Global Surveillance through Space-Based ADS-B

ADS-B Implementation Workshop

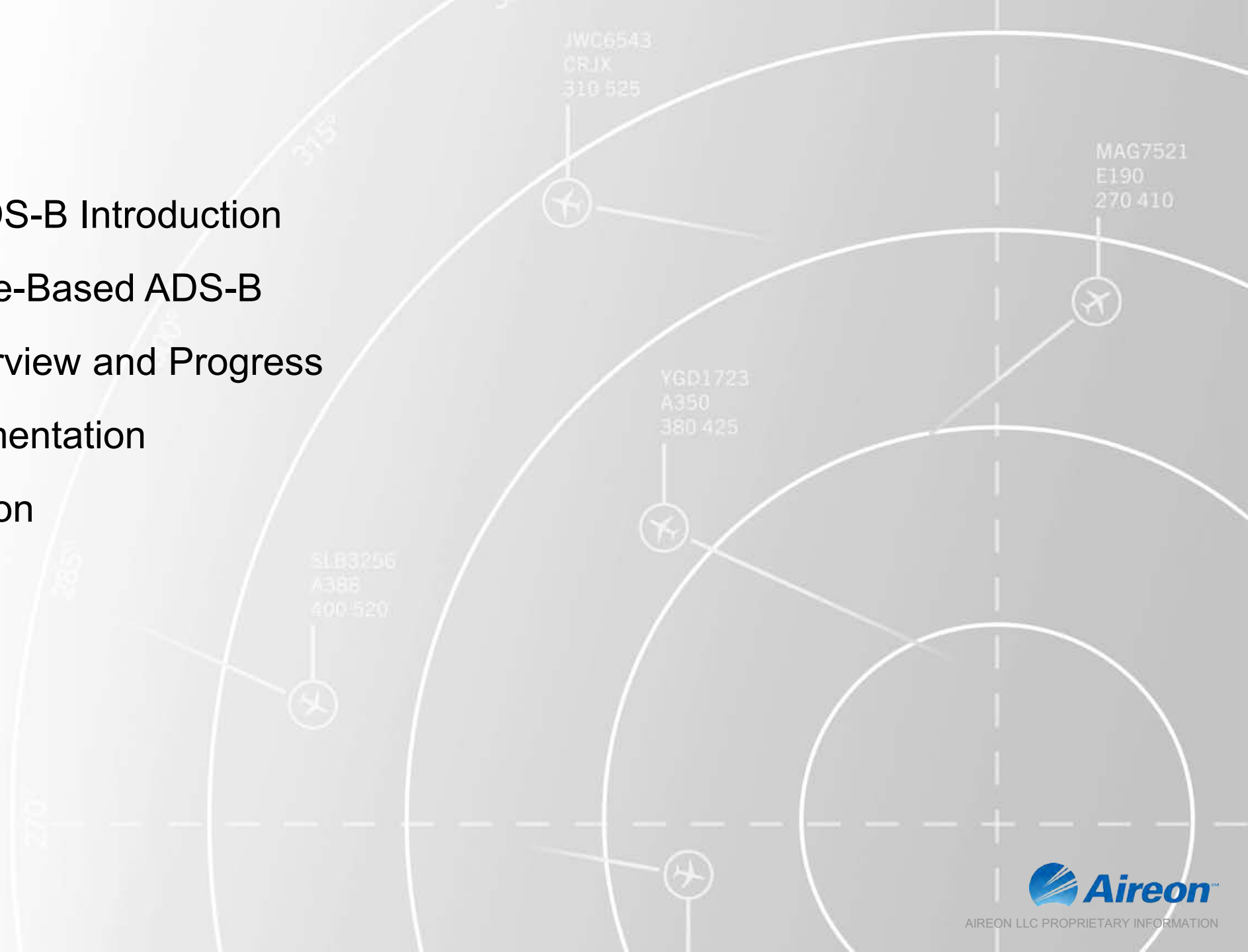
Lima, Peru

November 13-16, 2017

Aireon℠

Agenda

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



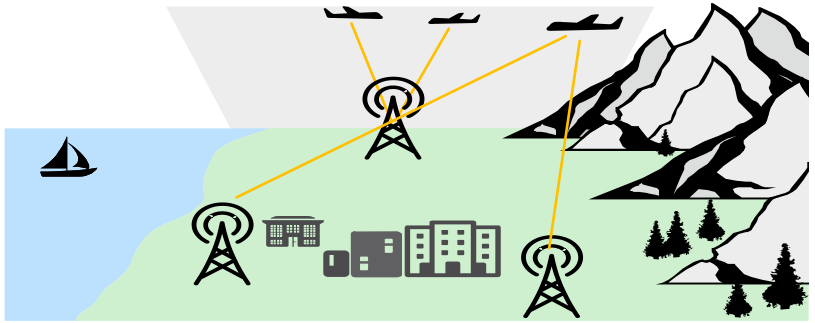
Space-Based ADS-B Introduction

Description & Structure

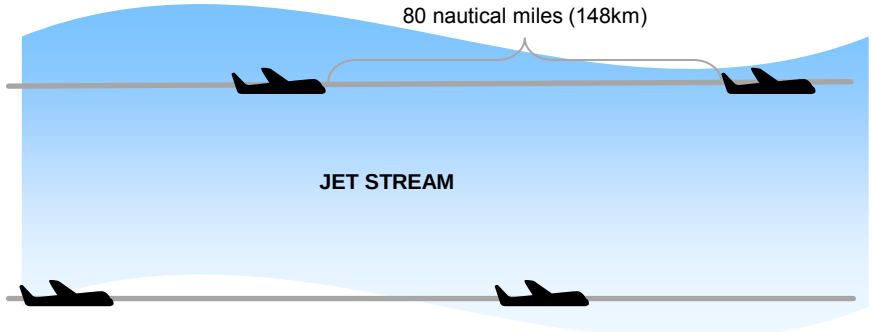
Over 70% of the World Remains Un-Surveilled

The problem: Today's ATC surveillance is insufficient and outdated

Current surveillance is ground-based and limited to terrestrial airspace



- 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



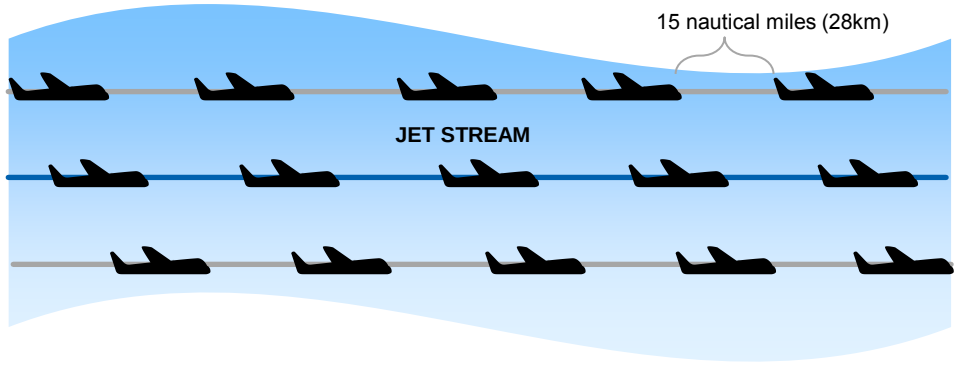
- Lack of precise aircraft location knowledge results in required large procedural separation distance to ensure safety
- Procedural separation causes suboptimal routes and thus higher fuel costs, longer travel times and "loss of separation" instances

The Aireon Solution: Space-Based Air Traffic Surveillance

Global, space-based 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

Efficient, real-time surveillance



- 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

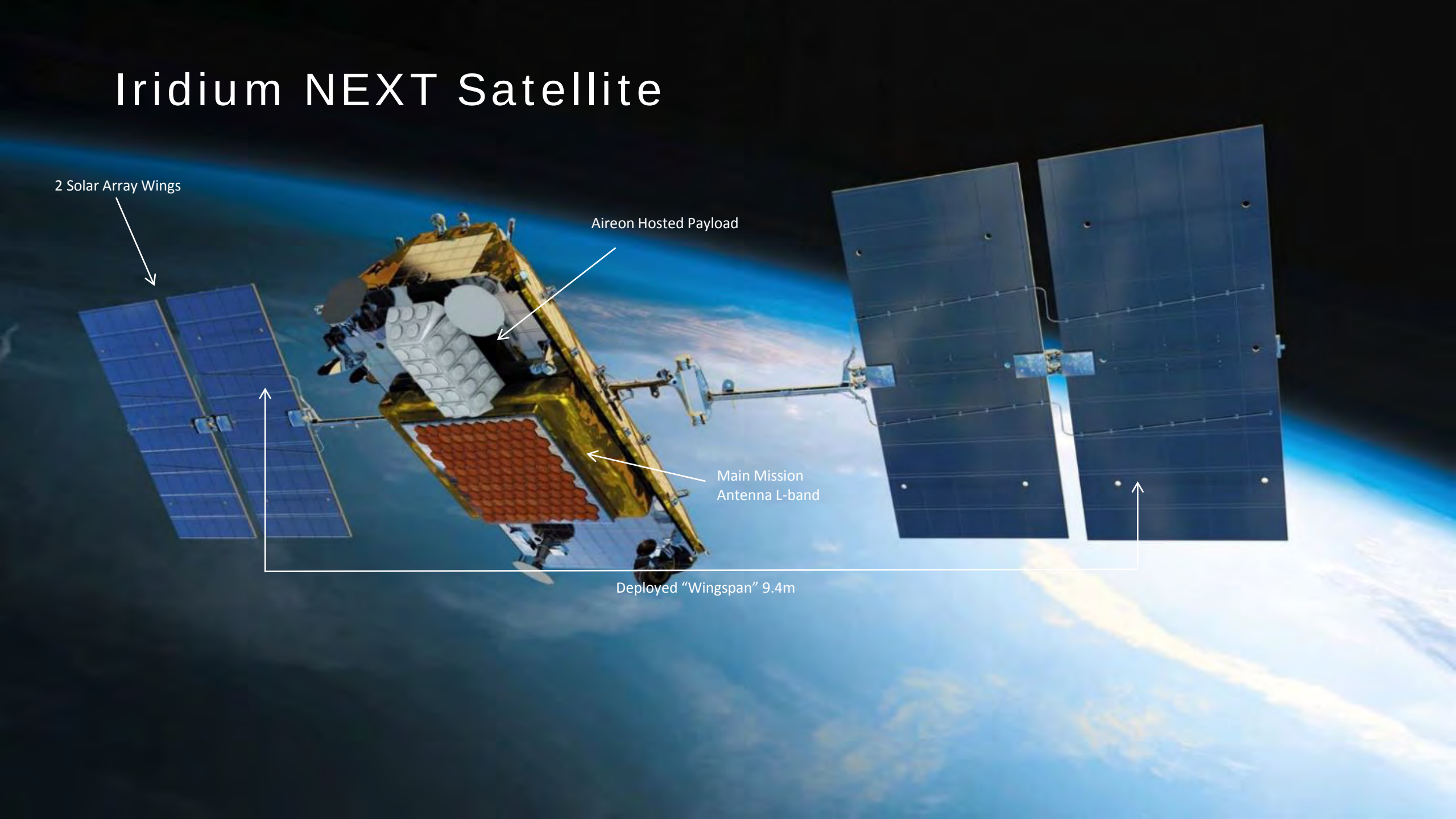
Provides an ANSP with near instantaneous transition to space-based ADS-B when an outage occurs with their primary surveillance source

Iridium NEXT Constellation Overview

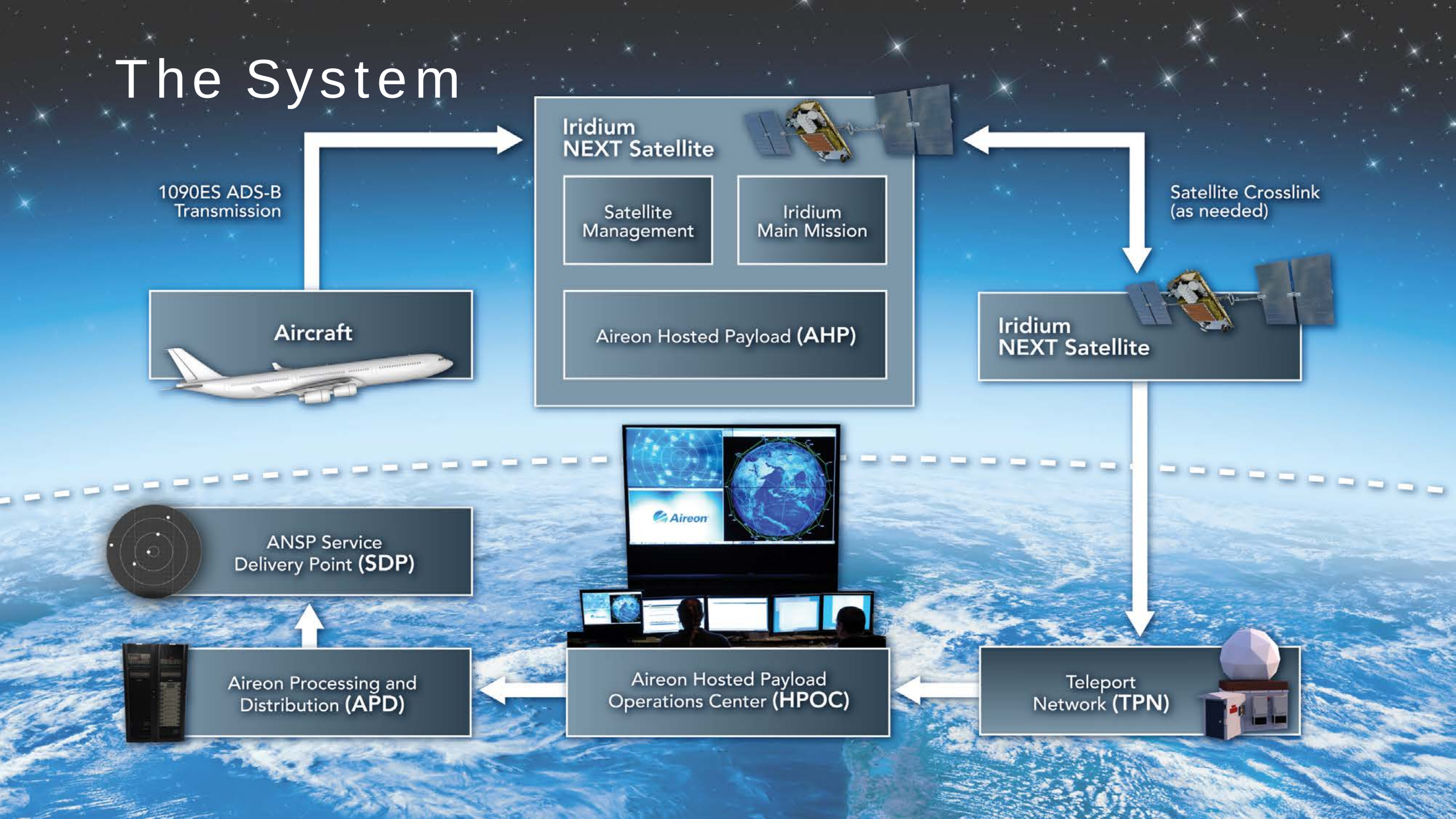
- Satellites in Orbit: 66
  - 11 satellites per plane
  - Plus 9 in-orbit spare satellites and 6 ground spare satellites
- Orbital Planes: 6
- Availability: ≥ 0.999
- Typical Lifecycle: 14 years
- Operational Altitude: approximately 485 miles (780 km)

