Regions were not possible due to deficiencies in the ATS Surveillance and VHF coverage, mainly in the boundaries of FIRs. An integrated planning of ADS-B and VFH coverage in the FIR boundaries to complement the existing infrastructure may boost the implementation of the Cross Border SDR, gradually evolving to the Crosse Border FRA.

7.1.3 Reduction of Large Height Deviation (LHD) and implementation of AIDC

The meeting of the GREPECAS Twenty-Third Scrutiny Working Group Meeting (GTE/23 informed that LHDs with Code "E" (error/failure of coordination between ATC facilities) were the most frequent in 2022, with 685 of 711 events (96%). The high number of "E" codes is being demonstrated since the beginning of the GTE work, after the RVSM implementation, which urges the need for better coordination between adjacent air traffic units, which could be achieved through awareness-raising and coordination training among controllers.
One of the main tools to improve the coordination between adjacent ATS facilities is the implementation of AIDC, and due to the amount of Code E LHD, its implementation is considered a high priority in CAR/SAM Regions.
The implementation of AIDC is dependent of an adequate ATS Surveillance in the boundaries of FIRs, including a suitable overlap. In this sense, the implementation of ADS-B in the FIRs limits to cover the actual gaps in the ATS Surveillance coverage is one the requirements for an adequate implementation of AIDC.
It is important to note that even without an AIDC implementation, a suitable ATS surveillance and VHF coverage is by themselves essential mechanism to mitigate errors in the coordination between ATS facilities.

7.2 Integrated CNS Planning in CAR/SAM Regions

The ADS-B implementation should be focus on the coverage of existing gaps in the Communication and ATS Surveillance in CAR/SAM Regions. An adequate coverage, mainly in the FIRs boundaries, will allow an improvement of safety and efficiency mentioned in the item 7.1.

APPENDIX A – Definitions and Glossary

ACAS	(ICAO) Airborne Collision Avoidance System
ACC	Area Control Centre
ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-C	Automatic Dependent Surveillance - Contract
ANS	Air Navigation Services
ANSP	Air Navigation Services Provider
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Service
CPDLC	Controller Pilot Data Link Communications
CRM	Collision Risk Model
CSP	Communication Service Provider
CTA	Control Area
DCPC	Direct Controller Pilot Communication
Doc 4444	(ICAO) Procedures for Air Navigation Services - Air Traffic Management (PANS-ATM)
FIR FL (number)	Flight Information Region Flight Level
GNSS	Global Navigation Satellite System
HF	High Frequency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IGA	International General Aviation
MNPS	Minimum Navigation Performance Specifications
MTCD	Medium Term Conflict Detection
NAT	(ICAO) North Atlantic (Region)
NM	Nautical Miles
OCA	Oceanic Control Area
PBN	Performance Based Navigation
RCP	Required Communication Performance
RNPC	Required Navigation Performance Capability
RVSM	Reduced Vertical Separation Minima
SAR	Search and Rescue

SATCOM	Satellite Communications
SATVOICE	Satellite Voice Communications
SMS	Safety Management System
TCAS	Traffic Collision Avoidance System
VHF	Very High Frequency

APPENDIX B: Hazard and Risk Evaluation of ADS-B Application:

Table Att-1. Severity table (basic)

Level	*Descriptor*	*Severity description (customize according to the nature of the product or the service provider's operations)*
1	Insignificant	No significance to aircraft-related operational safety
2	Minor	Degrades or affects normal aircraft operational procedures or performance
3	Moderate	Partial loss of significant/major aircraft systems or results in abnormal application of flight operations procedures
4	Major	Complete failure of significant/major aircraft systems or results in emergency application of flight operations procedures
5	Catastrophic	Loss of aircraft or lives

Table Att-3. Likelihood table

Level	*Descriptor*	*Likelihood description*
A	Certain/frequent	Is expected to occur in most circumstances
B	Likely/occasional	Will probably occur at some time
C	Possible/remote	Might occur at some time
D	Unlikely/improbable	Could occur at some time
E	Exceptional	May occur only in exceptional circumstances

Table Att-4. Risk index matrix (severity × likelihood)

	Severity				
Likelihood	*1. Insignificant*	*2. Minor*	*3. Moderate*	*4. Major*	*5. Catastrophic*
A. Certain/frequent	Moderate (1A)	Moderate (2A)	High (3A)	Extreme (4A)	Extreme (5A)
B. Likely/occasional	Low (1B)	Moderate (2B)	Moderate (3B)	High (4B)	Extreme (5B)
C. Possible/remote	Low (1C)	Low (2C)	Moderate (3C)	Moderate (4C)	High (5C)
D. Unlikely/improbable	Negligible (1D)	Low (2D)	Low (3D)	Moderate (4D)	Moderate (5D)
E. Exceptional	Negligible (1E)	Negligible (2E)	Low (3E)	Low (4E)	Moderate (5E)

(Adapted from Doc 9859)

