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North American, Central American and Caribbean Office

INFORMATION PAPER

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Automatic Dependent Surveillance – Broadcast (ADS-B) Implementation and Regulation Meeting for the NAM/CAR/SAM Regions (ADS-B/LEG)

Mexico City, Mexico, 26 to 30 November 2018

Agenda Item 8: Other business

BUILDING FROM THE AIREON SAFETY CASE AND CERTIFICATION TO SUPPORT AN ANSP SAFETY CASE

(Presented by Aireon and EASA)

EXECUTIVE SUMMARY	
This paper presents information regarding Aireon's "Surveillance as a Service" approach coupled with the European Aviation Safety Agency ATM / ANS organizational certification. Further the paper will outline a comprehensive approach in building from the Aireon safety case and certification to support an ANSP safety case for operational usage.	
Strategic Objectives:	• Safety • Air Navigation Capacity and Efficiency
References:	• See attachment

1. Introduction

1.1 ANSP Safety Case Development Approach

1.1.1 As further described in various international standards and guidance documentation, an Air Navigation Service Provider must demonstrate that acceptable levels of safety are achieved and documented. An ANSP's Safety Case provides the mechanism to document the achievement and maintenance of safety. According to guidance material published by the ICAO Asia Pacific Office, the ANSP Safety Case should:

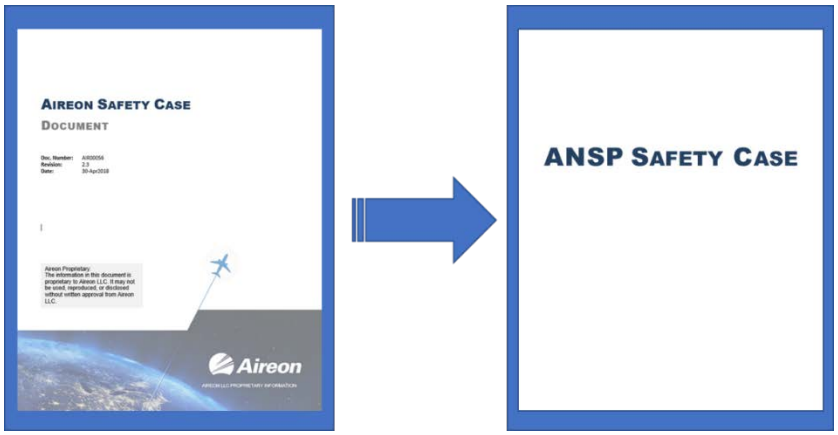
- Describe the surveillance system including the operational role and functions which it covers
- Define or reference the performance standards and specifications of the system
- Establish the safety objectives and the safety requirements for the system
- Identify the hazards and the operational consequences of the hazards. Identification of hazards and consequences must ensure that all possible failure and fault modes have been identified under all normal and abnormal modes of operation
- Assess the associated risks (in terms of frequency of occurrence and severity) of each identified operational consequence
- Categorize each of the risks within a recognized risk tolerability classification scheme
- Establish the controls necessary to ensure the risks are tolerable

2 ANSP Safety Case Implementation for Space-based ADS-B

2.1 ANSPs should develop a safety case (or safety assessment to amend an existing safety case) introducing space-based ADS-B into their ATC automation system by following the guidance provided by ICAO Circular 326. Summarized below, the approach is comprised of four processes:

1. Definition of an Airspace Concept
2. Identification of ADS-B Performance Requirements
3. Safety Assessment
4. Preparation for Implementation

2.2 As part of the Aireon service provision, Aireon will be certified as an ATM / ANS organization by EASA. EASA's extensive audits of Aireon processes and service performance independently validates the integrity of the Aireon service offering. Following industry best practices, Aireon has produced a safety case that serves the EASA process. Aireon ANSP customers receive the Aireon Safety Case as a deliverable which identifies the operational hazards related to any ADS-B surveillance system. These hazards formulated the foundation to develop safety requirements as mitigations that control the hazards as low as reasonably practicable. The Aireon Safety Case can be used as input to an ANSP safety case which encompasses a broader perspective taking into account the change to the existing operational environment.



2.3 The Aireon Safety Case structure and methodology can be extended in support of the ANSP safety case as highlighted in the following sections.

