THALES

Non-Radar Surveillance ADS-B/MLAT/WAM Products

HOLGER NEUFELDT

OPEN

Non-Radar Surveillance

New Methods for Air traffic Surveillance

> Automatic Dependent Surveillance Broadcast (ADS-B)

- Transfer of onboard data by an Aircraft

> Multilateration

- Hyperbolic/differential Multilateration – Time Difference of Arrival (TDOA)
- Elliptical/multi ranging Multilateration – Time Sum of Arrival (TSOA)

Thales Product: MAGS System

Multilateration and **A**DS-B **G**round **S**urveillance System

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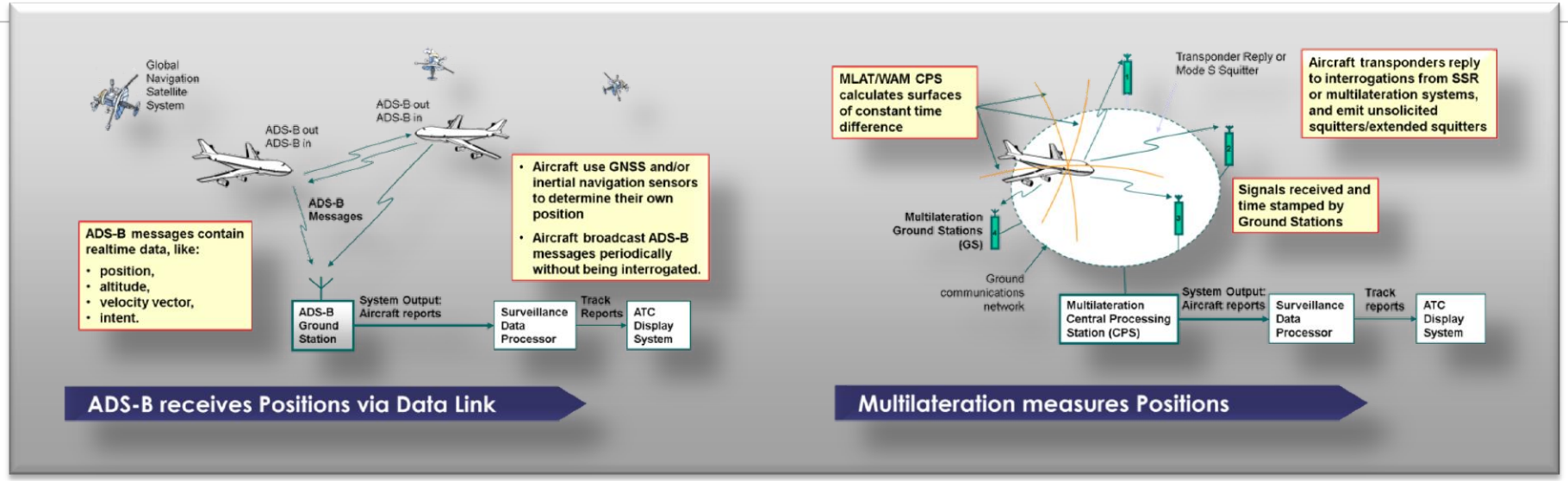
MAGS Product Line – Multilateration and ADS-B Ground Surveillance



- 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

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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)

ED117A

WAM/MLAT Transmitter

Monitoring Systems

- 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
- French DTI
- German DFS
- 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

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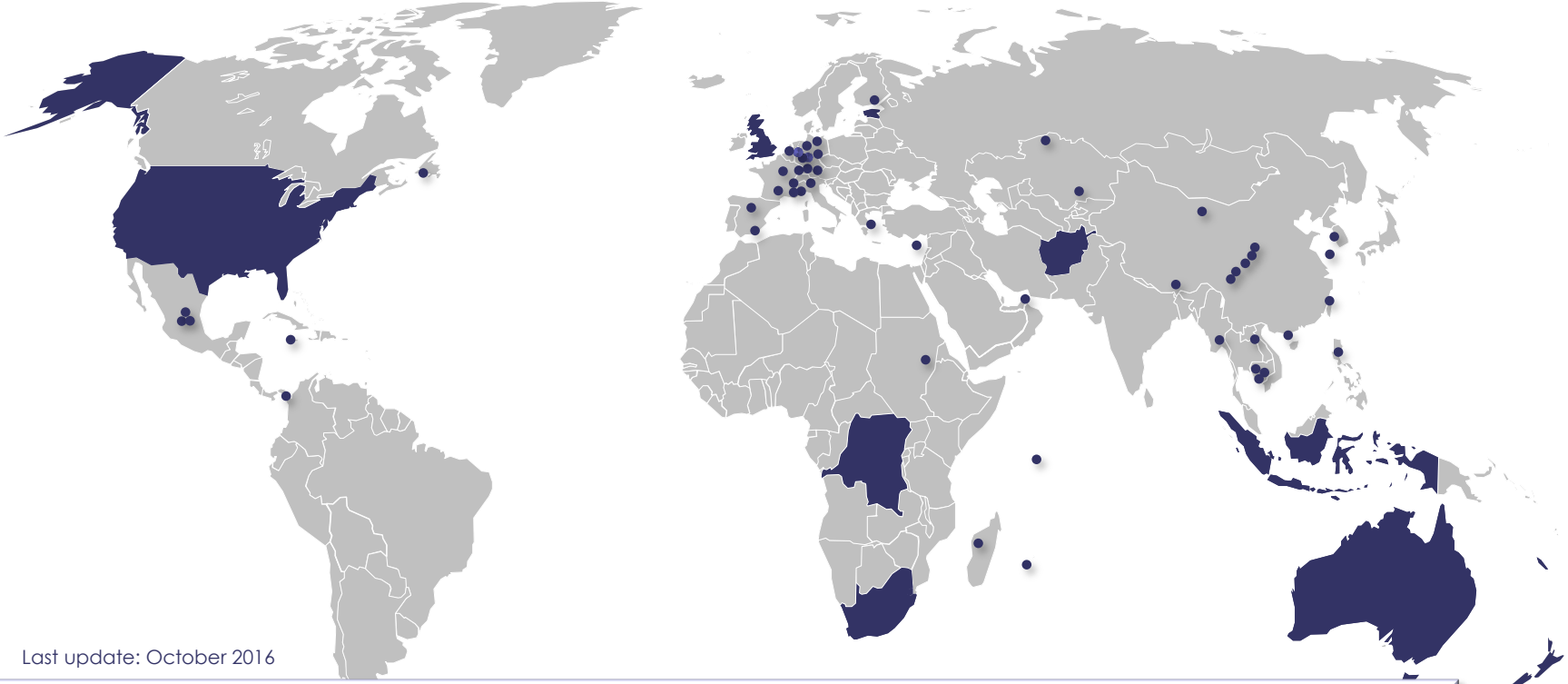
Thales Worldwide Non-Radar Surveillance References



Last update: October 2016

Thales has delivered over 2,000 ADS-B and Multilateration Ground Stations around the World

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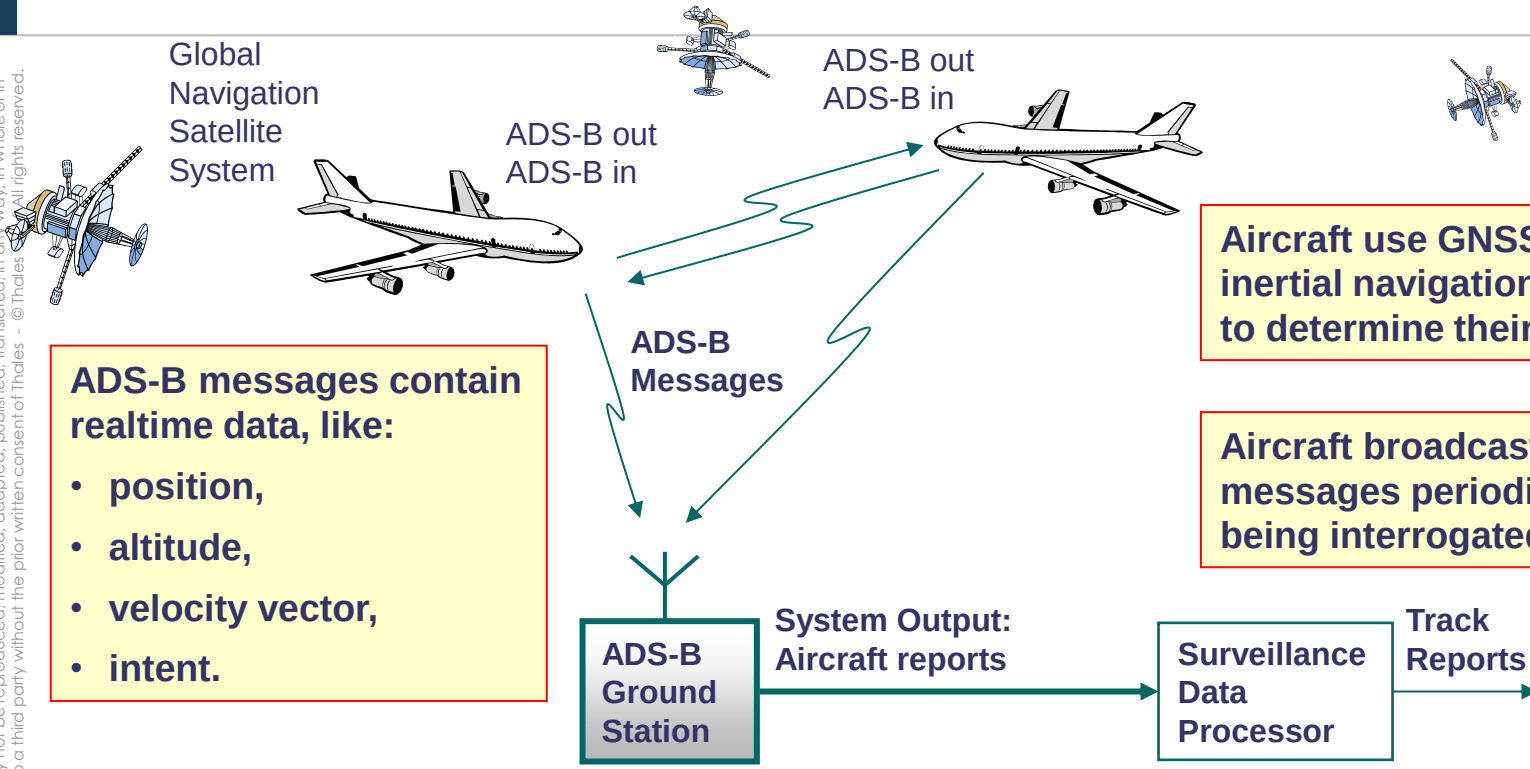
Thales ADS-B

ADS-B STANDALONE
ADS-B CENTRALIZED
ACTIVE ADS-B
ADS-B SERVER

OPEN

Automatic Dependant Surveillance Broadcast ADS-B



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

Aircraft broadcast ADS-B messages periodically without being interrogated.

ADS-B messages contain realtime data, like:

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

ADS-B acquires Positions via Data Link

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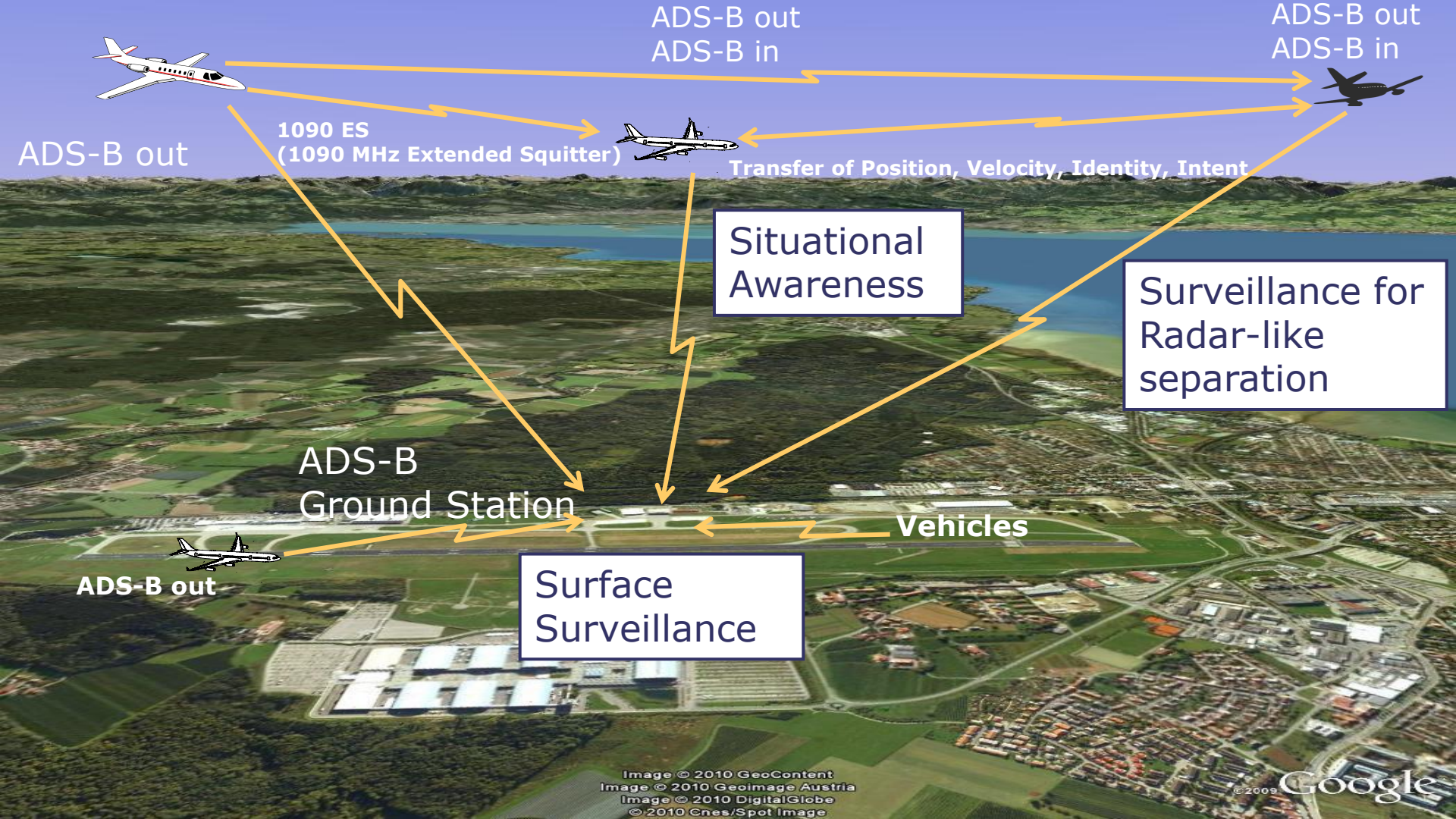
ADS-B out
ADS-B in
ADS-B out
ADS-B in
ADS-B out
1090 ES
(1090 MHz Extended Squitter)
Transfer of Position, Velocity, Identity, Intent
Situational Awareness
Surveillance for Radar-like separation
ADS-B Ground Station
Vehicles
ADS-B out
Surface Surveillance
Image © 2010 GeoContent
Image © 2010 Geoimage Austria
Image © 2010 DigitalGlobe
© 2010 Cnes/Spot Image
©2009 Google

