Global Surveillance through Space-Based ADS-B

ADS-B Implementation Workshop
Lima, Peru
November 13-16, 2017
Agenda

• Space-Based ADS-B Introduction
• Benefits of Space-Based ADS-B
• Operational Overview and Progress
• Technical Implementation
• Safety Certification
Space-Based ADS-B

Introduction

Description & Structure
Over 70% of the World Remains Un-Surveilled

The problem: Today’s ATC surveillance is insufficient and outdated

- Relies on line-of-sight technology, limiting coverage areas
- Upgrades to ADS-B technology for augmenting radar surveillance are also limited to terrestrial airspace
- Ground-based systems are highly capital intensive

- Lack of precise aircraft location knowledge results in required large procedural separation distance to ensure safety
- Procedural separation causes suboptimal routes and thus higher fuel costs, longer travel times and “loss of separation” instances
The Aireon Solution: Space-Based Air Traffic Surveillance

- Only global surveillance solution with ATC-grade availability
- Hosted payload on Iridium satellites – significantly cheaper vs. dedicated constellation with true economies of scale
- Surveillance for all ADS-B equipped aircraft everywhere
- Technologically superior solution with real-time delivery of ADS-B Out data to ANSPs
- No additional aircraft equipage required by airlines

Enables significantly reduced separation requirements, in particular on the congested North-Atlantic track

- Enhanced safety
- Shorter duration flights
- Less fuel burn
- Route optimization / enhanced use of jet stream and winds

Aireon provides surveillance to previously uncovered oceanic and remote air space and augments current, terrestrial-based infrastructure
Complementary Surveillance Services

**Sole Source Surveillance**
Surveillance in regions that currently lack surveillance coverage

**Augmented Surveillance**
ADS-B coverage where there are gaps in current surveillance infrastructure

**Contingency Surveillance**
Provides an ANSP with near instantaneous transition to space-based ADS-B when an outage occurs with their primary surveillance source
Iridium NEXT Constellation Overview

• Satellites in Orbit: 66
  • 11 satellites per plane
  • Plus 9 in-orbit spare satellites and 6 ground spare satellites

• Orbital Planes: 6

• Availability: ≥ 0.999

• Typical Lifecycle: 14 years

• Operational Altitude: approximately 485 miles (780 km)

• Full global Air Traffic Surveillance without the need for additional equipage
Benefits of Space-Based ADS-B
Oceanic / Remote Applicability

- Sole source surveillance with consistent communications
- Anticipated to be 15 nm separation or less
- Significant efficiency and safety benefits
Terrestrial Applicability

• Surveillance layer where direct communications exists
• “Hot standby” in case of ground surveillance failure
• Cross border contingency operations and traffic flow management
• 5 nm separation application
• Infrastructure cost reduction benefits
## Operational Use Scenarios