2.1.1 Definition of Airspace Concept

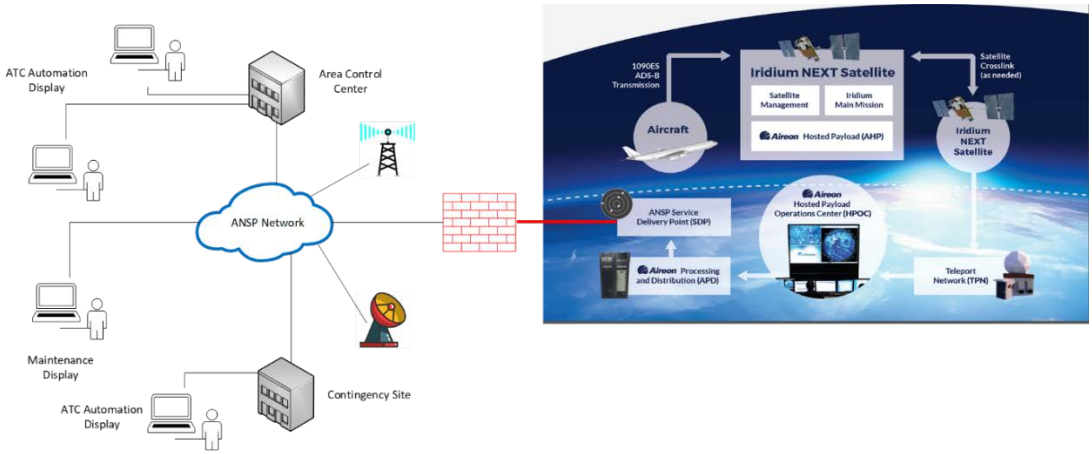
2.1.2 Deciding how ADS-B surveillance is to be used in a given airspace includes identifying the separation minima to be used in that airspace and ensuring that the ADS-B surveillance equipment can support the minima. This has a direct effect on the airspace concept. For example, an airspace concept which is supported by procedural control (i.e. without ATC surveillance) is usually not similar to one used where ATC surveillance is to be used.

2.1.3 The ANSP should develop the concept of operation unique to their objectives. This will assist in formulating the needed operational changes to integrate Space-based ADS-B into their operational environment because introducing a new surveillance source could affect:

- Routes
- Holding Areas
- Airspace Structure
- ATC Sectorization
- Air Traffic Management
- ATC Training

2.2.1 Identification of ADS-B Performance Requirements

2.2.2 It is recommended that ANSPs define the boundaries of the surveillance system as it interfaces with their pre-existing environment which includes the airspace, aircraft equipage types, existing ATC procedures and automation system.



2.2.3 The ANSP should validate the performance of the ADS-B source to ensure the system / service is robust and maintains the integrity and other service requirements commensurate with the intended separation minima that will be applied. The safety requirement derivation process should consider the estimated maximum 'instantaneous count' of flights that can be expected in the sector and average throughput. These are used to assist in the determination of operational effects from various surveillance system failures. These are not an ideal reflection of true complexity which includes coordination requirements, climbing and descending scenarios etc., however they are a reasonably simple way of determining workload effects on ATC in the event of failures.

2.2.4 The ANSP may have unique security gateways, specialized surveillance networks and maintenance operation locations that are unique ANSP requirements. Aireon will work with the ANSP to accommodate their needs and ensures service interoperability. As part of the implementation phase, Aireon provides the following to the ANSP:

- Service Definition
  - o Service Definition Document
  - o Interface Control Document leveraging ASTERIX format

- Testing Evidence
  - Verification Requirements Traceability Matrix (VRTM)
  - Implementation Service Acceptance Test (ISAT) Test Plan, Test Procedures and Test Report
  - Declaration of Verification
  - Declaration of Suitability for Use
  - Service Volume Description Document
  - Service Level Agreement

- Software Tools
  - Maintenance Display Software
  - Computer-based Training

- Aireon Documentation and Plans
  - Aireon Safety Case Document
  - Aireon Corporate Safety Plan
  - Aireon Security Plan
  - Service Sustainment Document

2.2.5 The ATC automation system with control and monitoring capability of the ADS-B source should interface via a standard method to ensure interoperability between the surveillance source and the ATC automation / display system. The ASTERIX CAT025 and CAT021 are meant to be interpreted by automation systems and/or trackers that could result in changes to a controller's display whereas the control and monitoring is meant to be interpreted by maintenance personnel.