ADS-B Extended Squitter

(Short) Squitter extended by 56 Bit data, hence „extended“ Squitter (1090 ES)

Required surveillance data split into different messages:

- Airborne Position Squitter: 2/s („odd“ and „even“)
- Airborne Velocity Squitter: 2/s
- Surface Position Squitter: 2/s („odd“ and „even“) ,
  1/5s when stationary
- Identification” Squitter: 1/5s (1/15s when stationary)

Further Squitter types:

- Target State and Status Squitter,
- Aircraft Operational Status Squitter, und
- Emergency and Priority Squitter

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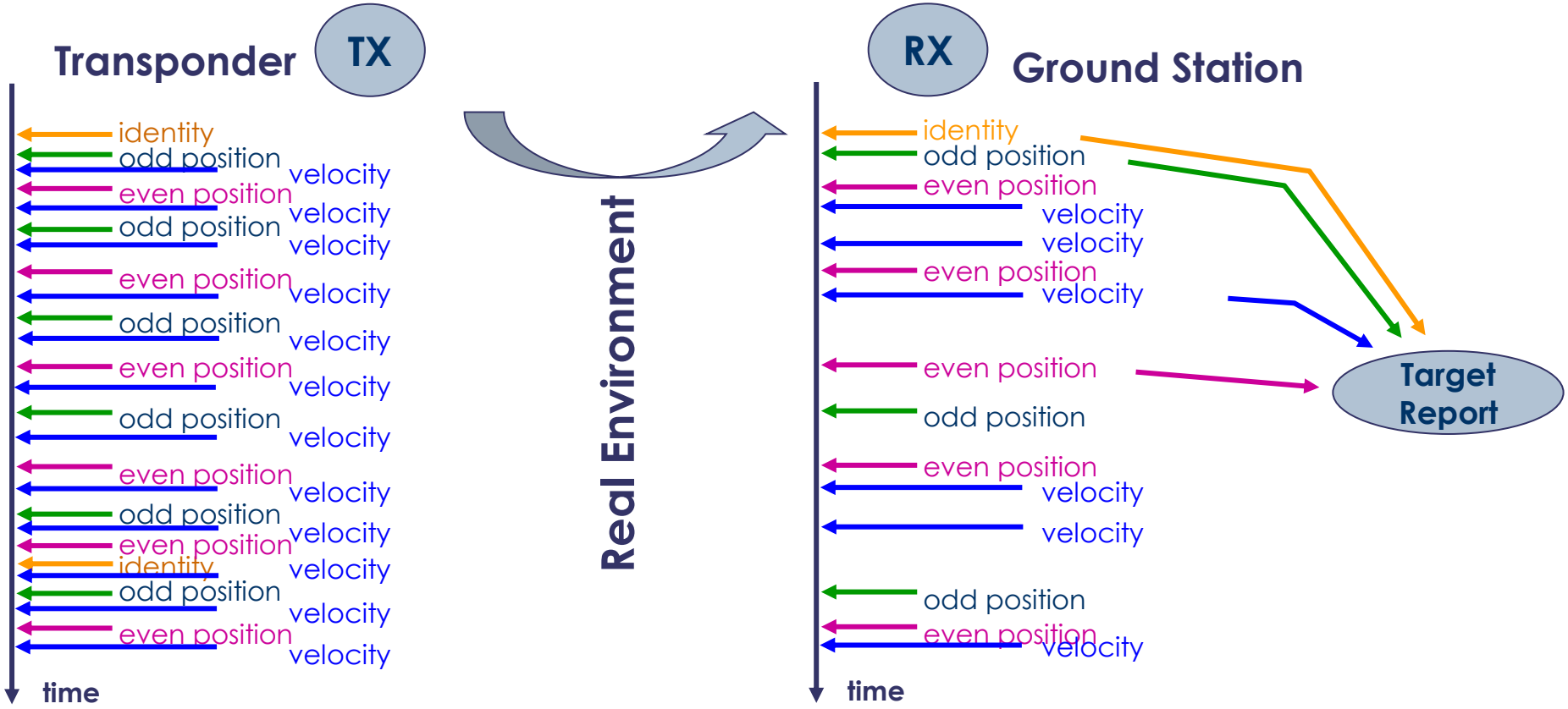
Ground Station Task



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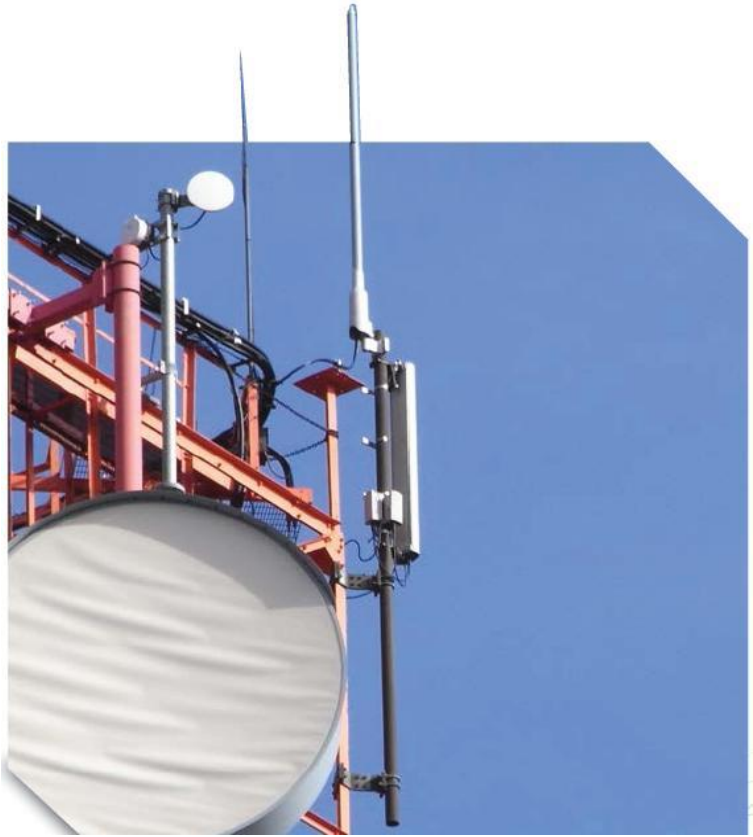
ADS-B Advantages

- 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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International Standards

- ICAO Annex 10 – Signals in Space

- DO260B / ED102A – MOPS for Avionics
  - data contents
  - encoding rules
  - Guidelines for algorithms/methods

MOPS Versions	
DO260/ED102	– Version 0
DO260A	– Version 1
DO260B/ED102A	– Version 2

- ED129B – Specifications for ADS-B Ground Systems

- ED 126, 161, 163 – Safety & Performance requirements for
  - Non Radar Airspace (ED126 – ADS-B NRA)
  - Radar Airspace (ED161 – ADS-B RAD)
  - Airports (ED163 – ADS-B APT)

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Typical Thales ADS-B equipment

AX680

Single/dual channel/link ground station (indoor version)

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

FAA SBS Radio

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Thales MAGS ADS-B System

Based on AX680 ADS-B Ground Station

Without central compontent – „ADS-B Standalone“

- Airservices Australia – Upper Airspace Program
- DGAC Indonesia – Nationwide ADS-B Deployment Program
- FAA – Surveillance Broadcast Services Program

With central component – „ADS-B Centralised“

- Hong Kong Civil Aviation Department – ADS-B Program
- DFS Germany – PAM FRA, WAM and ADS-B Program
- DTI France – Lyon and Nice Airports, Multilateration and ADS-B Program

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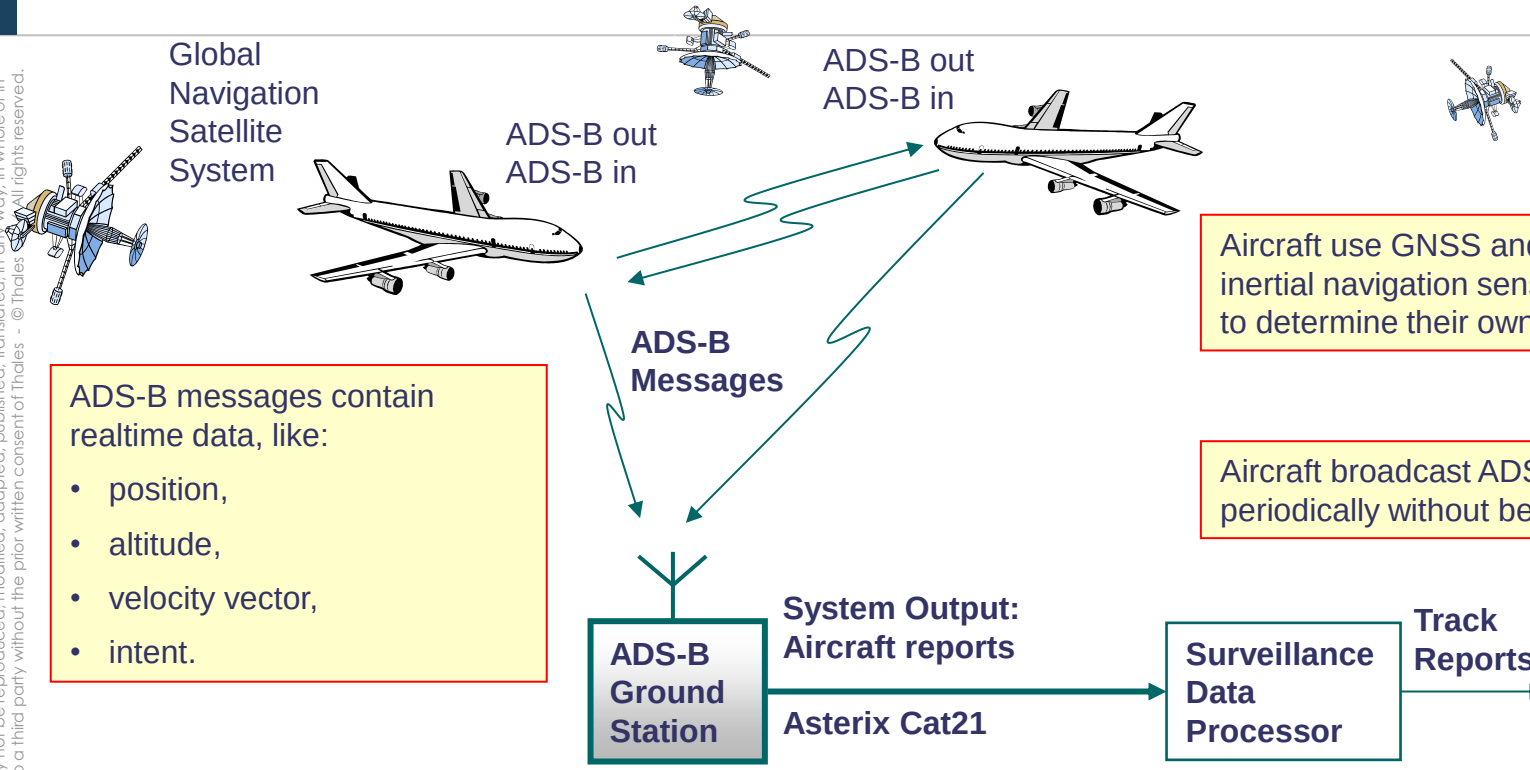
ADS-B Standalone



