ICAO

Aireon Space-Based ADS-B Implementation and Operation

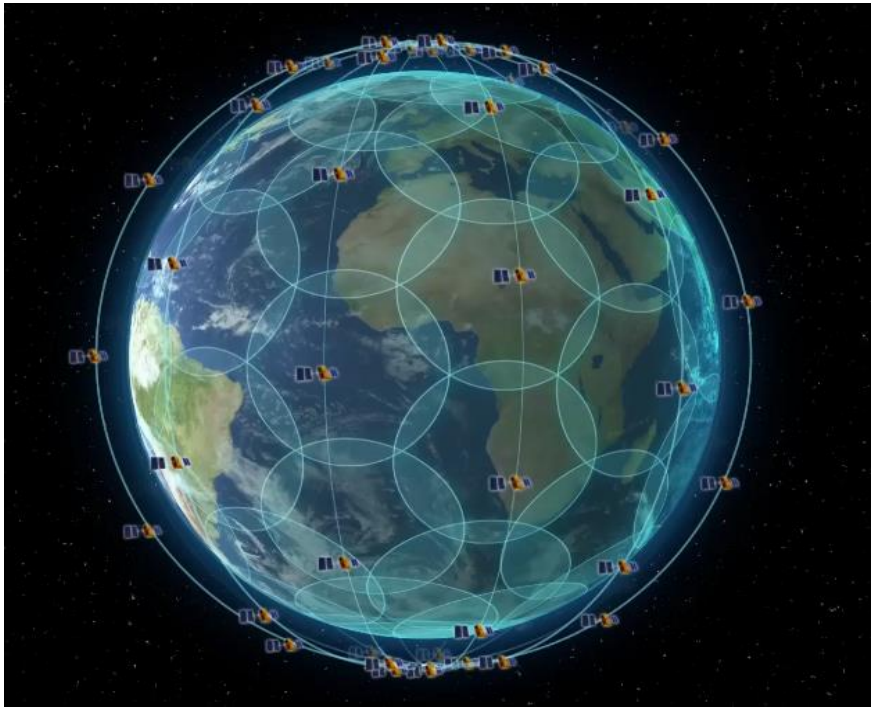
Vincent Capezzuto
Greg Dunstone

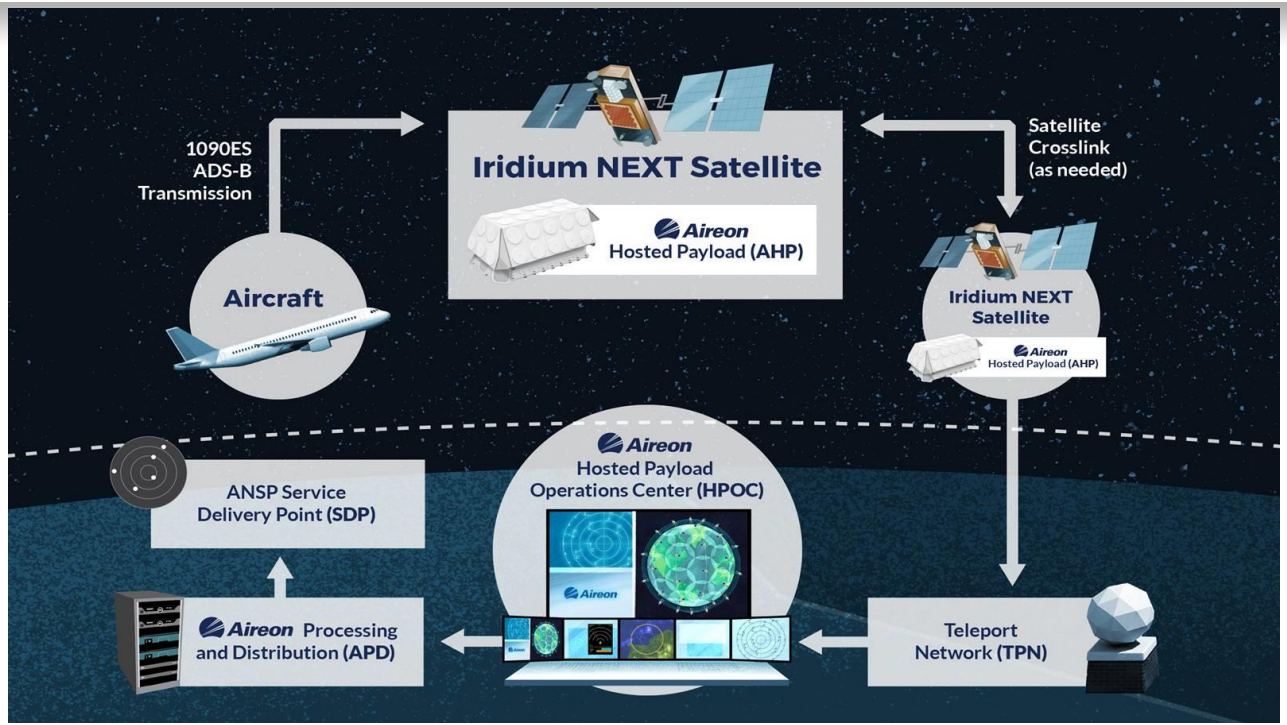
Bangkok, 5-November-2018

Overview and Status

Vincent Capezzuto

Surveillance For All ADS-B Equipped Aircraft EVERYWHERE



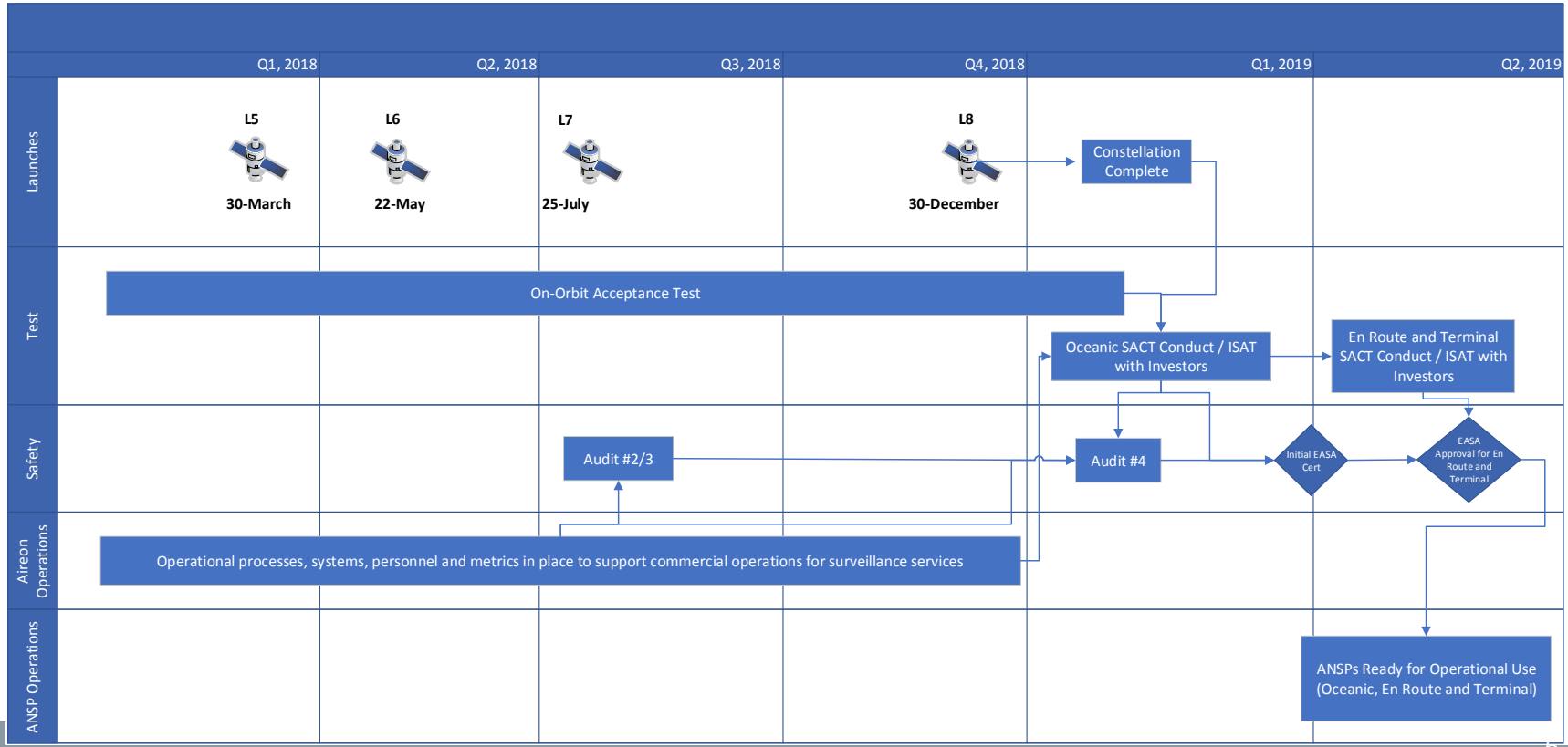


Highly Adaptable Technology Capable of Uploading New Receiver Design to Accommodate DO-260 Updates Ensuring Future Proofing

Space-Based ADS-B Operational Use Cases

Environment	Type of services	Horizontal Separation Minima
Oceanic - Advanced	AREA control service in Oceanic sector	15 NM
En-Route Non-Radar (NRA)	AREA control service in En-Route sector	5 NM
En-Route Radar (RAD)		
Terminal Area Non-Radar (NRA)	APPROACH control service in a TMA sector	3 NM
Terminal Radar (RAD)		

