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Technical and Operational Considerations for ADS-B Implementations

ADS-B IMPLEMENTATION AND REGULATION MEETING
FOR THE NAM/CAR/SAM REGIONS

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ADS-B Applications

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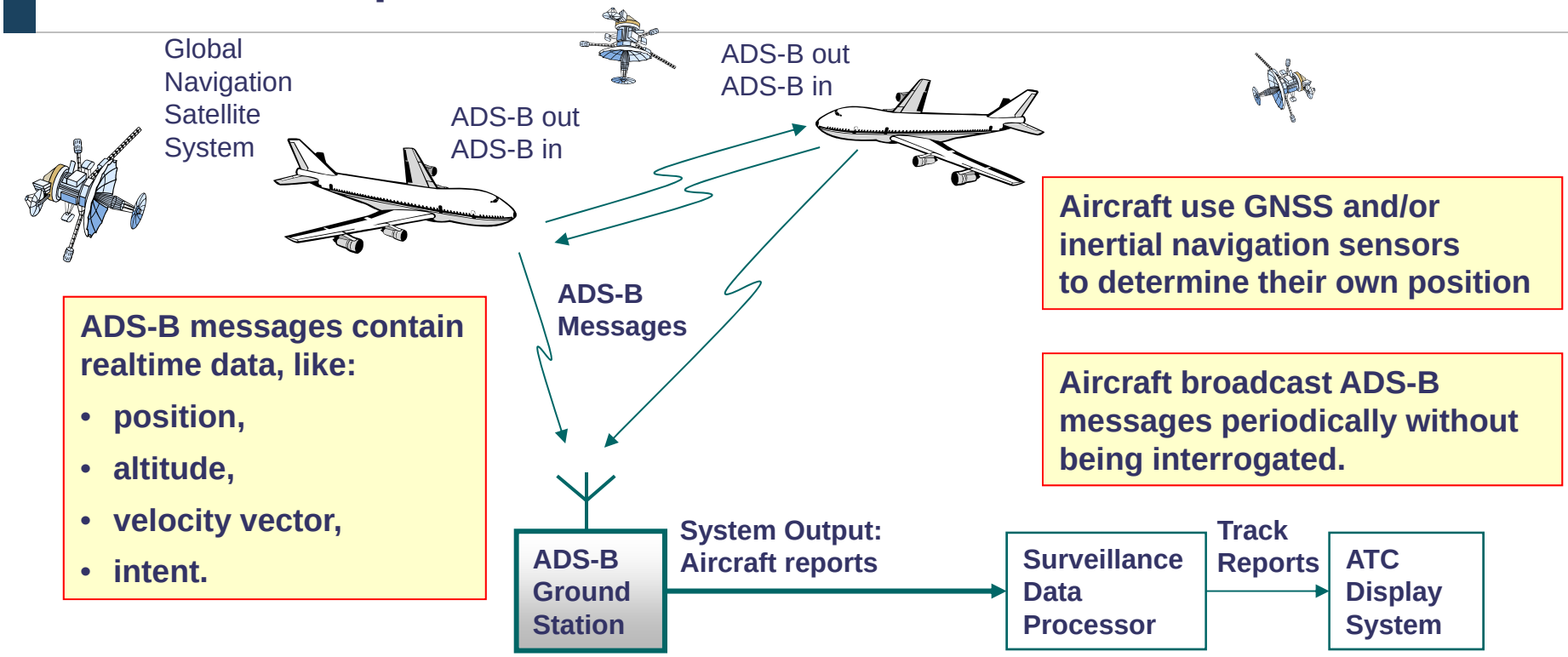
Automatic Dependant Surveillance Broadcast ADS-B - Standalone



Aircraft use GNSS and/or inertial navigation sensors to determine their own position

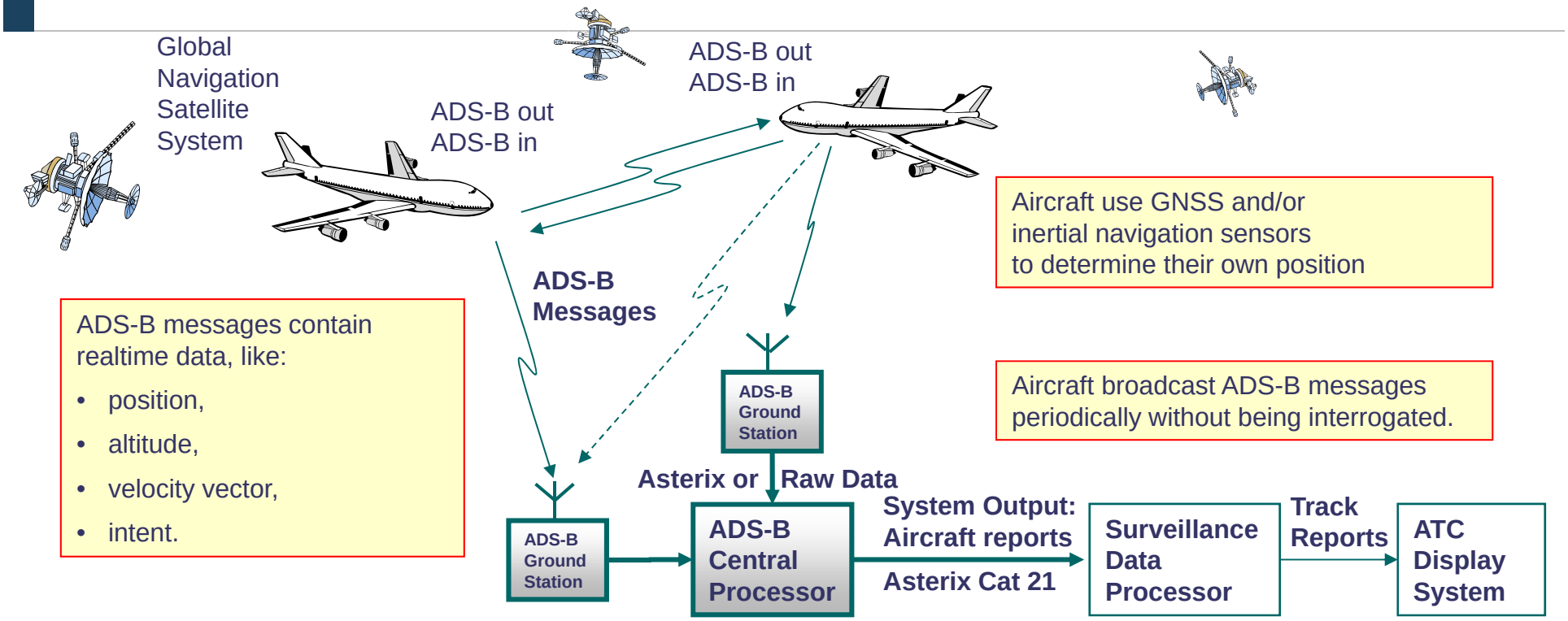
ADS-B messages contain realtime data, like:

- **position,**
- **altitude,**
- **velocity vector,**
- **intent.**

Aircraft broadcast ADS-B messages periodically without being interrogated.