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 Ground Station provides Asterix Target Reports

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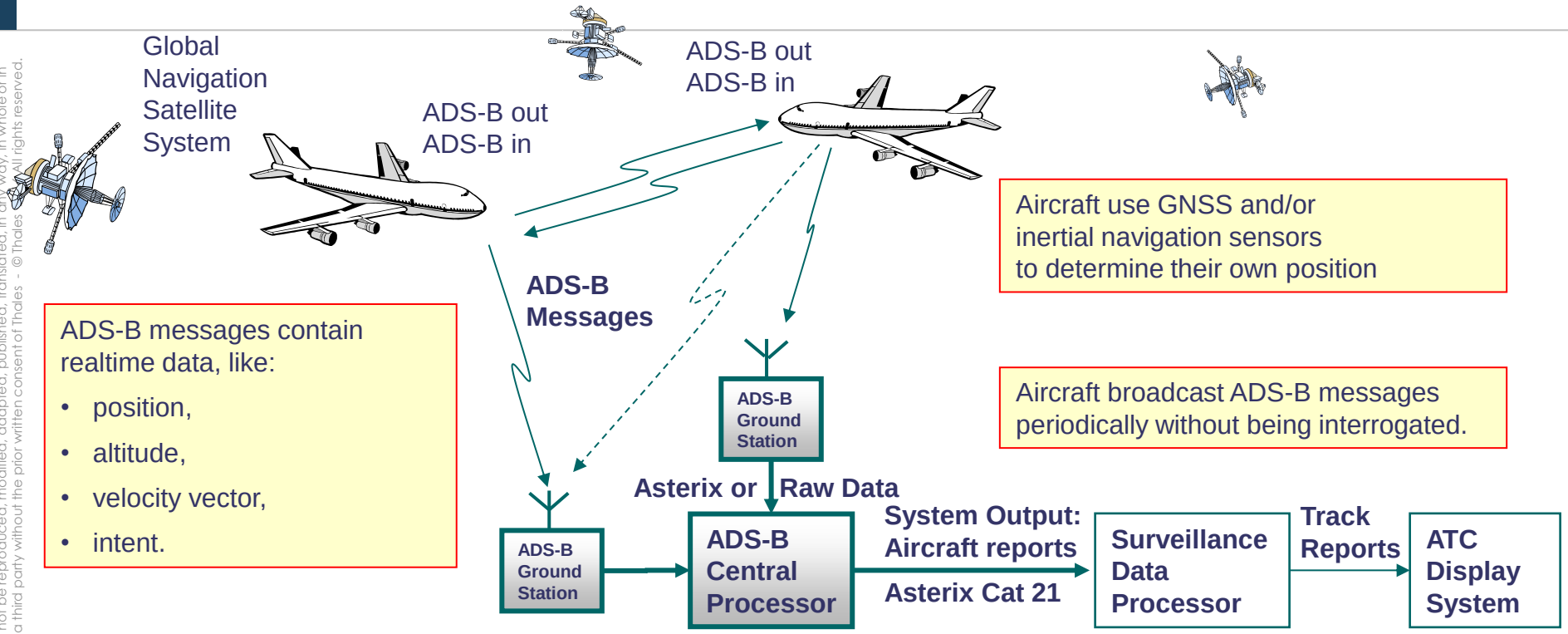
ADS-B Centralized



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Aircraft broadcast ADS-B messages periodically without being interrogated.

ADS-B messages contain realtime data, like:

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

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

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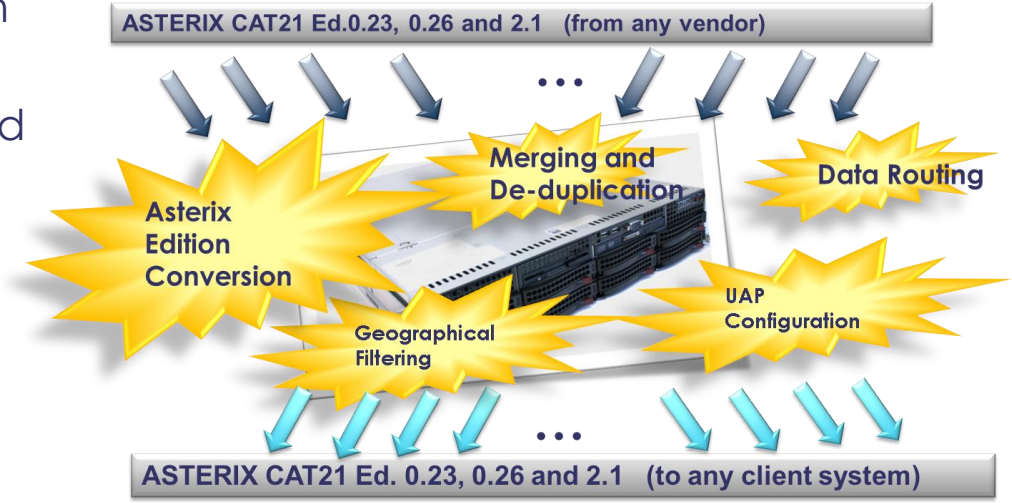
Thales MAGS ADS-B System

ADS-B Server

- Allows controlled data sharing with adjacent sectors and/or states
- Able to integrate thrid party ground stations from any vendor
- Converts Asterix versions
- Routes data streams to multiple destinations
- Provides geographical filtering
- Provides ADS-B security screening



ADS-B Server for well-controlled Data Sharing

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Special Case: 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

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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

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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

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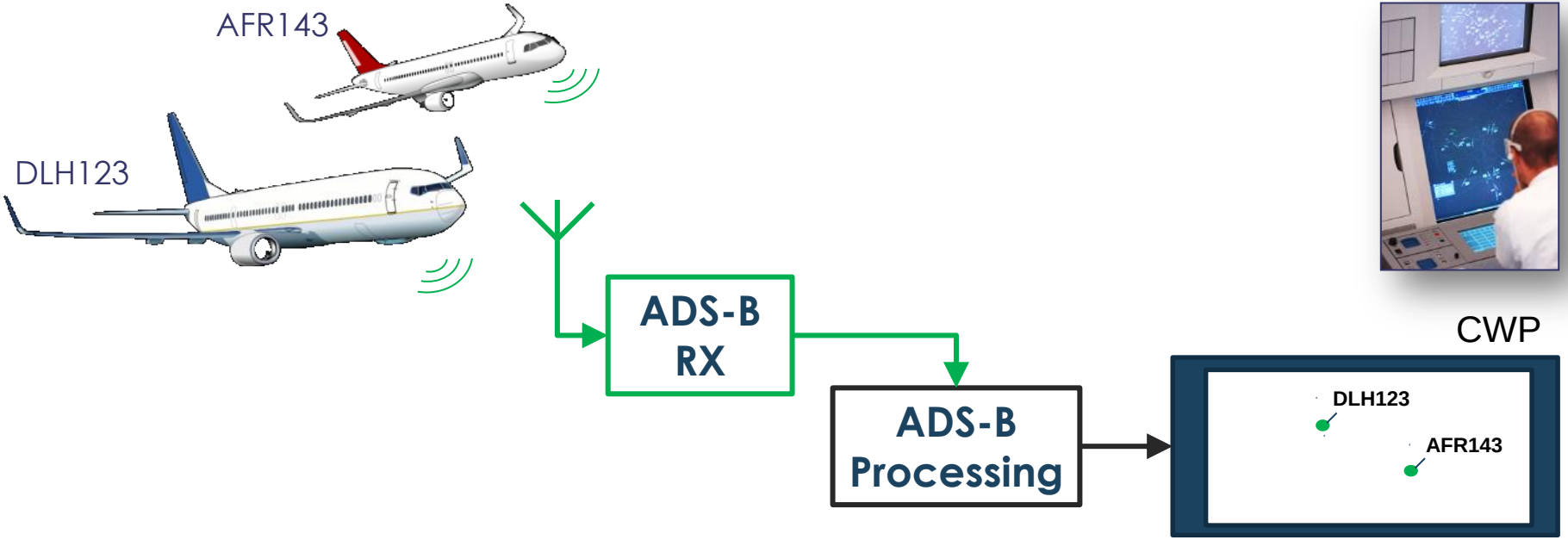
ADS-B



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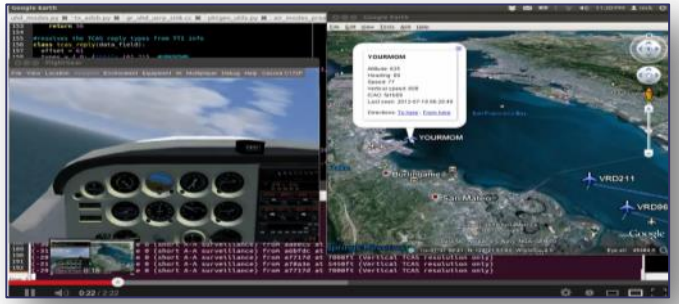
ADS-B Spoofing Demonstration

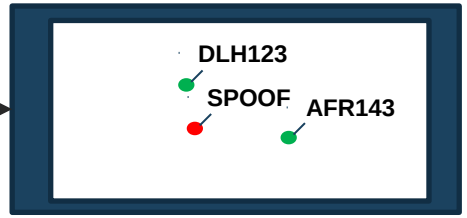


Source: http://www.youtube.com/watch?v=NSLqRXyxiBo

ADS-B RX

ADS-B Processing

CWP



Scenario (cable)

Flight Sim

SDR: ADS-B TX

ADS-B RX

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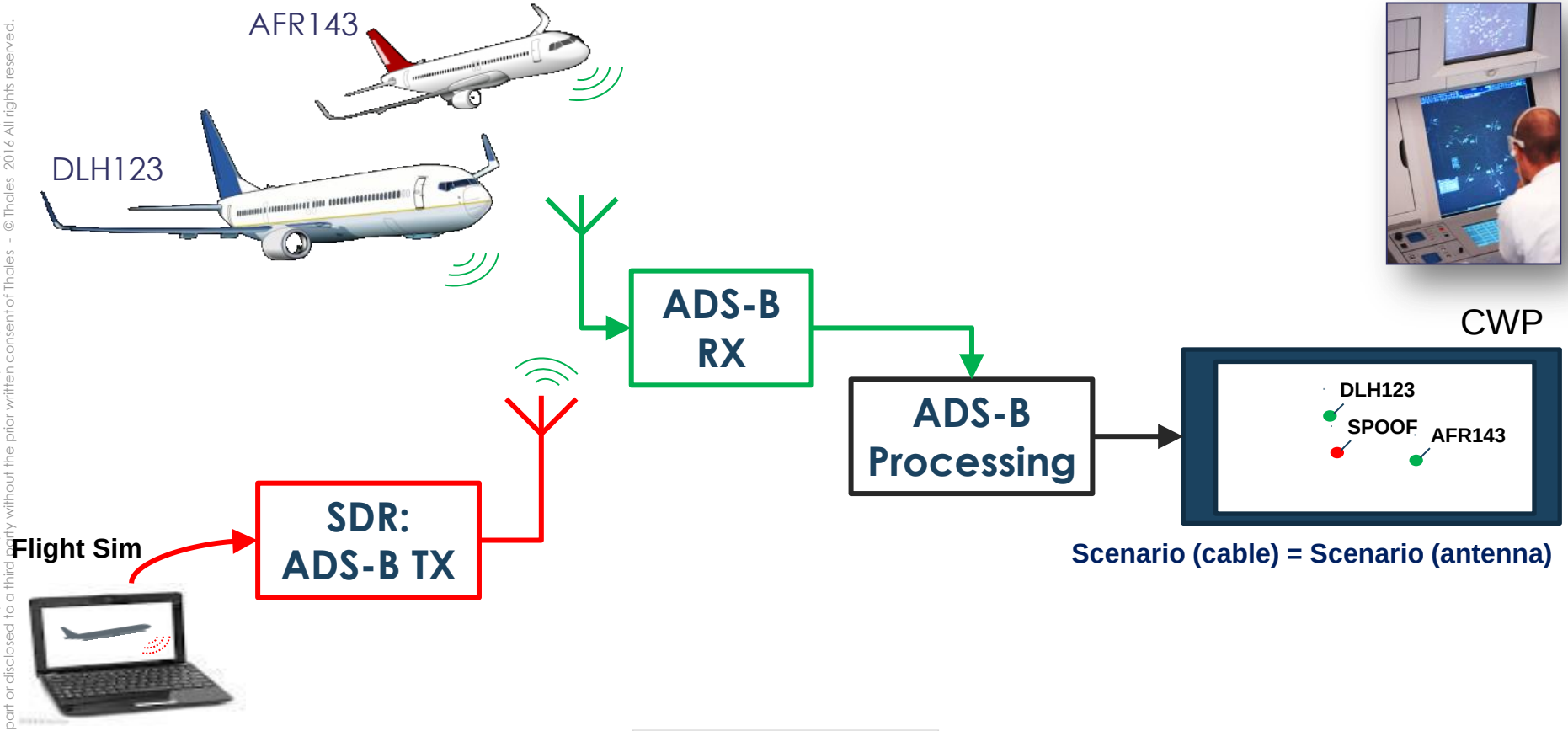
ADS-B Spoofing