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Capability</th>
<th>Communication</th>
<th>Navigation</th>
<th>Surveillance</th>
<th>Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Procedural Airspace</strong></td>
<td>Base Case</td>
<td>SATCOM or HF only</td>
<td>RNP-10</td>
<td><strong>Procedural</strong></td>
<td>Long 10 min (80 nm) Lat: 60nm</td>
</tr>
<tr>
<td></td>
<td>With Aireon</td>
<td>SATCOM or HF only</td>
<td>RNP-10</td>
<td>SB-ADSB Surveillance</td>
<td>Better than Long 10 min (80 nm) Lat: 60nm</td>
</tr>
<tr>
<td>Example Airspace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ADS-C Airspace</strong></td>
<td>Base Case</td>
<td>CPDLC with HF backup</td>
<td>RNP-4</td>
<td><strong>ADS-C</strong></td>
<td>30 nm</td>
</tr>
<tr>
<td></td>
<td>With Aireon</td>
<td>CPDLC with HF backup</td>
<td>RNP-4</td>
<td>SB-ADSB Surveillance</td>
<td>&lt;15 nm</td>
</tr>
<tr>
<td>Example Airspace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Procedural Airspace with VHF</strong></td>
<td>Base Case</td>
<td>DCPC Voice</td>
<td>RNP-10</td>
<td><strong>Procedural</strong></td>
<td>10 min (80 nm)</td>
</tr>
<tr>
<td></td>
<td>With Aireon</td>
<td>DCPC Voice</td>
<td>RNAV 5 (Europe) RNAV 2 (U.S.)</td>
<td>SB-ADSB Surveillance</td>
<td>5 nm</td>
</tr>
<tr>
<td>Example Airspace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Currently Surveilled Airspace</strong></td>
<td>Base Case</td>
<td>DCPC Voice</td>
<td>RNAV 5 (Europe) RNAV 2 (U.S.)</td>
<td><strong>Radar, WAM, or Ground Based ADS-B</strong></td>
<td>5 nm</td>
</tr>
<tr>
<td></td>
<td>With Aireon</td>
<td>DCPC Voice</td>
<td>RNAV 5 (Europe) RNAV 2 (U.S.)</td>
<td>SB-ADSB Surveillance</td>
<td>5 nm</td>
</tr>
<tr>
<td>Example Airspace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Procedural**:
  - For Procedural Airspace, the communication is SATCOM or HF only, and navigation is RNP-10. Surveillance is either Procedural or SB-ADSB Surveillance.
  - For ADS-C Airspace, the communication is CPDLC with HF backup, and navigation is RNP-4. Surveillance is ADS-C or SB-ADSB Surveillance.
  - For Procedural Airspace with VHF, the communication is DCPC Voice, and navigation is RNP-10. Surveillance is Procedural or SB-ADSB Surveillance.
  - For Currently Surveilled Airspace, the communication is DCPC Voice, and navigation is RNAV 5 (Europe) RNAV 2 (U.S.) or Radar, WAM, or Ground Based ADS-B. Surveillance is Radar, WAM, or Ground Based ADS-B or SB-ADSB Surveillance.

- **Example Airspace**:
  - Polar Region / Some remote areas in Africa / ASPAC
  - North Atlantic / Pacific oceanic or Some remote areas in Africa / ASPAC
  - VHF without surveillance. Common around small island States (Asia, Caribbean, Latin America) and large remote landmass (ASECNA)
  - Terrestrial Europe, North America, Brazil, Australia etc.
NAV CANADA Use Case

- Assured compliance with safety targets
- Harmonization with NATS for cross-border coordination
- Full terrestrial surveillance
- Redundancy in surveillance
- Reduced number of radars
CAAS - Singapore Use Case

- Situational awareness for safety
- Multiple surveillance layers for redundancy
- Increase operational efficiencies
- Cross-border collaboration
Naviair Case Study

• Current air traffic surveillance overview
  • Full Surveillance of Copenhagen FIR from PSR/MSSR systems
  • M-LAT/ADS-B (ground-based) is planned in operational use by 2017
  • Low level of Surveillance contingency in the North Sea

• Future plans for space-based ADS-B
  • Implementation of a Contingency layer of Surveillance from Space Based ADS-B
    • System will be integrated in the current tracking infrastructure and be “dormant” until failure of the primary system
  • Adding an extra surveillance layer in the North Sea for use in ATC and FIS for low level Helicopter traffic
    • The extra surveillance layer will enable Naviair to maintain standard separation in case of failure of one surveillance source in the North Sea

• Benefits expected
  • Improved operational efficiency and reduction of delay if primary radar sources fail
  • Enhanced safety
Flight Safety Foundation Identified Safety Benefits Of Surveillance Through Space-Based ADS-B

• 2016 public study identifies 23 safety and efficiency benefits of space-based ADS-B as compared to existing capabilities