ADS-B acquires Positions via Data Link

ADS-B Centralized



ADS-B Ground Station provides Raw Data or Asterix Target Reports
ADS-B Central Processor provides Asterix Target Reports

Active ADS-B

Issue

- ADS-B is fundamentally a passive receive-only mechanism
- ADS-B aircraft identification is done via the flight plan number
- Target correlation is based on the 24 Bit address.
- Some ATM system installations however can still use only SSR Mode A code to correlate tracks to flight plan data.
- Older ADS-B MOPS Version Avionics does not deliver Mode A code

Mitigation

- Use of passively received replies of ADS-B aircraft to radar interrogations - if within Mode S radar coverage
- Additional transmitter, able to interrogate aircraft for their Mode A code – if outside radar coverage

ADS-B Applications

ADS-B Basic Applications

- ADS-B in **NRA** – Non-Radar Airspace
- ADS-B in **RAD** – Radar Airspace
- ADS-B in **APT** – Airport Surface Operation

ADS-B Advantages

- Accuracy like GPS
  (quality independent of range)
- High update rate
  (2 positions/s, 2 velocity/s)
- Intent available
  (level-off altitude, next waypoint, etc.)
- Better surveillance in fringe areas of radar coverage
- Precise report of aircraft position
- Improving the airspace use, particularly in congested areas
- Low ground equipment cost and infrastructure requirements
- Low lifecycle cost

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ADS-B Standards and Versions

ADS-B Standards

- Signals in Space: **ICAO Annex 10, Vol. IV**
- Airborne Systems **MOPS: RTCA DO260B/Eurocae ED102A**
- Ground Systems: **Eurocae ED129B**
- Safety Performance Requirements
  - **Eurocae ED126 (ADS-B NRA)**
  - **Eurocae ED161 (ADS-B RAD)**
  - **Eurocae ED163 (ADS-B APT)**

MOPS versions have different abilities. MOPS V2 (DO260B) are mandatory in US and EU from 2020

ED129B supersedes all previous versions of ED129

Some Differences between ADS-B MOPS Versions

DO260 – MOPS V0, published in 2000

- Lat/Lon with HPL (NUC – integrity and accuracy mixed in the same category)
- Velocity, baro/geo altitude, identity, no Mode A code outside Radar or WAM coverage

DO260A – MOPS V1, published in 2003 (Change 1 and 2 in 2006)

- Integrity: Lat/Lon with HFOM (NIC, NAC_p, NAC_v, SIL – Navigation Integrity and Accuracy and Surveillance Integrity separately reported), Baro Altitude with NIC_{baro}
- New Squitter types: Aircraft Status, Target State and Status, Operational Status, Selected Altitude
- Mode A code reporting only available in US airspace, supplied within test message, Mode A code received also within Radar or WAM coverage

DO260B – MOPS V2, published in 2009

- Lat/Lon with 2 more NIC supplement bits, replaced surveillance integrity level with source integrity level (SIL) and system design assurance (SDA) level
- Includes regular Mode A code reporting worldwide

DO260C – MOPS V3, expected in 2019

MOPS Versions Processing

MOPS Version (VN) announced in Aircraft Operational Status Squitter

- VN field only available in MOPS VN > 0

Eurocae ED129B defines how to detect and declare MOPS VN

- Always assume MOPS version VN=0 (DO260/ED102) as a baseline
- Upon receipt of the Aircraft Operational Status Squitter, declare correct MOPS version (e.g. VN=1 or 2).
- If no update of VN received for 50 seconds, revert back to VN=0

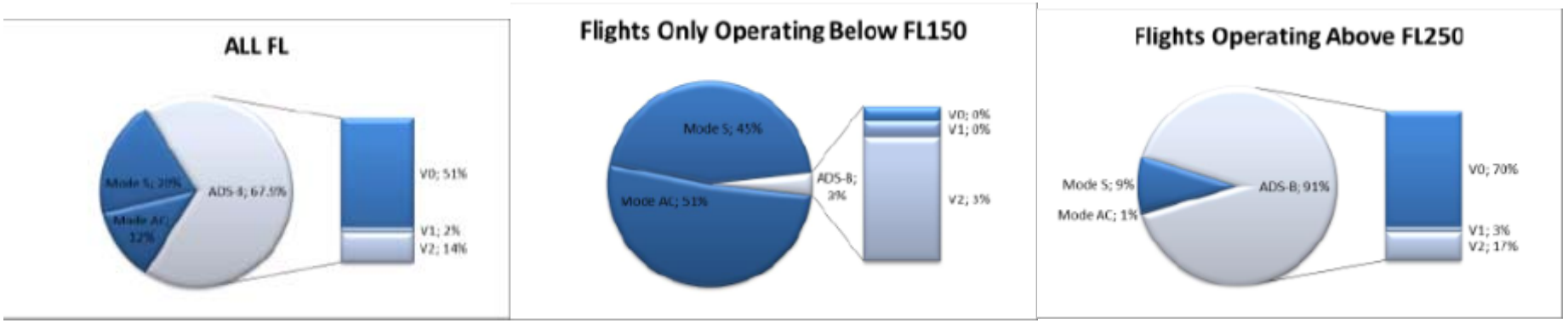
Latest Asterix Cat21 edition 2,4 required to make use of improvements

ADS-B Airborne Equipage

- Surveillance equipage different between aircraft operating at high altitude and low altitude
- Version 2 equipage mainly driven by new aircraft (forward-fit)
- ADS-B v2 retrofit equipage appears low however, the retrofit rate is expected to increase in the near term

Source: ECTL

Equipage per flight over Paris 2018



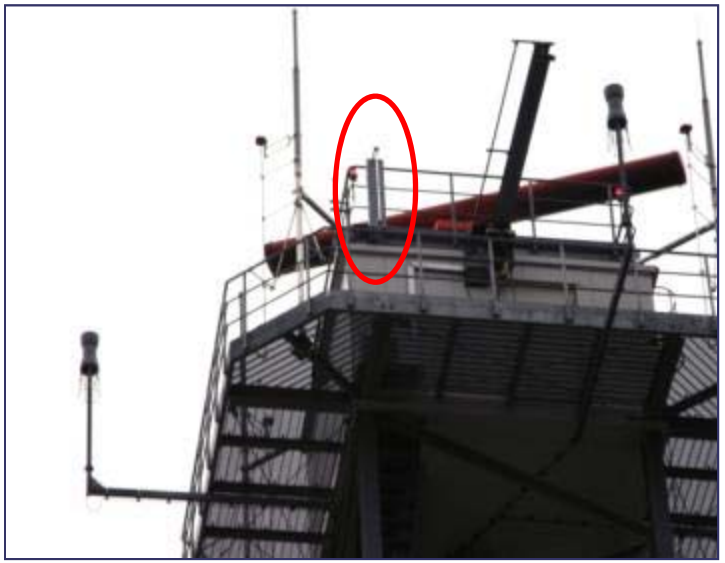
How to obtain missing DAPs in NRA?

- **Not all DAPs required are also available as ADS-B ADD**
- **If operationally required, other means to be considered**
- **ADS-B NRA: no interrogations triggering download of DAPs**
- **Options:**
  - Install an MSSR Radar
    - For the case of NRA, traffic levels do typically not justify use of Radar
  - Install a Wide Area Multilateration (WAM) System
    - To be assessed if useful: more infrastructure, but detects also non-ADS-B aircraft
  - Use Active ADS-B: ADS-B ground station with additional interrogator
    - Minimum cost solution

Co-location with Radar Systems

- **Usage as**
  - **Primary source of ADS-B Data**
  - **fall-back solution in case of Radar outage**

- Installation of ADS-B at the same location with primary or or secondary radar
- Antenna beneath the radar
- ADS-B receiver in radar cabinet
- Monitoring via RCMS

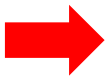


General ADS-B Characteristics: Advantages

Low Cost Surveillance Sensor

Best performance of all surveillance sensors:

- Highest Accuracy – GPS-like
- Highest Update Rate – up to 2 updates per second
- Accuracy independent of Range



"the perfect sensor"

However…

General ADS-B Characteristics: Entrance Barriers

All aircrafts must be equipped

- Mandatory equipment in US, EU, Australia, and many Asian countries
  - Population growing
- Preferred service arrangement possible

ADS-B is dependent

- ADS-B message delivery secured, but open link architecture allows interference
- Thales provides solutions to secure the surveillance system against
  - Spoofing
  - Modification
  - Suppression
  - jamming

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ADS-B Security

AN OVERVIEW

What Type of Security?