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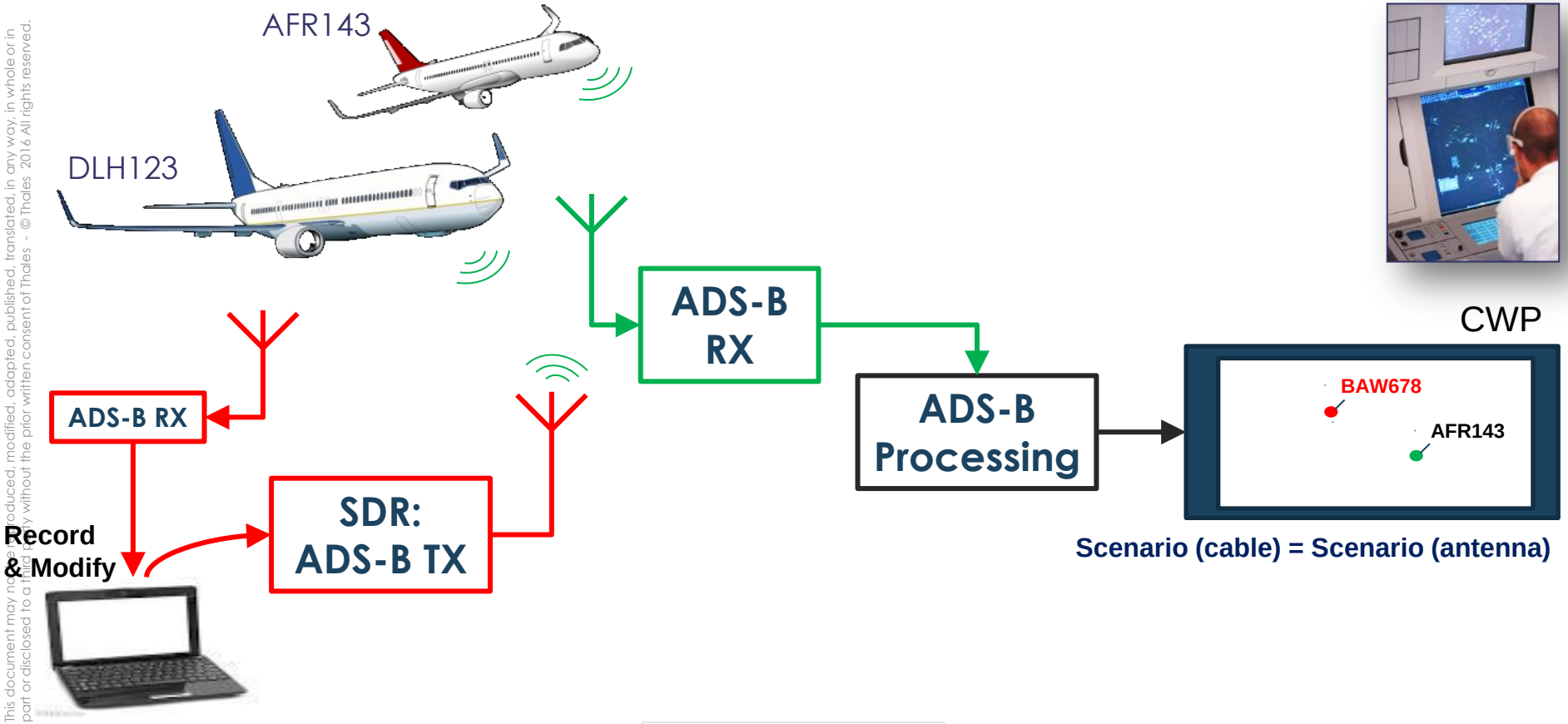
ADS-B Meaconing – Change of Identity



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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

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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

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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 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 standards – type approved and certified by German Regulator
- 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, and SBS System

ADS-B Hongkong

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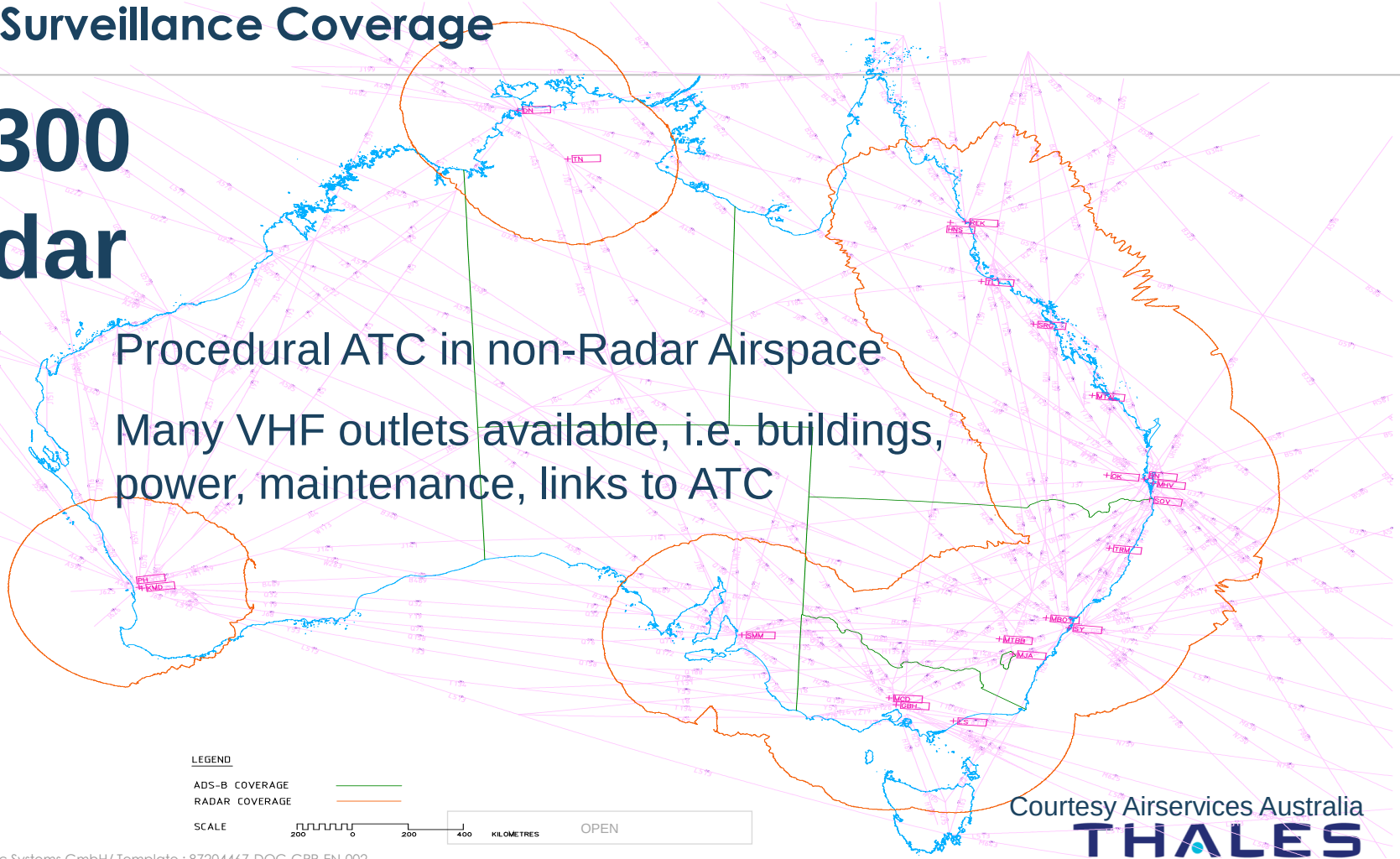
ADS-B Example Installations

Radar Surveillance Coverage

FL300 Radar

Procedural ATC in non-Radar Airspace

Many VHF outlets available, i.e. buildings, power, maintenance, links to ATC



Courtesy Airservices Australia

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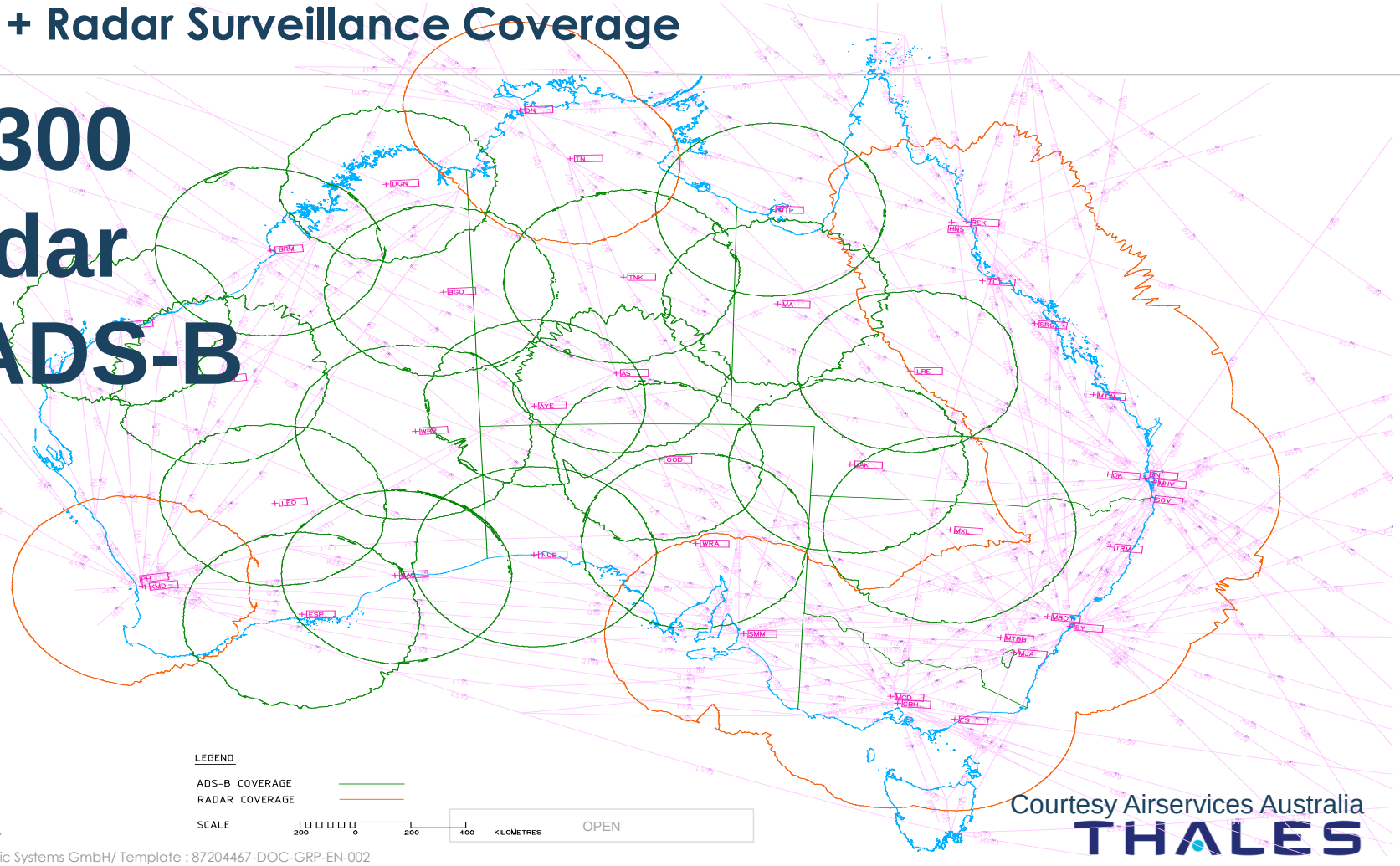
ADS-B + Radar Surveillance Coverage