2.2.6 Aireon provides ADS-B in the form of "surveillance as a service" with provisions for monitoring of the service by means of a local maintenance display and a cloud dashboard. Additionally, Aireon provides the ASTERIX CAT025 data for independent monitoring by the ANSPs, in either case this is intended to improve situational awareness regarding the ADS-B System health.

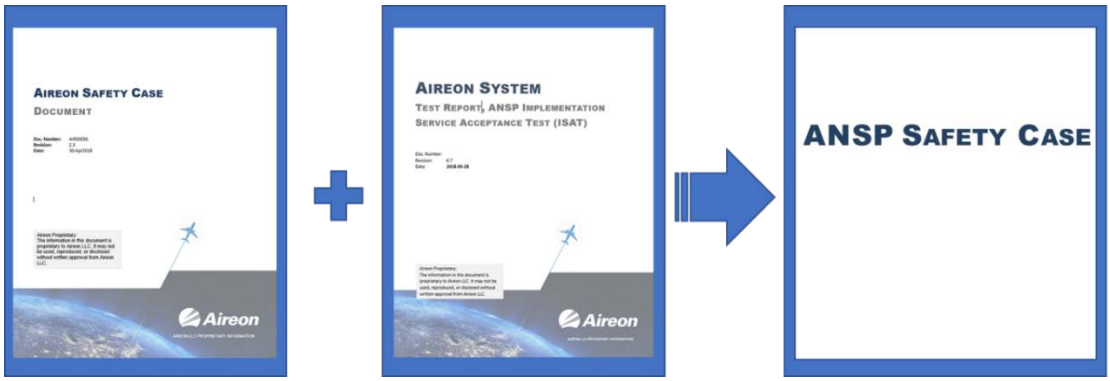
2.2.7 The Aireon Service Level Agreement (SLA) details the service levels applicable to the provision of data services and technical support services to an ANSP. The SLA technical performance measures are defined as:

- ANSP_Aireon001: Service Volume Availability of ≥ 99.9% in accordance with the ICAO Global Operational Data Link Document (GOLD) as set forth in the RSP Specification, Appendix C, Table C-3
- ANSP_Aireon002: Latency ≤ 2.0s (99th percentile) in accordance with the EUROCONTROL Safety & Performance Requirements Document for a Generic Surveillance System Support Air Traffic Control Services (GEN-SUR SPR VOLUME 1) as set forth in Section 3.7.3.1.5 (SUR Sensor + SUR Distribute) SPR 9 and Table 33
- ANSP_Aireon003: Probability of Update ≥ 96% for an Update Interval of 8 seconds in accordance with the EUROCAE Technical Specification for an 1090 MHz Extended Squitter ADS-B Ground System, ED-129B; as set forth in Section 3.3.1.1 [Probability of Update (PU) Requirement – See REQ 17 and Table 3, Row #1 (Low Density En Route)]

2.2.8 Aireon with the ANSP conducts an Implementation Service Acceptance Test (ISAT). The Aireon ISAT test report validates the surveillance service within the ANSP defined service volume. The ISAT consist of the following activities:

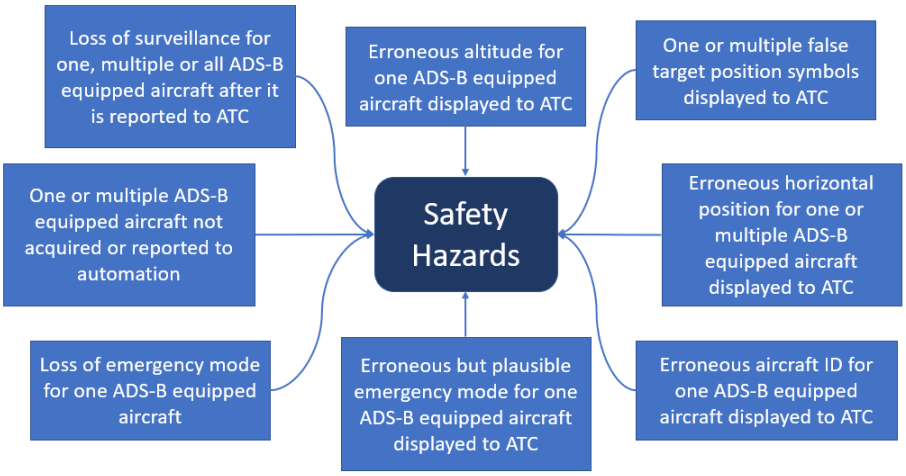
- Telco and Installation Test Cases
- Security Test Cases
- Operations Test Cases
- Local Maintenance Display
- Redundancy Test Cases
- Data Collection
- Performance Test Cases
- Aireon Dashboard
- Billing Test Cases
- Customer Specific Test Cases

2.2.9 The Aireon ISAT report can be used as input to the ANSP safety case which encompasses the unique test and validation of Aireon's service within the ANSP's airspace and operational environment.