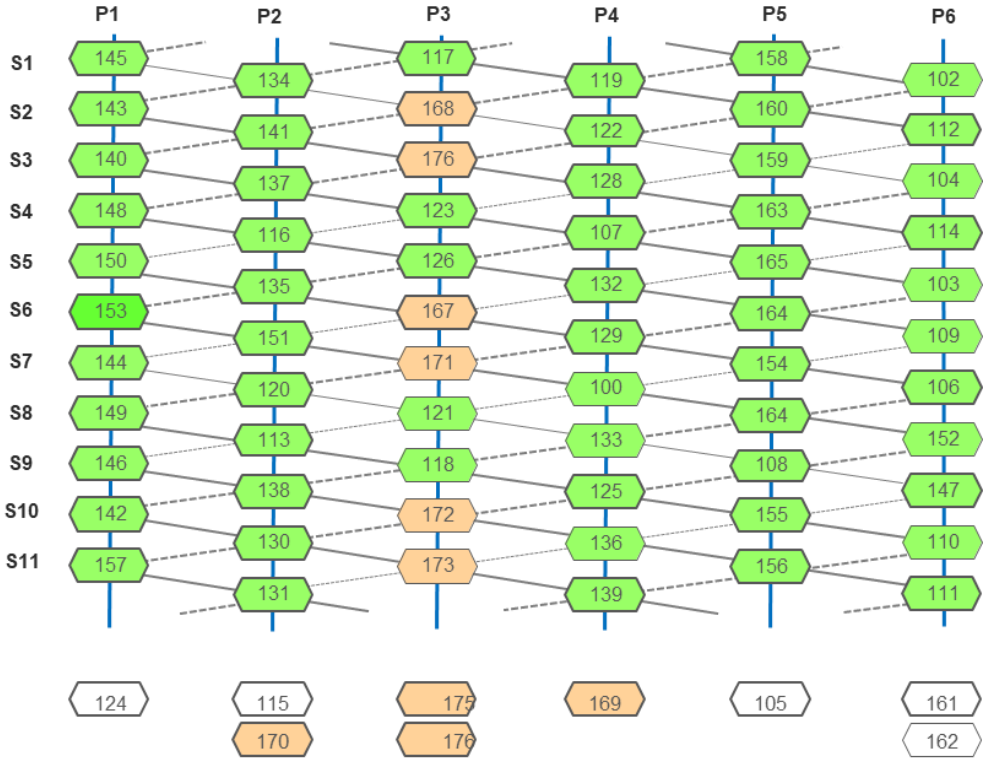
Objectives


Q1, 2018
Q2, 2018
Q3, 2018
Q4, 2018
Q1, 2019
Q2, 2019
Launches
Test
Safety
Aireon Operations
ANSP Operations
L5
30-March
L6
22-May
L7
25-July
L8
30-December
Constellation Complete
On-Orbit Acceptance Test
Oceanic SACT Conduct / ISAT with Investors
En Route and Terminal SACT Conduct / ISAT with Investors
Audit #2/3
Audit #4
Initial EASA Cert
EASA Approval for En Route and Terminal
Operational processes, systems, personnel and metrics in place to support commercial operations for surveillance services
ANSPs Ready for Operational Use (Oceanic, En Route and Terminal)

Seven Successful Launches!

- Successful 7th launch on July 25, 2018
- 65 satellites launched to date
- 10 more satellites will be launched in 2018
- Last launch targeted 30-December out of Vandenberg Air Force Base in California

Launch Deployment Update

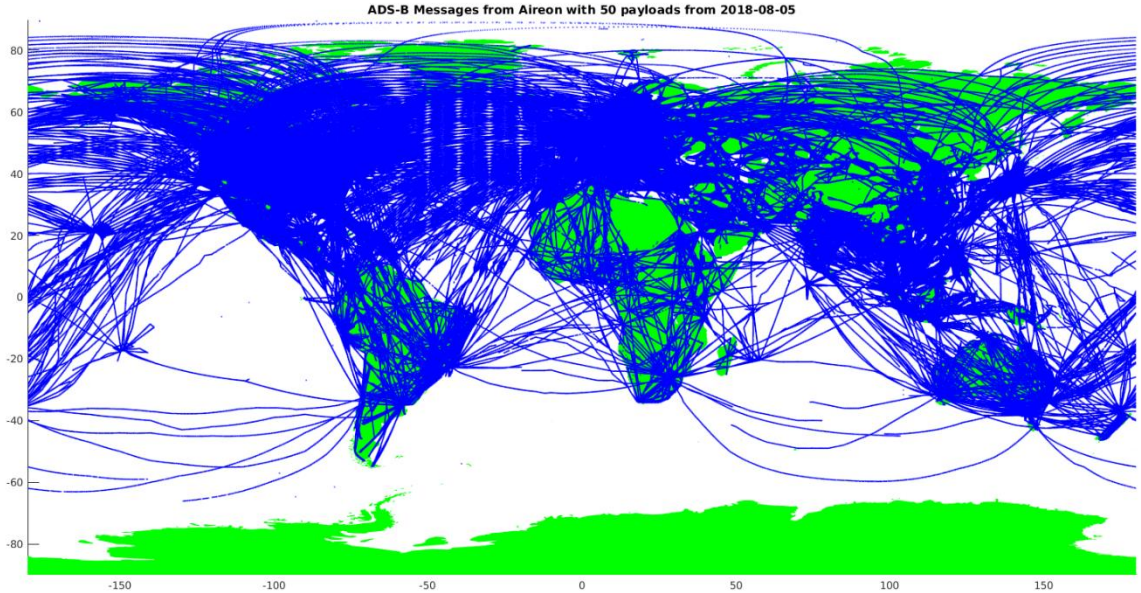


SV's in service NOW

Launch 8 Group HPLs

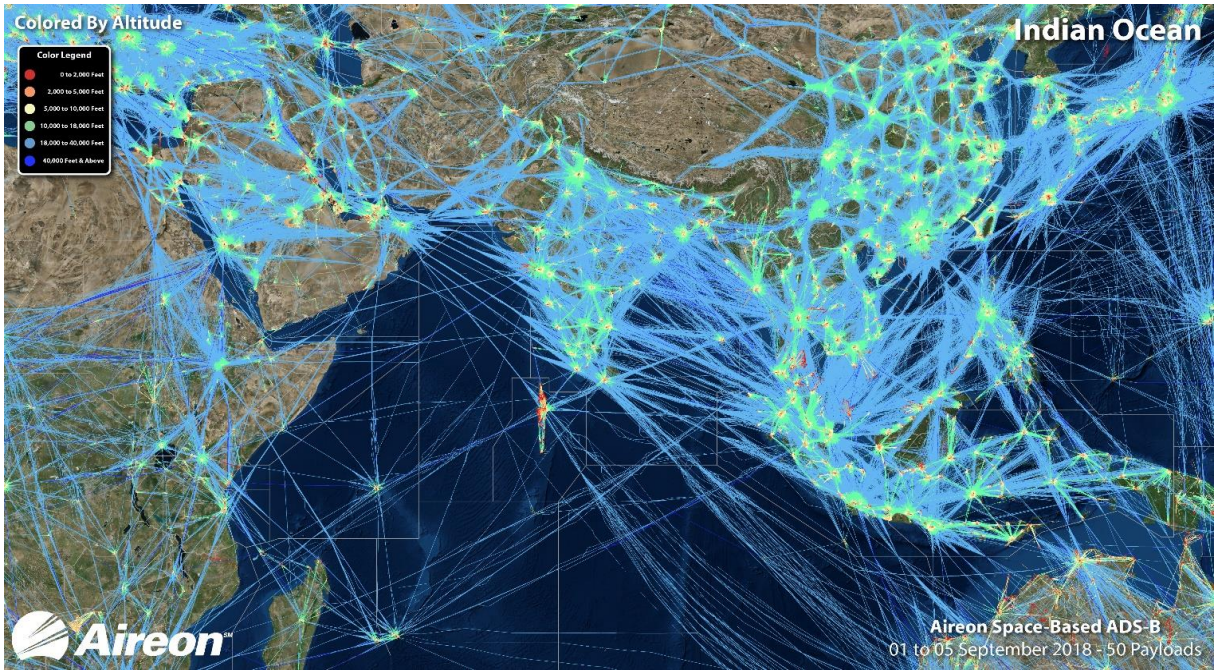
In service dates include DCO, HPL under APD control and Aireon beam tuning applied.

Coverage Plot from 2018-08-05

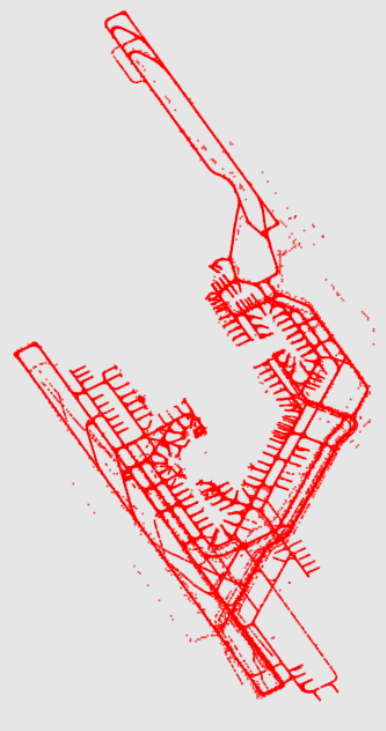


10 Billion ADS-B Position Messages / Month

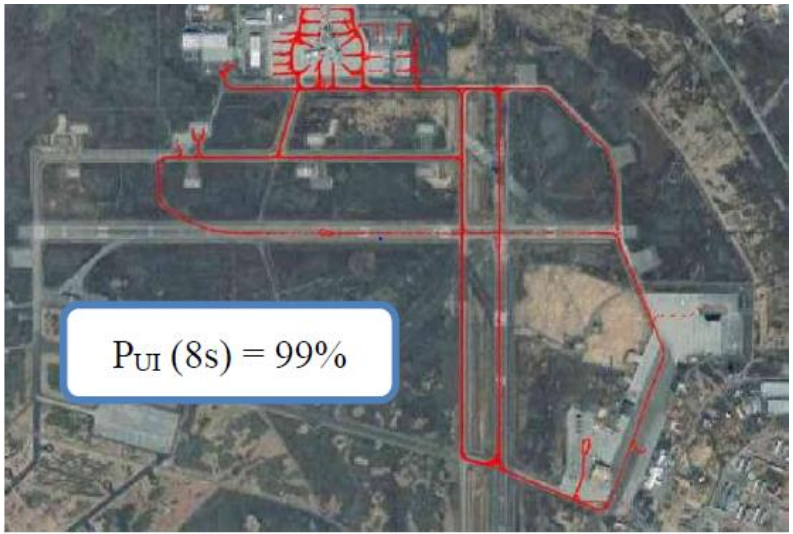
Aireon's ADS-B Coverage 1-5 September, 2018 (50 Payloads)