✓ 1. Physical Security (fences, locks, guards,…)

✓ 2. Networks and Software driven Elements (addressed by Cybersecurity)

? 3. RF Security

ADS-B Security

Simple protocol and signal structure, vulnerability discussed openly

- e.g. presentations at DEFCON, BlackHat and others also featured on YouTube*

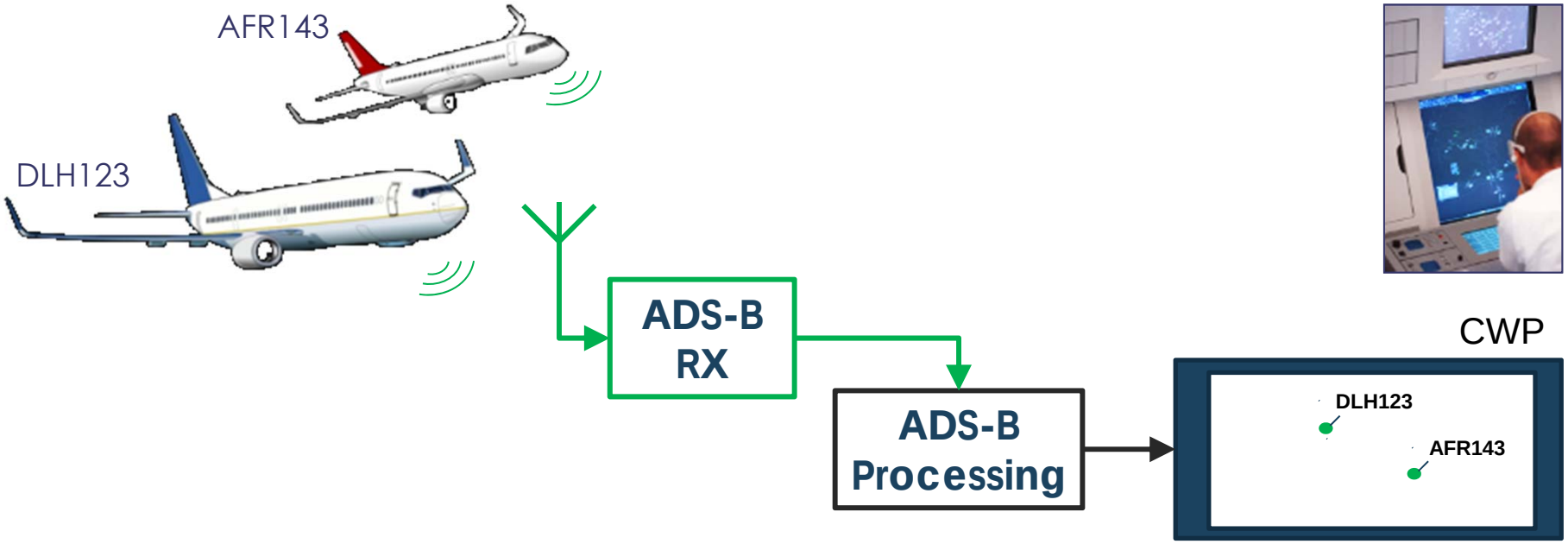
Software-Defined Radio (SDR) Technology available at low cost

- RX, but also TX available
- Software and Documentation from the internet

RF hacking is not anymore a challenge for experts and specialists

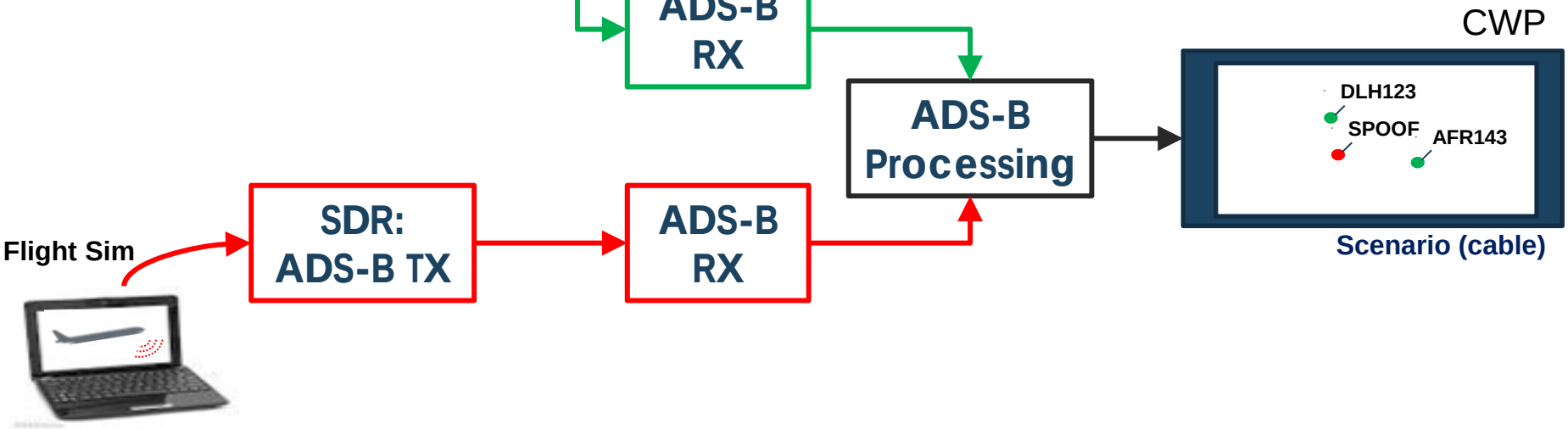
* Examples:
  - B. Haines, "Hacker + Airplanes = No good can come out of this", DEFCON20,
  - A. Costin, A. Francillon , "Ghost is in the Air (Traffic)" Black Hat USA 2012
  - B. Seeker, "Hacking the wireless world with SDR – 2.0" Black Hat Europe 2014