2.3.1 Safety Assessment

2.3.2 Based on the previous 2 steps of defining the ADS-B concept of operations and performance requirements, the ANSP can extend the hazards that are defined in the Aireon safety case to the existing automation system and workforce environment. The basic tenet of the ADS-B surveillance service is to not corrupt nor drop ADS-B target information received from the aircraft. The following identifies ADS-B safety hazards:



2.3.3 A safety review should be conducted to first ascertain that the identified hazards and the operational consequences of the hazards are valid, and also to consider if any additional hazards, unique to the ANSPs environment exist. The identification of hazards and consequences must ensure that all possible failure and fault modes have been identified under all normal and abnormal modes of operation. The safety review should assess the associated risks (in terms of frequency of occurrence and severity) of each identified operational consequence and categorize each of the risks within a recognized risk tolerability classification scheme. The ANSP can establish the controls necessary to ensure the risks are tolerable. The ANSP usually will have contingency plans and procedural back-ups procedures that can be included into the mitigation strategy.

2.3.4 A sample ANSP hazard identification and mitigation is provided below:

Operational Hazard	Description	ANSP Mitigation Strategy(ies)
Corruption of altitude information for a **single** aircraft	The altitude of a single aircraft provided to the controller is incorrect. The incorrect altitude is detected by the controller if the error is not plausible. When it is detected, the controller continues providing vertical separation without using the erroneous displayed altitude information. If it is not detected, the controller could potentially make decisions which would bring the aircraft into proximity to another aircraft believing it to be vertically separated therefore creating a conflict.	ANSP procedures exist to manage this scenario for a single aircraft (i.e. alternative separation)

2.4.1 Preparation for Implementation

2.4.2 As the safety case defines the change to the ANSP operational environment, an implementation plan defines the actions to be taken to implement the capability. Depending on the safety hazards and the associated mitigations there may be changes made to the ANSP systems, policy and procedures. Some examples of areas that may require change proposals would be:

- ATC Automation modifications to accept additional surveillance sensors
- ATC modifications to display ADS-B aircraft indicators
- ATC Training revisions
- ATC procedure changes/amendments
- ATC airspace boundaries definition
- Best equip – best served route changes
- Performance monitoring equipment
- Technician training

2.4.3 Discussions should take place between the ANSP and their safety regulator to inform them of the proposed change and to positively demonstrate that the relevant safety regulations are satisfied. The ANSP is responsible for demonstrating that acceptable levels of safety are and continue to be achieved. The ANSP's safety case acts as a vehicle to gain regulatory approval for the new service.

2.4.4 The ANSP's regulator may also acquire support from EASA, who has rigorously scrutinized the inner workings of the Aireon company processes, policies, procedures, personnel competency and design assurance approach. This provides other regulators with a unique view behind the service offering, and assists the regulator in understanding the ANSP safety case (see Appendix D).

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APPENDIX A
SOURCES

Id	Organization	Document Number	Title/Version	Date
[1]	Air Traffic Management Magazine	N/A	The Road to ADS-B: Partner Approach; Issue 3	Autumn 2018
[2]	Aireon	N/A	Service Level Agreement and Technical Support Between [Customer] and Aireon LLC for the Provision of ADS-B Surveillance Data Services	July 2018
[3]	EUROCAE	ED-129B	Technical Specification for a 1090 MHz Extended Squitter ADS-B Ground Station	March 2016
[4]	EUROCONTROL	GEN-SUR-SPR	Generic Surveillance Safety and Performance Requirements; Edition 1.3	October 2015
[5]	EUROCONTROL	DAP/SSH/091	Safety Case Development Manual; Version 2.2	November 2006
[6]	ICAO	Annex 11	Air Traffic Services	July 2016
[7]	ICAO	Circular 326	Assessment of ADS-B and Multilateration Surveillance to Support Air Traffic Services and Guidelines for Implementation	2012
[8]	ICAO	Doc 4444	Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM)	November 2014
[9]	ICAO	GOLD	Global Operational Data Link Document	April 2013
[10]	ICAO	Working Paper from ADS-B SITF/10	Guidance Material on Preparation of a Safety Case for Delivery of Separation Services	April 2011
[11]	ICAO Asia Pacific Office	Guidance Material	Guidance Material on Building a Safety Case for Delivery of an ADS-B Separation Service; Version 1.0	September 2011
[12]	ICAO SASP	Meeting Report	Separation and Airspace Safety Panel Report from Second Meeting	May 2018