• Some examples:
  • Jumping a generation of surveillance technology and improving service in remote and difficult-terrain regions
  • Reduced risk and early detection of gross-navigation errors, vertical, lateral and large high deviations in procedural airspace
  • Enhanced situational awareness for pilots and controllers
  • Enhanced search and rescue response
  • Reduced risk in procedural weather deviation
  • Improved global safety performance monitoring and analysis
  • Reduced oceanic separation standards
  • Improved cooperation in contingency management
  • Greater interoperability (an ICAO harmonization enabler)

The study can be downloaded here: https://flightsafety.org/wp-content/uploads/2016/10/ADS-B-report-June-2016-1.pdf
Value of Real-Time Global Air Traffic Surveillance

• Real-time ADS-B position information is expected to significantly reduce vertical collision risk in North Atlantic airspace

• Risk due to Vertical Deviation (same track)

• Comparison of selected flight level (cockpit $\approx 1.5$ seconds) with cleared flight level (ATM Systems $\leq 15$ seconds) will alert the Air Traffic Controller when these values are different

• Safety impact:
  • Detection of vertical deviation risks BEFORE they occur, reduces the number of vertical deviations
Enhancing SAR Operations: Less Time on Search & Faster Rescue

Position Accuracy / Update Interval

<table>
<thead>
<tr>
<th></th>
<th>A320</th>
<th>A330</th>
<th>A340/B77W</th>
<th>A380</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruise speed (kts)</td>
<td>427</td>
<td>475</td>
<td>482</td>
<td>488</td>
</tr>
<tr>
<td>Operational Radius Between Position Reports (sq./ km)</td>
<td>491,165</td>
<td>607,798</td>
<td>625,844</td>
<td>641,522</td>
</tr>
<tr>
<td>PIREP (30min)</td>
<td>122,791</td>
<td>151,949</td>
<td>156,461</td>
<td>160,380</td>
</tr>
<tr>
<td>ADS-C (15min)</td>
<td>9.7</td>
<td>12.0</td>
<td>12.4</td>
<td>12.7</td>
</tr>
</tbody>
</table>
Increasing Sector and Cross-Boundary Safety

- Lowered risk of data loss between airspace sectors through continuous surveillance
- Enabling availability of surveillance data on both sides of the sector boundary
- Reduce hand-off errors, early detection of altitude / position errors
- Early detection of emergency transponder codes
- Reduced complexity through harmonization of operating environment between ANSPs
Operational Overview and Progress
Satellite Launch Status

• First launch: January 14th, 2017
• Second launch: June 25th, 2017
• Third launch: October 9th, 2017
• Remaining launches: 5
• Service operational: mid-2018

Data from 13 Payloads over 24 Hours

Photos: SpaceX
### Early Testing: The Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique Targets Total</td>
<td>24,000</td>
</tr>
<tr>
<td></td>
<td>(3 payloads, 10 March – 17 March)</td>
</tr>
<tr>
<td>Unique Targets per day</td>
<td>19,351</td>
</tr>
<tr>
<td></td>
<td>(8 payloads, 11 April)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metric</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Received ADS-B Messages per day</td>
<td>57,306,930</td>
</tr>
<tr>
<td></td>
<td>(11 April 2017, 8 payloads, includes all messages)</td>
</tr>
<tr>
<td>Surface Vehicles per day</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>(8 payloads, 11 April)</td>
</tr>
</tbody>
</table>

Surface Vehicle Examples:
Early Flight Test Results Providing Assurance of ATC Grade Surveillance

From 1 Payload

<table>
<thead>
<tr>
<th></th>
<th>Best Expected</th>
<th>Best Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft Elevation (deg)</td>
<td>7.0</td>
<td>0.08</td>
</tr>
<tr>
<td>Slant Range (km)</td>
<td>2550</td>
<td>3229</td>
</tr>
<tr>
<td>95th % Update Int.(s)</td>
<td>8</td>
<td>4.09</td>
</tr>
</tbody>
</table>