ADS-B

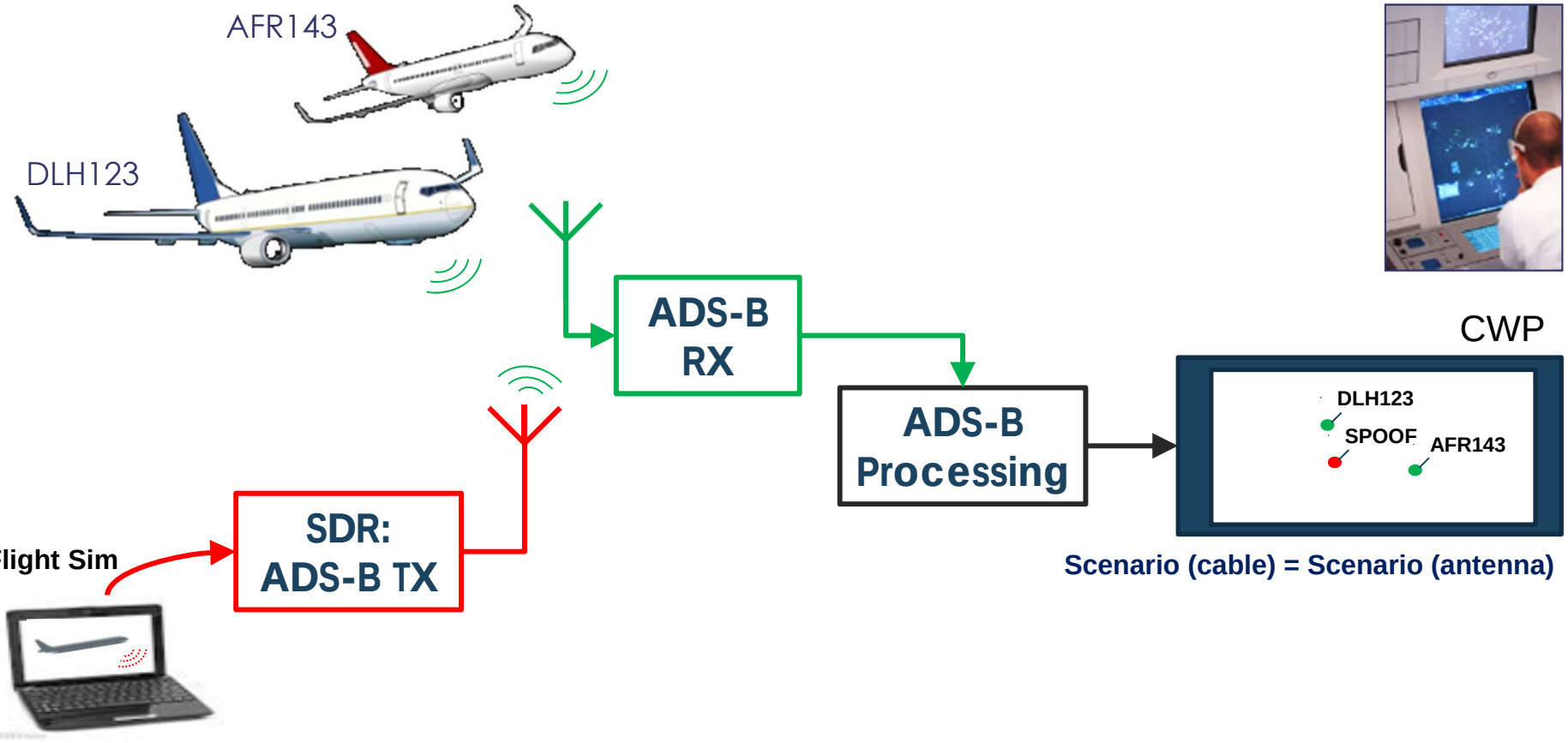


ADS-B Spoofing Demonstration

Source: http://www.youtube.com/watch?v=NSLqRXyxiBo

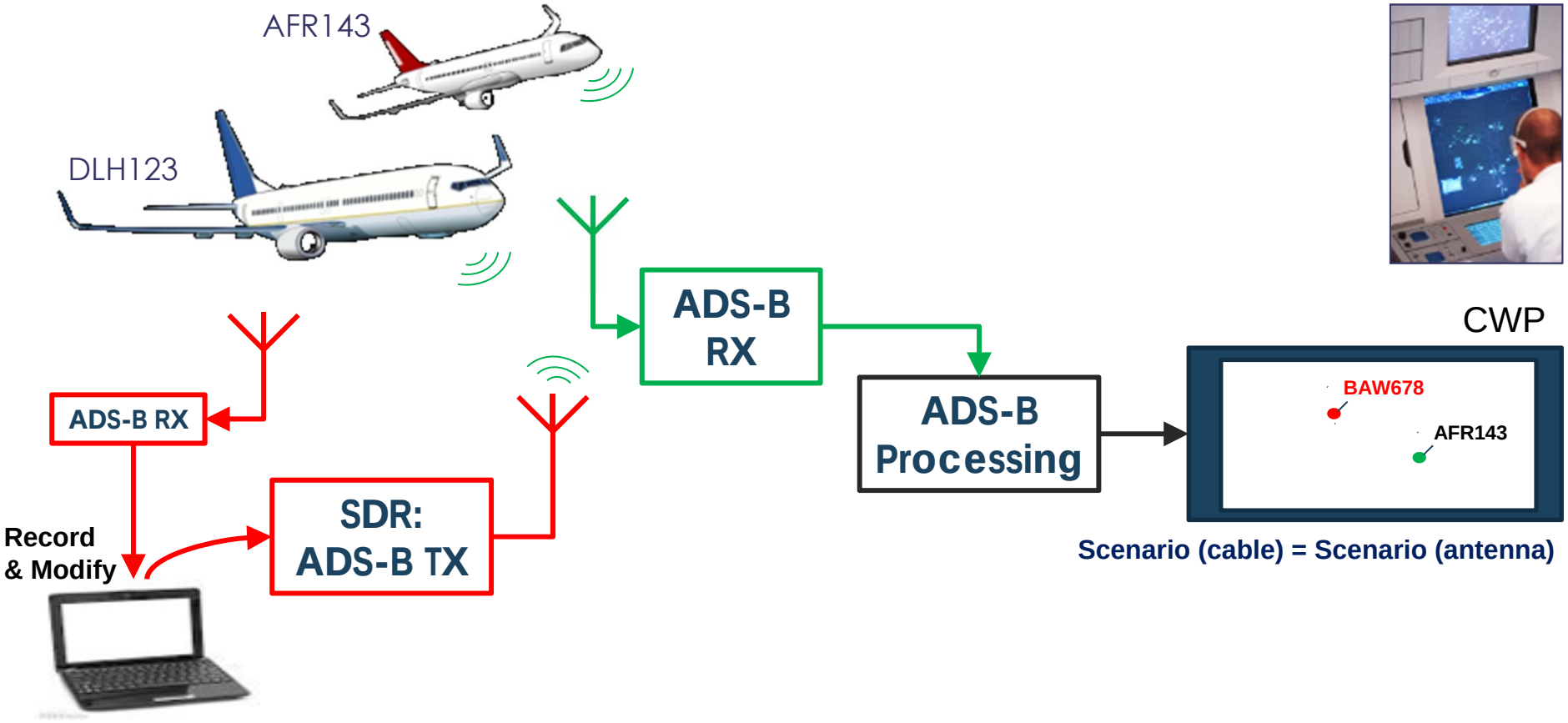


ADS-B Spoofing



Scenario (cable) = Scenario (antenna)

ADS-B Meaconing – Change of Identity



What is the impact on Operations?

	Radar/WAM Airspace	Non-Radar Airspace
Effect	False plots/tracks appear(spoofing), false codes/ACID or emergency indicators (modification), or complete failure of ADS-B sensor input (jamming)	False plots/tracks appear(spoofing), false codes/ACID or emergency indicators (modification), or surveillance data disappear completely (jamming)
Risk of not detecting	Low, due to other sensors and background data	Increased, only background data (flight plans, history)
Operational Impact	Slightly increased workload, safety not likely affected	Increased workload, no other surveillance data source
Mitigation	If detected use other sensors and disable ADS-B	Radio contact to actual pilots, fall back to procedural control

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What can we do? (as Sensor Manufacturers)

ON ADS-B SENSOR LEVEL
ON CENTRAL PROCESSING LEVEL

- DETECT THREAT
- REDUCE OR PREVENT IMPACT ON ATM SYSTEM
- ALERT AUTHORITIES

Sensor level – ADS-B / WAM Ground Station

Local view, raw data details available

Target specific behavior

- Anyone not behaving like a regular aircraft?

Additional measurements

- Consistency between measured and transferred data

Spectrum characterization – not target specific

- Anything unusual happening?
- Number of targets, messages, message types…

How to treat “normal” anomalies / malfunctions?

Thales AX680
Integrated Receiver and
Signal Processing Board
Digital, Software Defined Radio
High Sensitivity -91 dBm
Mode A/C/S
ADS-B Decoding DO260B
AL4/ED109A (SWAL3/ED153)

Spoofing Detection
Lab Demonstration at DFS

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Central Level – ADS-B Server / WAM Central Processor

Group view, comparing data from several ground stations

- difficult to attack multiple sites in a consistent way
  - Spectrum characterization – not target specific
  - Target behavior
  - Additional measurements
  - Able to identifying observations as anomalies

Thales ADS-B Server
Security Screening for Thales and 3rd party ADS-B systems
Asterix Edition conversion
Geographical Filtering
Multiple Output Streams
Data Routing
AL4/ED109A (SWAL3/ED153)

Multilateration position calculation

- No need for high precision for this purpose
- Checking if movement and position consistent with ADS-B
- Even single TDOA (single hyperbolic line of position) is sufficient

Tracker Level – Multisensor Tracker / ATM System Level

- **Global view – various sensor inputs, flight plans, background data**
- **Filtering, observing, characterizing targets**
- **Comparing ADS-B data to other sensor feeds – diversity is key!**

- **Eliminate false positives via flight plans and other sensors**
  - SWIM across sector borders
- **If threat detected - alert supervisor ! (or anyone else to alert?)**
  - To do what? → operational Level

Results of R&D Project with DFS and Eurocontrol

Ground Station prototype proven to detect various threats

- Spoofing
- Modification
- Jamming
- Detects also anomalies – great for conformance monitoring!