Aireon Surface Data

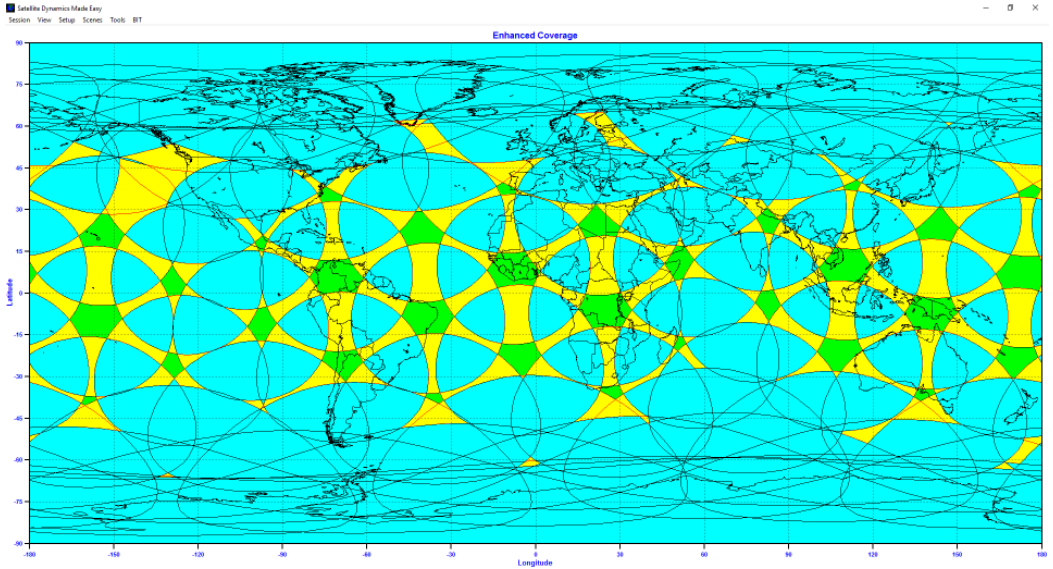


Narita International Airport



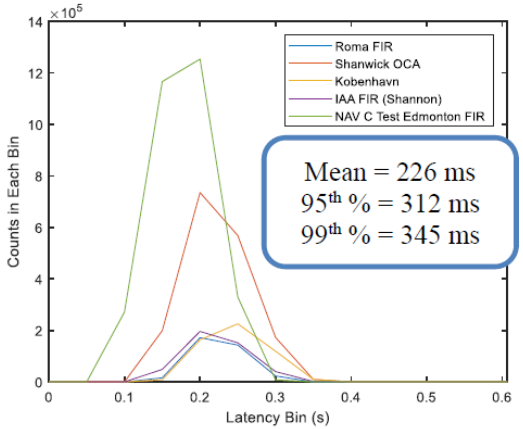
Surface coverage of Keflavik Airport

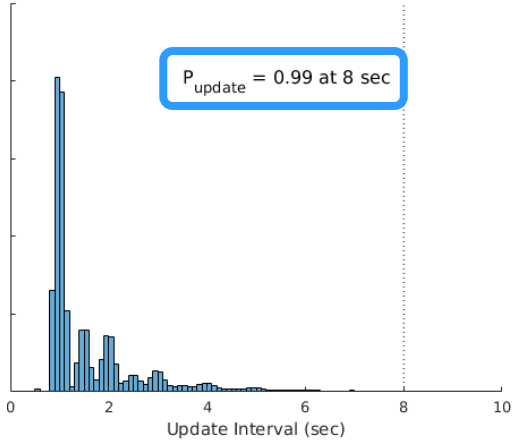
Redundant Payload Coverage



- Payload footprint size represents predominant coverage type of triple (or greater):
  - Persistent overlapping coverage at ±43°
  - Global overlapping coverage roughly 94% of the time
  - 80% probability of overlapping coverage at the equator (worst case)

Measured Performance Results





Latency Measurement – September 2018

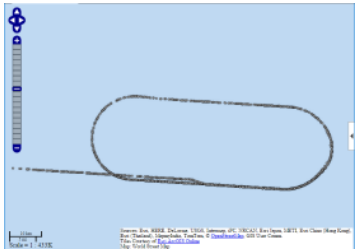
ED-129B Requirement: 1.5 Seconds

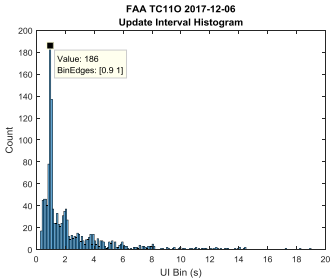
Update Interval Measurement – September 2018

ED-129B Requirement: 8s UI, 96% Probability

FAA Performance and Integration

- FAA has engaged Harris to interconnect space-based ADS-B to FAA infrastructure in support of advanced surveillance enhanced procedural separation (ASEPS)
  - Added independent validation with time difference of arrival (TDOA)
  - Flight test the service capability
  - Perform continuous monitoring
- FAA is supporting early testing
  - Update Interval (UI) results from FAA flight test is 8.05 sec for oceanic holding pattern
- Space-based ADS-B can be routed to any service delivery point within the FAA network connecting to ATOP / MEARTS / ERAM same as ground based ADS-B





EASA Certification: Audit Scope

- The following audits are identified in the context of the Aireon initial certification:

Audit	Scope	Place
Audit #1	Compliance with Reg. 482/2008 (Software Assurance) System Verification Activities	Aireon HQs
Audit #2	Aireon management processes	Aireon HQs
Audit #3	SNOC Operation APD Operation Contingency/Disaster Recovery Site operation	SNOC Contingency Site
Audit #4	Findings closure, On-Orbit (SACT) testing	Aireon HQs

EASA Certification: Audit 2/3 Results

Results of the audit: positive aspects

- Clear company vision and goals
- Highly professional staff met
- Positive attitude towards the audit
- Transparent and open minded
- Good collaboration between Aireon and its partners

Results of the audit

- Observations
  - A way to communicate and draw third parties and future audit teams attention on specific matters that deserve scrutiny

23

- Level II findings
  - non-compliance with applicable requirements or organisation´s procedures and manuals

15

- Level I findings
  - Significant non-compliance with applicable requirements or organisation´s procedures and manuals
  - Lowers safety or seriously endangers safety

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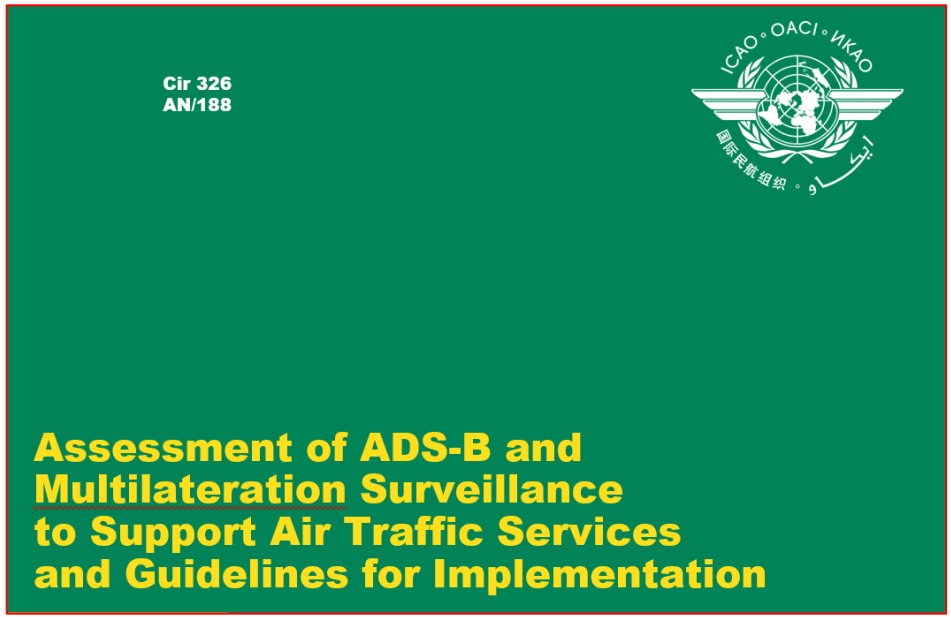
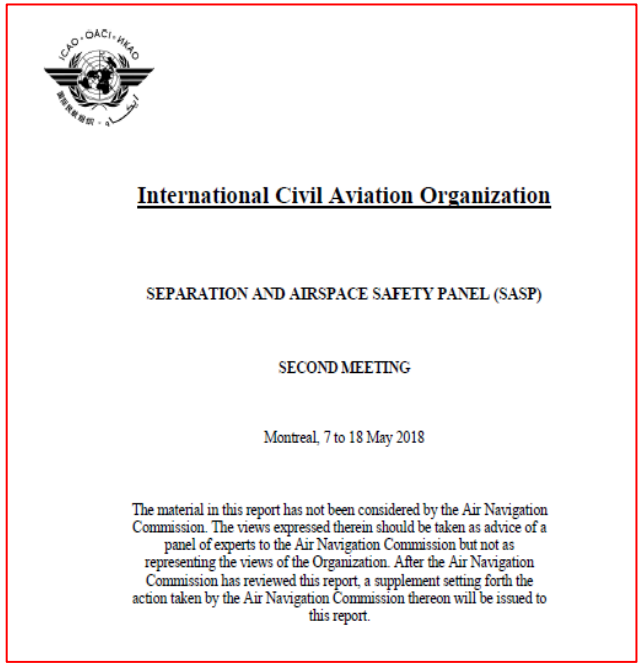
Comparative Assessment Approach