FL300 Radar & ADS-B



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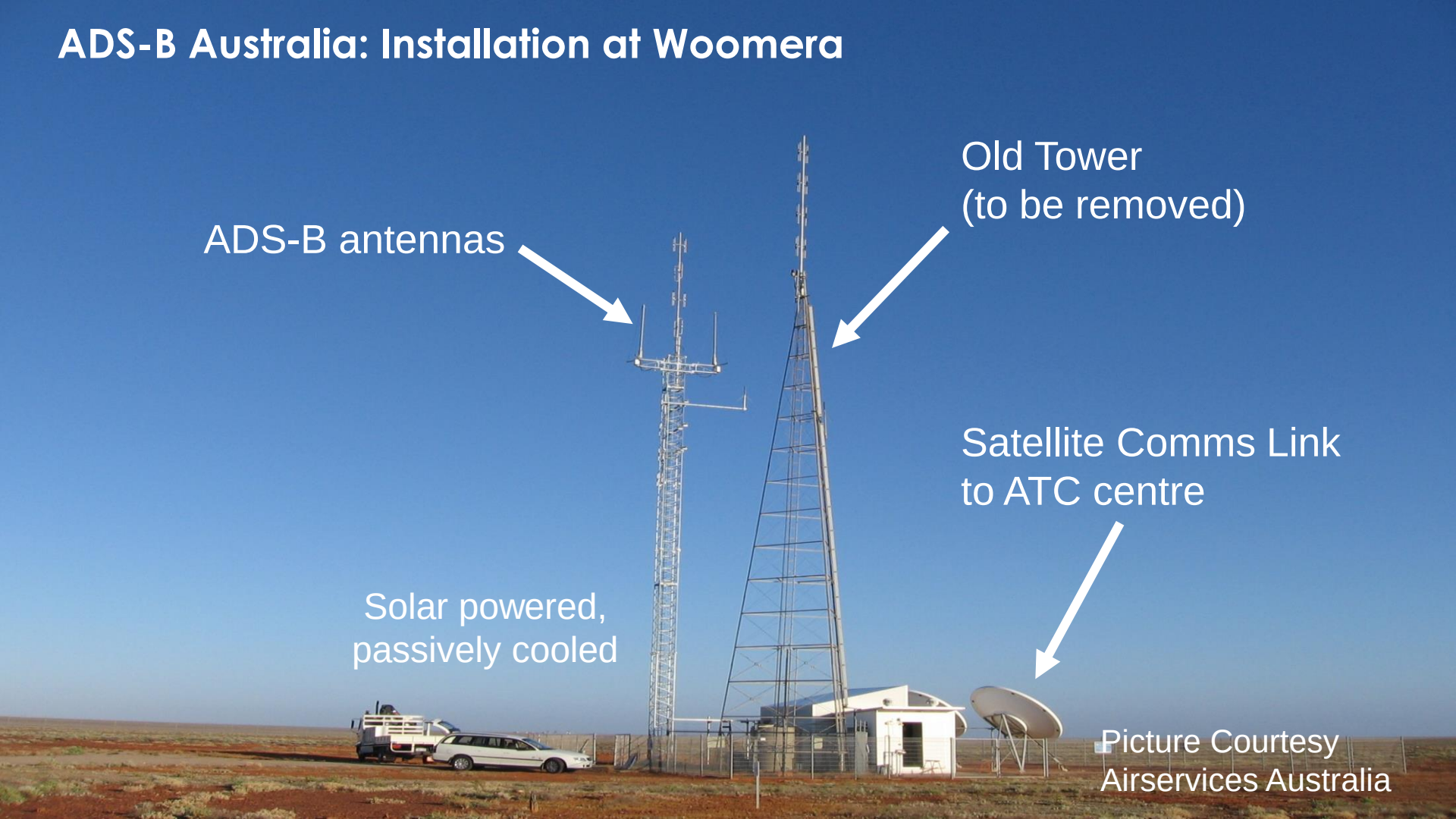
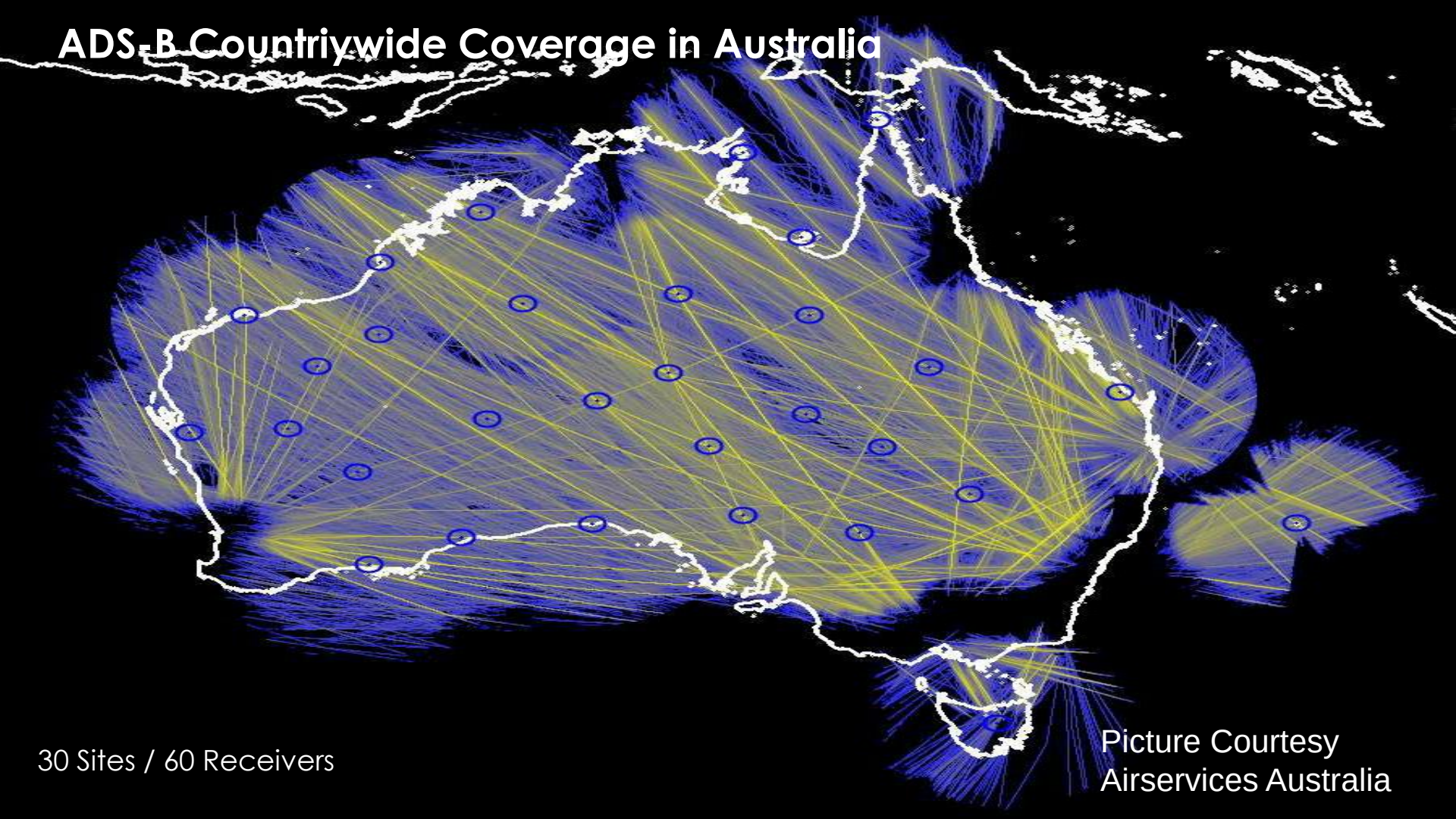
ADS-B Australia: Installation at Woomera



Picture Courtesy
Airservices Australia

ADS-B Countrywide Coverage in Australia



30 Sites / 60 Receivers

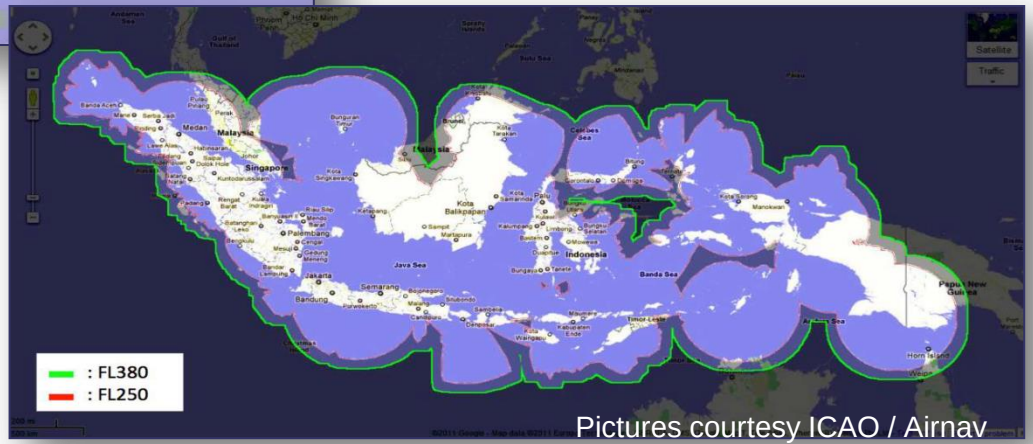
Picture Courtesy
Airservices Australia

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!

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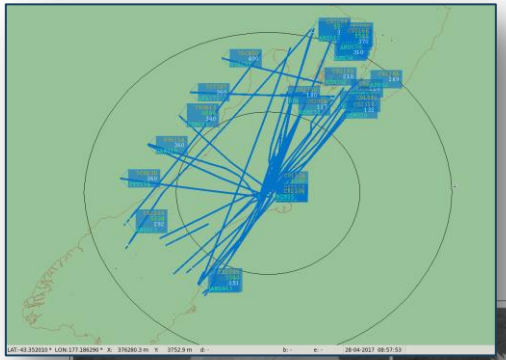
ADS-B Countrywide New Zealand



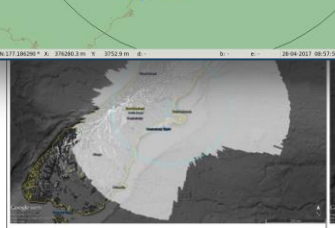


Figure 165 – Airways Lab coverage at 24500 ft ASL

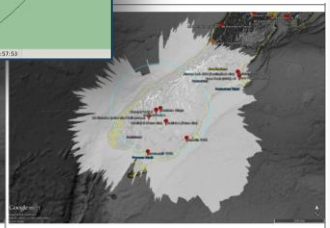


Figure 166 – Cardrona coverage at 24500 ft ASL

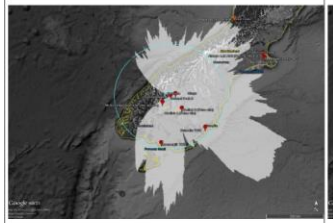


Figure 167 – Coronet Peak A coverage at 24500 ft ASL

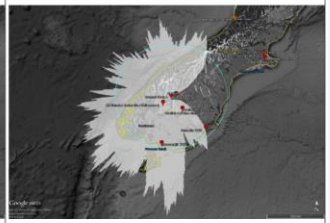
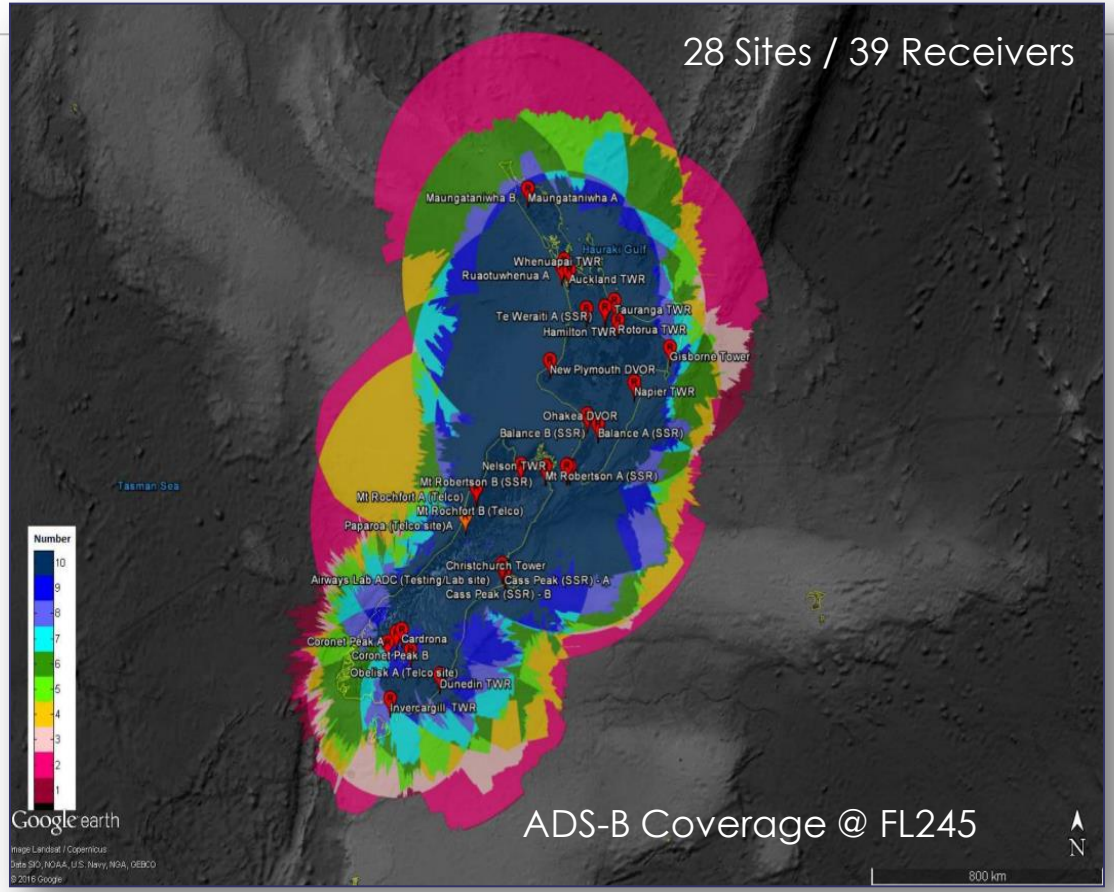