From 2 Payloads

<table>
<thead>
<tr>
<th></th>
<th>Best Expected</th>
<th>Best Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft Elevation (deg)</td>
<td>4.00</td>
<td>-1.37</td>
</tr>
<tr>
<td>Slant Range (km)</td>
<td>2800</td>
<td>3392</td>
</tr>
<tr>
<td>95th % Update Int.(s)</td>
<td>15.00</td>
<td>9.97</td>
</tr>
</tbody>
</table>

From 3 Payloads

<table>
<thead>
<tr>
<th></th>
<th>Best Expected</th>
<th>Best Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft Elevation (deg)</td>
<td>7.00</td>
<td>-4.58</td>
</tr>
<tr>
<td>Slant Range (km)</td>
<td>2550</td>
<td>3768</td>
</tr>
<tr>
<td>95th % Update Int.(s)</td>
<td>15.00</td>
<td>10.02</td>
</tr>
</tbody>
</table>
## Initial Technical Scorecard – Update Interval

<table>
<thead>
<tr>
<th>Metric</th>
<th>Design Goal</th>
<th>Measured</th>
<th>Performance Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Update Interval</strong></td>
<td>8 s</td>
<td><strong>6.21 seconds</strong> (using known targets)</td>
<td>Below OK Exceeds</td>
</tr>
<tr>
<td>125 Watt Max UI 95%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td>429 ms</td>
<td><strong>321.29 ms</strong> (8 payloads, limited bandwidth, 11 April 2017)</td>
<td>Below OK Exceeds</td>
</tr>
<tr>
<td>(Payload to APD Input Maximum)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Slant Range (Footprint)</strong></td>
<td>2250 km</td>
<td><strong>3806.8 km</strong></td>
<td>Below OK Exceeds</td>
</tr>
<tr>
<td>Maximum</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Current System Stats: ADS-B Messages Per Month

Over 2.5 billion ADS-B Position Messages Received Per Month!
Full global coverage, triple redundancy
Live data – 13 active satellites
### Activities to Operation

<table>
<thead>
<tr>
<th>Aireon Acceptance Testing</th>
<th>On Orbit Acceptance Test (OOAT)</th>
<th>Aireon Service Acceptance Test (SACT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations Development</td>
<td>Infrastructure Design &amp; Specification</td>
<td>Infrastructure Implementation &amp; Integration</td>
</tr>
<tr>
<td></td>
<td>AOC Design, Staffing &amp; Training, Dry Runs &amp; Test</td>
<td>Aireon Ops Go Live</td>
</tr>
<tr>
<td>Aireon Safety</td>
<td>Aireon SMS Implementation</td>
<td>EASA Certification</td>
</tr>
<tr>
<td>ANSP Acceptance</td>
<td>Gander / Shanwick Initial Operations</td>
<td>ANSP Operations (#3 - #n)</td>
</tr>
</tbody>
</table>

Safety is part of developing the system and maintaining operations for the life of the service.
Technical Implementation
Aireon Service Delivery Point (SDP)

- Demarcation between the Aireon System and the ANSP system(s)
- The SDP tallies the number of messages received at the ANSP for reporting
  - This feedback loop allows Aireon to monitor Service Level Agreement performance
- SDP consists of COTS redundant servers and routers
- Enables connection of ASTERIX data stream to the ANSP automation system and tracker
Service Delivery Point (SDP)

• The SDP is the demarcation point for Aireon ADS-B Data

• The SDP consists of a router and monitoring server – both have redundant backups

• The monitoring server is the TPMM, or Technical Performance Measure Monitor (TPMM)
  • Determines Update Interval for each target
  • Determines Latency for each target
  • Monitors availability

• The TPMM is like a power meter, but for ADS-B data
ANSP Message Flow

ANSP Target Reports
ANSP Equipment Status Report
ANSP Service Volume Status Report
ANSP Service Volume Statistics Report
ANSP SDP Status Report