- Definition of an Airspace Concept
- Identification of ADS-B Performance Requirements
- Safety Assessment
- Preparation for Implementation

SASP Oceanic 15NM Separation Standard



International Civil Aviation Organization

SEPARATION AND AIRSPACE SAFETY PANEL (SASP)

SECOND MEETING

Montreal, 7 to 18 May 2018

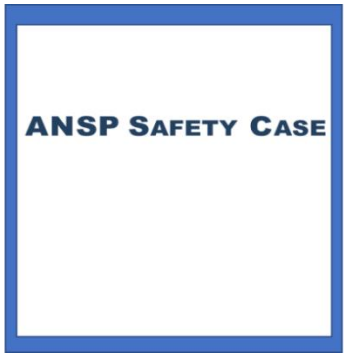
The material in this report has not been considered by the Air Navigation Commission. The views expressed therein should be taken as advice of a panel of experts to the Air Navigation Commission but not as representing the views of the Organization. After the Air Navigation Commission has reviewed this report, a supplement setting forth the action taken by the Air Navigation Commission thereon will be issued to this report.

CNS-ATM Requirements	
SUR requirements	ATS surveillance system (Radar, ADS-B or MLAT)
NAV requirements	Aircraft capable of RNP4 or RNP2
COM Requirements	RCP 240 (Performance based, could be CPDLC but not defined as ADS-C)
Contingency Requirements … should normal COM fail	Alternative means of COM: Recognize, Intervene, Resolve conflict – Total Time 9 mins*. Note: No ADS-C contingency requirement Note: No Next & Next + 1 requirement
ATS System: Lateral Conformance- Reduced Separation	Lateral warning threshold set: 3NM
ATM System: Lateral Conformance- Basic	Lateral warning threshold set: 3NM

Next Steps:

- **November 2018 SASP Meeting to approve PANS / ATM Doc 4444 Proposal for Amendment**
- **November 2020 Publish Revision in PANS / ATM Doc 4444**

Aireon Deliverables as Input to ANSP Safety Case



Contents:
- EASA ATM / ANS Org Cert
- Declaration of Verification
- Declaration of Suitability
- Environment Description
- Service Definition Doc
- Safety Arguments
- Safety Requirements
- Hazards Analysis

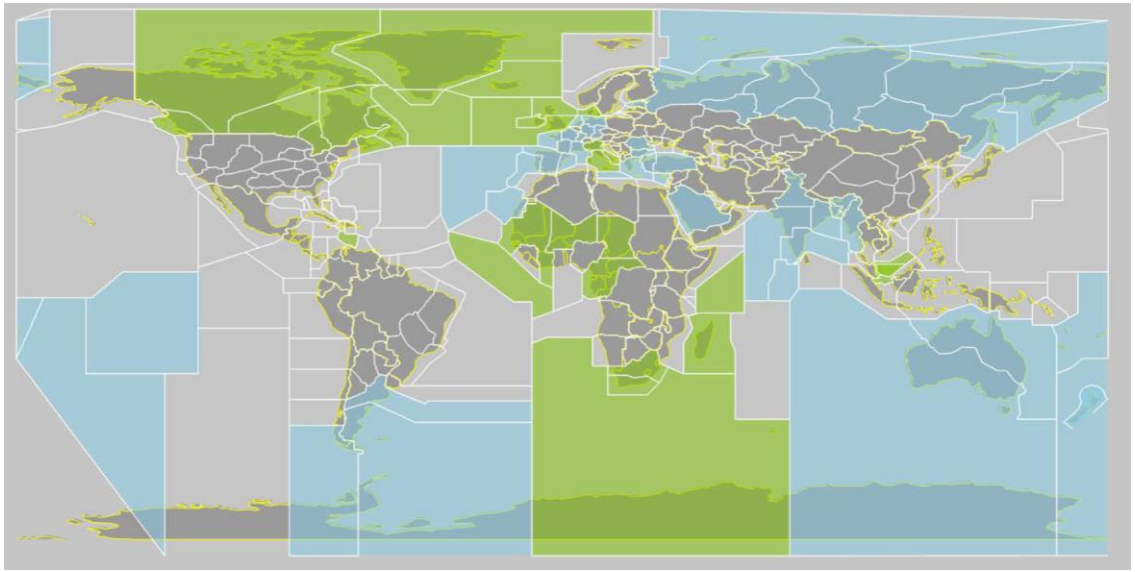
Contents:
- Installation Test Cases
- ICD / TELCO
- Security Test Cases
- Operations Test Cases
- Local Maintenance Display
- Redundancy Test Cases
- Performance Test Cases
- Aireon Dashboard
- Customer Test Cases

Contents:
- Concept of Use
- Routes
- Holding Areas
- Airspace Structure
- ATC Sectorization
- Air Traffic Management
- ATC Training

Global Equipage Mandates

State/Adm.	What	When Effective	Standard
Australia	At or above FL290 All IFR levels	December 2013 February 2017	DO-260 Looking at TSO199 for GA
USA	Most aircraft in controlled airspace	January 2020	DO-260B
Europe	Aircraft operating IFR>5,700KG or >250K TAS cruise	June 2020	DO-260B
UAE	All IFR	January 2020	DO-260B
Singapore	At or above FL290 on specified routes	December 2013	DO-260
Vietnam	At or above FL290 on specified routes		DO-260
Hong Kong	At or above FL290 on airways L642 and M771	February 2016	DO-260
Indonesia	At or above FL290	January 2018	DO-260
Taibei FIR	At or above FL290 on two routes All flights at or above FL290	September 2016 December 2019	DO-260
Colombia	All airspace	January 2020	DO-260B
China	Proposed and currently under consultation	July 2019 December 2022	DO-260 DO-260B
New Zealand	NPRM released – All aircraft above FL245 Proposed – All aircraft in controlled airspace	31 December 2018 31 December 2021	DO260 (with forward fit for DO260B) Looking at TSO 199 for GA
Canada	No mandate proposed; preferential service in Hudson Bay		DO-260

Global ANSP Launch Customers Supporting Rollout



= Signed Contract

= MOU

Data Services Agreements in Place
• NAV CANADA
• NATS (United Kingdom)
• ENAV (Italy)
• IAA (Ireland)
• Naviair (Denmark)
• DC-ANSP (Curacao)
• Air Traffic Navigational Services Co. Ltd (South Africa)
• Civil Aviation Authority of Singapore
• Seychelles
• ISAVIA (Iceland)
• Aerial Navigation Safety in Africa and Madagascar (ASECNA)

ANSP Planned Usage

ANSP	Airspace	Environment
NAV CANADA (Canada)	Canadian Domestic	En Route
	Gander OCA	Oceanic
NATS (United Kingdom)	Southeast Corner of Shanwick FIR	Oceanic
	Shanwick FIR	Oceanic
Enav (Italy)	Brindisi FIR	En Route
	Roma FIR	En Route
Naviair (Denmark)	Kobenhavn FIR	En Route
	Airspace in Adjacent FIR with Delegation of Air Traffic Services to Denmark	En Route
IAA (Ireland)	Shannon FIR	En Route
	Shannon Oceanic Transition Area (SOTA)	En Route
	Northern Oceanic Transition Area (NOTA)	En Route
	Dublin	Terminal Test Case

ANSP Planned Usage

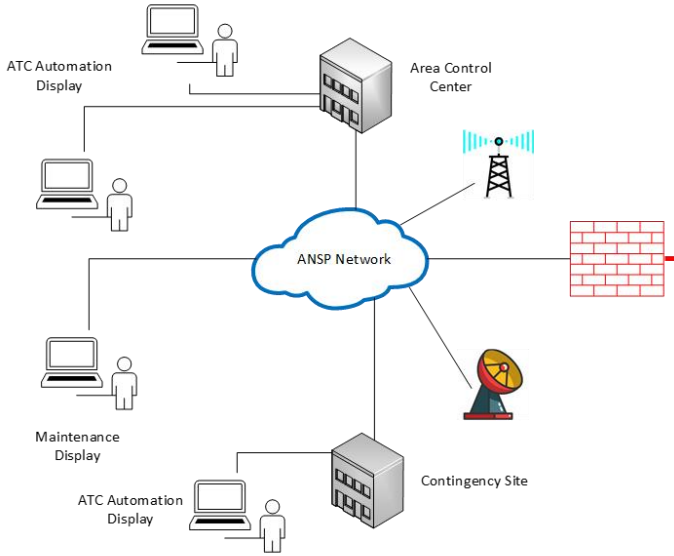
ANSP	Airspace	Environment
DC-ANSP (Curacao)	Oceanic West	Oceanic
	Oceanic & Terrestrial East	Oceanic and En Route
ATNS (South Africa)	Johannesburg Oceanic	Oceanic
	Johannesburg Terrestrial	En Route
	Capetown FIR	En Route
CAAS (Singapore)	Singapore FIR	En Route
SCAA (Seychelles)	Seychelles FIR	Oceanic and En Route
Isavia (Iceland)	Reykjavik Control Area	En Route
	Sondrestrom FIR	En Route
ASECNA	Dakar FIR Oceanic & Terrestrial	Oceanic and En Route
	Antananarivo FIR	Oceanic and En Route
	Niamey FIR	En Route
	N'Djamena FIR	En Route
	Brazzaville FIR	En Route

