THE AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST (ADS-B) SEMINAR, OPERATIONAL CONCEPT

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1. INTRODUCTION

The ICAO Global Air Navigation Plan (GANP) has recognized ADS-B out (and MLAT) as transformational capabilities under the Surveillance Systems Block Module B0.

On the Surface, ADS-B information is used when available as an element of an A-SMGCS to provide traffic situational awareness to the controller in the form of surveillance information. The availability of the data is dependent on the level of aircraft and vehicle equipage.

The GANP recognizes three (3) key developments in the Block 0 time frame

I. A significant deployment of cooperative surveillance systems including ADS-B (ground- and space-based),

II. Ground processing systems will become increasingly sophisticated as they will need to fuse data from various sources and make increasing use of the data available from aircraft.

III. In addition to the provision of ATS Surveillance, surveillance data from various sources along with aircraft data will be used to provide basic safety net functions and for non-separation purposes.

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 and oceanic 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 low orbiting satellites to receive and relay ADS-B data from aircraft.

The CAR Region is working on using the commissioning of ground-based ADS-B stations data from aircraft to offer Air Traffic services in its various Flight Information Regions (FIRs). The supporting safety analyses, ATM Integration, testing and monitoring for these implementations provides the foundation for expansion of ATS surveillance services based on ADS-B. in this manner, the CAR Region also strives to promote regional harmonization and the sharing of best practices.

Besides the Safety benefits of introducing ATS Surveillance for use by Air Traffic Controllers in areas currently using Procedural Separation, ATM system integration can deliver tangible ground-based safety net functions by using downlinked aircraft parameters. Deployment of ATS Surveillance enables enhancement of airspace capacity through safe reduction of horizontal/longitudinal separation between aircraft is-implemented with an operational benefit that can be realized by implementing an appropriate surveillance and communication infrastructure. Operators also benefit from the ability to file routings that closely resemble their user preferences (UPRs) and gain tactical benefits from efficient ‘shortcuts’ and being granted optimum flight levels and speeds.
1.1 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 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 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.

1.2 Operational use

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

a. Enroute – Terrestrial, Remote, and Oceanic Areas
b. Terminal
c. Surface Airports
d. Search and Rescue
ed. Oceanic Areas
f. Aircraft Tracking
1.3 System Overview

1.4 References:


2. OPERATIONAL NEED:
The use of ADS-B technology is needed to help ensure the provision of ATS Surveillance services and thereby optimizing the use of airspace. Improved availability, integrity, through improved surveillance capability, reliability and accuracy of flight tracking data with reduced latency, which should result in reduced separation minima, while reducing the cost of providing surveillance services. In addition, the reduction of separation minima may provide flight time reductions to passengers, lowers fuel savings, and reduces 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. There are currently large airspace volumes where Controllers are unable to “see” their traffic. Due to this basic inability of the ATS system to track aircraft, controllers rely instead on pilots to relay their current and next aircraft position. This is done either using Voice or by datalink (ADS-C). This method of Air Traffic Control relies entirely on pilots adhering to this established procedure- hence classified as Procedural Control.

3. SYSTEM JUSTIFICATION

3.1. Description of Desired Change
ADSB Out uses global navigation satellite system technology to determine specific aircraft position and velocity information, which is then broadcast directly to other suitably equipped aircraft and air traffic controllers. This capability allows ATS systems to display and monitor the more frequent position update rates than radar. The improved accuracy of ADS-B over radar means air traffic controllers may also be able to safely reduce the mandatory separation between aircraft. ADS-B Out also provides greater surveillance coverage, since ADS-B receivers stations are much easier to place than radars.
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 broadcast 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 broadcast, along with track vector information. Like a Mode S transponder,
certain alert conditions are broadcast 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/Airport 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 Enroute airspace – Terrestrial, Remote, and Oceanic Areas

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 ADS-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 antenna. 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 broadcast 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 can not 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 system 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, if needed, should be designed to minimally impact current procedures.

Emerging 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 enabled by ADS-B will give pilots users the ability to achieve spacing and separation without fundamentally changing the overall responsibilities between pilots and controllers. If using a new ADS-B IN application, 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 new application or operations. Examples include, but are not limited to:

- 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 operational environments (ADS-B participants versus non-participants);
- 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 regulations 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.
## APPENDIX A – Definitions and Glossary

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

Table 1. Severity table (basic)

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

Table 2. Likelihood table

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

Table 3. Risk index matrix (severity × likelihood)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Certain/frequent</td>
<td>Moderate</td>
<td>Moderate (1A)</td>
<td>Moderate (2A)</td>
<td>High (3A)</td>
<td>Extreme (4A)</td>
<td>Extreme (5A)</td>
</tr>
<tr>
<td>B. Likely/occasional</td>
<td>Low</td>
<td>Low (1B)</td>
<td>Moderate (2B)</td>
<td>Moderate (3B)</td>
<td>High (4B)</td>
<td>Extreme (5B)</td>
</tr>
<tr>
<td>C. Possible/remote</td>
<td>Low</td>
<td>Low (1C)</td>
<td>Low (2C)</td>
<td>Moderate (3C)</td>
<td>Moderate (4C)</td>
<td>High (5C)</td>
</tr>
<tr>
<td>D. Unlikely/improbable</td>
<td>Negligible</td>
<td>Negligible (1D)</td>
<td>Low (2D)</td>
<td>Low (3D)</td>
<td>Moderate (4D)</td>
<td>Moderate (5D)</td>
</tr>
<tr>
<td>E. Exceptional</td>
<td>Negligible</td>
<td>Negligible (1E)</td>
<td>Negligible (2E)</td>
<td>Low (3E)</td>
<td>Low (4E)</td>
<td>Moderate (5E)</td>
</tr>
</tbody>
</table>