False Alarm Rate not yet where it should be – continue within SESAR2020

Central Processing System

- ADS-B Server: Additional layer to ADS-B Threat Detection
- WAM configuration rejects threats – difficult to spoof

Decision to industrialize and integrate first set of functionalities into product

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Thales ADS-B Solutions

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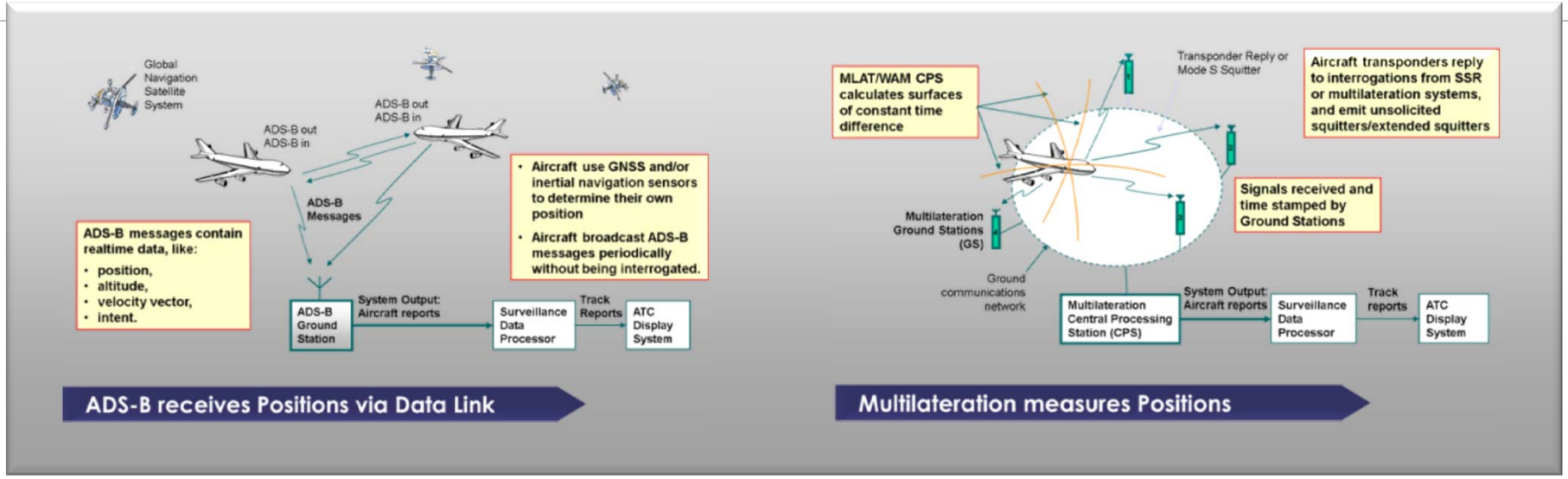
MAGS Product Line – Multilateration and ADS-B Ground Surveillance



- Based on 1030/1090 MHz SSR ATCRBS and Mode S signals (and UAT)
- Using Multilateration and Automatic Dependent Surveillance Broadcast (ADS-B) technology

MAGS – a product family of co-operative non-radar secondary surveillance sensors

Thales Product Line Non-Radar Surveillance

Automatic Dependent Surveillance Broadcast (ADS-B)

- Standalone ADS-B
- Centralized ADS-B
- Active ADS-B
- ADS-B Server

ED129B

ADS-B and WAM/MLAT Ground Station

Multilateration Systems

ED142

- Wide Area Multilateration (WAM) Systems
- Precision Approach Monitoring (PAM) Systems
- Airport Multilateration Systems (MLAT)

WAM/MLAT Transmitter

Monitoring Systems

ED117A

- 1030/1090 MHz Spectrum Monitoring Equipment
- TCAS Monitoring Equipment and ACAS Server

DFS Radio Field Monitor Ground Station

Key ADS-B Operational References:

- FAA Next Gen SBS
- Airservices Australia
- DTI France
- DFS Germany
- CAD Hong Kong
- AirNav Indonesia
- Airways New Zealand

Key Multilateration Operational References:

- UK MoD Marshall Program
- German DFS
- French DTI
- Estonian EATNS
- South African ATNS

Key Monitoring References:

- DFS Radio Field Monitor – countrywide system
- US NASA, MIT Lincoln Lab

Thales ADS-B Solution

- Easy to implement, best performance, low risk
- Extremely reliable and robust solution
  - Maintenance free
  - Excellent record on low failure rates from the field
- Extremely low lifecycle cost
- Compliant to all international
- Safe and secure implementation
  - on ADS-B level
  - on Network Level – Thales CyberSecurity
- Centralized or standalone architecture – tailored to customer needs
- Growth potential towards full WAM, Airport MLAT

ADS-B Hongkong

Typical Thales ADS-B Equipment

AX680

Single/dual channel/link
ADS-B ground station:

- Indoor configuration: AX680
- Outdoor configuration: BX680

BX680

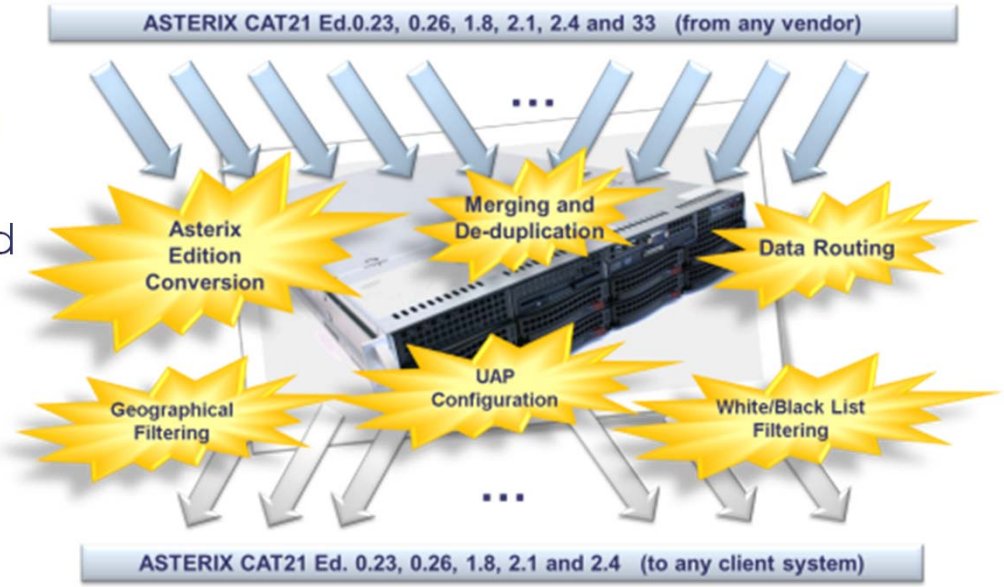
FAA SBS Radio

- High Performance Receiver
- AL4/ED109A compliant Software
- Fully DO260B compliant
- Autonomous ADS-B Processing
- Asterix Cat21 Output
- Full WAM / MLAT Processing

Thales ADS-B Central Processor

ADS-B Server

- De-duplication of Target Reports
- Allows controlled data sharing with adjacent sectors, states, or clients
- Able to integrate third party ground stations from any vendor
- Converts Asterix versions
- Routes data streams to multiple destinations
- Provides geographical filtering
- Output organized in Service Volumes



ADS-B Server for well-controlled Data Sharing

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ADS-B in TopSky-ATC

TopSky-ATC : Main Features

- Operator Interface
- Flight Data Processing
- Surveillance Processing
- Safety Nets and Alerts
- Workload Management
- Safe, Secure and Reliable
- Flexible Architecture
- Extendable with TopSky Solutions
- Modern, efficient training
- Currency through Subscription
- Through-life Experience