- Full global Air Traffic Surveillance without the need for additional equipage

Iridium NEXT Satellite



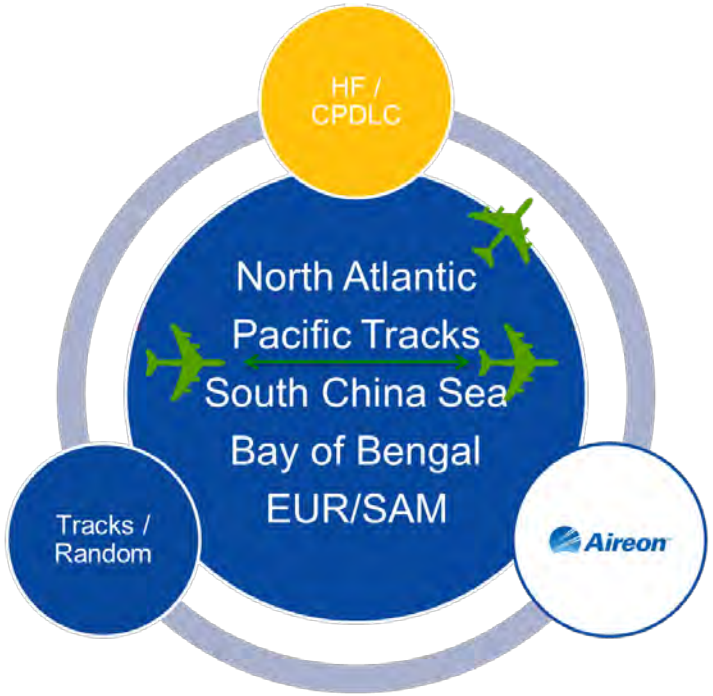
The System

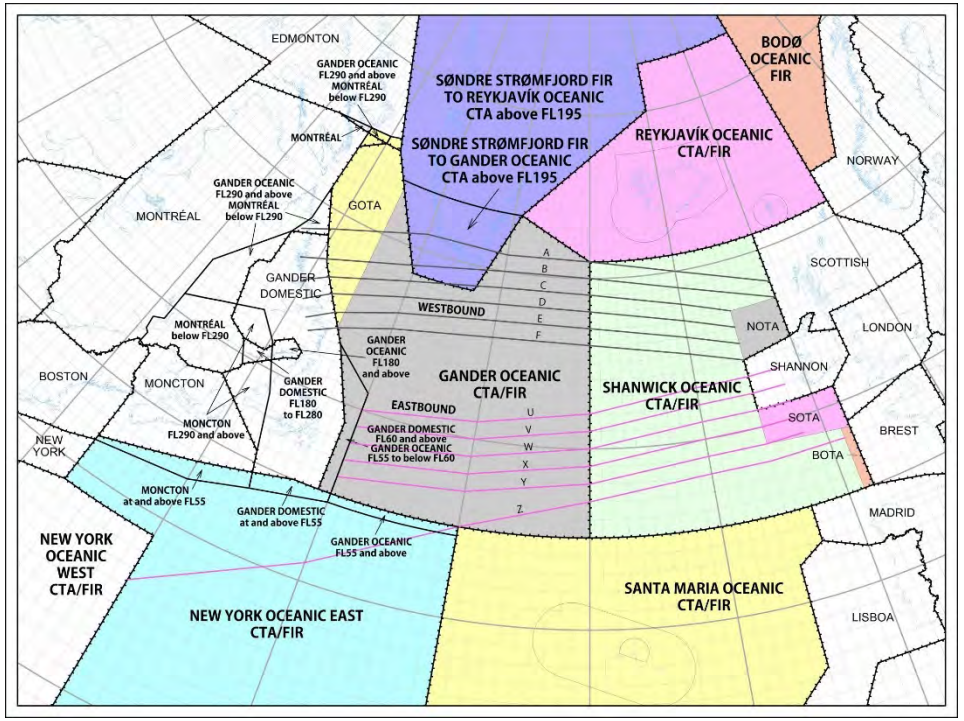

Iridium
NEXT Satellite
Satellite
Management
Iridium
Main Mission
Aireon Hosted Payload (AHP)
1090ES ADS-B
Transmission
Aircraft
Satellite Crosslink
(as needed)
Iridium
NEXT Satellite
Aireon
ANSP Service
Delivery Point (SDP)
Aireon Processing and
Distribution (APD)
Aireon Hosted Payload
Operations Center (HPOC)
Teleport
Network (TPN)

Benefits of Space-Based ADS-B

Oceanic / Remote Applicability

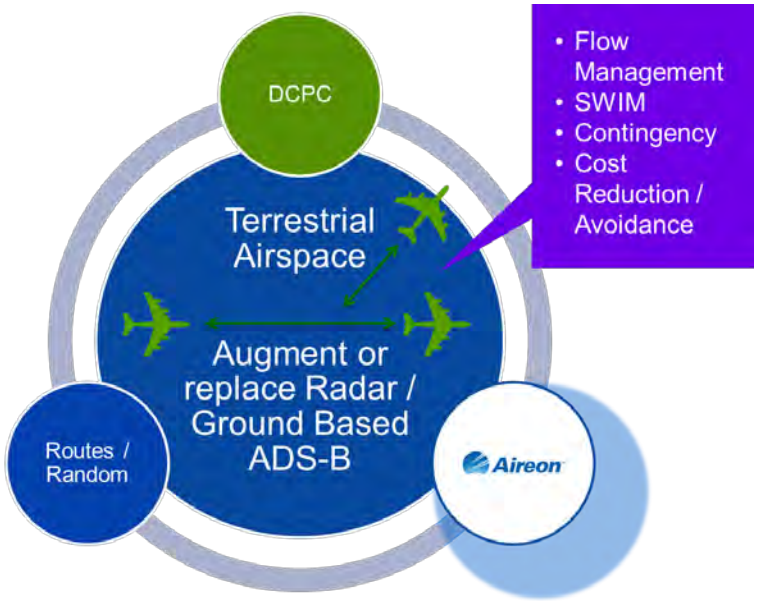
- Sole source surveillance with consistent communications
- Anticipated to be 15 nm separation or less
- Significant efficiency and safety benefits





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



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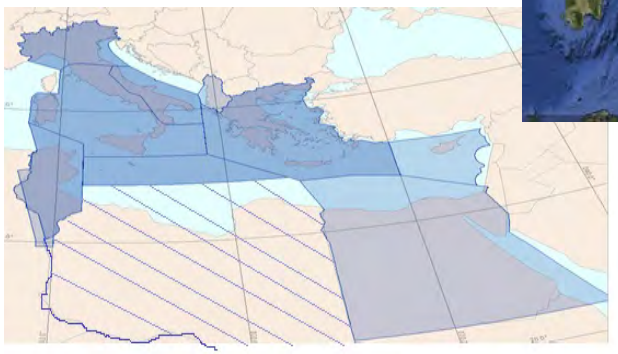


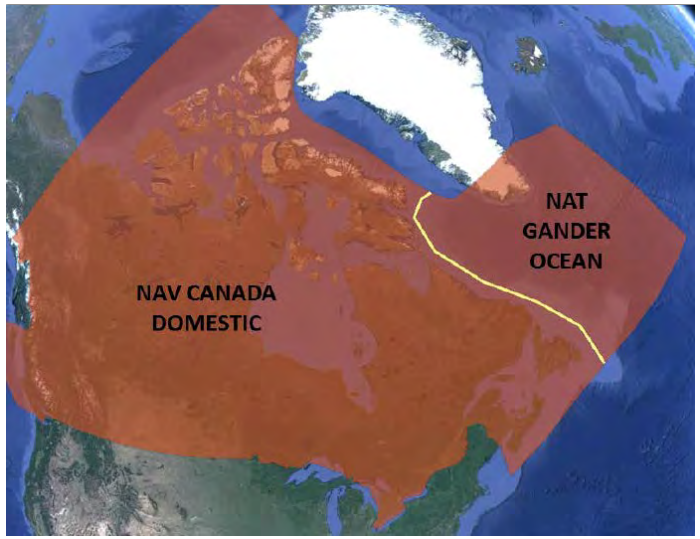
BlueMed Functional Airspace Block

Operational Use Scenarios

Scenarios	Capability	Communication	Navigation	Surveillance	Separation
Procedural Airspace	Base Case	SATCOM or HF only	RNP-10	**Procedural**	Long 10 min (80 nm) Lat: 60nm
	With Aireon	SATCOM or HF only	RNP-10	SB-ADSB Surveillance	**Better than** Long 10 min (80 nm) Lat: 60nm
	Example Airspace	Polar Region / Some remote areas in Africa / ASPAC			
ADS-C Airspace	Base Case	CPDLC with HF backup	RNP-4	**ADS-C**	30 nm
	With Aireon	CPDLC with HF backup	RNP-4	SB-ADSB Surveillance	<15 nm
	Example Airspace	North Atlantic / Pacific oceanic or Some remote areas in Africa / ASPAC			
Procedural Airspace with VHF	Base Case	DCPC Voice	RNP-10	**Procedural**	10 min (80 nm)
	With Aireon	DCPC Voice	RNAV 5 (Europe) RNAV 2 (U.S.)	SB-ADSB Surveillance	5 nm
	Example Airspace	VHF without surveillance. Common around small island States (Asia, Caribbean, Latin America) and large remote landmass (ASECNA)			
Currently Surveilled Airspace	Base Case	DCPC Voice	RNAV 5 (Europe) RNAV 2 (U.S.)	**Radar, WAM, or Ground Based ADS-B**	5 nm
	With Aireon	DCPC Voice	RNAV 5 (Europe) RNAV 2 (U.S.)	SB-ADSB Surveillance	5 nm
	Example Airspace	Terrestrial Europe, North America, Brazil, Australia etc.			