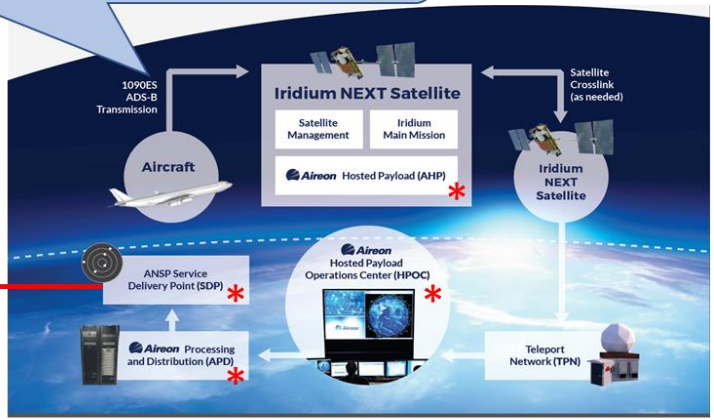
Regional ANSP Implementation

Greg Dunstone

Space-based ADS-B: Just like a super capable ADS-B ground station

- DO-260, 260A, 260B / ED-109, ED-109A (and future versions)
- DO-178C / ED-12C





Aireon is working with EASA for certification approval as an ATM/ANS Surveillance Service Provider Organization

*DO-278A / ED-109A / ED-129B / ASTERIX

Contracts: Three Phase Approach

Key Deliverables:

- Global Interface Control Document
- Initial Integrated Master Schedule
- Customer Requirements Definition Document

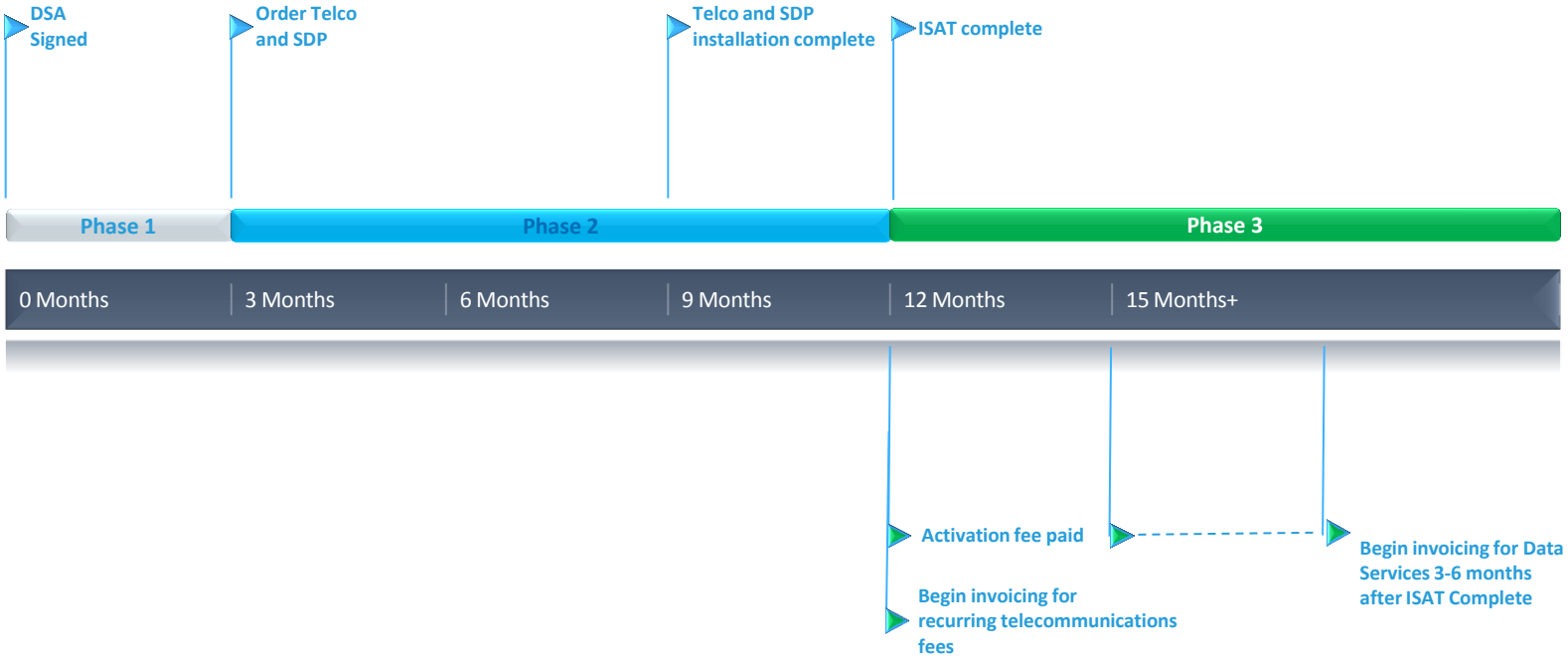
Key Deliverables:

- Maintenance Display Software
- Computer-based Training
- Aireon Corporate Safety Plan
- Aireon Safety Case Document
- Aireon Security Plan
- VRTM
- ISAT Test Plan and Procedures
- Service Volume Description Document
- Service Sustainment Document
- ISAT Test Report

Key Deliverables:

- Operational Data
- Monthly Performance Report

Implementation Schedule



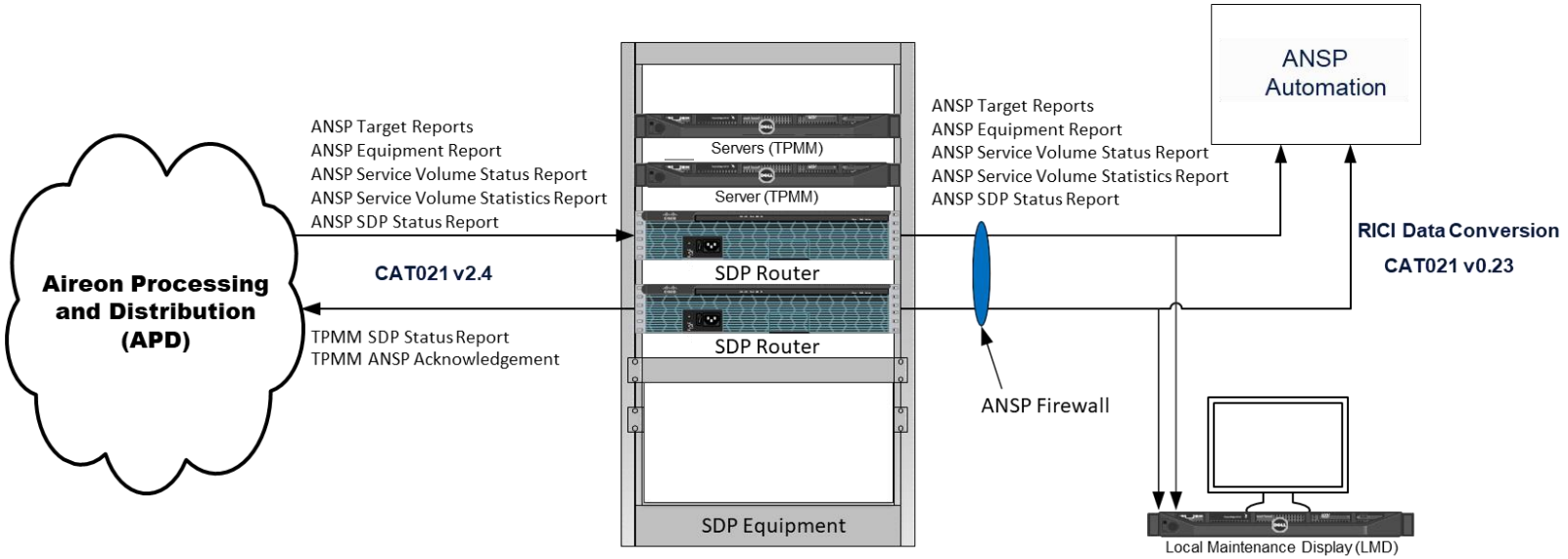
Service Level Agreement (SLA): Data Services Performance Metrics

- **[CUSTOMER]_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
- **[CUSTOMER]_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 (ATC SUR Processing + SUR Distribute) SPR 9 and Table 33
- **[CUSTOMER]_Aireon003:** Probability of Update ≥ 96% for an Update Interval of [X] seconds in accordance with [STANDARD]; as set forth in [CITATION]

SLA: Technical Support Performance Metrics

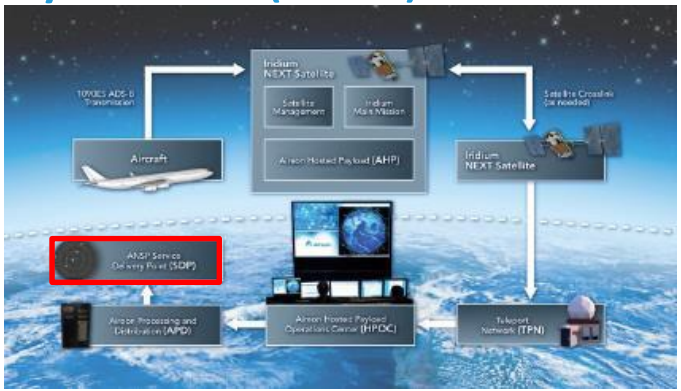
- **[CUSTOMER]_Aireon004:** The response time for technical support shall be two hours, to be measured from the time that the incident was reported to the Aireon technical support desk being requested to respond (i.e. not from the actual time of the failure) to the time when [CUSTOMER] is advised of the action being taking to restore the Service and an estimated restoration time.
- **[CUSTOMER]_Aireon005:** Problem Trouble Report (“PTR”) adjudication time from reporting to fix:
  - Category 1 – Critical: Response time from reporting to fix is a maximum of 24 hours
  - Category 2 – Major: Response time from reporting to fix is a maximum of 7 days
  - Category 3 – Minor: Response time from reporting to fix will be coordinated with [CUSTOMER] scheduled Service updates

