Space-Based ADS-B

Implementation Progress & Distribution through REDDIG
ICAO SAM IG/19 Meeting
May 26th, 2017
Space-Based ADS-B System Overview
Space-Based ADS-B Concept

• Augments current radar systems with oceanic and remote air space coverage

• Delivers true pole-to-pole global coverage, with near real-time delivery of “ADS-B Out” data to ANSPs
  • No additional aircraft equipage by using 1090 MHz ES
  • Adheres to all current and future ADS-B standards
By 2018, space-based ADS-B will provide global, real-time air traffic surveillance
The Aireon System

1090ES ADS-B Transmission

Aircraft

ANSP Service Delivery Point (SDP)

Aireon Processing and Distribution (APD)

Iridium NEXT Satellite

Satellite Management

Iridium Main Mission

Aireon Hosted Payload (AHP)

Satellite Crosslink (as needed)

Iridium NEXT Satellite

Aireon Hosted Payload Operations Center (HPOC)

Teleport Network (TPN)
Space-Based ADS-B Implementation Status
Satellite Launch Status

• First launch: January 14th, 2017
• Second launch: June 29th, 2017
• Remaining launches 3-8: next 12-15 months
• Service operational: mid-2018

Photos: SpaceX
Launch 1 Coverage

Data from Eight (8) Payloads over 24 Hours

<table>
<thead>
<tr>
<th>Aircraft Seen</th>
<th>Approximately 2.4M unique positions, per day with 8 payloads (testing not complete)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types of Aircraft</td>
<td>Commercial Jets, Business Jets, General Aviation, Helicopters</td>
</tr>
<tr>
<td>Airspace Domains</td>
<td>Polar, Oceanic, En Route, Terminal, and Surface</td>
</tr>
</tbody>
</table>

Slots 1-7 and 11 are Filled

Mid-April
Preliminary Data: Polar Traveling Aircraft

These two aircraft are travelling Eastbound together at about 490 knots at the same altitude (35,000’) with a separation distance of ~155 NM.

Data Observations from these aircraft from 2017-02-01 02:24-02:35Z
On Orbit Test Campaign

- Detailed antenna pattern measurement with ground transmitters
- Time Stamp Accuracy
- Bandwidth Characterization
- Low-power target performance
- Track Aircraft in high-FRUIT regions
- TPM Collection (Update Interval and Latency)

Commanding:
- Test target message rate
- Antenna schedule dwell
- Payload Redundancy

Status:
- ADS-B target processing
- Payload Redundancy
Flight Test Aircraft and Tools

NAV CANADA
Test Flight
March 7th, 2017

Polaris Flight Systems
Test Flight
March 20th, 2017

FAA
Test Flight
March 30th, 2017

Performance Exceeding Design Standards For Surveillance
Test Flights for Performance Testing

- Aireon has completed three test flights with NAV CANADA, Polaris Flight Systems and the FAA.
  - This commenced the Initial Performance Verification (IPV) of the Aireon payload.
    - The first test flight was with NAV CANADA in the northern part of the continent. This was with a low-power antenna (125W) in remote airspace.
    - The second test was performed by Polaris Flight Systems with a 200W antenna in a high FRUIT environment.
    - The third test flight was done by the FAA test aircraft. This was with a low-power antenna (125W) over both oceanic and high FRUIT environments.
NAV CANADA Test Flight – March 7th, 2017

- Only one Aireon payload was providing ADS-B data due to the stepwise schedule in gradually implementing the new satellites into the constellation.
- 6,935 ADS-B messages were received during the test flight.
- The table below summarizes expected versus measured performance for some key parameters:

<table>
<thead>
<tr>
<th>From 1 Payload</th>
<th>Best Expected</th>
<th>Best Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft Elevation (deg)</td>
<td>7.00</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>8.00</td>
<td>4.09</td>
</tr>
</tbody>
</table>
Polaris Flight Systems Test Flight – March 20th, 2017

• Two Aireon payloads were providing ADS-B during the time of this test flight.

• The UI performance shifted due to the high density of aircraft with 1090 MHz transmissions (ADS-B, Mode S, and ATCRBS).

• There was a 95th percentile UI, which is about 10s, an improvement on the performance of the expected value of 15s for two payloads.

<table>
<thead>
<tr>
<th>From 2 Payloads</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>
FAA Test Flight – March 30th, 2017

• During this flight test, three Aireon payloads were available to receive data, offering significantly more samples than if only one payload was in operation.

• The measured UI performance and the results look strikingly similar to terrestrial ADS-B coverage.

• 2,462 ADS-B messages were received during the test flight.