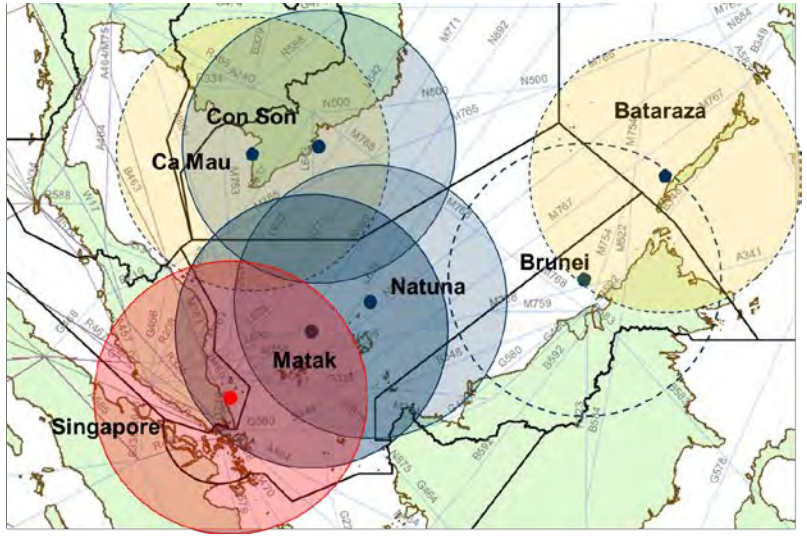
NAV CANADA Use Case

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



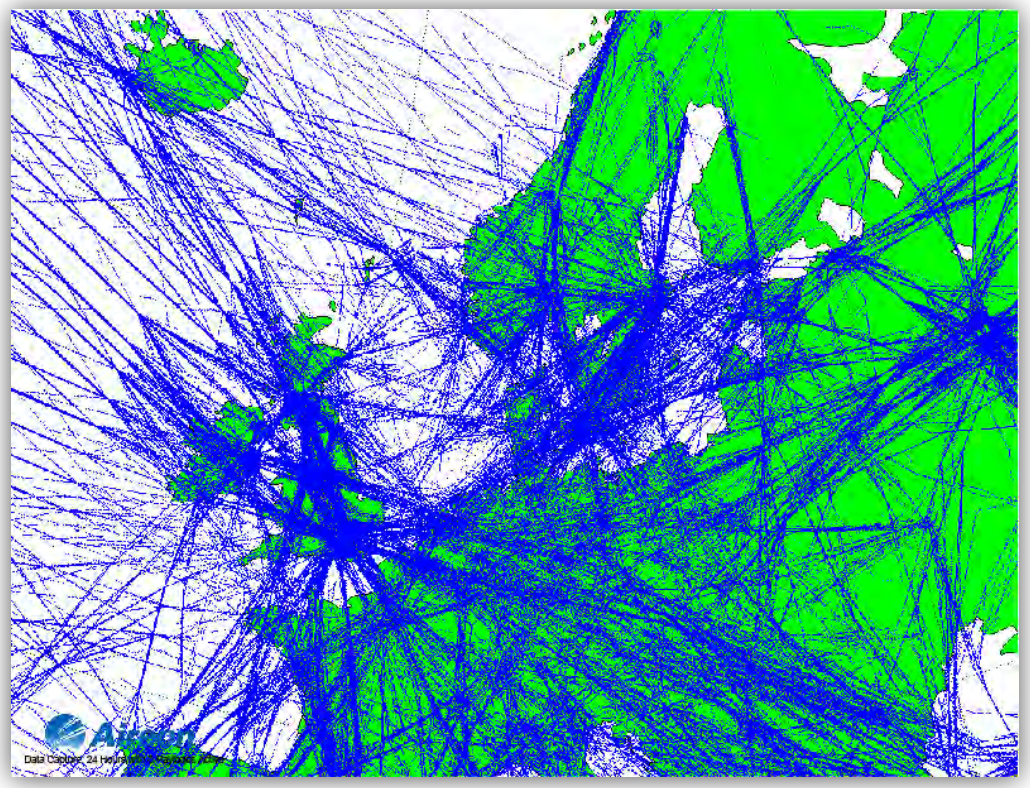
CAAS - Singapore Use Case

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



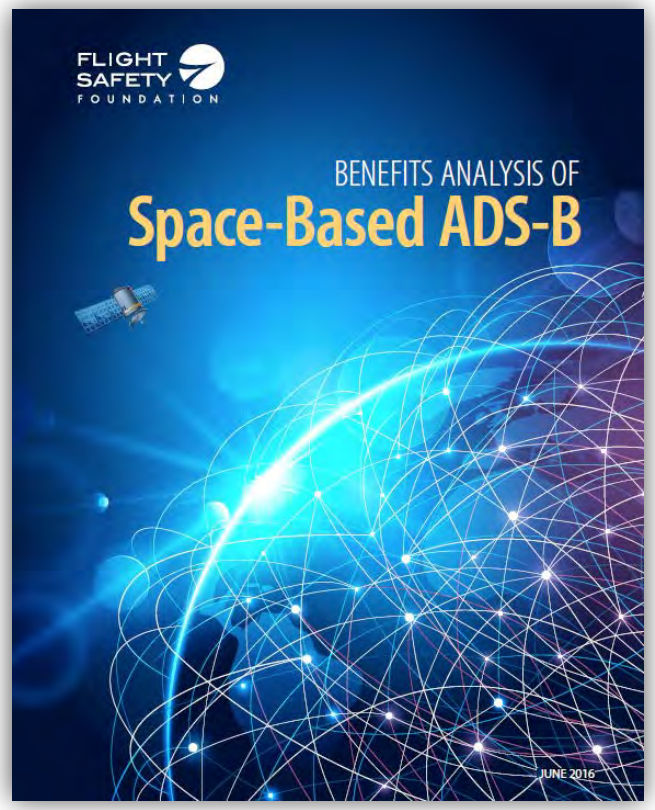
Naviair Case Study

- 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 an 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

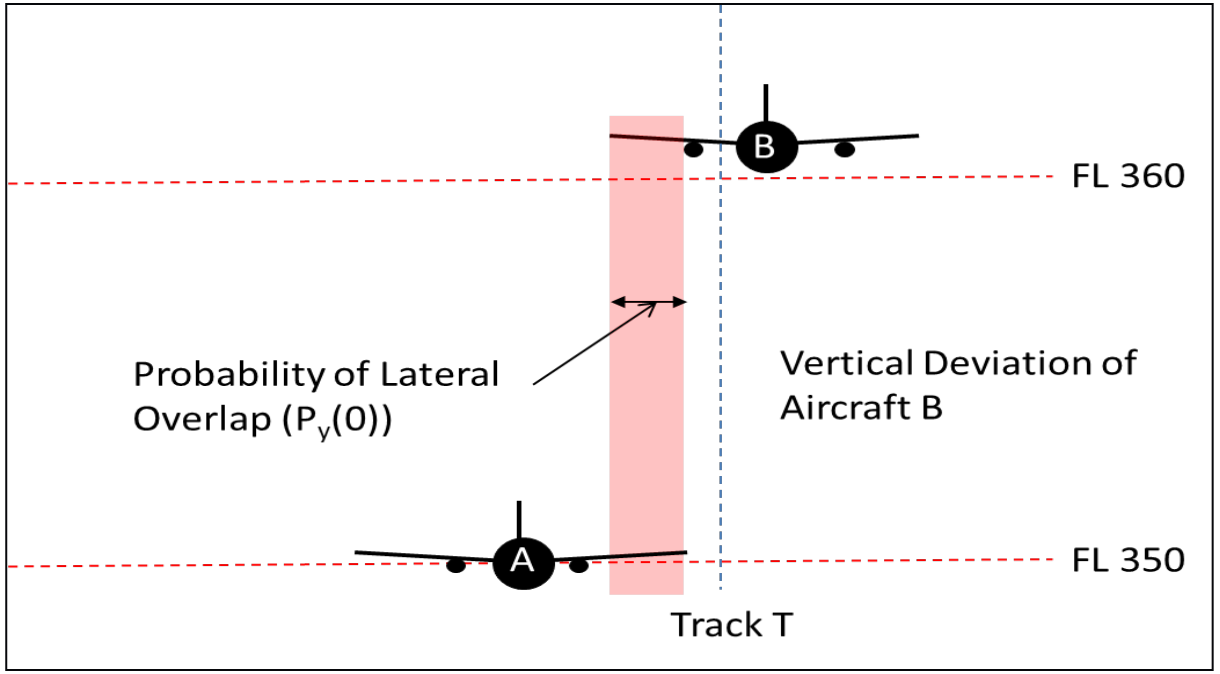
- 2016 public study identifies 23 safety and efficiency benefits of space-based ADS-B as compared to existing capabilities
- Some examples:
  - Jumping a generation of surveillance technology and improving service in remote and difficult-terrain regions
  - Reduced risk and early detection of gross-navigation 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

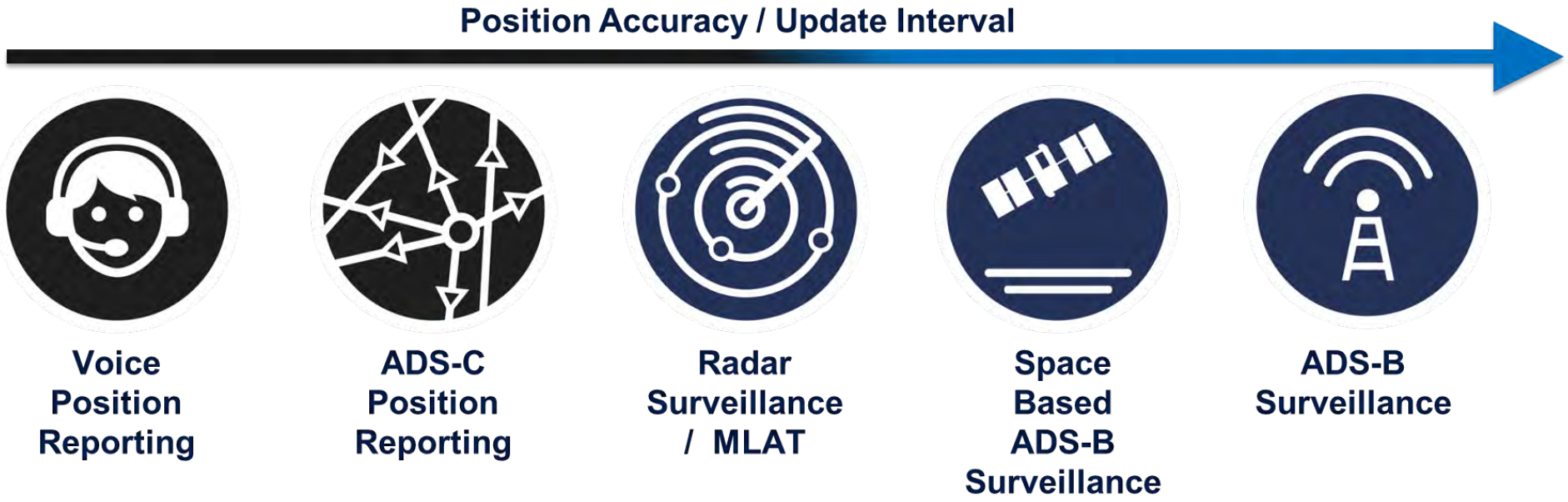
Value of Real-Time Global Air Traffic Surveillance

- 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 ≅1.5 seconds) with cleared flight level (ATM Systems ≤ 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

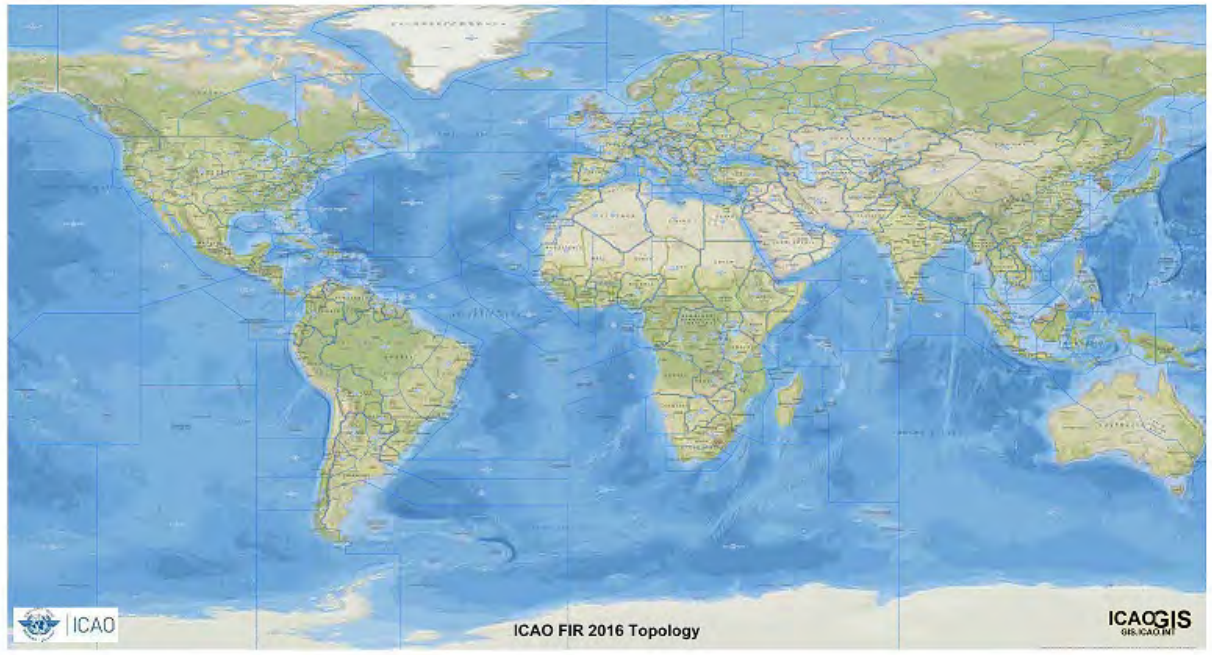
Enhancing SAR Operations: Less Time on Search & Faster Rescue



		Area of uncertainty during a trigger event			
		A320	A330	A340/B77W	A380
	Cruise speed (kts)	427	475	482	488
Operational Radius Between Position Reports (sq./ km)	PIREP (30min)	491,165	607,798	625,844	641,522
	ADS-C (15min)	122,791	151,949	156,461	160,380
	ADS-B (8sec)	**9.7**	**12.0**	**12.4**	**12.7**

Increasing Sector and Cross-Boundary Safety

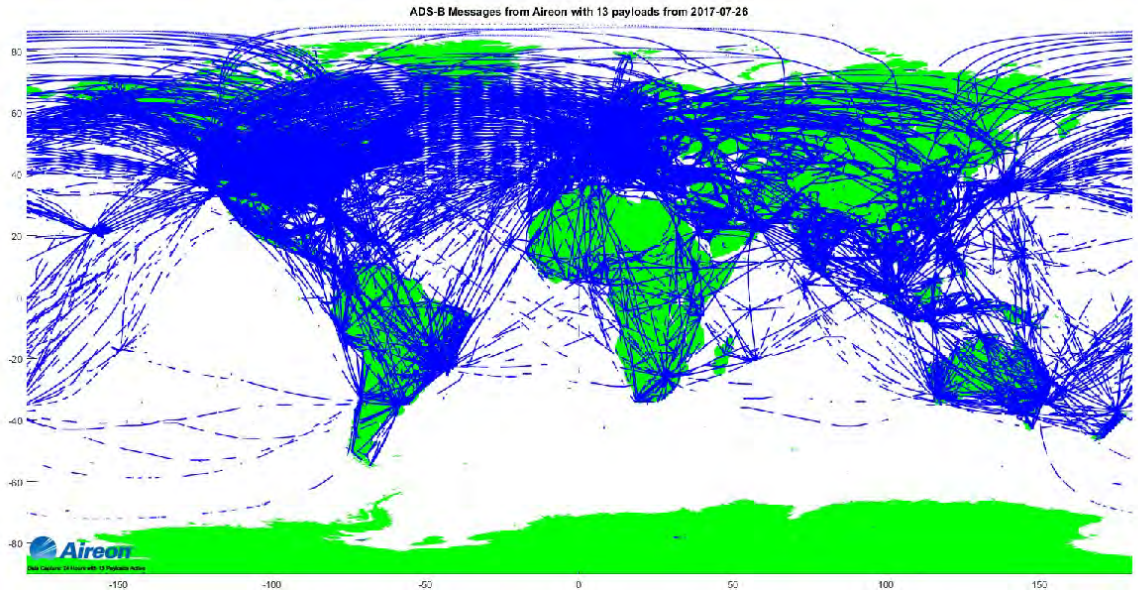
- Lowered risk of data loss between airspace sectors through continuous surveillance
- Enabling availability of surveillance data on both sides of the sector boundary
- Reduce hand-off errors, early detection of altitude / position errors
- Early detection of emergency transponder codes
- Reduced complexity 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