Service Delivery Message Flow



Aireon Service Delivery Point (SDP)

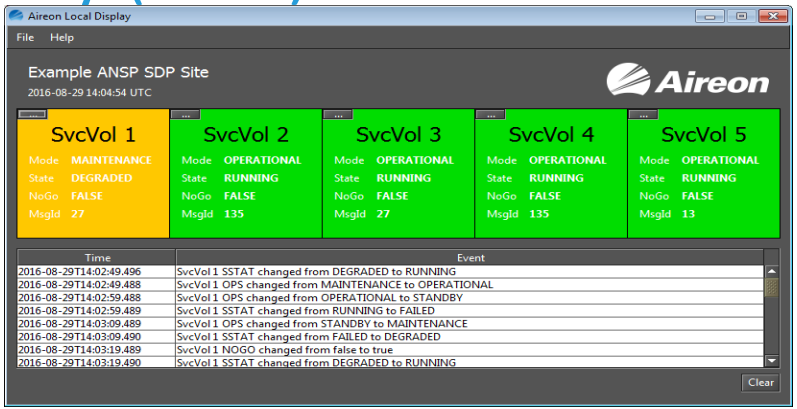
- Demarcation between the Aireon System and the ANSP system(s).
- The SDP tallies the number of messages received at the ANSP for reporting. This feedback loop allows Aireon to monitor Service Level Agreement performance.
- SDP consists of COTS redundant monitoring servers and routers.
- Enables connection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

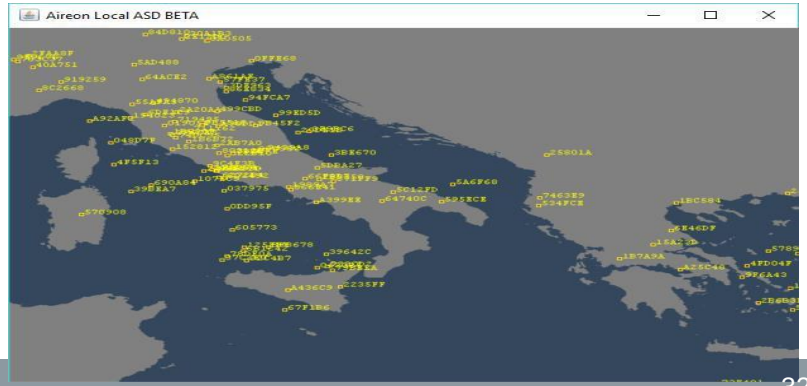


Example: Racksource RACK-151-18U

Local Maintenance Display (LMD) Overview

- Used to show key status for ANSP service volumes per ED-129B requirements
  - Service Volume Mode – Operational, Standby, or Maintenance
  - Service Volume State – Running, Degraded, or Failed
  - Service Volume NoGo Flag – False or True
  - Message ID – Unique identifier of the status message
- Used to show Faults and Errors
  - Target Overload
  - Communications Overload
  - Time Source Invalid or Coasting
- Air Situation Display (ASD) used to display aircraft targets within the ANSPs Service Volume(s)
  - Ensures CAT021 messages are being properly received





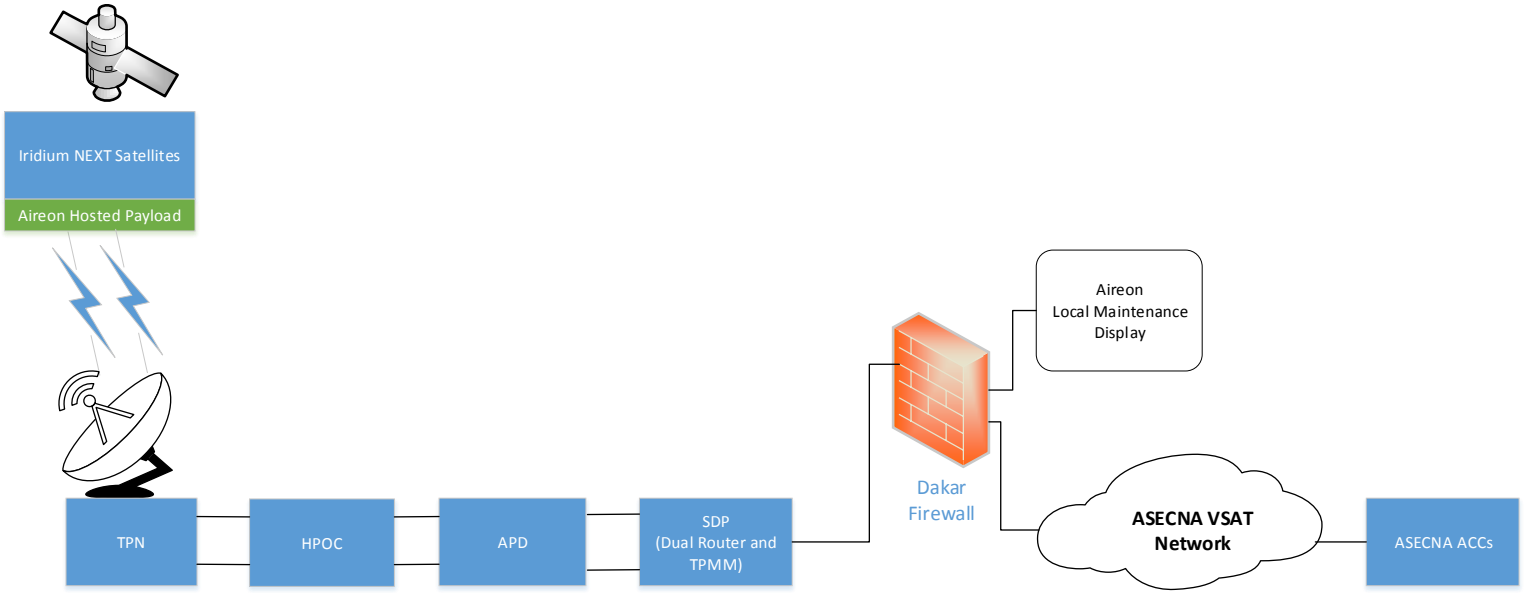
Local Maintenance Display (LMD) Cont.

- Hardware Requirements
  - The LMD is not part of the Service Delivery Point (SDP). It is connected to the output of the SDP in parallel with the ANSP automation system or tracker.

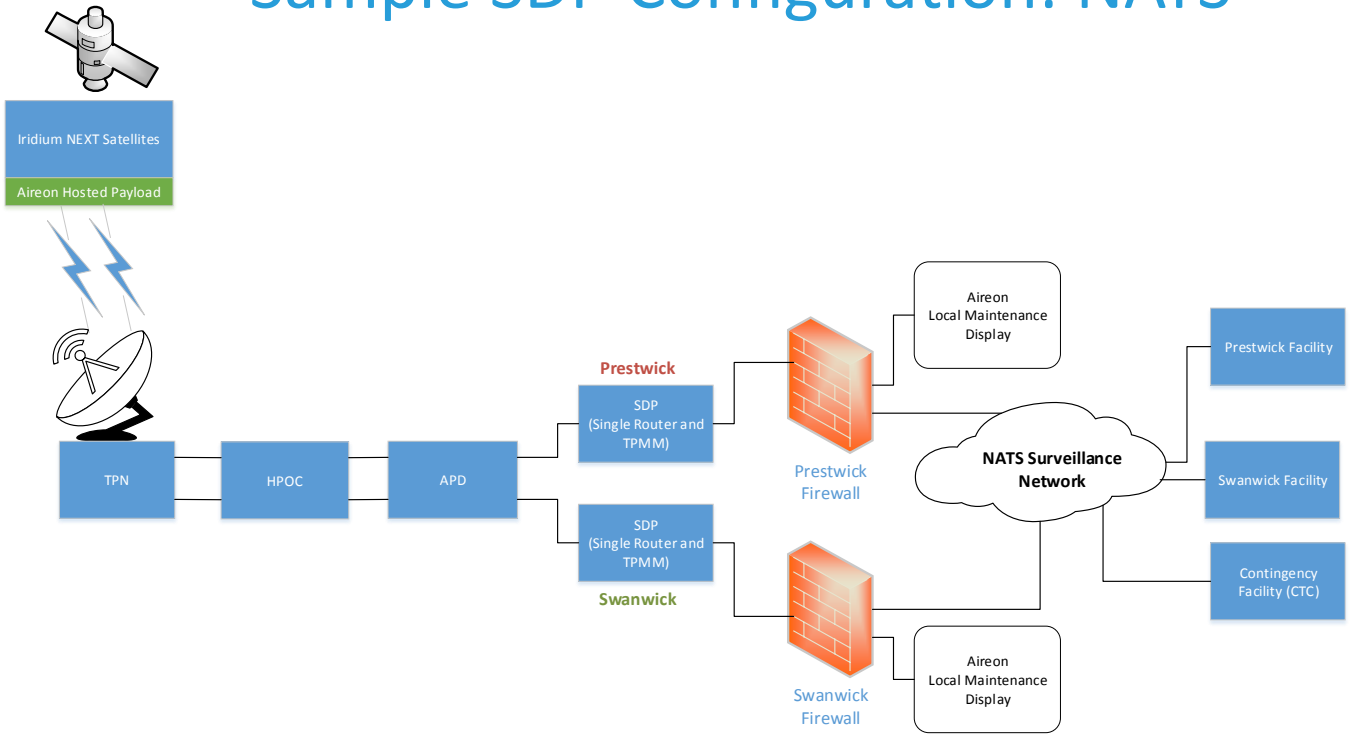
- Server required to run the LMD must meet the following requirements:
  - Xeon E5 or greater
  - At least 8GB of error-correcting code (ECC) memory
  - At least 60GB of hard disk space
  - Hardware RAID controller
  - Redundant power supplies
  - DVD drive
  - Running 64-bit CentOS Linux or other binary-compatible Linux OS (ex: RedHat)