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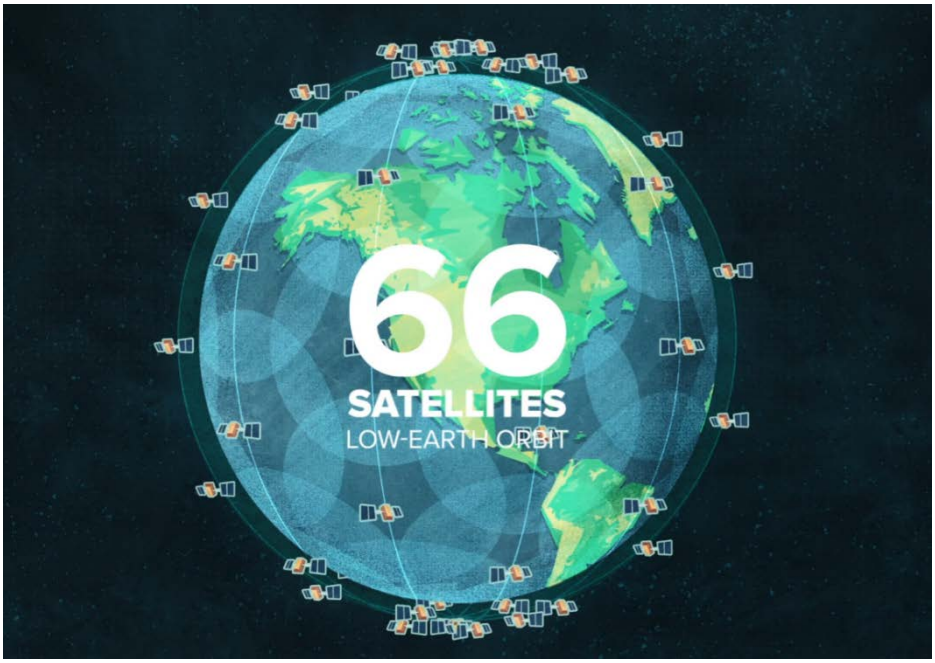
APPENDIX B
AIREON BACKGROUND

Aireon is on the pathway of deploying Automatic Dependent Surveillance-Broadcast (ADS-B) receiver payloads into space for providing Air Traffic Control (ATC)-grade "surveillance-as-a-service." This is being accomplished as part of the Iridium next-generation satellite replacement program, Iridium NEXT.

Aireon is a hosted payload on every new Iridium NEXT satellite and is given real estate, power, and communication bandwidth to capture ADS-B transmitted messages and relay to a ground processing center capable of redistributing to Air Navigation Service Providers (ANSPs) around the world. The ANSPs use this data feed as input to their ATC automation and display systems to present aircraft tracks to the controllers for the purposes of providing separation services to the users of the airspace.



The Iridium NEXT constellation with Aireon ADS-B payloads will be fully deployed in 2018, providing space-based ADS-B as a transformational air traffic surveillance technology, eliminating the coverage limitations of terrestrial-based solutions. Aireon's space-based ADS-B system will support an array of services. The primary service is to provide surveillance data for ATC use. Space-based ADS-B can serve as the sole source of surveillance data, augment existing surveillance systems, or provide a contingency in the case of a failure with existing surveillance systems. Space-based ADS-B will be the sole source of surveillance in regions that currently lack surveillance coverage. This will provide opportunities for replacing non-surveillance procedural control methods with surveillance-based methods, as well as lowering the infrastructure costs associated with obtaining surveillance data.

Examples of safety benefits provided by space-based ADS-B to an ANSP include:

- Improved controller situational awareness through 100% surveillance in all sectors, Flight Information Regions (FIRs) and across FIR boundaries
- Elimination of surveillance gaps
- Improved search and rescue response

Space-based ADS-B can provide continuous surveillance, more frequent and timely position data to the ATC automation systems, translating into improved controller situational awareness, more dynamic conflict probing and reporting, and enhanced safety across the given airspace. This enhanced surveillance capability can enable surveillance-based ATC methods in current oceanic, non-radar remote and domestic airspace.