Operational Activity	Identified Hazards and Risks	Description of Risk	Initial Risk Assessment			Further Mitigation factors	Revised Risk Assessment		
			Likelihood	Consequence	Risk Level		Likelihood	Consequence	Risk Level
ADS-B Operational Trial	Failure of Ground Station	Loss of ADS-B positional data to the controller. Increase in workload due to transitioning to procedural control and reassess traffic.	unlikely	Insignificant	3D	Revert to procedural control and apply appropriate separation standard for affected aircraft. A site monitoring system shall provide a degree of on-line integrity monitoring. Warnings would be provided to ATC if site monitoring is not received.	unlikely	insignificant	3D
Incorrect Data broadcast by an aircraft due to data corruption	Incorrect data due to data corruption broadcast by the aircraft ADS-B transponder. The GNSS on the aircraft still operating correctly.	Significant error in the displayed position of the aircraft that could lead to a breakdown in separation without the controller being aware.	remote	moderate	3D	controller observation of history trail and look for track jump	remote	minor	2D

Corruption of Data by the ground station	Incorrect data displayed to the controller due to data corruption at the ADS-B ground station	Error in the reported position of the aircraft therefore could lead to a breakdown in separation without the controller being aware. This may affect all data.	Improbable		3D	Controller observation of history trail and look for track jump. Ensure only tested and proven ADS-B ground station are used in the operational trials. Ensure Route adherence monitoring is implemented for ADS-B tracks.			
Loss of position accuracy of reported position	The accuracy performance of the navigational equipment in the aircraft has deteriorated to the level that it is not acceptable to support the specified separation standard	Loss of ADS-B positional data to the controller. Increase in workload due to transitioning back to procedural control and reassess traffic	remote	moderate	3D	Ensure the ATM system will detect degradation in accuracy performance below a specified threshold and provide appropriate visual notification to the Unit concerned (NUC value). Revert to procedural control for the affected aircraft. Site monitoring is used to validate that it is only one aircraft affected.	remote	minor	2D
Incorrect processing of ADS-B Data by the ATM system	Data reaching the ATM system processed in such a way as to give a false indication of position, altitude or trajectory	Possible error in the displayed position of the aircraft therefore could lead to a breakdown in separation	remote	moderate	3C	Conduct comprehensive testing of the ADS-B processing and displaying functionality of the ATM. Test should include the conduct flight tests and compare results to commissioned radar information.	improbable	moderate	3D

Failure of GNSS satellites	Loss of ADS-B tracks at the ATS unit	Loss of ADS-B data and Nuc drops causes an increase in workload and procedural control in re-established.	unlikely	moderate		site monitoring installed to provide a degree of on-line monitoring and warning to ATC if site monitoring			
Inadequate ATS Training	Introduction of ADS-B function to an ATS unit without adequate training introduces a new hazard.	Insufficient training in MHI, new procedures and transition from ADS-B control to procedural control and may increase the probability of breakdown in separation.	possible	moderate	3C	prove comprehensive training that covers all operational aspects including contingencies	unlikely	moderate	3D
Inadequate Operational Procedures	Introduction of new ADS-B function is new to ATS and adequate operational procedures will introduce a hazard to the system	inadequate operational procedures for managing and controlling ADS-B areas increases the probability of a breakdown	remote	minor	3C	Maximize the reuse of proven operational procedures to handle ADS-B control areas. Ensure sufficient procedures are developed and tested for the transition between ADS-B and Procedural control	unlikely	minor	2D
RF Jamming	Radio Frequency Jamming of ADS-B due to deliberate or non-deliberate actions	Loss of ADS-B positional data to the ATS unit result in in an increase in workload due to transitioning to procedural control.	improbable		3D	Increase in the level of security and security response at ground installations			

incorrect altitude data transmitted by aircraft	Aircraft transmitting wrong altitude because or faulty barometer or wrong geometric levels on display	Could lead to a loss of separation between aircraft or CFIT	unlikely	major	4D	obtain verbal verification of altitude when ADS-B target is observed	improbable	major	4D
Incorrect 24 bit code	incorrect 24 bit code filed on the flight plan leading to mismatch or no match ADS-B target to filed FPL	wrong call sign affixed to aircraft track leading to increase work load for controller to rationalize the proper callsign	remote	minor	2C	work by plight plan monitoring group to identify how often this occurs and put measures to reduce the incidents with operator	improbable	minor	2D
Failure of communication link between the ground station and ATS unit	loss of ADS-B position at the ATS unit due to the loss of data from ground station	increase in controller workload transitioning to procedural control and possible loss of separation between aircraft	unlikely	moderate	3D	ensure redundancy of communication lines and power and reliability of technical support for the ground installation	unlikely	moderate	3D
failure of site monitor	site monitor relays information on the suitability of data received from ADS-B returns	erroneous data could be reaching the ATM system and be undetected by the controller leading to loss of separation	remote	moderate	3C	scheduled checks on site monitoring equipment done at frequent intervals and data collection and analysis	remote	moderate	3C
Mixed operating environment	controller having different tracks to work with ADS-B, Flight Plan and SSR	increase in controller workload transitioning different separation	possible	moderate	3C	adequate initial training in procedures and regular refresher training to ensure controller competence	unlikely	moderate	3D

	tracks	standards and possible loss of separation between aircraft							

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