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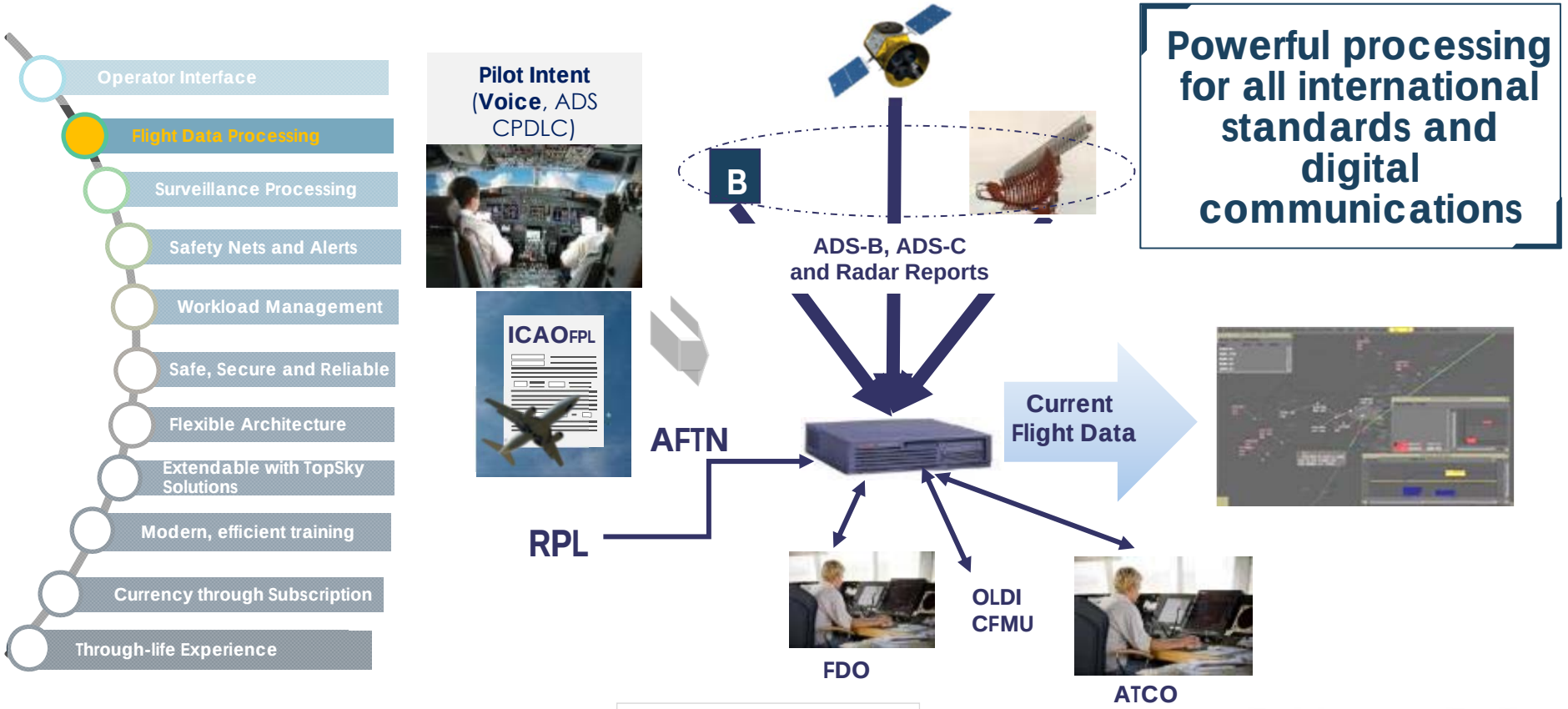
TopSky-ATC Flight Data Processing

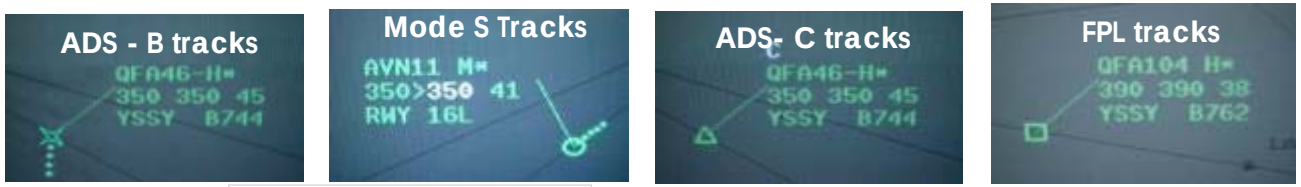


TopSky-ATC Surveillance Processing

- Operator Interface
- Flight Data Processing
- **Surveillance Processing**
- Safety Nets and Alerts
- Workload Management
- Safe, Secure and Reliable
- Flexible Architecture
- Extendable with TopSky Solutions
- Modern, efficient training
- Currency through Subscription
- Through-life Experience

- Accurate and proven multi sensor track processing
- Radar (P&S), ADS-B, WAM, Multi-lateration, ADS-C
- A single Air Situation Display for operator convenience
- Integrated Mode-S downlink parameter management

Accurate and unique track in all airspaces for enhanced safety



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Major considerations for successful ADS-B System implementation

Considerations for successfull ADS-B implementations

- **Operational needs**
- **Location of sites**
  - Altitude (high altitude enables better coverage)
  - Local constrains (mountains, buildings, etc)
  - Accessibility
- **Available Infrastructure**
  - Communication network (low bandwidth required)
  - Power supply (main power supply, UPS, Solar panels, etc)
- **Required redundancy**
  - Partial or full redundancy
  - Local or geographical redundancy

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Thales ADS-B Implementations

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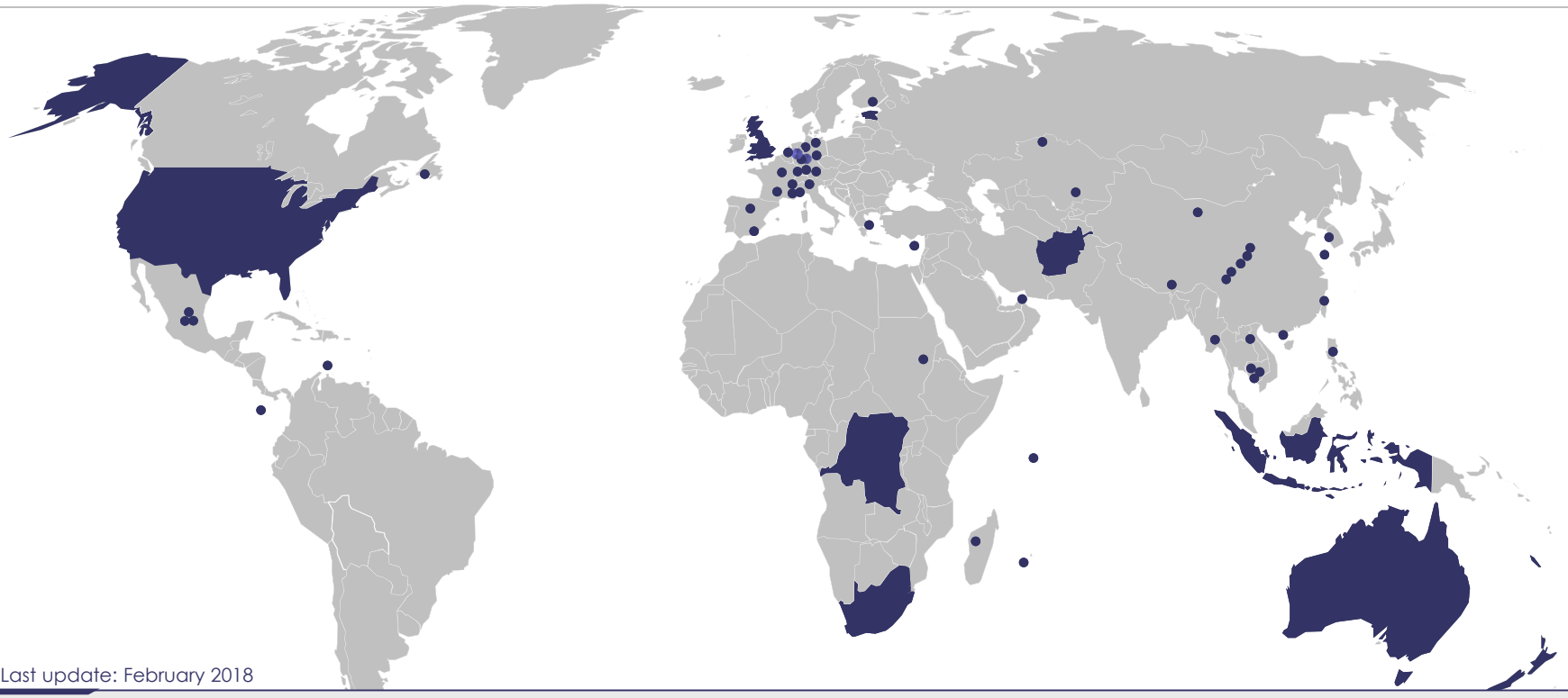
Thales Worldwide Non-Radar Surveillance References