- Note: The Aireon-recommended server is the 1U Dell R630 with hardware RAID controller

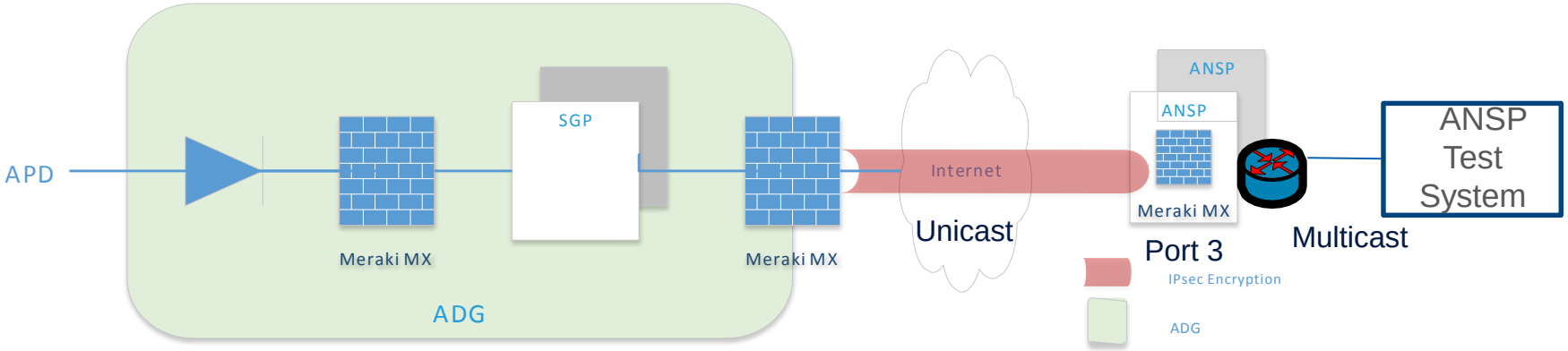
Sample SDP Configuration: ASECNA



Sample SDP Configuration: NATS

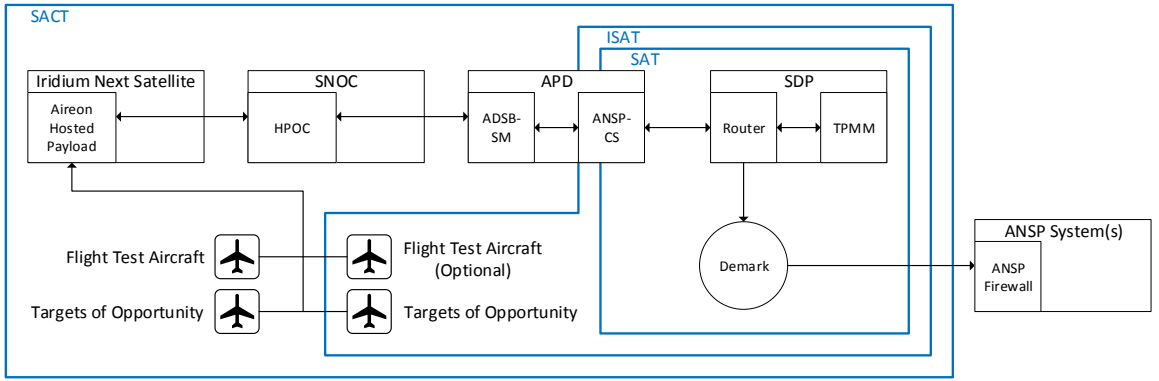


Early Data Delivery Via VPN



Generic ISAT – Overview

- Test Readiness Review
- Test performed prior to Full Integration
  - Telco and Installation Test Cases
  - Security Test Cases
  - Operations Test Cases
  - Local Maintenance Display
  - Redundancy Test Cases
- Test performed after Full Integration
  - Data Collection
  - Performance Test Cases
  - Aireon Dashboard
  - Billing Test Cases
  - Customer Specific Test Cases



Generic ISAT – Test Readiness Review (TRR)

- Objective: To make a Go/No-Go decision to conduct ISAT
- Participants
  - Program Management
  - Engineering
  - Quality Assurance
  - Configuration Management
- Inputs
  - SVDD
  - Hardware configuration
  - Software configuration
  - Test procedures
  - Test Input Files
  - Test equipment
  - Programmatic dependencies

Generic ISAT – Data Collection

- Objective: To collect 7 days worth of APD, ABS, and Shadow System (if applicable) data recordings at each ANSPs SDP. This data will be used in subsequent test cases.
- Parts
  - Targets of Opportunity (TOO)
  - Flight Test (if required)
  - Target Capacity
  - Shadow System

Generic ISAT – Performance

- Objective: To verify APD performance against ED-129B test cases for customer specific service volumes. The following test cases will utilize the data collection recordings to TOO & Flight Test if applicable.
- Test Cases
  - Capacity
  - Latency
  - Target Report Mandatory and Conditional Fields
  - Probability of Update
  - Probability of Long Gap
  - Aireon Dashboard

Performance – *ISAT TC20 – Capacity*

- Objective: To verify the Aireon Service can receive, process, and output ADS-B Targets within SVDD defined service volumes. The test will also verify the service provides a mechanism to detect message overload conditions when message counts exceed receiver capacity.
- General Test Approach
  - A scenario containing ADS-B messages with unique target addresses will be sent across the customer telco and through the customer SDPs and recorded at the output of the SDP to verify the service can process and output a capacity target load. The target overload threshold will be lowered via adaptation to simulate a target overload condition to verify an alarm is provided.

Performance – ISAT TC21 – Latency

- Objective: To verify the Aireon Service delivers targets updates in a timely manner and meets the total latency requirements for target data delivery.
- General Test Approach
  - A scenario containing ADS-B messages with unique target addresses will be played back into the system and recorded at the output of the SDP to verify the service can process and output a capacity target load within the latency requirements.

Performance – *ISAT TC22 – Target Report Mandatory and Conditional Fields*

- Objective: To verify that each ASTERIX CAT021 Target Report contains the correct specification for the Reserved Expansion Field.
- General Test Approach
  - Using TOO or if Avail the Flight Test. A select number of messages will be selected and decoded to populate demonstrated fields of the FSPEC, according to the Global ICD Rev F.

Performance – ISAT TC23 – Probability of Update

- Objective: To verify the Aireon Service meets the required probability of horizontal position update within the ANSP's defined operational service volume.
- Approach
  - Target of opportunity data will be collected to verify the probability of update for each aircraft within the defined service volume. This data will be analyzed to verify the service meets the 8 second update rate. In addition to target of opportunity data recordings, test aircraft may be used to verify the update interval within the service volume under test.

Performance – ISAT TC24 – Probability of Long Gap

- Objective: To verify the Aireon Service meets the required probability of long gap of the horizontal position update throughout the ANSP's defined operational service volume.
- General Test Approach
  - Target of opportunity data will be collected to verify the probability of long gap for each aircraft within the defined service volume. The data will be analyzed to verify the service meets the requirement of < 1 in 1000 long gaps exceeding 60 seconds in the service volume. In addition to target of opportunity data recordings, test aircraft may be used to verify the probability of long gap at the SDP.

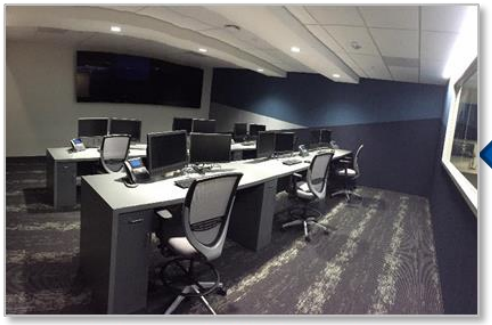
Generic ISAT – Aireon Dashboard

- Objective: To verify proper reporting of SVol status using the Internet-based Dashboard tool
- Test Cases
  - Service Volume Status Reporting
  - CAT021 Target Display

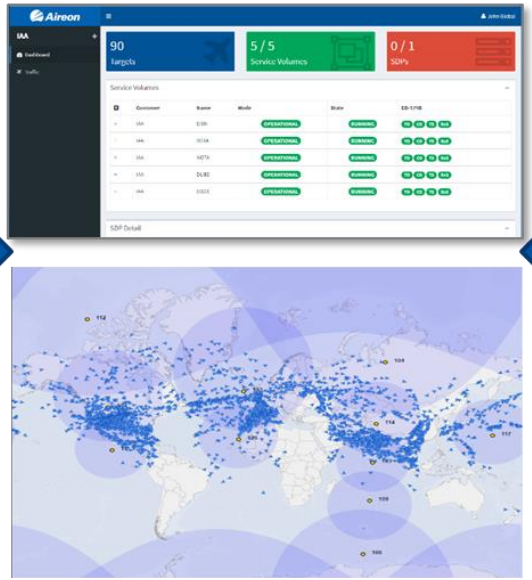
Aireon Dashboard – ISAT TC25 – SVol Status Reporting

- Objective: To verify the proper reporting of Service Volumes status on the Local Maintenance Display.
- General Test Approach
  - While injecting a test input file, verify the proper “Operational”, “Degraded”, “Failed”, or “Unknown” state is reported.
  - Also verify that Target counts are being incremented as configured.