Aireon
SM

Caribbean Airspace

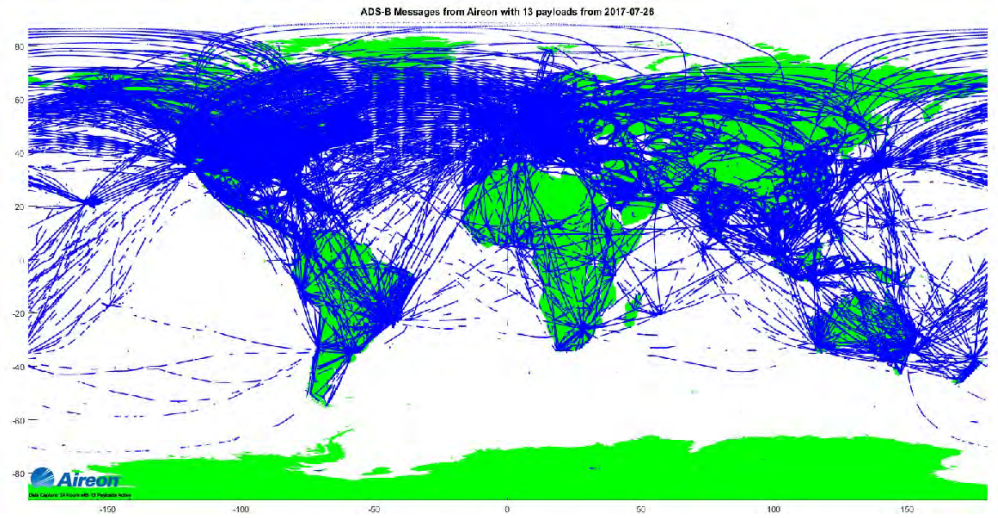
Ecuador, Peru, Chile


Aireon
SM

Early Testing: The Metrics

Metric	Measured
Unique Targets Total	**24,000** (3 payloads, 10 March – 17 March)
Unique Targets per day	**19,351** (8 payloads, 11 April)

Metric	Measured
Received ADS-B Messages per day	**57,306,930** (11 April 2017, 8 payloads, includes all messages)
Surface Vehicles per day	**107** (8 payloads, 11 April)



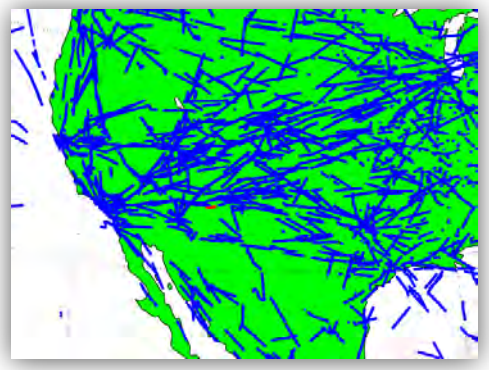
Surface Vehicle Examples:

Early Flight Test Results Providing Assurance of ATC Grade Surveillance

NAV CANADA, Mar 7th

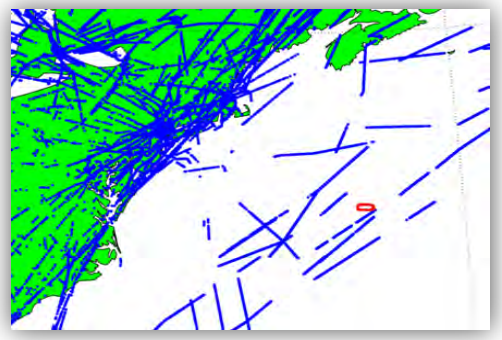
From 1 Payload	Best Expected	Best Measured
Aircraft Elevation (deg)	7.0	0.08
Slant Range (km)	2550	3229
95th % Update Int.(s)	8	4.09

Polaris, Mar 20th



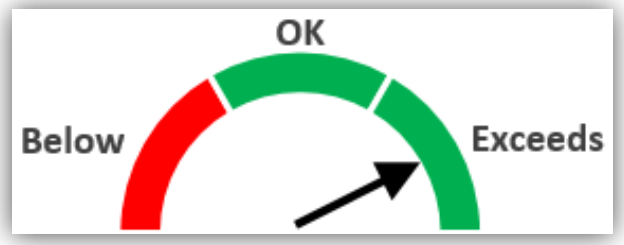
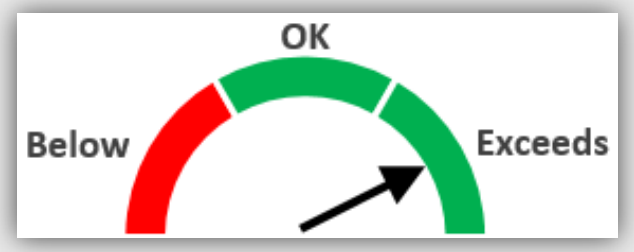
From 2 Payloads	Best Expected	Best Measured
Aircraft Elevation (deg)	4.00	**-1.37**
Slant Range (km)	2800	3392
95th % Update Int.(s)	15.00	9.97

FAA, Mar 30th

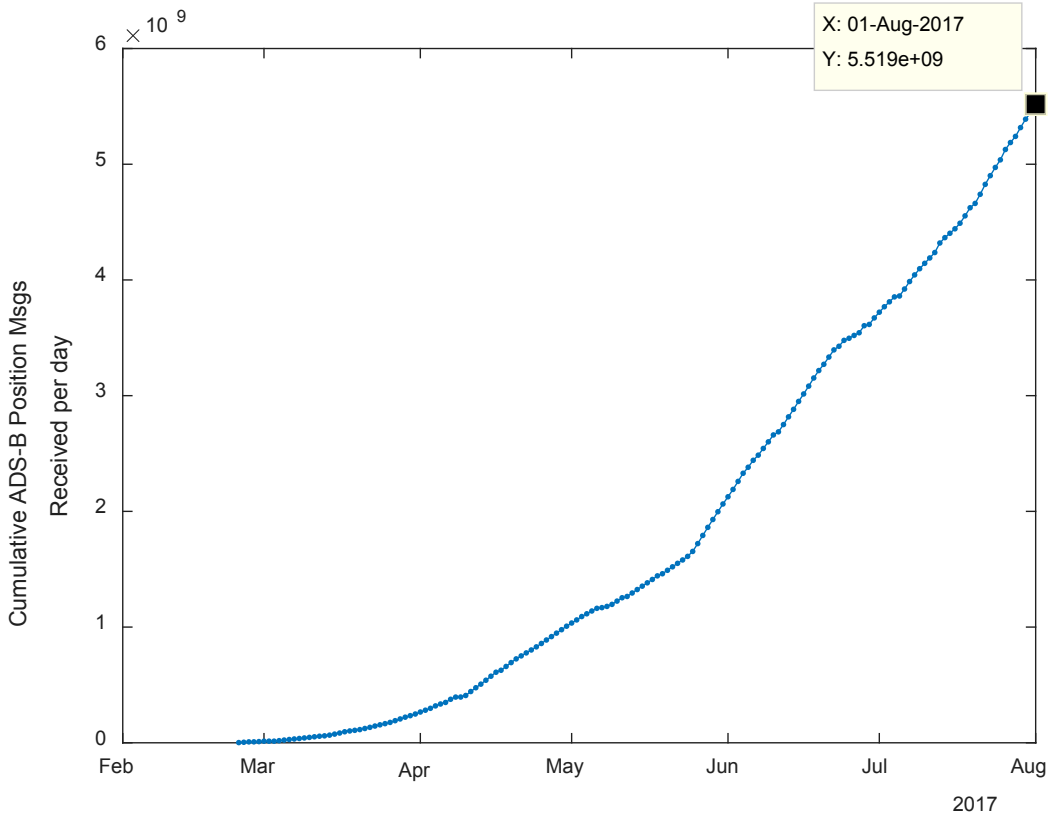


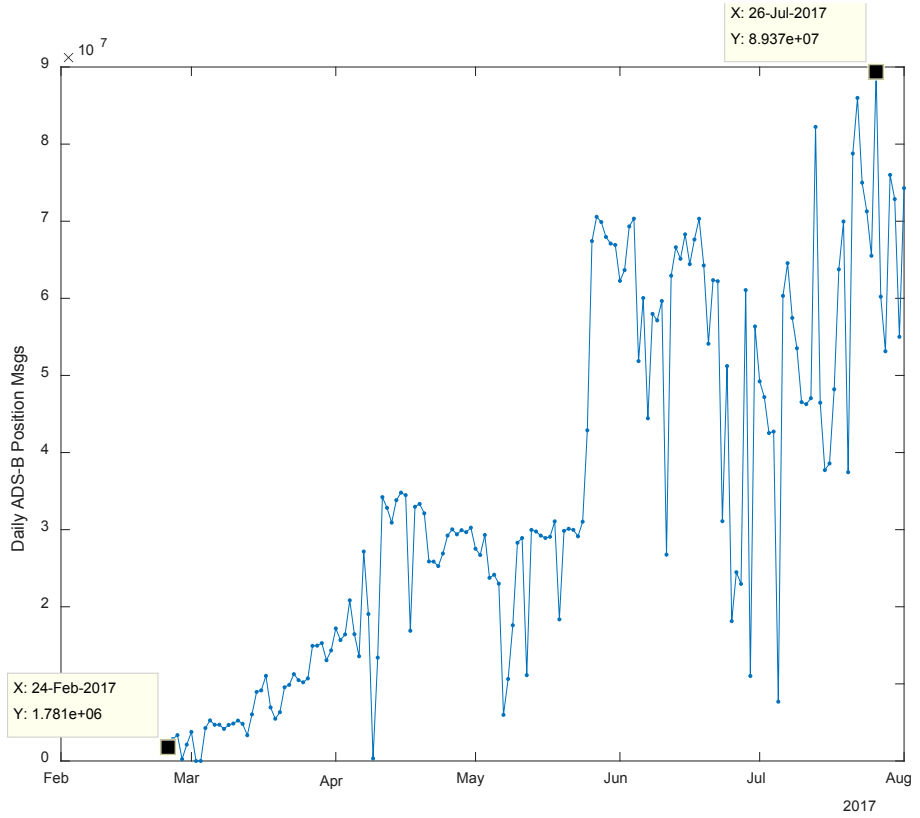
From 3 Payloads	Best Expected	Best Measured
Aircraft Elevation (deg)	7.00	**-4.58**
Slant Range (km)	2550	3768
95th % Update Int.(s)	15.00	10.02

Initial Technical Scorecard – Update Interval

Metric	Design Goal	Measured	Performance Gauge
Update Interval 125 Watt Max UI 95%	8 s	**6.21 seconds** (using known targets)	
Latency (Payload to APD Input Maximum)	429 ms	**321.29 ms** (8 payloads, limited bandwidth, 11 April 2017)	
Slant Range (Footprint) Maximum	2250 km	**3806.8 km**	

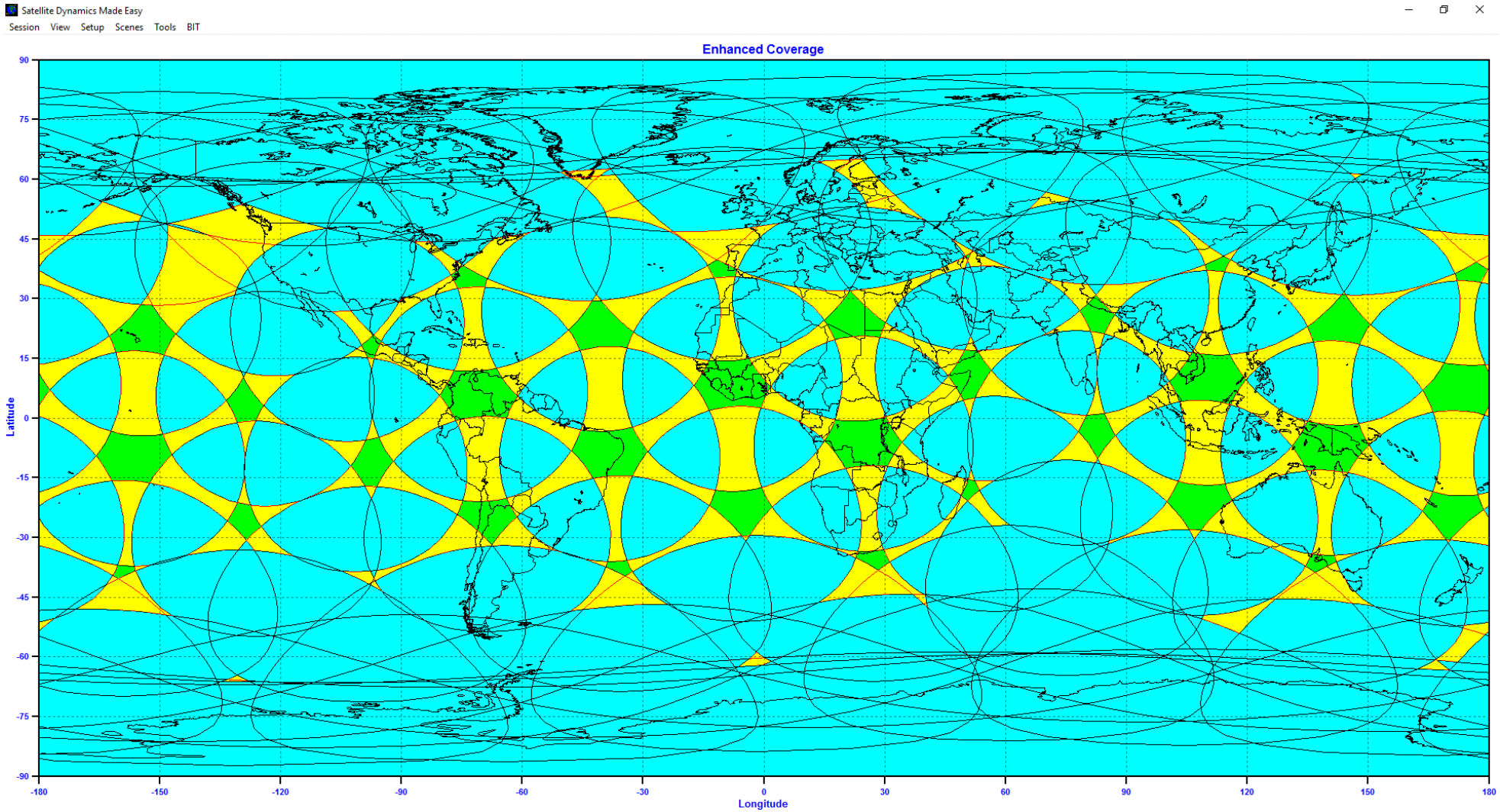
Current System Stats: ADS-B Messages Per Month