ANSP ADS-B Out mandates enable the surveillance capability for space-based ADS-B. The ADS-B position, velocity and identification data is transmitted from the aircraft on the 1090 MHz Extended Squitter (1090-ES) link and received by Aireon's ADS-B receiver payloads. The ADS-B payload decodes the ADS-B messages it receives and (using the Iridium space and ground network) sends the content of the message to the Aireon ground segment for processing and distribution. The data is then routed to ANSP customer automation platforms for use in surveillance applications.

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APPENDIX C
AIREON'S INITIAL EASA CERTIFICATION JOURNEY

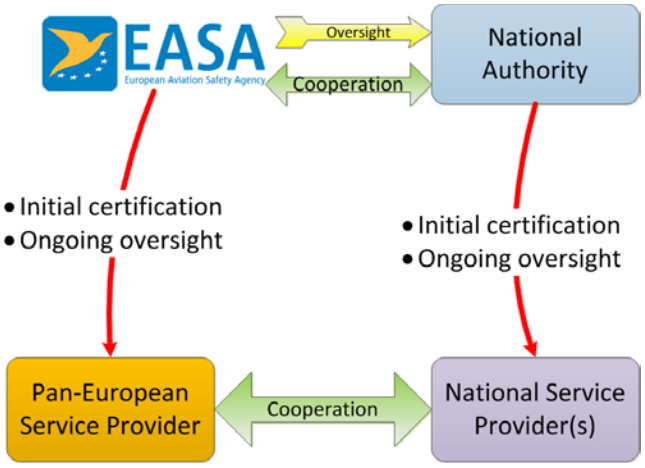
As part of developing a strategy for operational approval of a new capability such as Space-based ADS-B, the ANSP may develop a safety case that defines the intended function of the change to their operations. The ANSP safety case can be supported by Aireon certification from EASA and the International Civil Aviation Organization (ICAO) standards and recommended practices.

Aireon has engaged the European Aviation Safety Agency (EASA) to acquire an initial Air Traffic Management (ATM)/Air Navigation Services (ANS) organization certification. The certification process is a rigorous, holistic endeavor that ensures the integrity and compliance with European regulation of the Aireon company and data is compliance with the service requirements to be used to support the safety-of-life application of ATC separation of aircraft.

EASA as an agency of the European Union (EU), is promoting the highest common standards on civil aviation safety and environmental protection. Having its headquarters in Cologne, Germany, EASA has offices worldwide, in Brussels, Washington, D.C., Singapore, Montreal and Beijing.

EASA's main responsibilities are:

- Drafting of aviation safety legislation. This includes those regulations which define minimum requirements for organizations providing ATM/ANS services.
- Providing advice to the Commission of the EU
- Monitoring the application of EU legislation in member states (standardization)
- Certification of aviation products, parts and appliances and by this ensuring a single regulatory and certification process among EU Member States
- Approval of organizations, e.g. ATM/ANS service providers. For this type of service, EASA approves those organizations having their principle place of business outside the EU, but providing services within the airspace of EU member states.



EASA acts as a safety regulator in different domains by this ensuring a total system approach for:

- Airworthiness
- Operations and Flight Crew Licensing
- Non-EU ("3rd Country") Operations
- Aerodromes
- ATM/ANS services and Air Traffic Control Training organisations

EASA has already gained experience and competence as oversight authority for the European Satellite-Based Augmentation System, European Geostationary Navigation Overlay Service (EGNOS) and its service provider European Satellite Services Provider (ESSP).

The Aireon certification process falls under EASA competence as Aireon has its principle place of business in the U.S. but intends to offer services to several ANSPs within the EU. The EASA certificate is valid for all EU member states and ensures that, for Aireon, once approved, no additional certification activities are necessary.

Initial Certification: In the Beginning

When Aireon approached EASA for initial certification, the details of the company setup and the technical elements were already well defined. This allowed EASA to immediately start assessing the Aireon documentation for compliance with EU regulations, e.g.