Figure 168 – Coronet Peak B coverage at 24500 ft ASL



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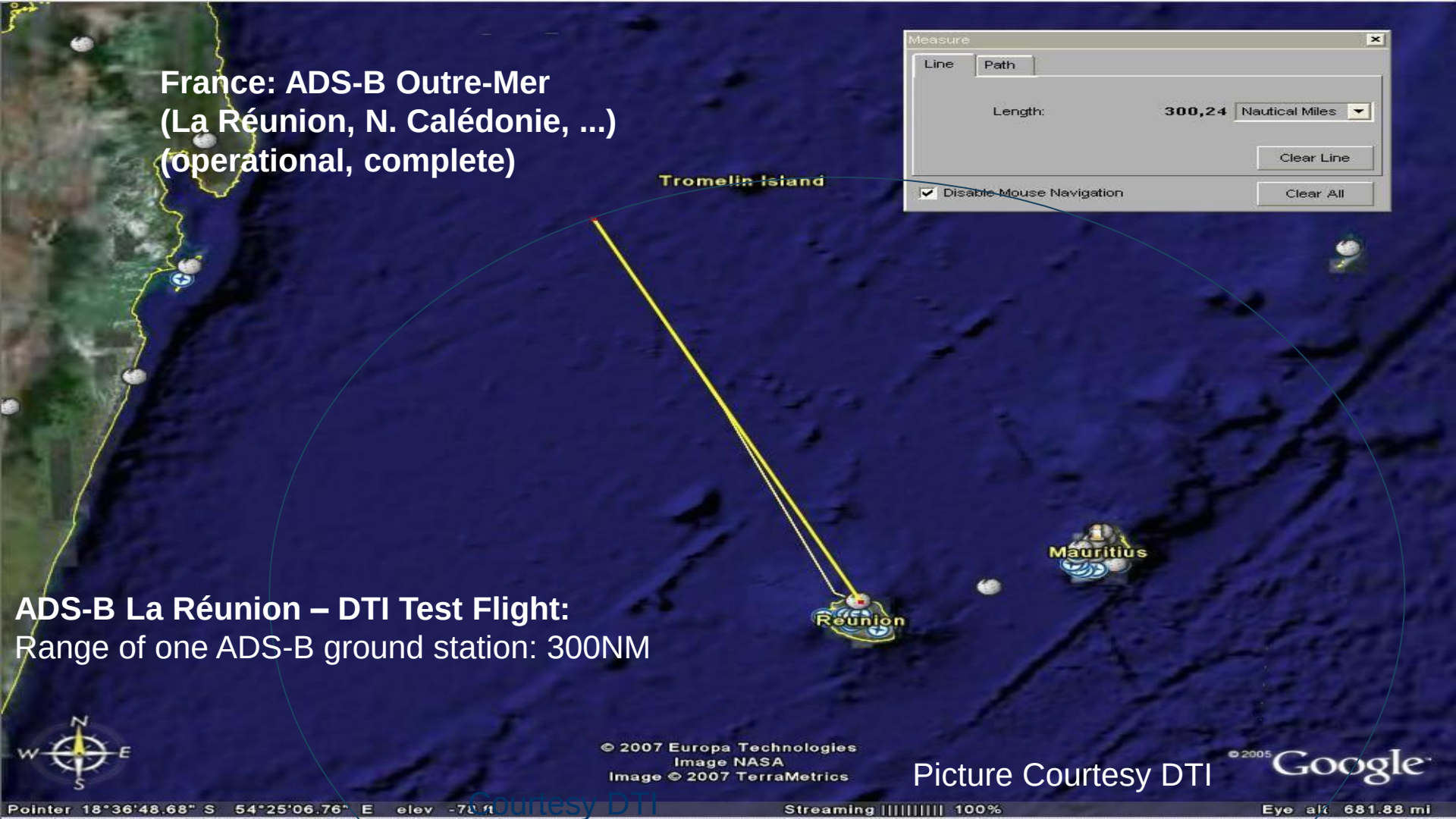
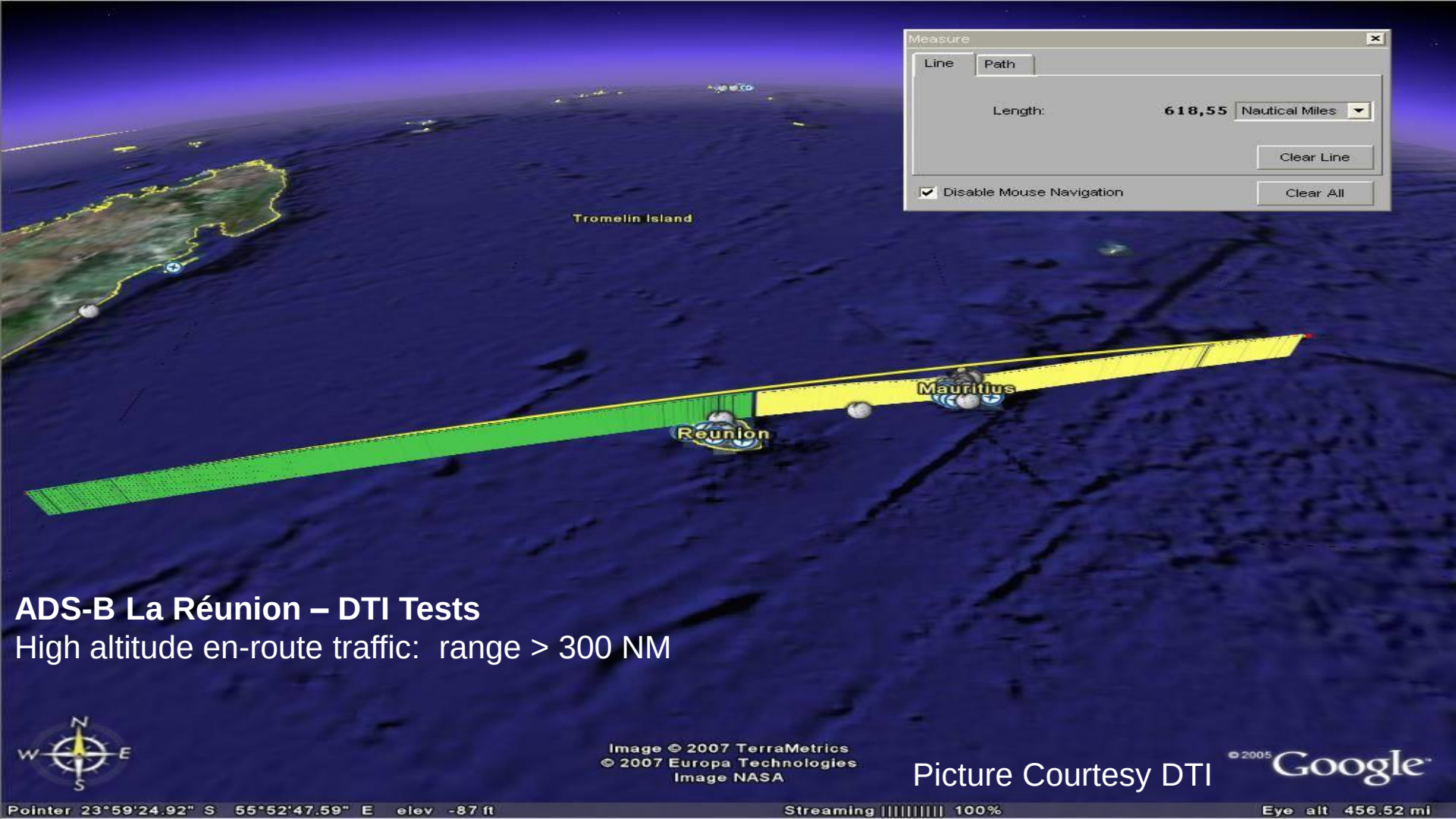


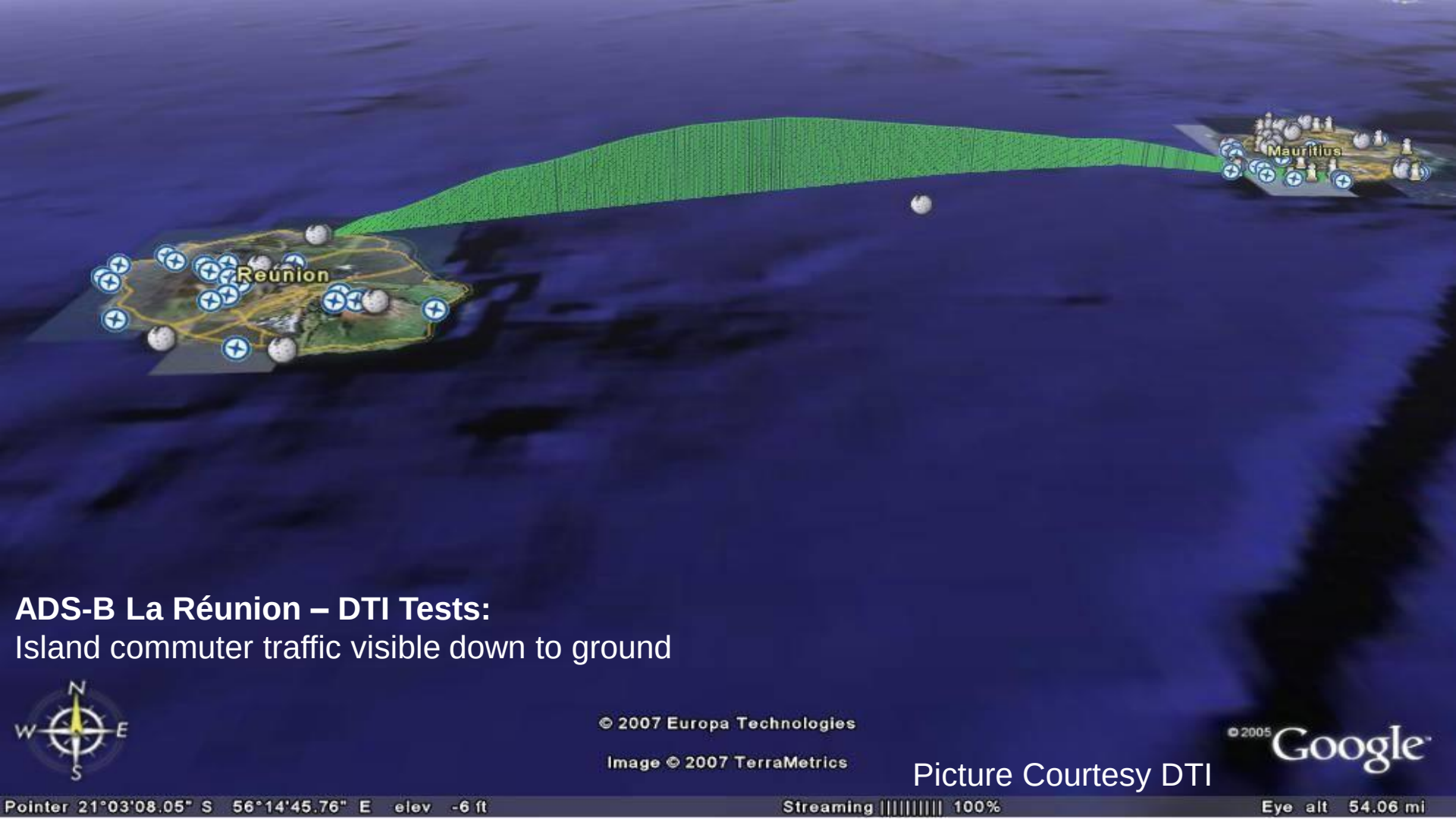
Courtesy DTI



ADS-B La Réunion – DTI Tests

High altitude en-route traffic: range > 300 NM

Picture Courtesy DTI



ADS-B La Réunion – DTI Tests:
Island commuter traffic visible down to ground

Picture Courtesy DTI

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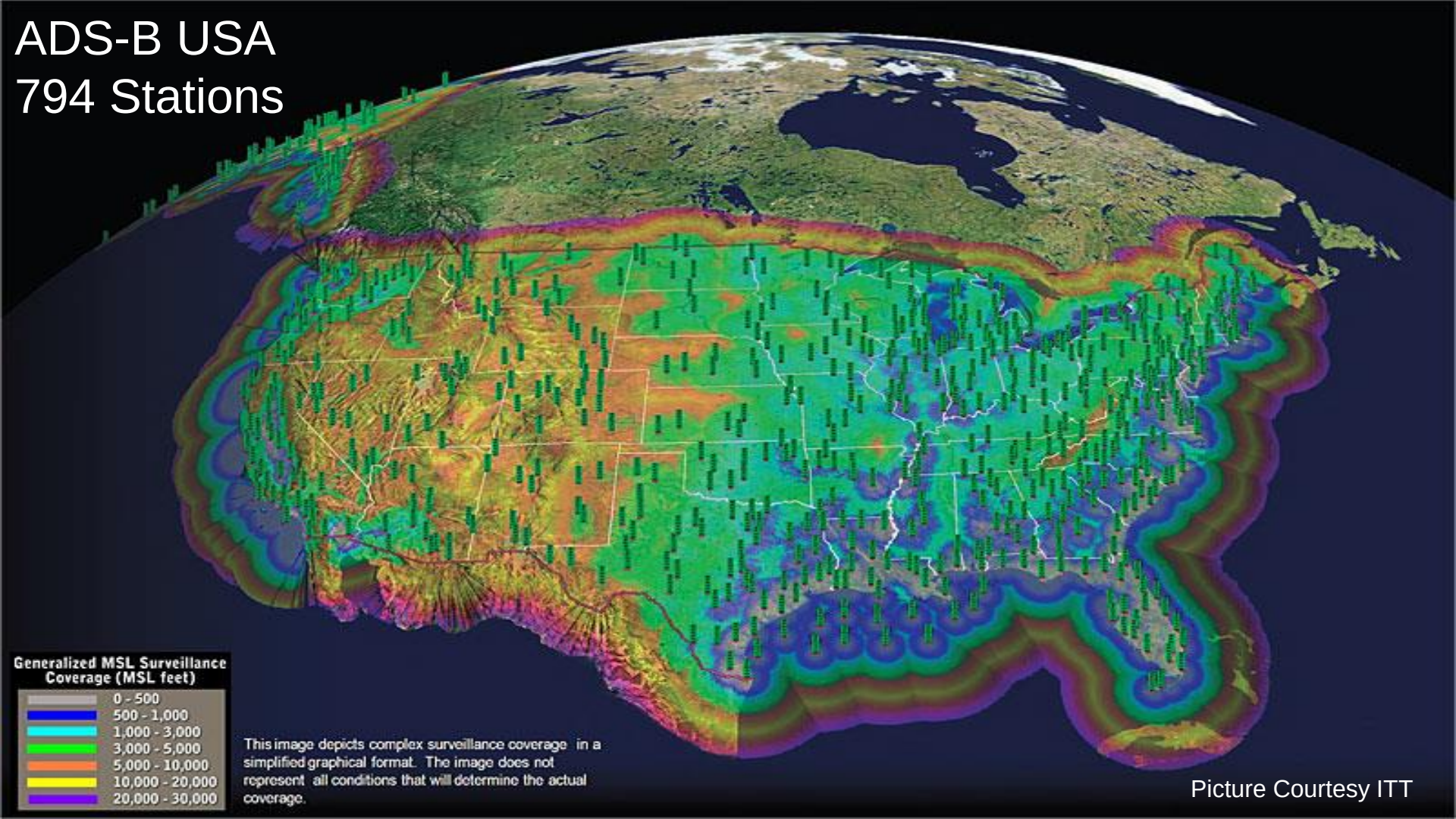
NextGen/SBSS USA