(Adapted from Doc 9859)
<table>
<thead>
<tr>
<th>Operational Activity</th>
<th>Identified Hazards and Risks</th>
<th>Description of Risk</th>
<th>Initial Risk Assessment</th>
<th>Further Mitigation factors</th>
<th>Revised Risk Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS-B Operational Trial</td>
<td>Failure of Ground Station</td>
<td>Loss of ADS-B positional data to the controller. Increase in workload due to transitioning to procedural control and reassess traffic.</td>
<td>unlikely Insignificant 3D</td>
<td>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.</td>
<td>unlikely insignificant 3D</td>
</tr>
<tr>
<td>Incorrect Data broadcast by an aircraft due to data corruption</td>
<td>Incorrect data due to data corruption broadcast by the aircraft ADS-B transponder. The GNSS on the aircraft still operating correctly.</td>
<td>Significant error in the displayed position of the aircraft that could lead to a breakdown in separation without the controller being aware.</td>
<td>remote moderate 3D</td>
<td>controller observation of history trail and look for track jump</td>
<td>remote minor 2D</td>
</tr>
<tr>
<td>Scenario</td>
<td>Cause</td>
<td>Probability</td>
<td>Impact</td>
<td>Action</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>-------------</td>
<td>--------</td>
<td>------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Corruption of Data by the ground station</td>
<td>Incorrect data displayed to the controller due to data corruption at the ADS-B ground station</td>
<td>Improbable</td>
<td>3D</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>Loss of position accuracy of reported position</td>
<td>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</td>
<td>remote</td>
<td>moderate</td>
<td>3D</td>
<td>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.</td>
</tr>
<tr>
<td>Incident Description</td>
<td>Description</td>
<td>Likelihood</td>
<td>Probability</td>
<td>3C Description</td>
<td>3D Description</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Incorrect processing of ADS-B Data by the ATM system</td>
<td>Data reaching the ATM system processed in such a way as to give a false indication of position, altitude or trajectory</td>
<td>remote</td>
<td>moderate</td>
<td>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.</td>
<td>improbable</td>
</tr>
<tr>
<td>Failure of GNSS satellites</td>
<td>Loss of ADS-B tracks at the ATS unit</td>
<td>unlikely</td>
<td>moderate</td>
<td>site monitoring installed to provide a degree of on-line monitoring and warning to ATC if site monitoring</td>
<td></td>
</tr>
<tr>
<td>Inadequate ATS Training</td>
<td>Introduction of ADS-B function to an ATS unit without adequate training introduces a new hazard.</td>
<td>possible</td>
<td>moderate</td>
<td>prove comprehensive training that covers all operational aspects including contingencies</td>
<td>unlikely</td>
</tr>
<tr>
<td></td>
<td>Insufficient training in MHI, new procedures and transition from ADS-B control to procedural control and may increase the probability of breakdown in separation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inadequate Operational Procedures</td>
<td>Introduction of new ADS-B function is new to ATS and adequate operational procedures will introduce a hazard to the system</td>
<td>inadequate operational procedures for managing and controlling ADS-B areas increases the probability of a breakdown</td>
<td>remote</td>
<td>minor</td>
<td>3C</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>RF Jamming</td>
<td>Radio Frequency Jamming of ADS-B due to deliberate or non-deliberate actions</td>
<td>Loss of ADS-B positional data to the ATS unit result in an increase in workload due to transitioning to procedural control.</td>
<td>improbable</td>
<td>3D</td>
<td>Increase in the level of security and security response at ground installations</td>
</tr>
<tr>
<td>incorrect altitude data transmitted by aircraft</td>
<td>Aircraft transmitting wrong altitude because or faulty barometer or wrong geometric levels on display</td>
<td>Could lead to a loss of separation between aircraft or CFIT</td>
<td>unlikely</td>
<td>major</td>
<td>4D</td>
</tr>
<tr>
<td>Incorrect 24 bit code</td>
<td>incorrect 24 bit code filed on the flight plan leading to mismatch or no match ADS-B target to filed FPL</td>
<td>wrong call sign affixed to aircraft track leading to increase workload for controller to rationalize the proper callsign</td>
<td>remote</td>
<td>minor</td>
<td>2C</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------</td>
<td>------</td>
<td>----</td>
</tr>
<tr>
<td>Failure of communication link between the ground station and ATS unit</td>
<td>loss of ADS-B position at the ATS unit due to the loss of data from ground station</td>
<td>increase in controller workload transitioning to procedural control and possible loss of separation between aircraft</td>
<td>unlikely</td>
<td>moderate</td>
<td>3D</td>
</tr>
<tr>
<td>Failure of site monitor</td>
<td>site monitor relays information on the suitability of data received from ADS-B returns</td>
<td>erroneous data could be reaching the ATM system and be undetected by the controller leading to loss of separation</td>
<td>remote</td>
<td>moderate</td>
<td>3C</td>
</tr>
<tr>
<td>Mixed operating environment</td>
<td>controller having different tracks to work with ADS-B, Flight Plan and SSR tracks</td>
<td>increase in controller workload transitioning different separation standards and possible loss of separation between aircraft</td>
<td>possible</td>
<td>moderate</td>
<td>3C</td>
</tr>
</tbody>
</table>