- Technical and operational competence and capacity
- Organisational structure and management
- Safety and quality management
- Security
- Human resources
- Financial strength
- Liability and insurance cover
- Quality of services
- Reporting requirements

Audits are performed to review all items. The total length of such an initial certification process cannot be predicted precisely. It depends on the complexity of the company and the service, but at least during the kick-off meeting some rough estimated timeline can be agreed between the company and EASA. In total, the initial certification process looks like this:

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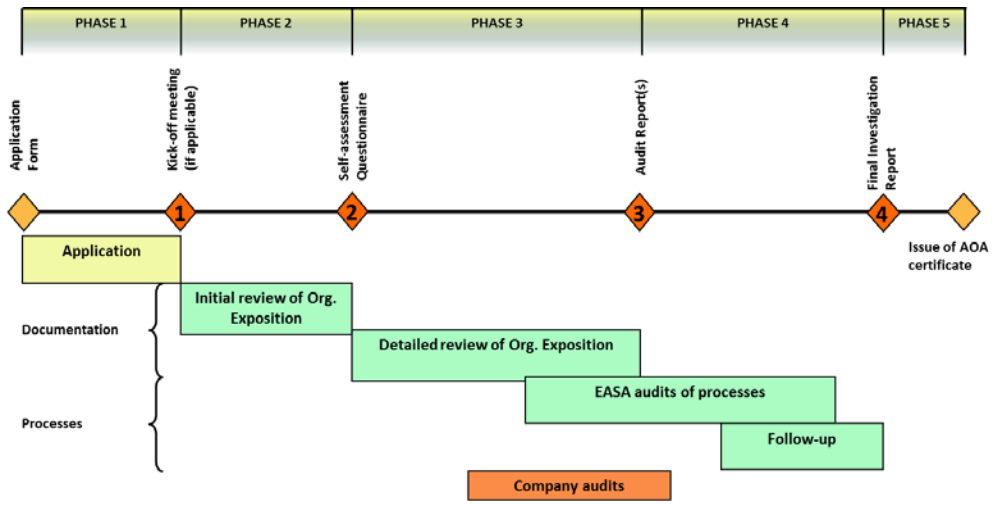

Introduction: Where is Aireon in the Initial Certification Process?

Aireon and EASA have been working through the initial certification process since June 2016. This journey has included three audits and extensive review of Aireon's compliance matrix in alignment with the appropriate EU / ICAO safety regulations. Foundational to the verification of Aireon's Safety Management System (SMS) is the Aireon Safety Case which establishes the framework for defining the intended function the service has been designed to support. In general, the Aireon Safety Case will contain:

- Description of the Aireon Service and environment
- Scope of the Safety Case
- Safety Arguments based on the operational uses of the service
- Assessments of the Safety Arguments
- Safety Requirements and Assumptions
- Conclusions and Recommendations
- Appendices to include the Operational Safety and Environment Description (OSED) and Fault-Tree Analysis

The Aireon Safety Case provides detailed information as evidence that the use of ADS-B air traffic surveillance data provided by the Aireon Service to support the provision of ATC service is acceptably safe. This includes that the Aireon service will be safely operated throughout its service life to support the provision of safe ATC service.

The Aireon service is intended to be used in two main types of airspace: airspace where ADS-B ground-based surveillance could be used such as domestic en-route and terminal area plus airspace where no ADS-B ground-based surveillance is possible such as remote and oceanic airspace. The following table summarizes the operational use cases for Space-based ADS-B:

Environment	Type of services	Horizontal Separation Minima	Reference
Oceanic - Advanced	AREA control service in Oceanic sector	15 NM	SASP May 2018 Meeting Report; Appendix A
En-Route Non-Radar (NRA)	AREA control service in En-Route sector	5 NM	PANS-ATM Doc. 4444; Section 8.7.3.1
En-Route Radar (RAD)			
Terminal Area Non-Radar (NRA)	APPROACH control service in a TMA sector	3 NM	PANS-ATM Doc. 4444; Section 8.7.3.2 (a)
Terminal Radar (RAD)			

In parallel, with the EASA certification process, Aireon has been developing and testing the Aireon system that underlies the Aireon air traffic surveillance service. Seven Space-X launches have successfully deployed 65 Iridium satellites with Aireon payloads on board. These payloads plus the ground system infrastructure are undergoing service acceptance testing as Aireon prepares for the final eighth launch planned for Q4 2018. After the eighth launch, the finalization of service acceptance will be completed, including ADS-B data and customer service delivered to five ANSP service delivery points.