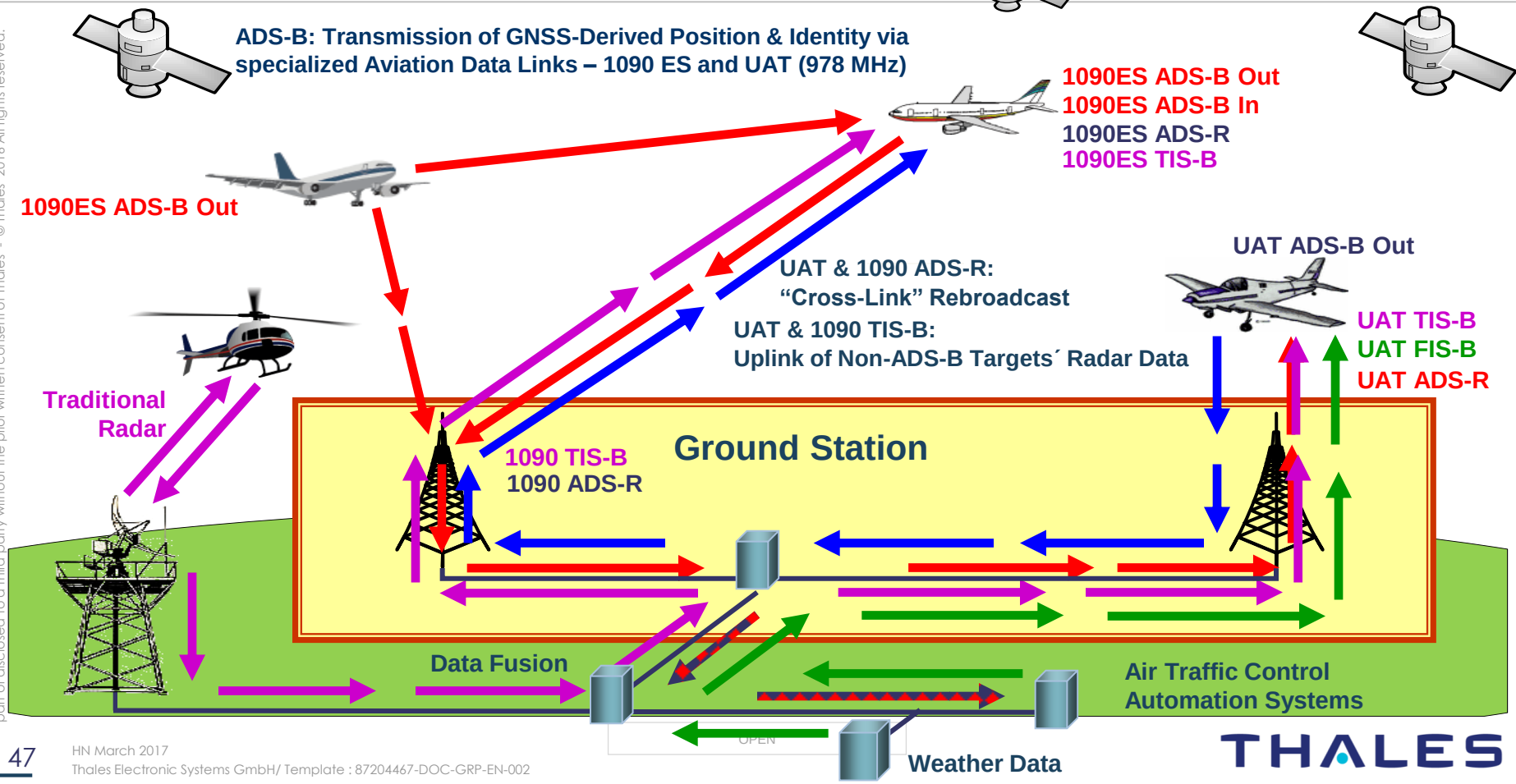
SUBCONTRACT TO ITT EXELIS, NOW HARRIS

ADS-B USA
794 Stations



Picture Courtesy ITT

ADS-B & Broadcast Services - Principles



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Surveillance Broadcast Ground Station - SBGS

- Used in FAA SBS program
- Based on proven AX680 HW components
- 19”, 8 HU form factor
- Includes multiple receivers, dual transmitters
- Redundant configuration

RX-Services 1030, 1090 and UAT

- Up to 6 channel ADS-B on 1090 ES
- Single channel UAT (978 MHz)
- Optional 1030 MHz receiver for TX blanking

TX-Services 1090 and UAT

- ADS-R crosslink
- TIS-B
- FIS-B

All services locally processed

FAA SBGS in redundant configuration

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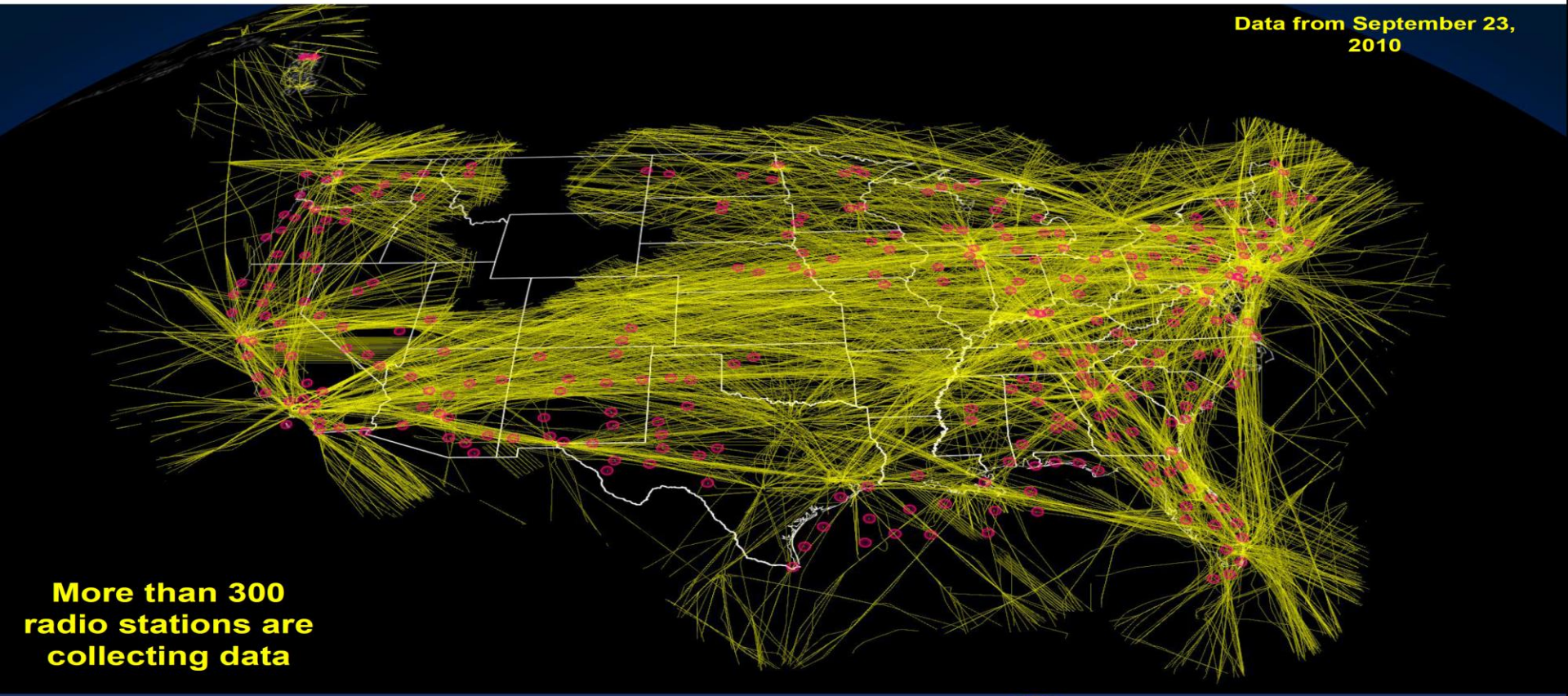
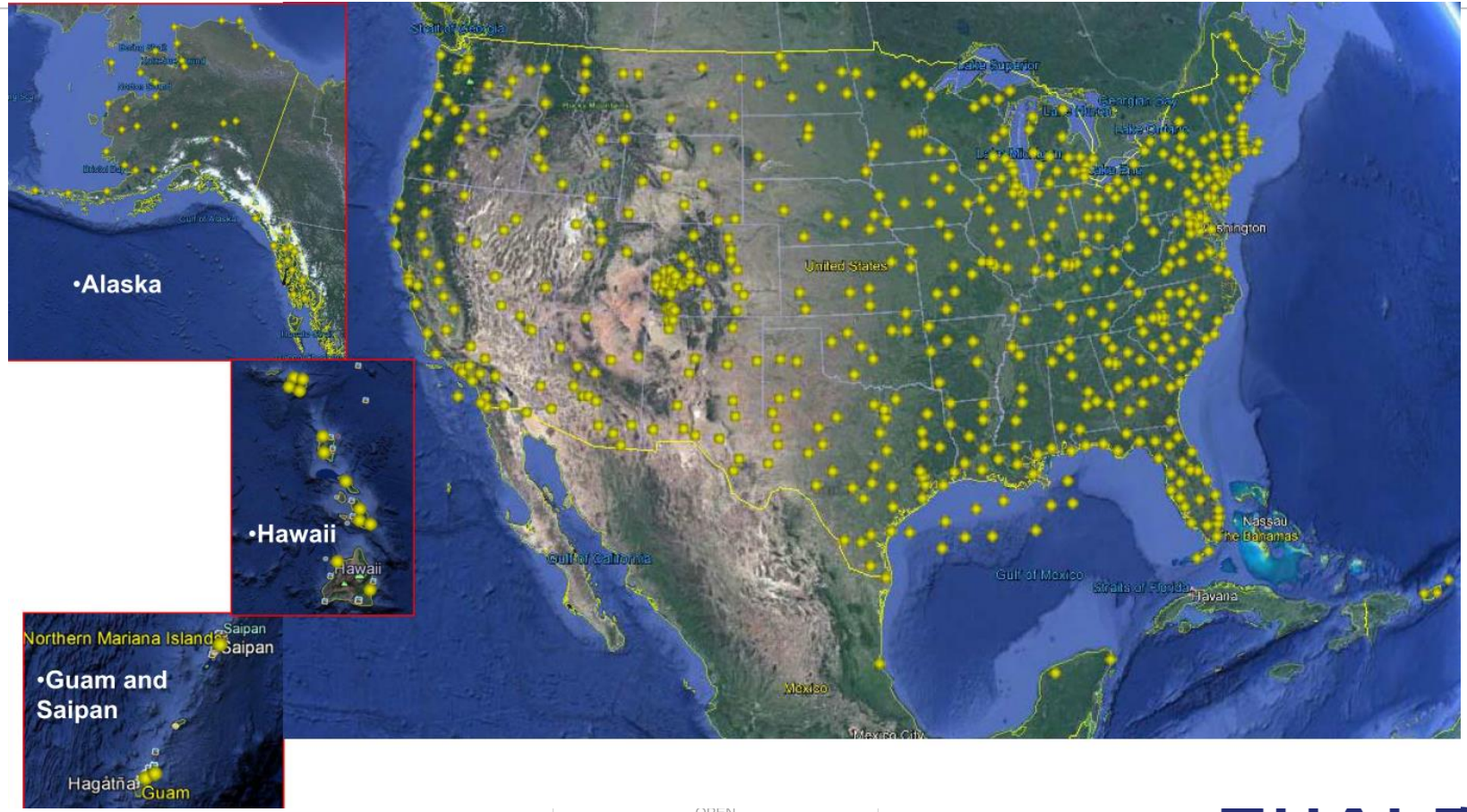
Coverage from Radio Stations