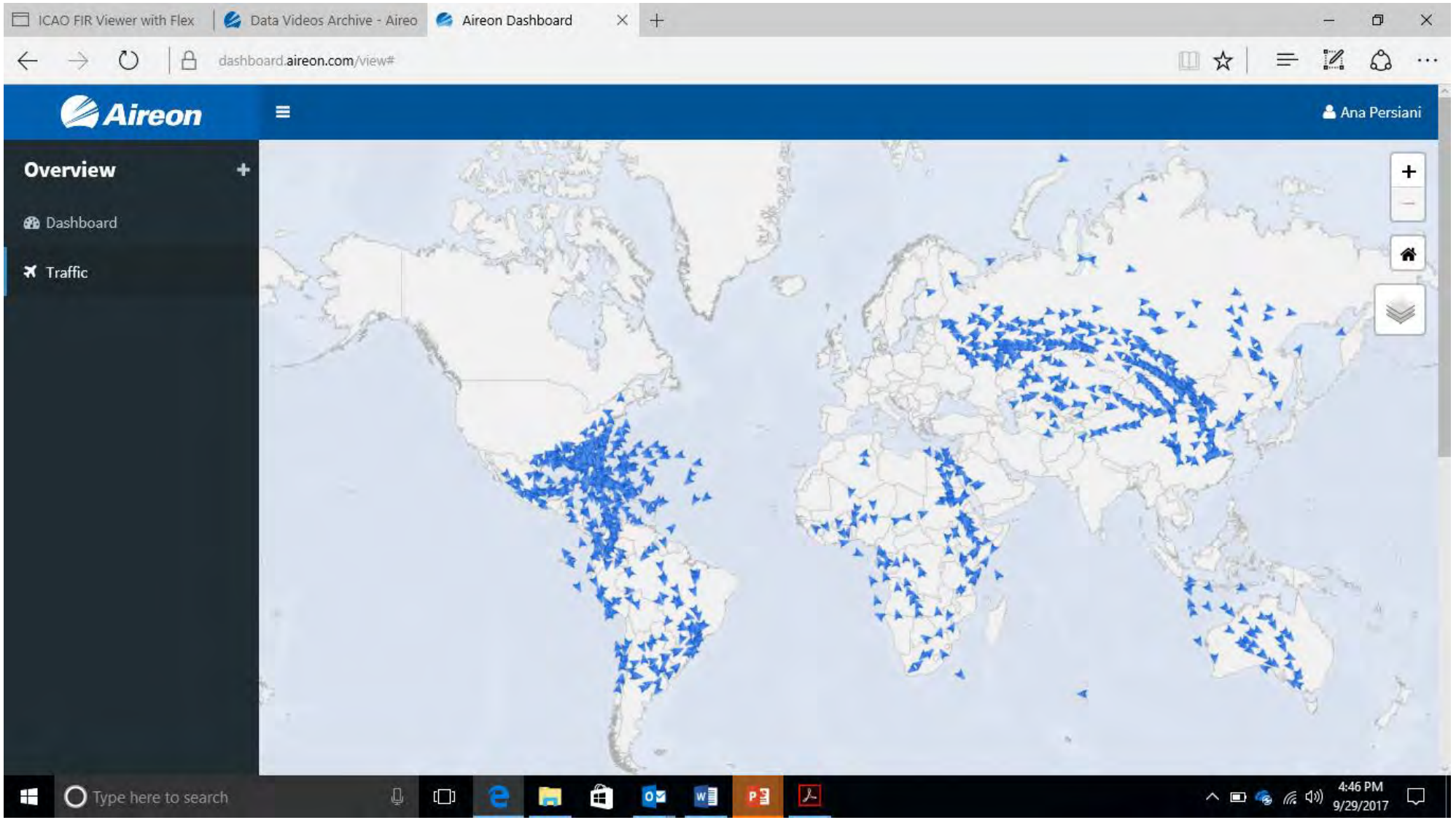


Over 2.5 billion ADS-B Position Messages Received Per Month!

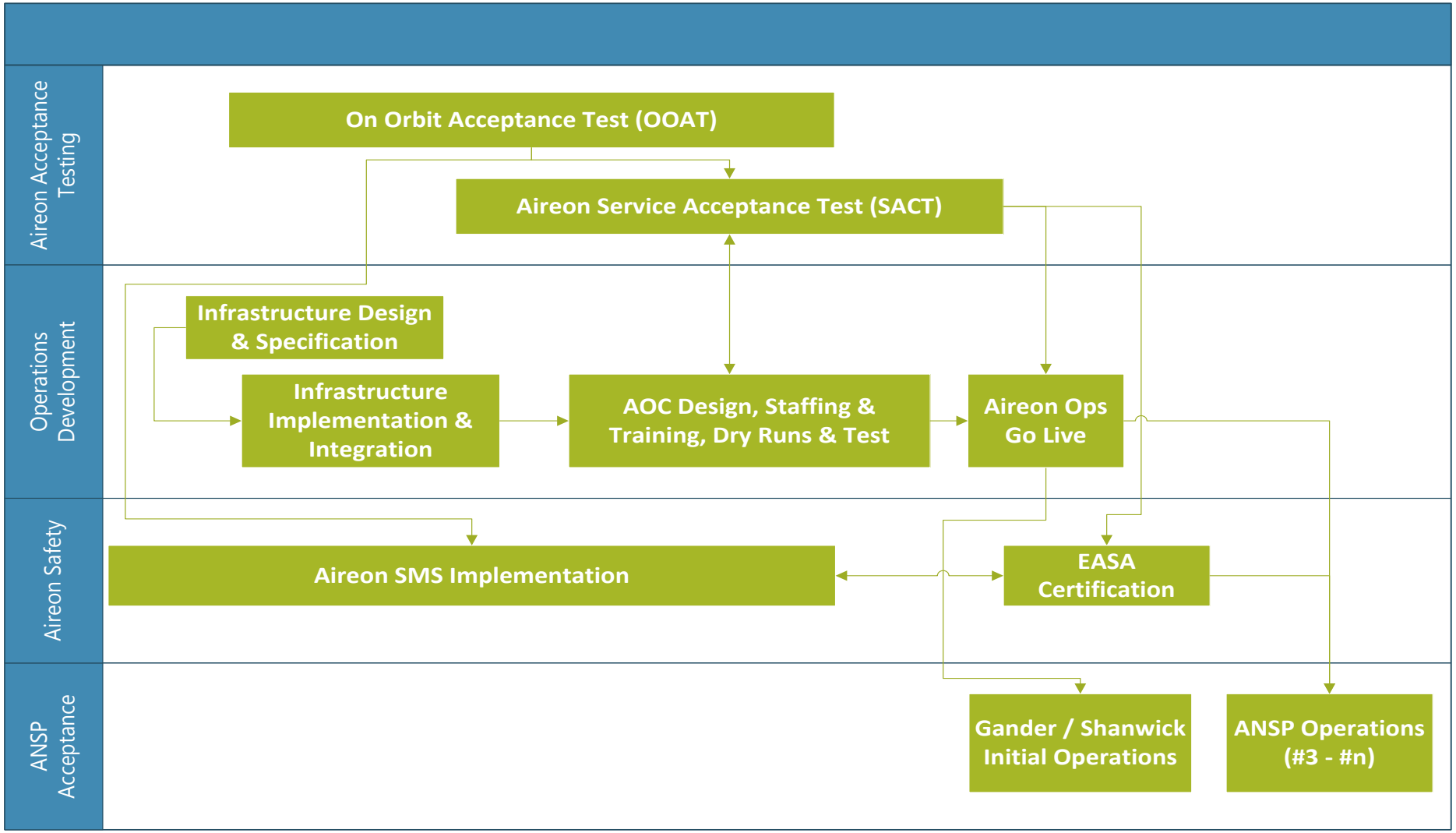
Full global coverage, triple redundancy



Live data – 13 active satellites



Activities to Operation



Safety is part of developing the system and maintaining operations for the life of the service

Technical Implementation

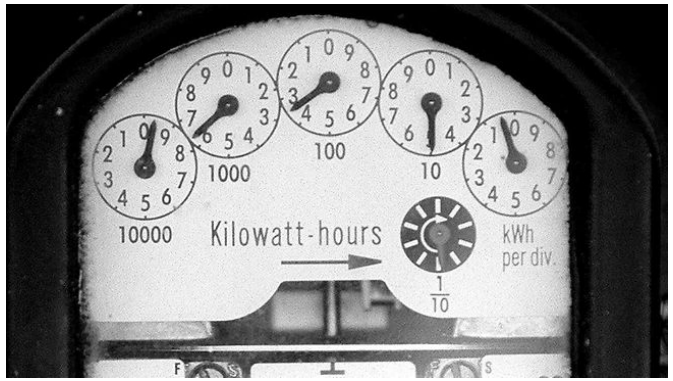
Aireon Service Delivery Point (SDP)

- 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

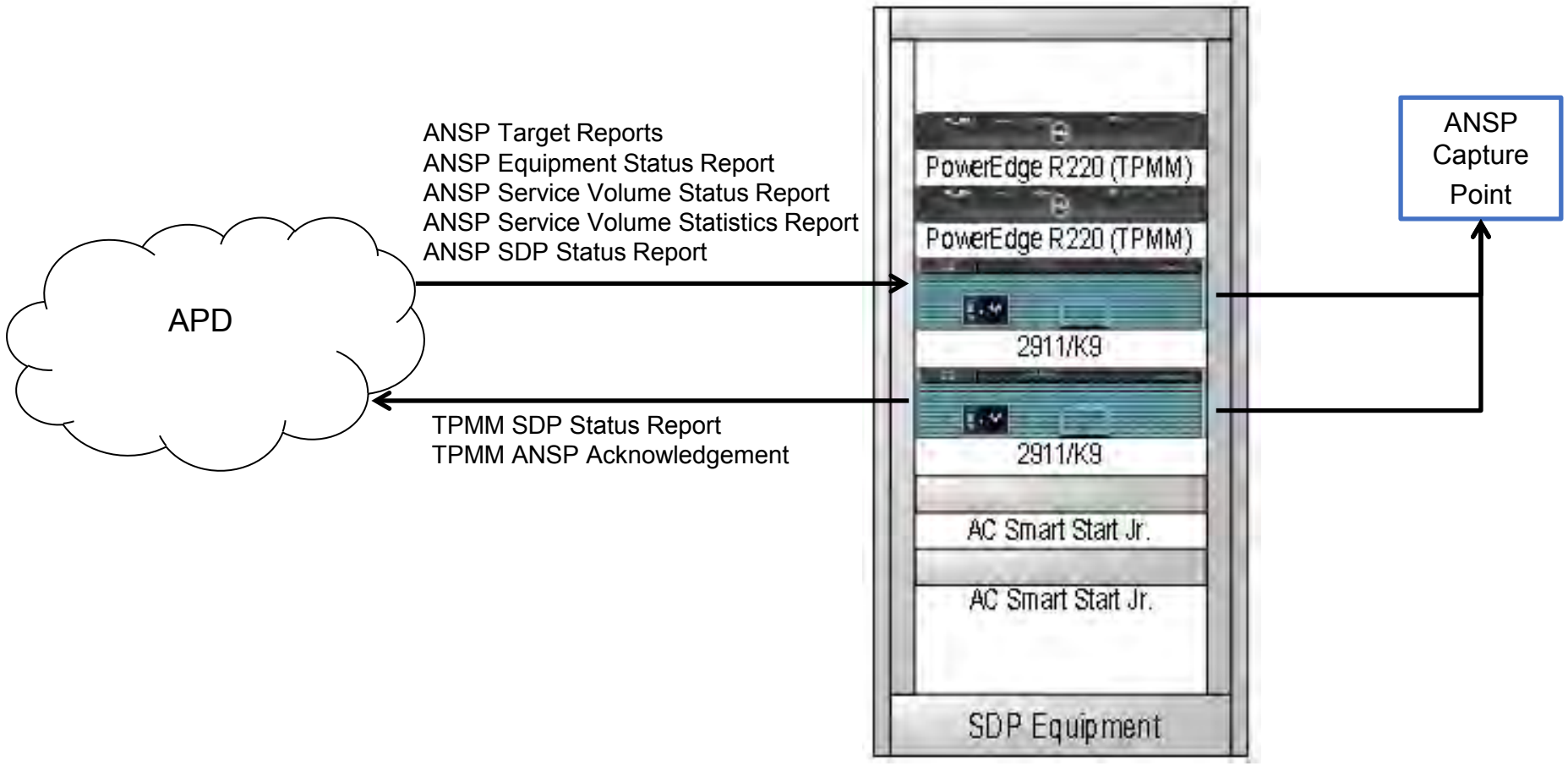
Example: Racksource RACK-151-16U

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

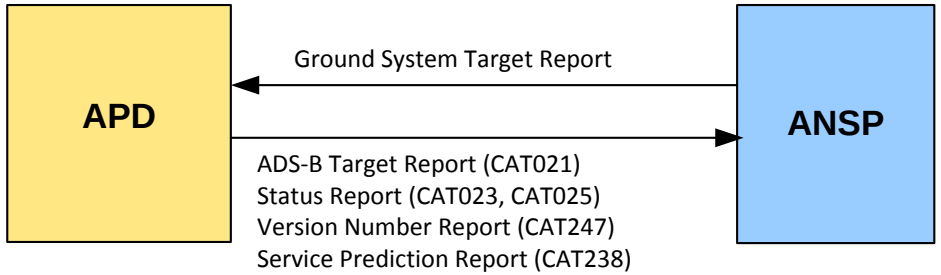


ASTERIX Overview

- Aireon ADS-B data is sent to ANSPs using the ASTERIX format
- ASTERIX is the **A**ll Purpose **ST**ructured **E**urocontrol Su**R**veillance **I**nformation E**X**change
- 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