Automation for Maintenance Personnel



Aireon Network Operations Center



Aireon Maintenance Display

ANSP Ops Center

Observation: Bottom Mount Antenna

Cessna 402C Bottom-Only Reception from Puerto Rico to St. Thomas

PUI over 30s intervals is 98.5% - suitable for situational awareness and tracking applications

ADS-B Avionics Issues Observed (from a new perspective)

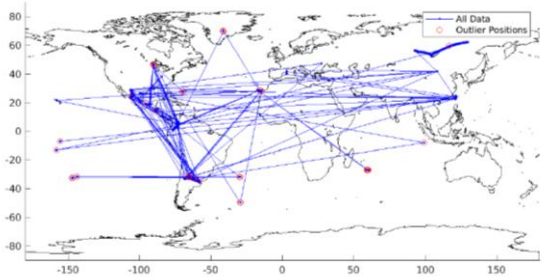


Figure 1: 000001 Outlier Positions

Total Position Messages: 52245

Number of Outlier Positions: 1218

Largest Outlier: 13436km observed 04-Aug-2018 14:44:43Z by SV113

- Target Address = 000001 is not a valid code
- It appears this code is being used by some targets and possibly some spoofers

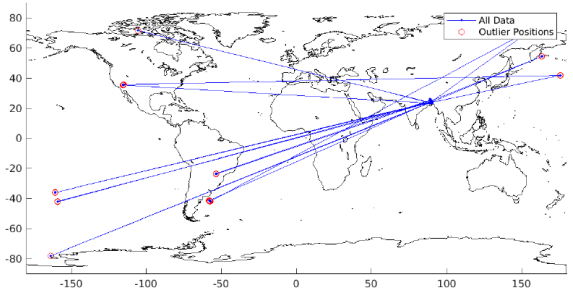


Figure 43: 702039 Outlier Positions

Total Position Messages: 53151

Number of Outlier Positions: 343

Largest Outlier: 13468km observed 30-Jul-2018 10:26:07Z by SV114

- Many of the targets perform well most of the time but occasionally report repeated bad data that causes a jump to some random location

ADS-B Avionics Issues Observed (from a new perspective)

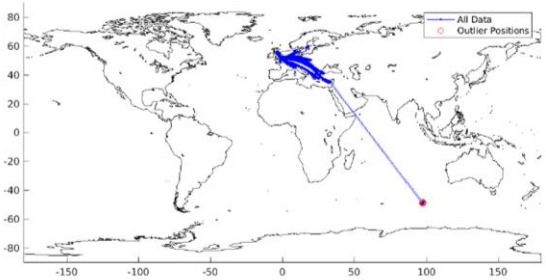


Figure 23: 405A4A Outlier Positions

Total Position Messages: 18144

Number of Outlier Positions: 214

Largest Outlier: 11564km observed 04-Aug-2018 10:52:16Z by SV123

- In this case the target is consistently correct but suffers position outliers when flying near regions where there is GPS jamming

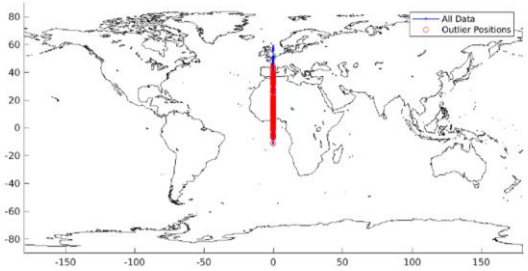


Figure 25: 406B88 Outlier Positions

Total Position Messages: 9141

Number of Outlier Positions: 4793

Largest Outlier: 8933km observed 30-Jul-2018 22:31:04Z by SV126

- This target appears to have a valid ICAO but is part of a group of targets that just fly up and down the prime meridian

Future State

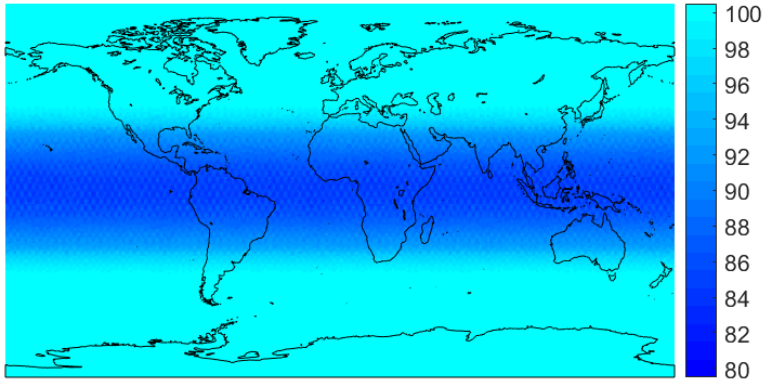
Vinny Capezzuto

GlobalBeacon - Go-Live on 5 November 2018

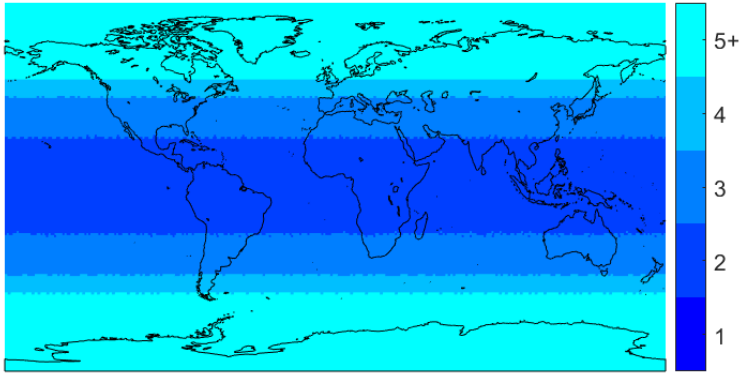
- GlobalBeacon is a joint product from Aireon and FlightAware
  - Pole-to-pole, global, minute-by-minute aircraft tracking
  - Assist airlines meet the ICAO GADSS SARPs for flight tracking
- Combines Aireon's space-based ADS-B tracking data with FlightAware's web interface and worldwide airline flight tracking information
  - Origin, destination, flight plan route and ETA
- GlobalBeacon was designed based on ICAO GADSS criteria for flight tracking
  - Beginning in 8th November 2018, airlines and aircraft operators will be expected to track their fleet anywhere in the world at a frequency of one position every 15 minutes during normal operations
  - By 2021, they will need to automatically receive positions once-per-minute for aircraft in distress
- GlobalBeacon facilitates communication between aircraft operator and air traffic control organizations with constant fleet monitoring, automated distress alerts and tools that make it easy to share information
- Designed to work with existing processes and tools commonly used by aircraft operators
- Qatar Airways signed on to be the GlobalBeacon launch customer. Bangkok Airways has also signed up

Independent Position Validation

- APD Build 9 is scheduled to be deployed in Q1 of 2020 and will include position validation to verify:
  - Simple range
  - Time Difference of Arrival (TDOA)

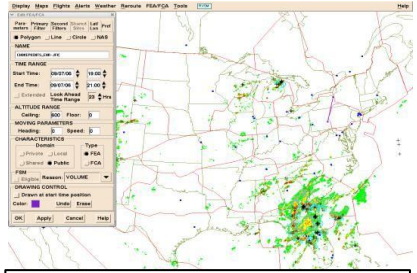


TDOA Probability

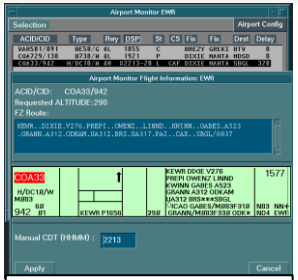


Average Satellite Overlap

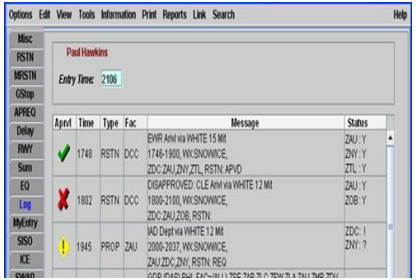
Traffic Flow Management



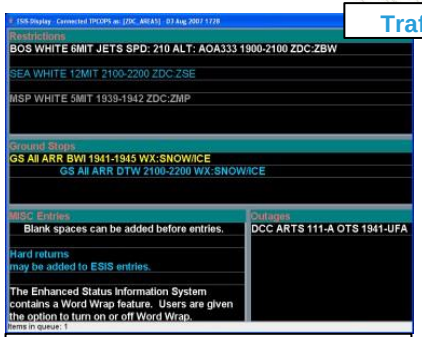
Traffic Situation Display



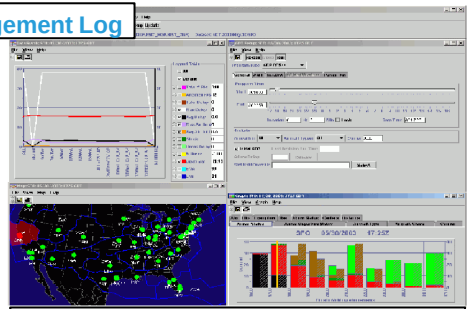
Departure Spacing Program



National Traffic Management Log



Enhanced Status Info System



Flight Schedule Monitor

Space-Based ADS-B Will Be Operational Soon!

- Global ADS-B coverage over oceans, remote and terrestrial airspace will be available to all ANSPs
- Remaining launch on track to complete system deployment, testing and certification
- 11 launch customers representing 28 nations are planning to use the service operationally
- Significant work is being done by the FAA in preparation for the use of space-based ADS-B
- Ongoing EASA oversight post-certification throughout the service lifecycle

ICAO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South American (SAM) Office Lima
ICAO Headquarters Montréal
Western and Central African (WACAF) Office Dakar
European and North Atlantic (EUR/NAT) Office Paris
Middle East (MID) Office Cairo
Eastern and Southern African (ESAF) Office Nairobi
Asia and Pacific (APAC) Sub-office Beijing
Asia and Pacific (APAC) Office Bangkok
THANK YOU