TPMM SDP Status Report
TPMM ANSP Acknowledgement

APD

SDP Equipment

ANSP Capture Point
ASTERIX Overview

• Aireon ADS-B data is sent to ANSPs using the ASTERIX format
• ASTERIX is the All Purpose STructured Eurocontrol SuRveillance Information EXchange
• It’s an open, international standard used to represent surveillance/radar data, tracks, and status
  • ASTERIX is not limited to Europe – other countries including the US, Canada, and Australia make use of ASTERIX for ATC surveillance systems
  • The Eurocontrol ASTERIX team has a wonderful working relationship with ANSPs, EUROCAE, and implementers/industry
• ASTERIX is broken down into categories, or CATs, each with a particular purpose – sensor data, status information, fused track data
• Eurocontrol ASTERIX website: https://www.eurocontrol.int/asterix
# ASTERIX Overview

- Examples of common categories:

<table>
<thead>
<tr>
<th>Category</th>
<th>ASTERIX Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT021</td>
<td>ADS-B position and velocity reports</td>
</tr>
<tr>
<td>CAT023</td>
<td>Ground station (equipment) status</td>
</tr>
<tr>
<td>CAT025</td>
<td>Surveillance system status reports (In progress, new for ED-129B)</td>
</tr>
<tr>
<td>CAT247</td>
<td>Version number exchange</td>
</tr>
<tr>
<td>CAT238</td>
<td>Service Prediction reports</td>
</tr>
<tr>
<td>CAT253</td>
<td>Two-Line Element (TLE) report</td>
</tr>
</tbody>
</table>
ADS-B Data through MEVA III & REDDIG II

• Analysis is Underway for potential distribution in Latin America & Caribbean through MEVA III & REDDIG II

• By using the Regional Networks, States can benefit from:
  • Reduction of telco lines cost
  • Reduction of SDP cost
  • Platform for data sharing for ATFM, SWIM and other applications
Aireon Global Surveillance Network Overview
Aireon Hardware Needs to Support MEVA

Aireon Processing and Distribution (APD)

Region Target Reports
Region Equipment Report
Region Service Volume Status Report
Region Service Volume Statistics Report
Region SDP Status Report
TPMM SDP Status Report
TPMM ANSP Acknowledgement

ANSP Target Reports
ANSP Equipment Report
ANSP Service Volume Status Report
ANSP Service Volume Statistics Report
ANSP SDP Status Report

Located at Miami MEVA Node

Located at ANSP

MEVA Network

Local Maintenance Display (LMD)

ANSP Automation
MEVA SDP Network Diagram

Aireon Global Surveillance Network Overview

Backup/Secondary connection will need to be identified
REDDIG SDP Architecture (Dual Nodes)
Safety Certification
Specifics on ICAO Alignment
Global & Regional

• 12th ICAO Conference of 2012 recommendations:
  • Recognition of ADS-B as a Surveillance system equivalent to that of radar and exploit full potential
    • Support the inclusion in the GANP, development and adoption of space-based ADS-B surveillance as a surveillance enabler;
    • Develop Standards and Recommended Practices and guidance material to support space-based ADS-B as appropriate; and
    • Facilitate needed interactions among stakeholders, if necessary, to support this technology
  • Complement current surveillance (gaps) & enabler for Global Tracking
  • Standards for reduced separation in oceanic airspace to be issued in 2020

Source: ICAO Global Surveillance Roadmap, Doc. 9750
Specifics on ICAO Alignment
Regional Planning & Implementation Strategy

- Consensus-driven Strategy Objective of all States in CAR/SAM Region for short, medium and long term implementation

- Define an evolutionary path that will promote safety, interoperability and cost effectiveness of the required infrastructure to meet the future ATM needs.