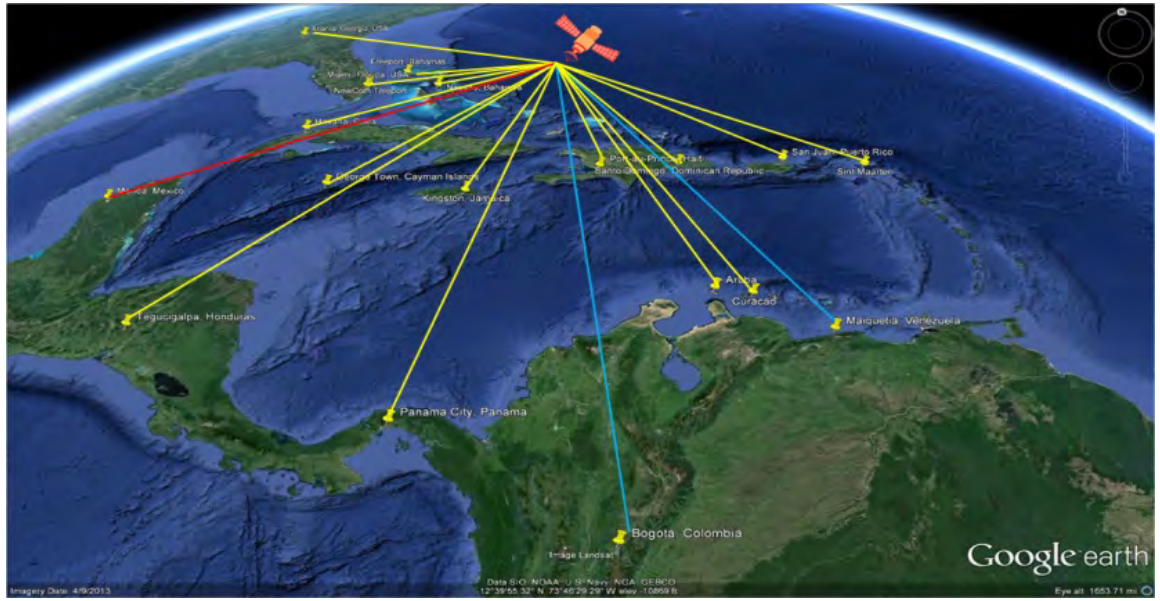
- Examples of common categories:

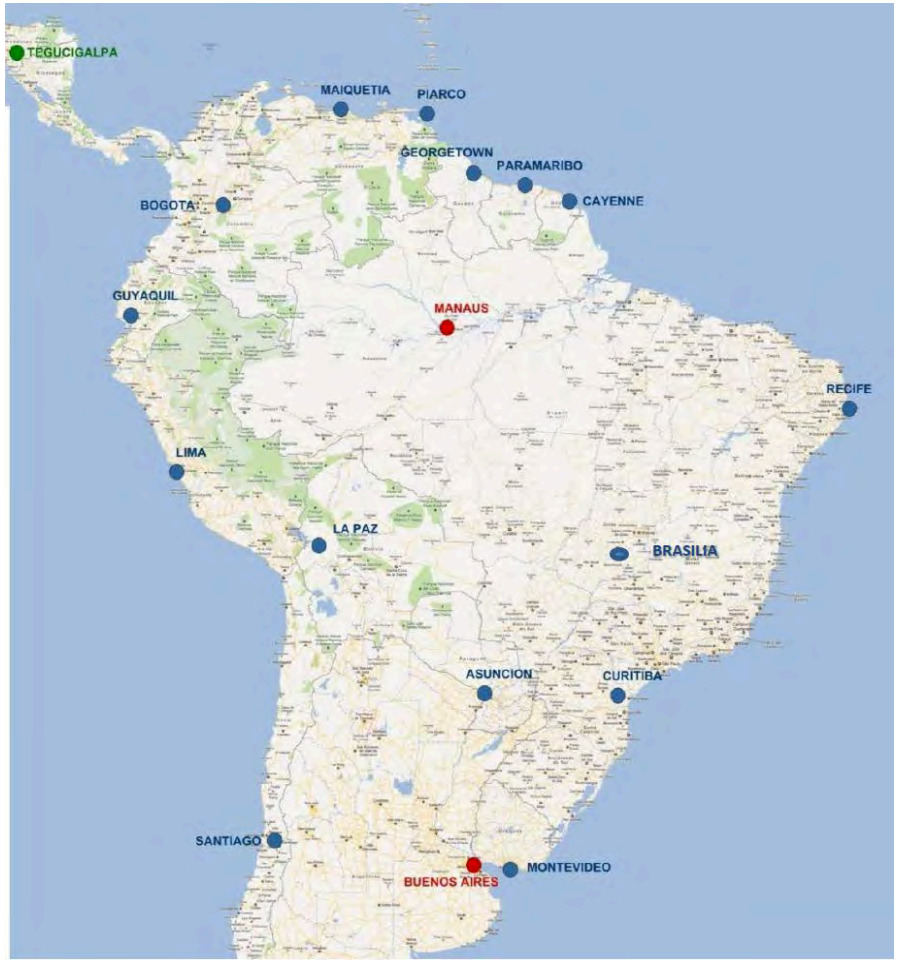


Category	ASTERIX Message
CAT021	ADS-B position and velocity reports
CAT023	Ground station (equipment) status
CAT025	Surveillance system status reports (In progress, new for ED-129B)
CAT247	Version number exchange
CAT238	Service Prediction reports
CAT253	Two-Line Element (TLE) report

ADS-B Data through MEVA III & REDDIG II

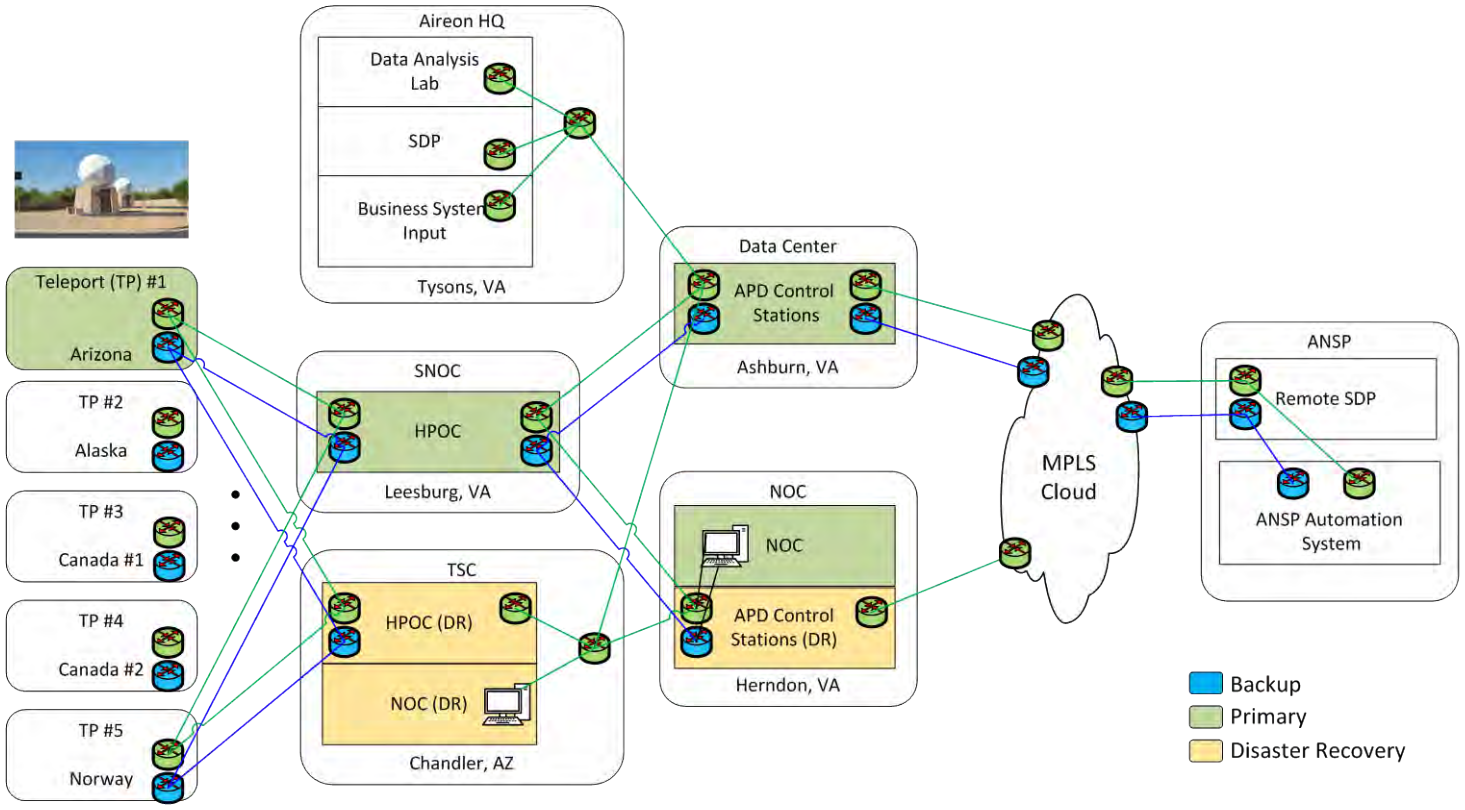
- Analysis is Underway for potential distribution in Latin America & Caribbean through MEVA III & REDDIG II



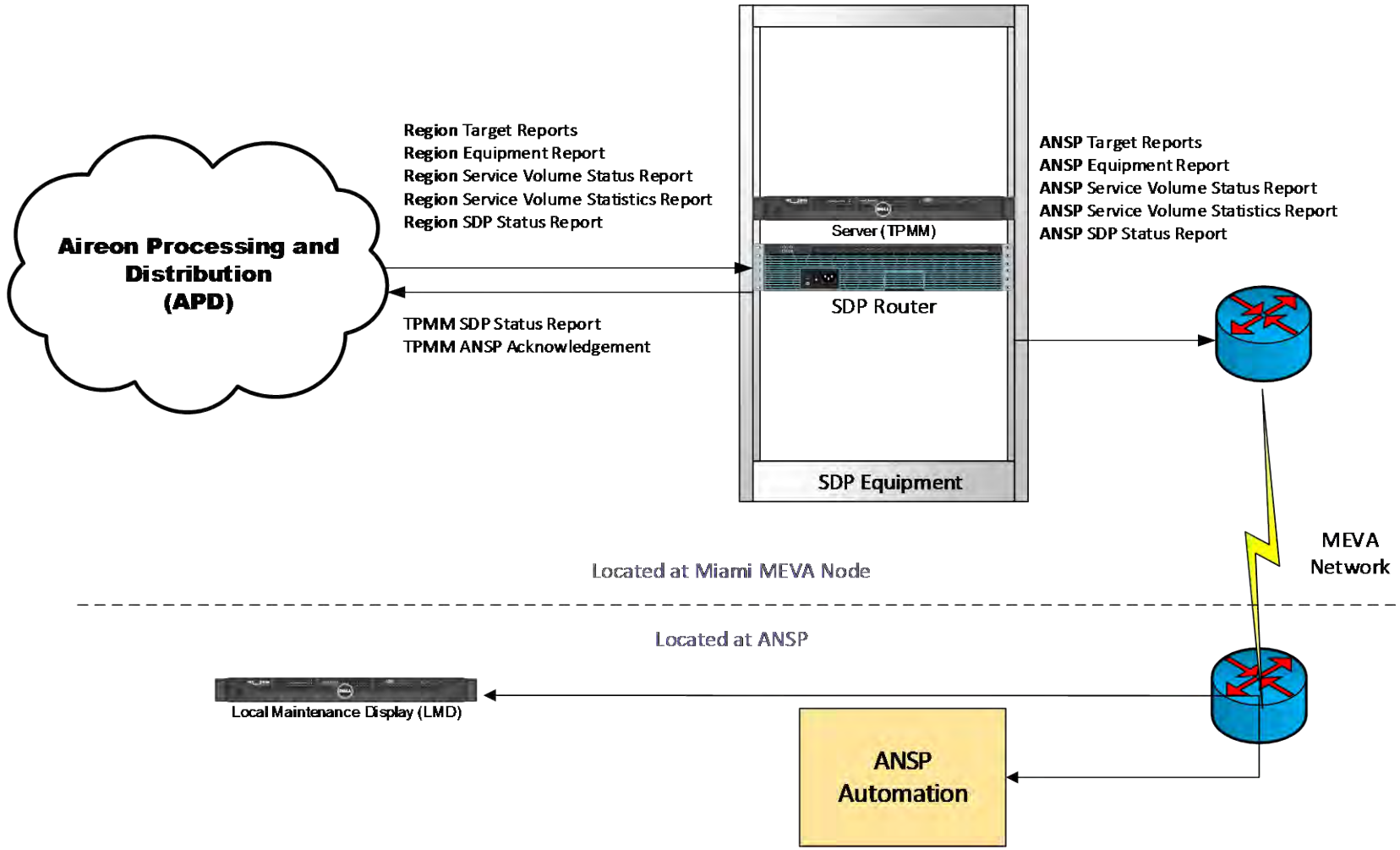


- By using the Regional Networks, States can benefit from:
  - Reduction of telco lines cost
  - Reduction of SDP cost
  - Platform for data sharing for ATFM, SWIM and other applications