Last update: February 2018

Thales delivered over 2,150 ADS-B and Multilateration Ground Stations around the World

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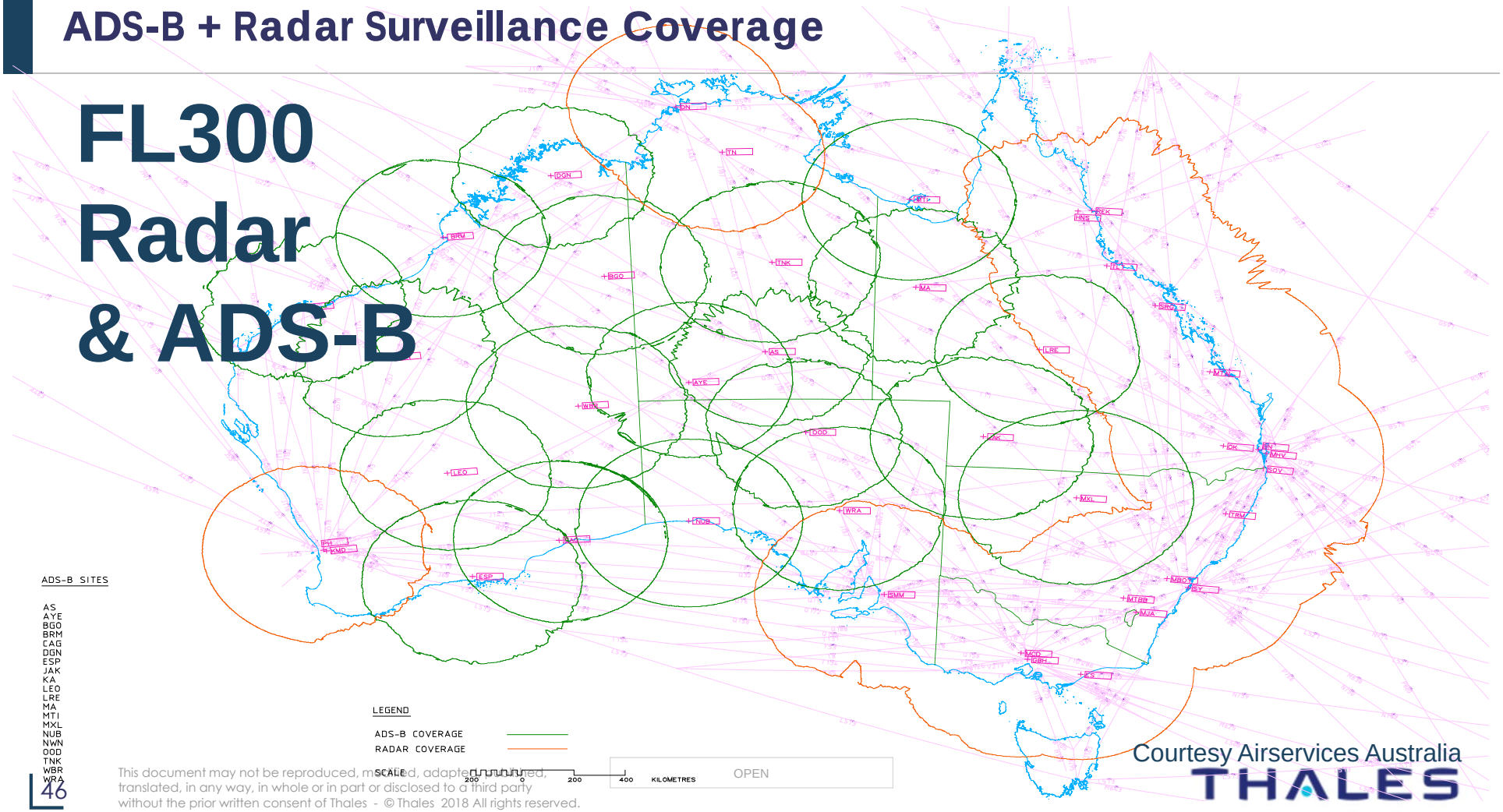
ADS-B + Radar Surveillance Coverage

FL300 Radar & ADS-B



Courtesy Airservices Australia

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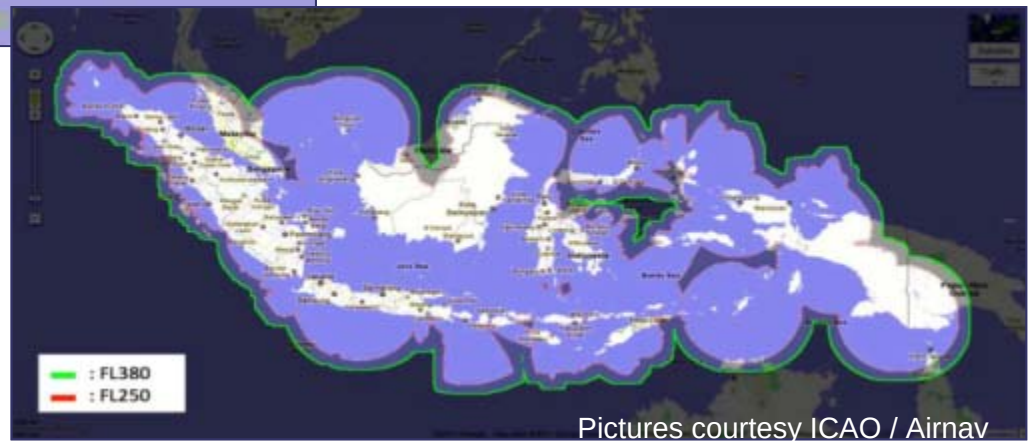
The countrywide ADS-B System in Indonesia

ADS-B Networks

30 dual redundant ADS-B sites
+ 1 Test Site

ADS-B Coverage



Pictures courtesy ICAO / Airnav

Indonesia is a pioneer of countrywide ADS-B!