- Each Air Navigation Authorities will publish via AIP when the use of new surveillance techniques is to be introduced in the States. Mandates if required

- Noted the existence of new technology ADS-B based with transmission via satellite which beginning is foreseen by early 2018.

- Surveillance technologies considered in this strategy to meet present and future ATM expectations

- Short Term (till 2018)
  - Primary Radar (SMR/ASDE);
  - Secondary Surveillance Radar (SSR);
  - Automatic Dependent Surveillance-Broadcast (ADS-B); ground and/or satellite;
  - Automatic Dependent Surveillance-Contract (ADS-C); and
  - Multi-lateration.

- Medium term (2019-2024)
  - A new ADS-B satellite option is foreseen to be available by early 2018 to cover oceanic and ground air spaces.
CANSO’s Support for ANS Surveillance Strategy
Guidelines for Implementation

• Space-based ADS-B has the potential to revolutionize air traffic services (ATS) surveillance in the aviation industry. It will enable global ATS surveillance, which provides opportunities to improve safety, efficiency and interoperability between air navigation services providers (ANSP) at the State, regional and global level.

• This document provides ANSPs with an overview of the technical capabilities and requirements associated with providing ATS surveillance services. It also provides guidance for linking space-based ADS-B implementation to enabling or facilitating the implementation of some of the advances detailed in the International Civil Aviation Organization’s (ICAO) Aviation System Block Upgrades (ASBU) framework. This document also outlines how space-based ADS-B will support the requirements for ICAO’s performance-based standard on global flight tracking (GFT).
Aireon Safety Objectives

- Establish safety **policy** and objectives
- Establish and sustain a **culture** that instills safety as a core value
- Safety Risk Management
  - Develop **hazard identification** process based on a combination of reactive, proactive and predictive methods
  - **Validate** safety requirements
- Provide **assurance** that safety controls are effective and pertinent software was developed at an appropriate level of rigor
  - Improve safety continuously by identifying and mitigating shortfalls
- **Promote** safety throughout the organization
Safety Certifications

• Safety certification starting with individual regulators such as FAA, UK-CAA and Transport Canada.

• Aireon is seeking EASA certification approval as a Surveillance Data Service Provider.
  • Allows Aireon to be a provider for Pan-European services to multiple ANSPs.
  • Support non-European ANSPs with smoothing certification process with their regulators
  • Certifies the Aireon service from the ADS-B payload input to the SDP
  • EASA certification application submitted. Certification is expected for Q3 2018
    • Safety case and regulatory process will be shared with other ANSP customers.
Safety Assurance in Action

You cannot fix what you do not measure

Aireon Safety Action Group (SAG)

Change Management Process

Hazard Database

Safety Risk Management Panel (SRMP)

Responsible for:
- Overseeing the implementation of Aireon’s Safety Management process
- Forming SRMPs, as necessary
- Identifying SMS cost and schedule impacts

Responsible for:
- Assessing safety hazards
- Developing controls and mitigations
- Reviewing and processing all safety related artifacts

Self Reporting

Incident Driven
Summary

• Space-based ADS-B will enable global surveillance capabilities to ANSPs, by providing real-time aircraft positioning in all airspaces, including oceanic and mountainous areas

• Space-based ADS-B will increase industry’s safety and improve operational efficiencies from more direct routes and flexible airspace

• Space-based ADS-B requires only a Service Delivery Point on site to connect to Aireon’s Processing and Distribution Center. Additional efficiencies can be reached with the use of MEVA III and REDDIG II networks for a regional connection, distribution and implementation

• Space-based ADS-B initial testing provides assurance of ATC grade surveillance

• Space-based ADS-B will be fully operational by mid-2018. Aireon will get EASA’s certification as a surveillance data provider by Q3 2018, which aims to facilitate certification processes

• Space-based ADS-B is part of the ICAO GANP as an enabler of ASBU’s and it has been incorporated into CAR/SAM air navigation plan. CANSO has also issued guidelines for its implementation
Thank You