The ANSP testing provides the opportunity to collect performance data in the oceanic, en-route and terminal airspace. This data will be used to evidence the Aireon Safety Case argument, validating the hazard analysis safety requirements and completing the Aireon ADS-B service provision baseline.

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APPENDIX D
SAFETY CASE OUTLINE

1) Introduction
   a) Purpose and scope of the Safety Case Document (SCD)
   b) Applied Method
   c) Document Content
   d) Applicable Documents
   e) Definition of terms

2) Description of the Service and environment
   a) ATC Service ICAO Definition
   b) Operational Environments and ATC services
   c) Operational Surveillance Information provided to the Air Traffic Controller
   d) Functional Architecture of the Surveillance System
   e) Architecture and Functional Description of the Surveillance System
   f) External Systems supporting the ATC Service
   g) System Human Interface

3) Scope of the Safety Case
   a) In-Scope of the Safety Case
   b) Out of Safety Case Scope

4) Safety Arguments

5) Assessment for airspace where ADS-B ground stations could be used
   a) Overview of the Process
   b) Identification of Safety and Performance requirements and assumptions
   c) Evidence for the design of the Surveillance System
   d) Evidence for the implementation of the Surveillance System

6) Assessment for airspace where ground-based surveillance is not possible
   a) Overview of the process
   b) Specifications of the Surveillance Service
   c) Evidence for the design of the Surveillance System
   d) Evidence for the implementation of the Surveillance System

7) Safe operations of the Surveillance Service
   a) Roles, responsibilities, interfaces and agreements with suppliers and customers
   b) Procedures for operations and maintenance
   c) Procedures to ensure that transition to a new build of the Surveillance system does not affect the safe provision of the Surveillance Service
   d) Safety assurance and monitoring procedures
   e) Safety promotion activities
   f) Quality Management

8) Synthesis of Requirements and Assumptions
   a) Safety Case Requirements and Assumptions
   b) ADS-B-NRA Requirements
   c) ADS-B-RAD Requirements and Assumptions
   d) ICAO Annex 10 Requirements
   e) OSED Requirements and Assumptions
   f) Safety Requirements and Assumptions

9) Conclusions and recommendations

Appendix A: OSED
Appendix B: OSED comparison to ADS-B RAD and NRA Standards
Appendix C: Fault Tree analysis

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APPENDIX E
ACRONYMS AND DEFINITIONS

Acronyms:

ADS-B: Automatic Dependent Surveillance - Broadcast
ANSP: Air Navigation Service Provider
ASTERIX: All Purpose Structured Eurocontrol Surveillance Information Exchange
ATC: Air Traffic Control
ATM/ANS: Air Traffic Management / Air Navigation Services
EASA: European Aviation Safety Agency
EGNOS: European Geostationary Navigation Overlay Service
ESSP: European Satellite Services Provider
EU: European Union
FIR: Flight Information Region
GOLD: Global Operational Data Link Document
ICAO: International Civil Aviation Organization
ISAT: Implementation Service Acceptance Test
MHz: Megahertz
NRA: Non-radar Airspace
OSED: Operational Safety and Environment Description
PANS-ATM: Procedures for Air Navigation Services-Air Traffic Management
PU: Probability of Update
RAD: Radar Airspace
SASP: Separation and Airspace Safety Panel
SCD: Safety Case Document
SLA: Service Level Agreement
SMS: Safety Management System
TMA: Terminal Maneuvering Area
VRTM: Verification Requirements Traceability Matrix

SLA Definitions:

Whereas service volume availability, latency, probability of update and data categories are defined as:

Service Volume Availability – means the percentage availability target (99.9%) for the Data Services over a calendar monthly period
Latency – means the amount of time it takes to deliver ADS-B data from the input of the Aireon Space-based receiver to the output of the Service Delivery Point equipment, corresponding to the processing and communication durations.
Probability of Update - means the probability that at least one ADS-B target report was received at the Service Delivery Point within a required period of time. The required period of time for this Update Interval is relative to an aircraft separation standard applicable to the Service Volume airspace
Data Categories – are the ASTERIX CAT 021, 023, and 025 radar data formats for ADS-B data that Aireon will provide to the Service Delivery Point. These Data Category formats are defined as follows:

- CAT 021 are the ADS-B target report messages
- CAT 023 are Service Volume status reports
- CAT 025 are Service and system status reports

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