Aireon Global Surveillance Network Overview

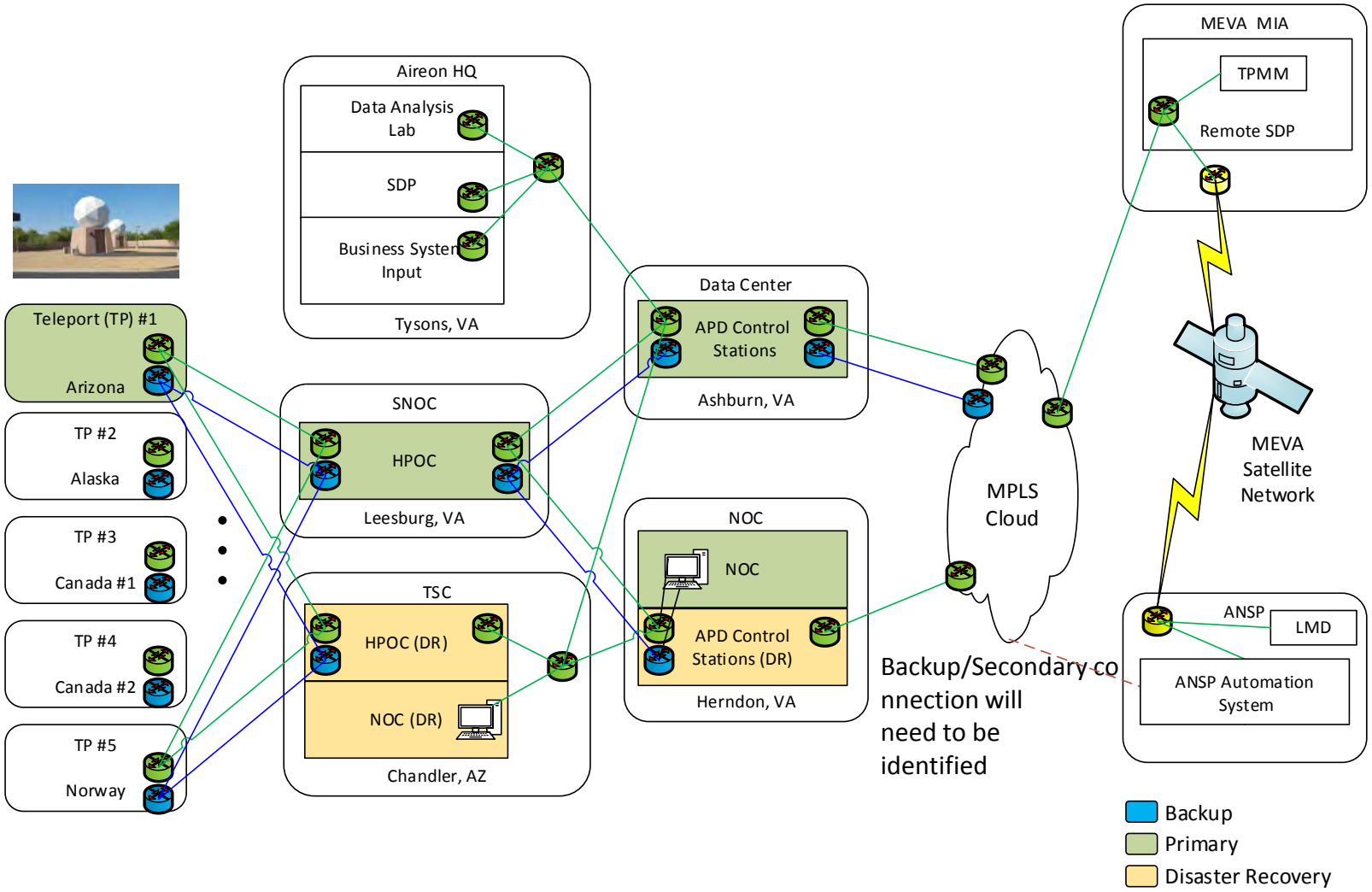


Aireon Hardware Needs to Support MEVA

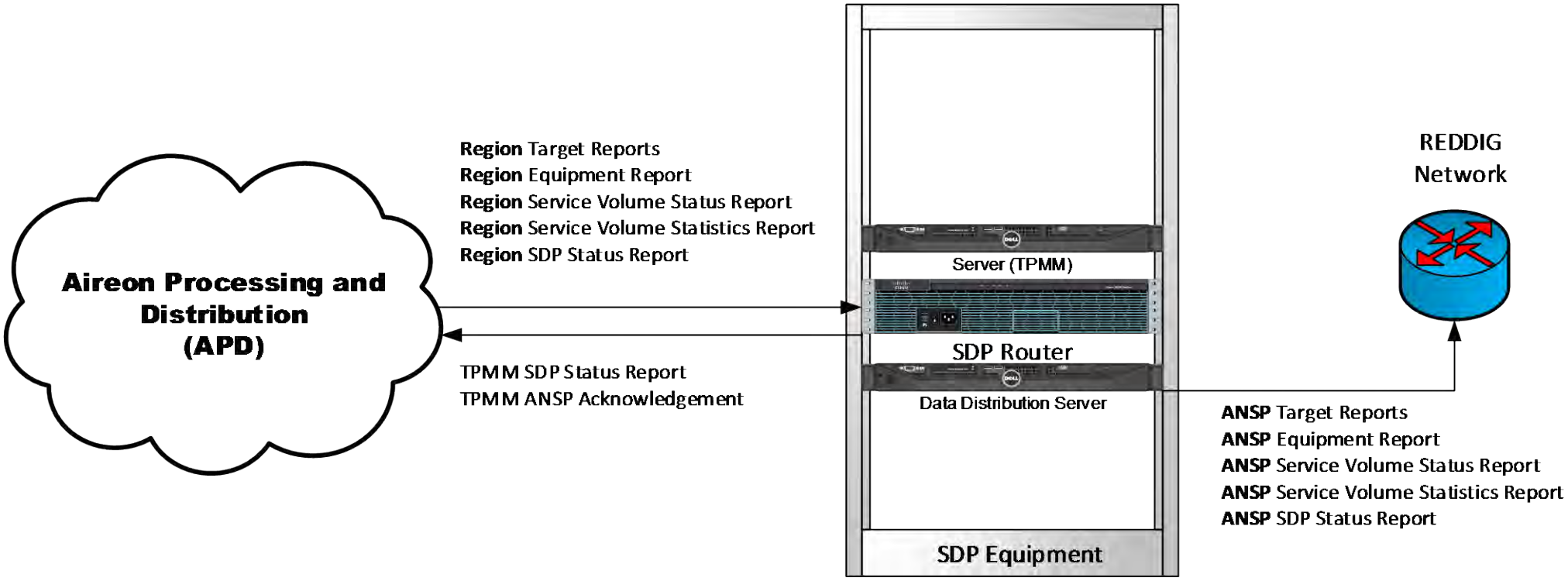


MEVA SDP Network Diagram

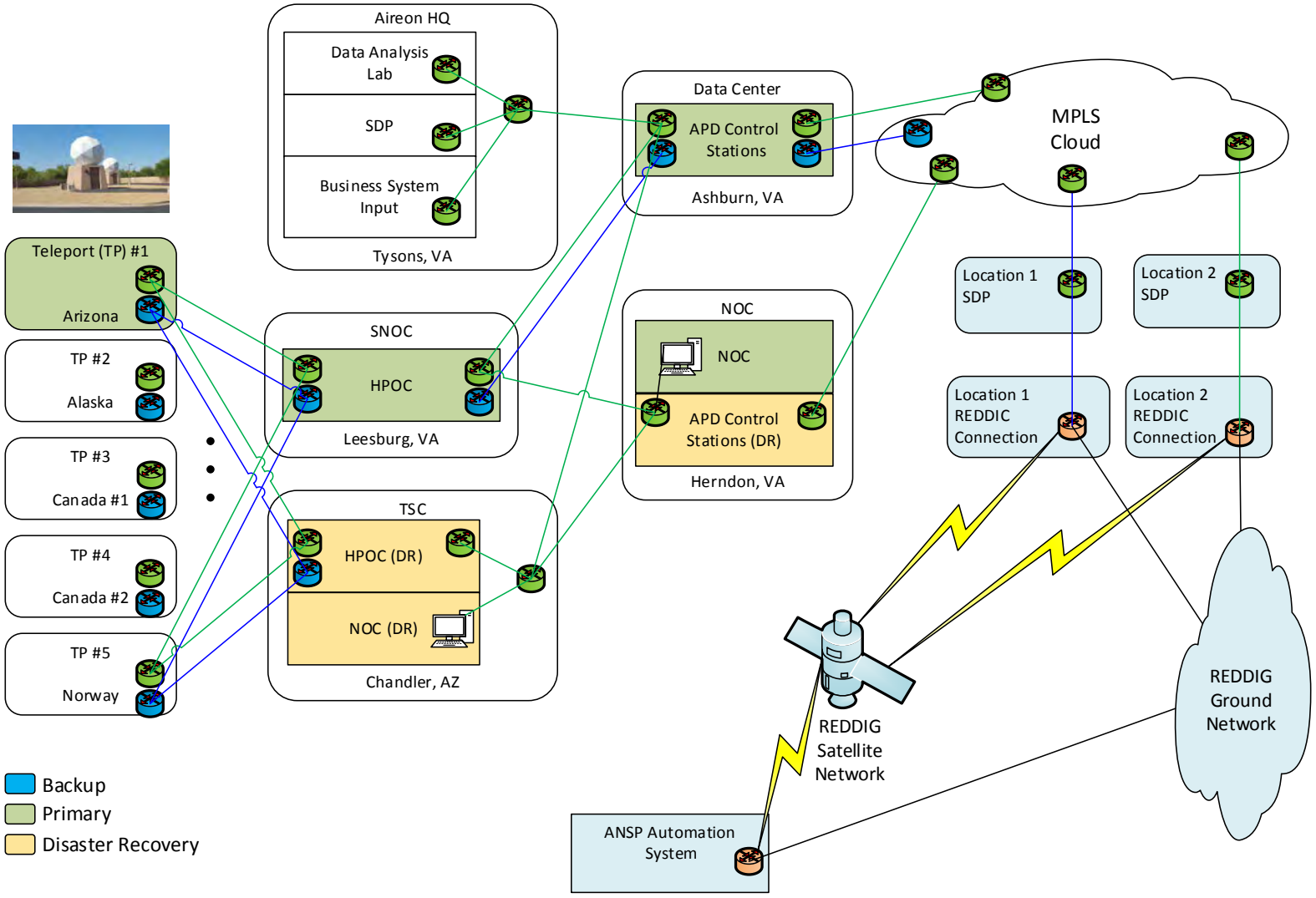
Aireon Global Surveillance Network Overview



REDDIG SDP Architecture (Dual Nodes)