• The table below summarizes expected versus measured performance for some key parameters:

<table>
<thead>
<tr>
<th>From 3 Payloads</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>
ANSP Implementation of Space-Based ADS-B
Safety is part of developing the system and maintaining operations for the life of the service.
Launch Customer’s Team Meeting at IAA Facilities Mar ‘17
Data Distribution through REDDIG Network
Analysis is underway for potential distribution in Latin America and Caribbean through MEVA III and 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 Processing and Distribution (APD)

Typical SDP Architecture (Single Node)

- SDP Equipment
  - Cisco 2900 Series
  - AC OK
  - 100-240V~
  - 6-2A
  - 50-60 Hz
  - POE

- SDP Router
  - Cisco 2900 Series
  - AC OK
  - 100-240V~
  - 6-2A
  - 50-60 Hz
  - POE

- Server (TPMM)
- PDU

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

- TPMM SDP Status Report
- TPMM ANSP Acknowledgement

- ANSP Capture Point (Automation)
  - ANSP Target Reports
  - ANSP Equipment Report
  - ANSP Service Volume Status Report
  - ANSP Service Volume Statistics Report
  - ANSP SDP Status Report
Typical SDP Network Diagram

Aireon Global Surveillance Network Overview
REDDIG SDP Architecture (Dual Nodes)

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

REDDIG Network

SDP Equipment

Data Distribution Server

Server (TPMM)
REDDIG SDP Network Diagram

Aireon Global Surveillance Network Overview

- Teleport (TP) #1: Arizona
- TP #2: Alaska
- TP #3: Canada #1
- TP #4: Canada #2
- TP #5: Norway

- SNOC: Leesburg, VA
- HPOC: Herndon, VA
- TSC: Ashburn, VA
- NOC: Herndon, VA

- Aireon HQ: Tysons, VA
- Data Center: Ashburn, VA
- Data Analysis Lab
- SDP
- Business System Input

- MPLS Cloud
- Backup
- Primary
- Disaster Recovery

- ANSP Automation System

- Location 1 SDP
- Location 1 REDDIG Connection

- Location 2 SDP
- Location 2 REDDIG Connection

Aireon Proprietary:
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Things to Note about using the REDDIG Network

• TMPs are measured at the SDP
  - Availability - 0.999
  - Update Interval – 8s, ≥ 96%
  - Latency - ≤ 2s
  - Availability and Latency will be affected by the REDDIG network and is not included

• Data billing is calculated on what is delivered to the SDP

• Aireon will maintain configuration of all system components up to the SDP

• Aireon will maintain security up to the SDP

• We need to rely on REDDIG’s system to deliver data to ANSPs across SAM region
Calculated Availability System using REDDIG Network

Availability using two single string SDPs that feed a single Automations Systems

System Availability is 0.99912

Assuming REDDIG Network (including firewalls and ANSP Automation system network) has an availability of 0.999764
REDDIG Network Requirements

• System Availability > 0.999
• Accepts Multicast Data
• Delivery to Automation system in low latency
• Surveillance data segregation for each of the connected ANSPs
• Bandwidth: Total Estimated Bandwidth Usage of 2,061 Kbps, considering the following scenario:
  • Full Usage of all 14 States that compose SAM region
  • Full Usage in both terrestrial and oceanic airspaces
  • Full Usage in lower and upper airspaces
  • Air Traffic at levels of 2030
## Estimated Data Distribution Costs

<table>
<thead>
<tr>
<th>Estimated Cost using REDDIG</th>
<th>US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. SDP deployment and test costs (2 SDPs) – one-time cost</td>
<td>320,000</td>
</tr>
<tr>
<td>b. Telco Cost on 2 locations (single line in each location)/year – recurring cost</td>
<td>95,000</td>
</tr>
<tr>
<td>c. Implementation/service acceptance cost per ANSP – one-time cost</td>
<td>112,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated Cost per ANSP direct connection</th>
<th>US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. SDP at ANSP location-one-time cost</td>
<td>300,000</td>
</tr>
<tr>
<td>b. Telco Cost per ANSP (dual line)/year-recurring cost</td>
<td>95,000</td>
</tr>
<tr>
<td>c. Implementation/service acceptance per ANSP</td>
<td>112,000</td>
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</tbody>
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Implementing Space-based ADS-B through REDDIG would have significant economic benefits for ANSPs
Conclusions and Suggested Actions

• Initial assessment shows it is feasible to distribute space-based ADS-B air traffic surveillance data, through REDDIG

• Implementing Space-based ADS-B data distribution through REDDIG would have significant savings to ANSPs in the SAM region

• Aireon would guarantee availability to the SDP and REDDIG system guarantees availability to ANSPs sites

• Suggested Actions:
  • Take note of the information presented herein;
  • Continue with the development of the cost analysis to distribute Space-based ADS-B data to interested States through REDDIG
  • States to consider the implementation of Space-based ADS-B data services as a regional project
Thank You
Investors, Customers and Innovators:

A company created by ANSPs for ANSPs and airlines
Iridium NEXT Satellite

- 2 Solar Array Wings
- Aireon Hosted Payload
- Main Mission Antenna L-band
- Deployed "Wingspan" 9.4m