ADS-B Countrywide New Zealand

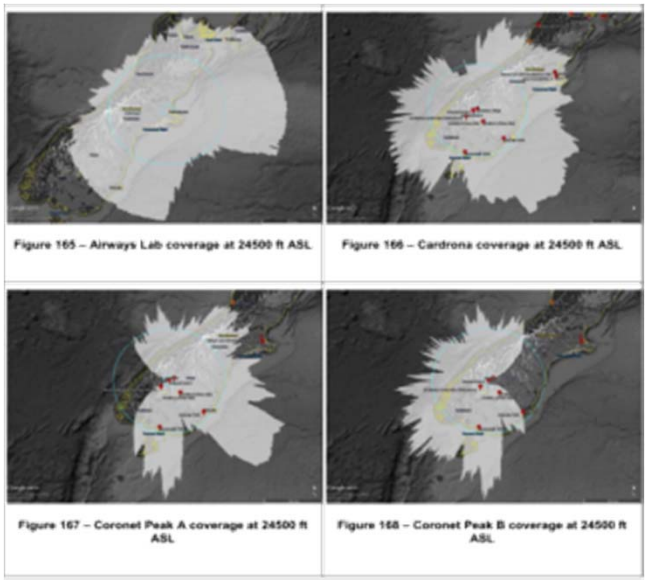
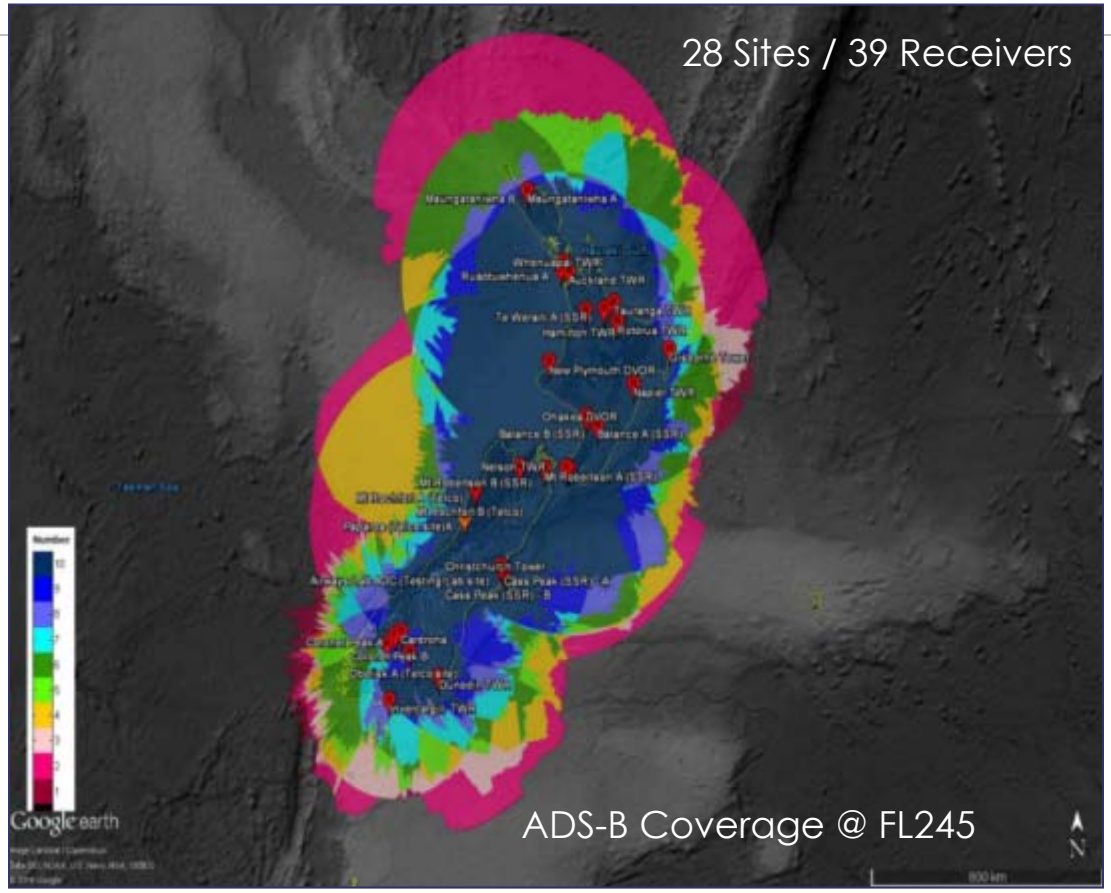


Figure 165 – Airways Lab coverage at 24500 ft ASL

Figure 166 – Cardrona coverage at 24500 ft ASL

Figure 167 – Coronet Peak A coverage at 24500 ft ASL

Figure 168 – Coronet Peak B coverage at 24500 ft ASL



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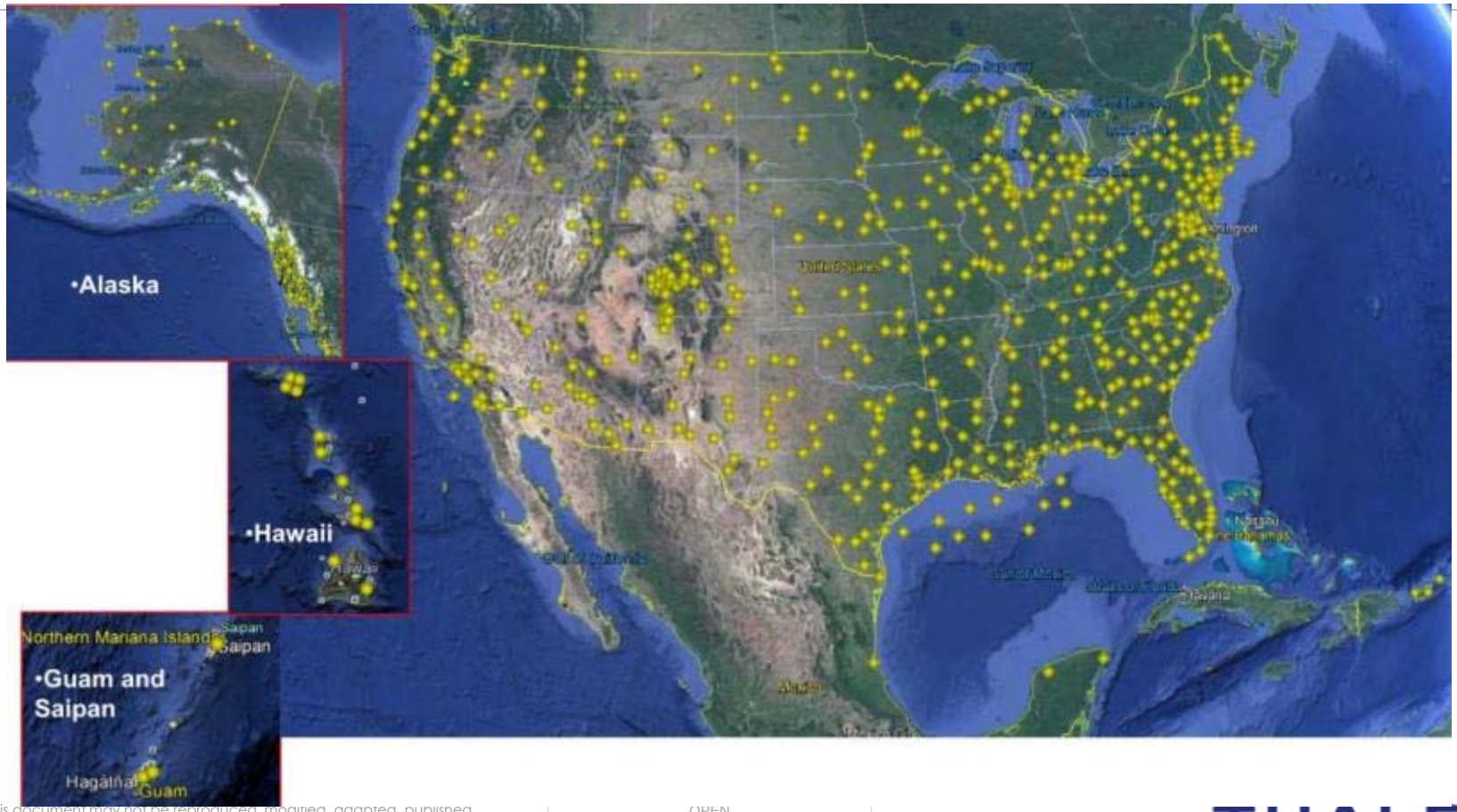
Status FAA SBS Program 06/2017



ADS-B in Hannover – Germany – (ASTA)

The ADS-B system will support:

- – ground position display in the tower.
- – en-route and approach air traffic display in the area control center.

Main objectives are:

- – to enrich the SMR track information with surveillance information (ADS-B derived).
- – to make the taxiing course of the aircraft/ground vehicles more precise and smooth
- – to prevent track interruptions

ASTA is the pilot implementation for a larger country wide ADSB rollout project in Germany. The project is aiming at establishing ADS-B as a third level of surveillance layer.

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Thank you very much!
Happy to answer Questions

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