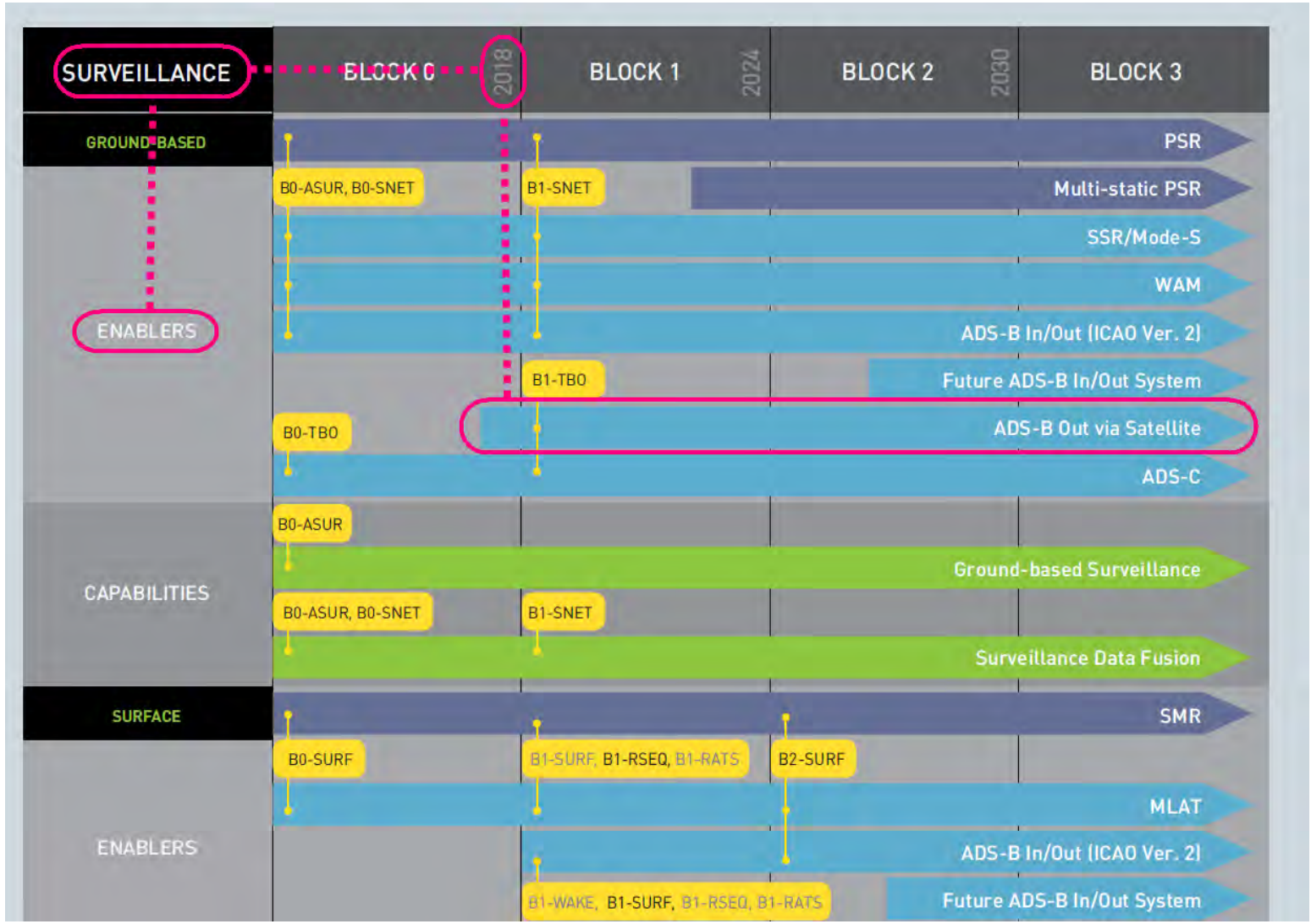
REDDIG SDP Network Diagram



Safety Certification

Specifics on ICAO Alignment
Global & Regional

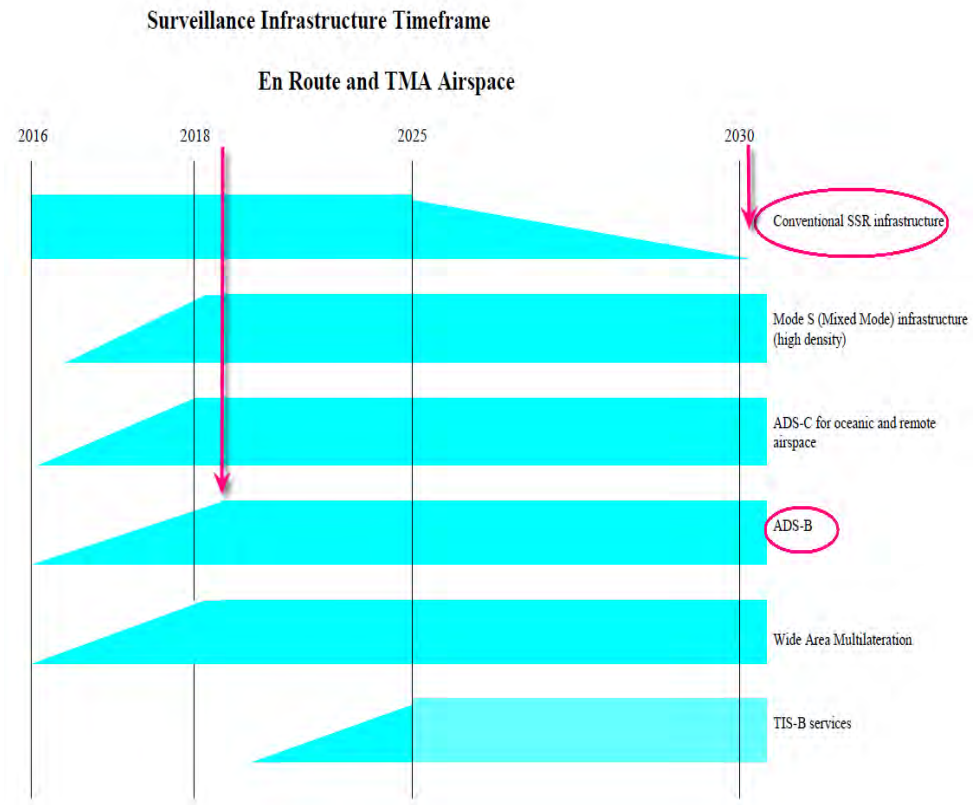
- 12th ICAO Conference of 2012 recommendations:
- Recognition of ADS-B as a Surveillance system equivalent to that of radar and exploit full potential
  - Support the inclusion in the GANP, development and adoption of space-based ADS-B surveillance as a surveillance enabler;
  - Develop Standards and 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



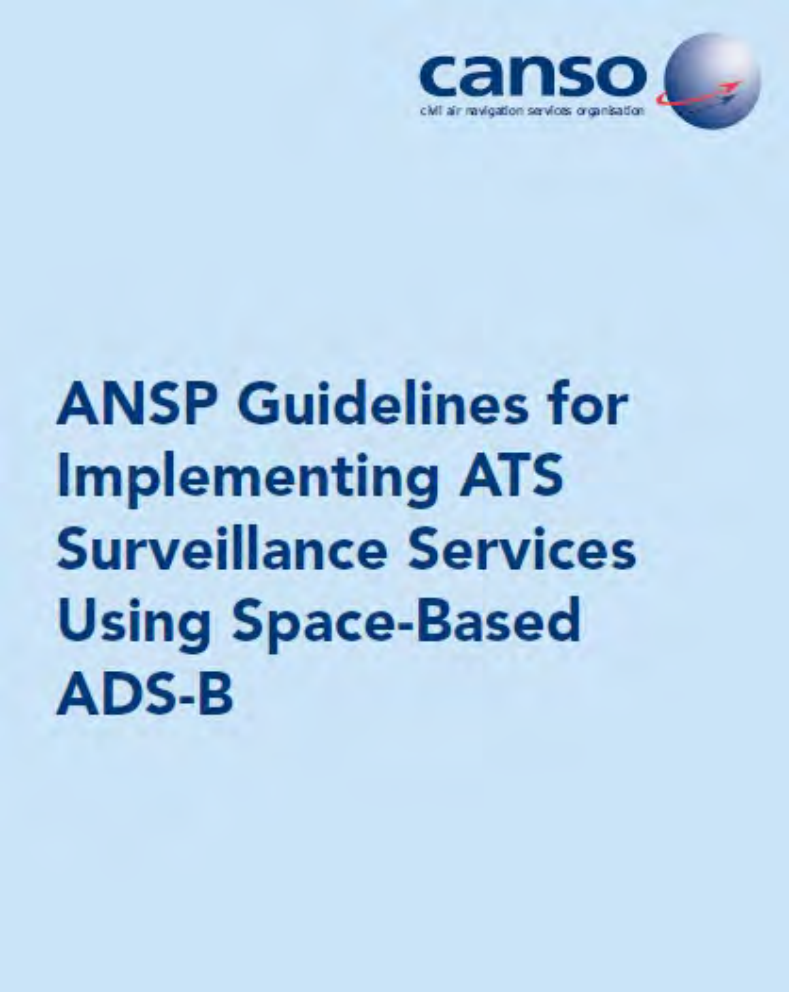
Source: ICAO Global Surveillance Roadmap, Doc. 9750

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

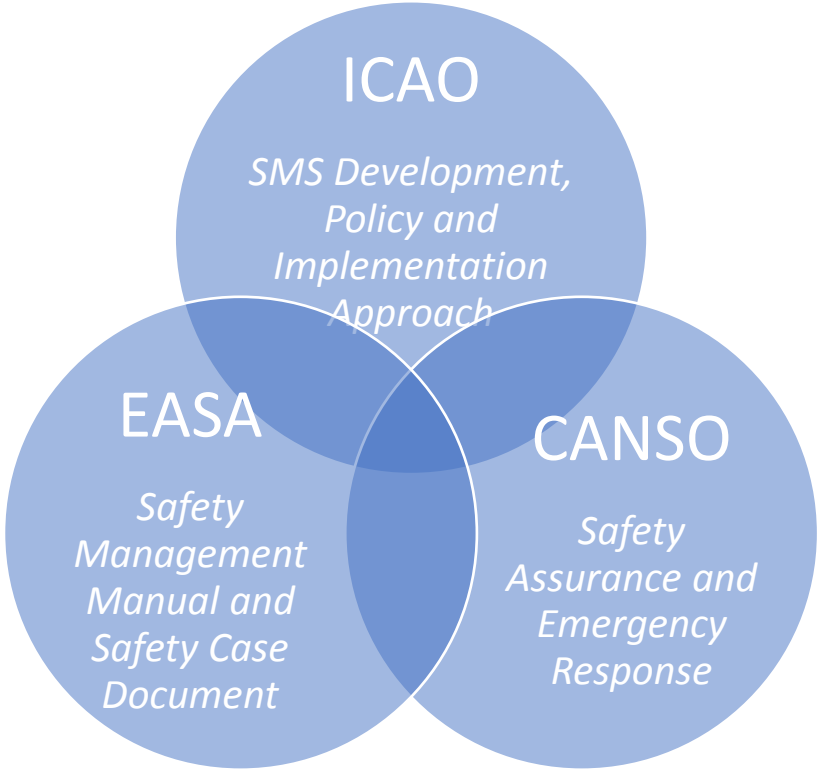


- Space-based ADS-B has the potential to revolutionize air traffic services (ATS) surveillance in the aviation industry. It will enable global ATS surveillance, which provides opportunities to **improve safety, efficiency and interoperability** between air navigation services providers (ANSP) at the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

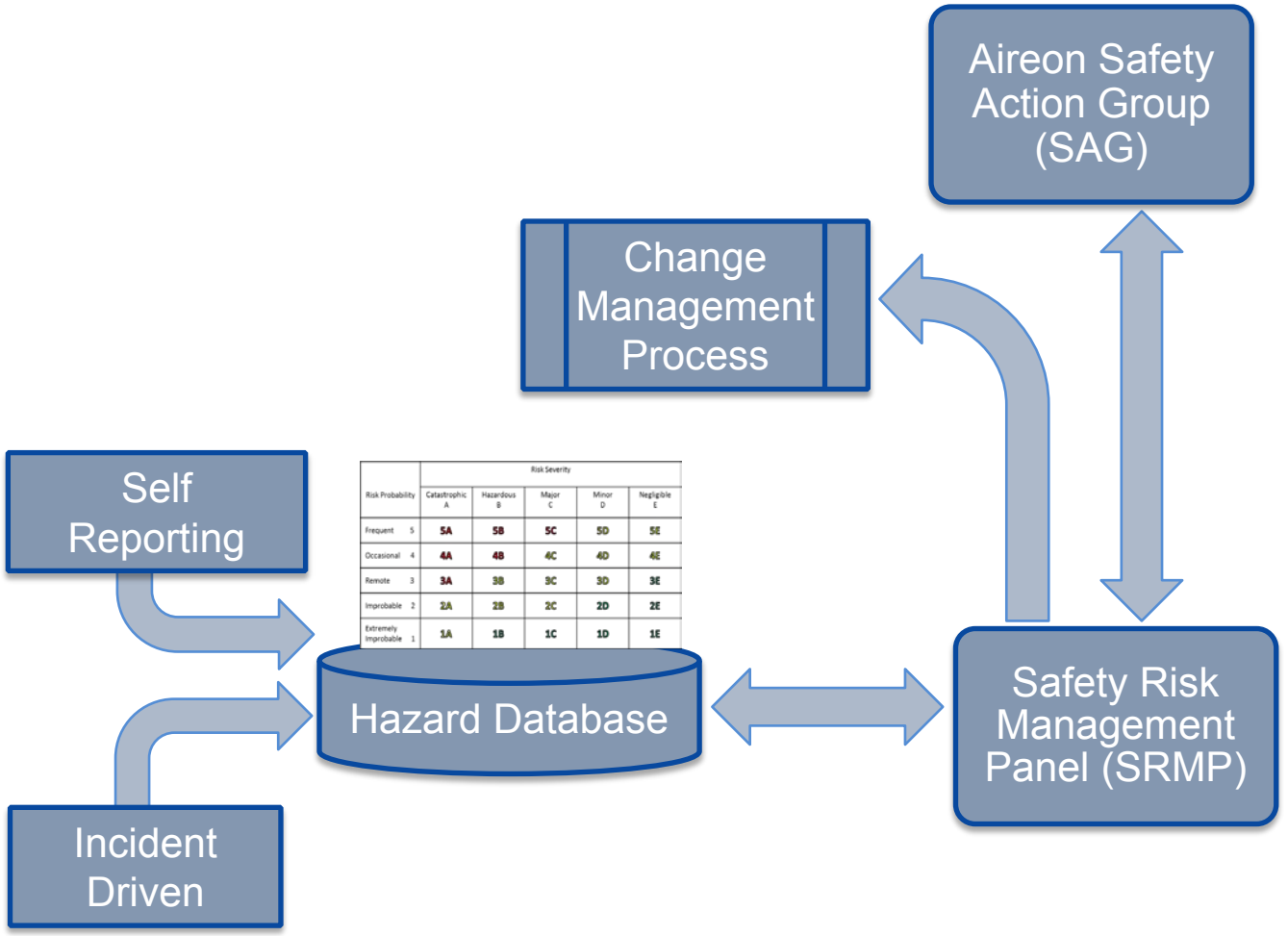
- Establish safety **policy** and objectives
- Establish and sustain a **culture** that instills safety as a core value
- Safety Risk Management
  - Develop **hazard identification** process based on a combination of reactive, proactive and predictive methods
  - **Validate** safety requirements
- Provide **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



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*

You cannot fix what you do not measure

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 ASBUs and it has been incorporated into CAR/SAM air navigation plan. CANSO has also issued guidelines for its implementation