Status FAA SBS Program 06/2017



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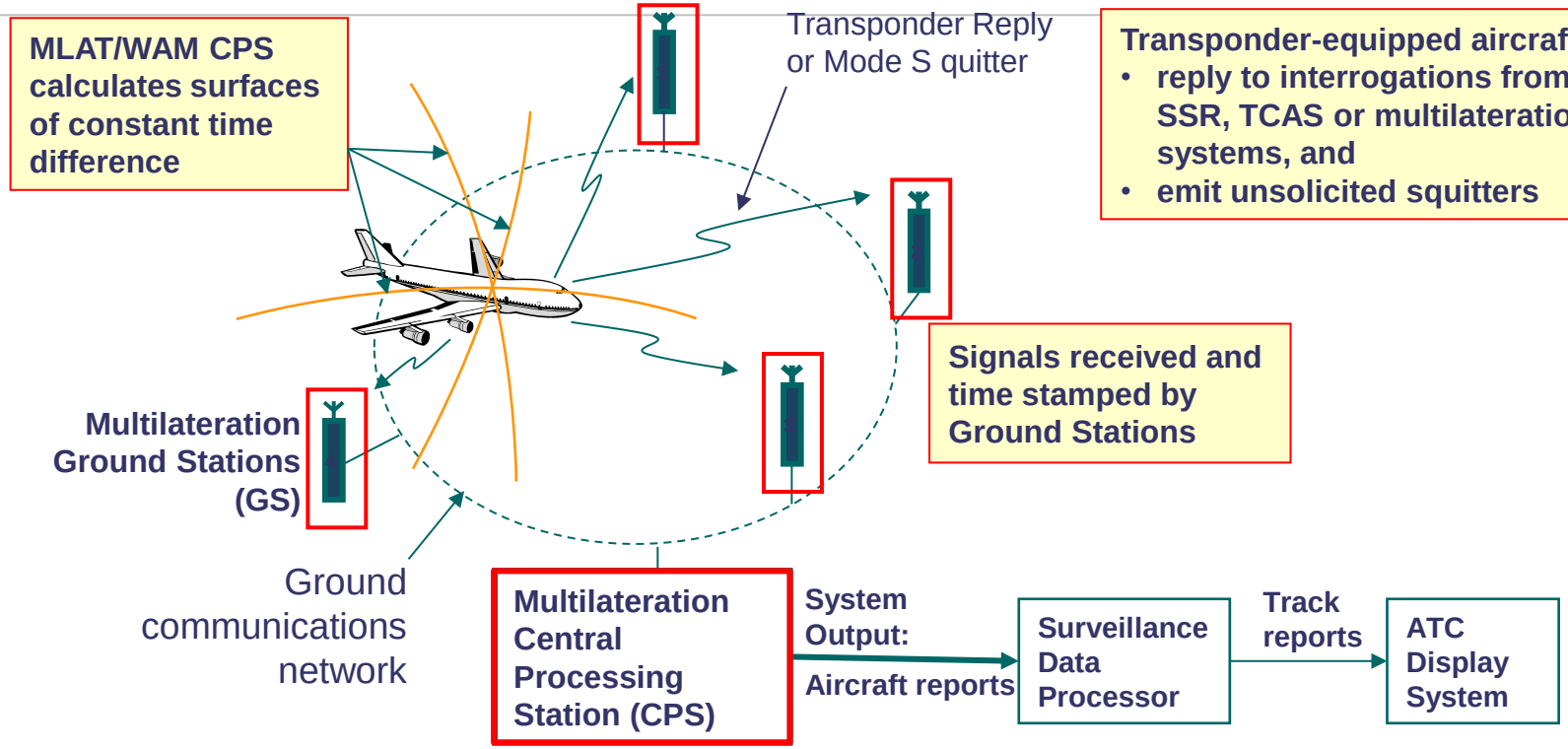
THALES

Multilateration Systems

AIRPORT SURFACE MULTILATERATION (MLAT)
PRECISION APPROACH MONITORING (PAM)
WIDE AREA MULTILATERATION (WAM)

Fundamental Principle of Multilateration



Multilateration measures Positions

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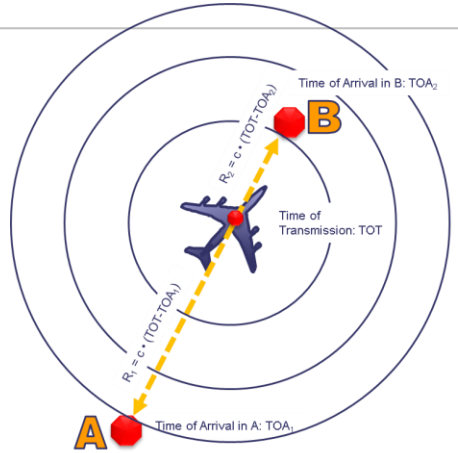
Recapitulation : Multilateration Principle (TDOA)



A and B are a pair of ground stations receiving both a signal from an aircraft.

The range between aircraft and ground station is

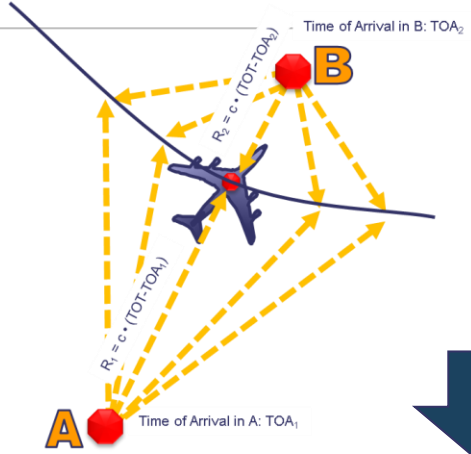
$$R = c \cdot (TOA - TOT)$$

The time difference TOA_1-TOA_2 thus corresponds to the range difference

$$R_2 - R_1 = c \cdot (TOA_2 - TOA_1)$$

as the Time of Transmission TOT cancels in the difference.

(c = wave propagation speed)

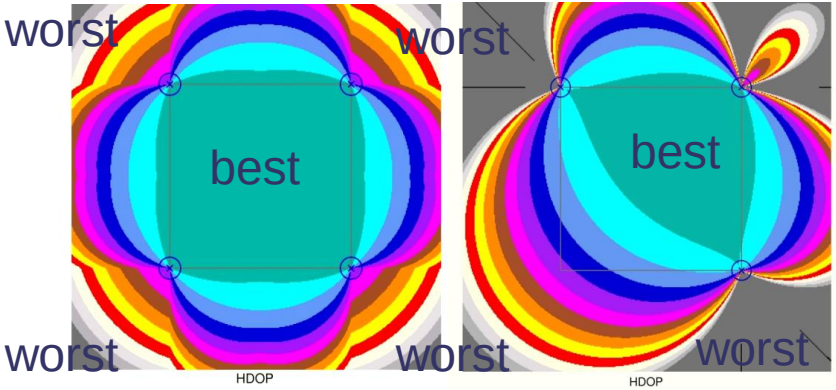


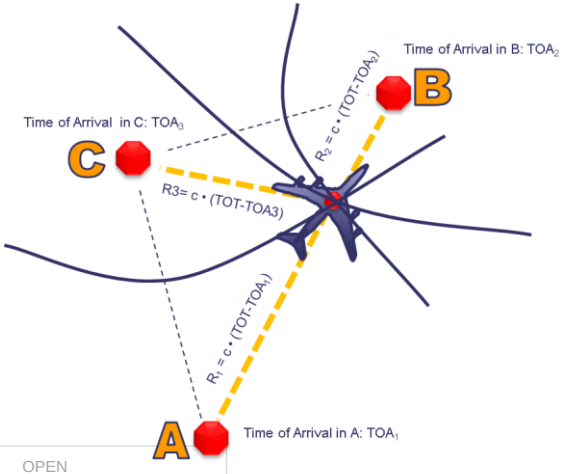
At a given time, the aircraft is located somewhere on the line whose points have a constant range difference to the ground stations:

$$R_2 - R_1 = c \cdot (TOA_2 - TOA_1)$$

This line is a hyperbola with the ground stations representing the focal points.

Typical Accuracy Distribution from Theory





A third ground station in C gives two more differences

$$R_2 - R_1 = c \cdot (TOA_2 - TOA_1)$$
$$R_2 - R_3 = c \cdot (TOA_2 - TOA_3)$$
$$R_1 - R_3 = c \cdot (TOA_1 - TOA_3)$$

and thus two more hyperbolas follow.

The aircraft can be located at the intersection of the hyperbolas

OPEN

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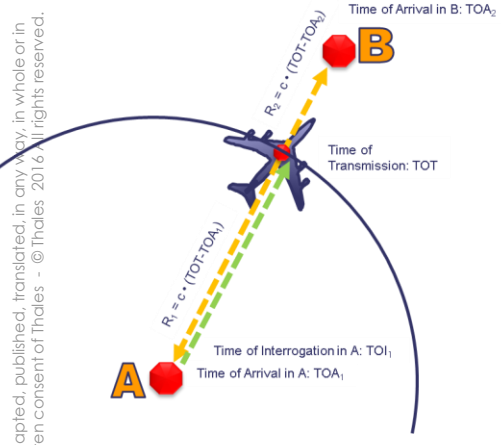
Recapitulation : Multilateration Principle (TSOA)



Ground station A is interrogating at TOI_1 an aircraft eliciting a response at TOT that is received by ground stations A and B.

The range between aircraft and ground station is

$$R = c \cdot (TOA - TOT)$$

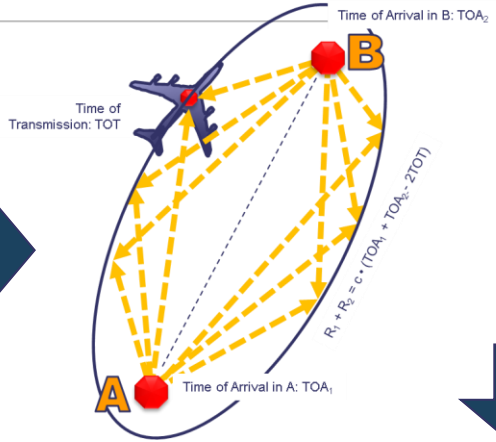
with the unknown TOT, i.e.

$$TOT = TOI_1 + ½ \cdot (TOA_1 - TOI_1)$$

So that

$$R_1 = c \cdot ½ \cdot (TOA_1 - TOI_1)$$

(c = wave propagation speed)



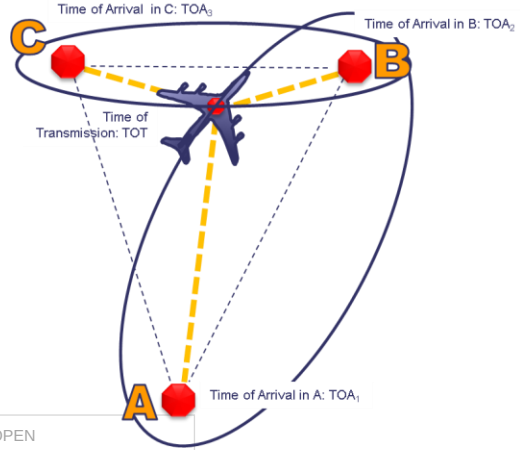
At a given time, the aircraft is located somewhere on the line whose points have a constant range sum to the ground stations:

$$R_1 + R_2 = c \cdot (TOA_1 + TOA_2 - 2\,TOT)$$

or

$$R_1 + R_2 = c \cdot [½ \cdot (TOA_1 + TOA_2) - TOI_1]$$

This line is an ellipsis with the ground stations representing the focal points.



A third ground station in C gives another range sum:

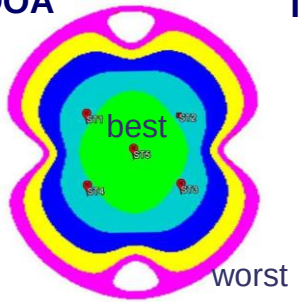
$$R_1 + R_2 = c \cdot (TOA_1 + TOA_2 - 2\,TOT)$$
$$R_2 + R_3 = c \cdot (TOA_2 + TOA_3 - 2\,TOT)$$

and thus another ellipsis follows.

The aircraft can be located at the intersection of the ellipses.

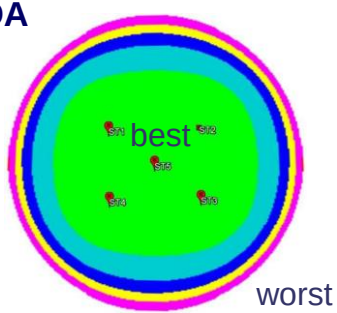
Typical Accuracy Distribution from Theory

TDOA



Hyperbolic

TSOA



Elliptical

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Multilateration Characteristics

Advantages:

- Excellent Performance – depends heavily on system geometry
- High update rate – every received signal used to locate target
- Mode S communication possible (downlink of aircraft parameters)
- Same ground stations as for ADS-B – intrinsic ADS-B capability
- Inherent Integrity/Security Features
- Low ground equipment cost – Low lifecycle cost

Requirements:

- Multiple sites required,
- No of sites strongly depend on vertical coverage limit and terrain
  - Avoid over-specification that may lead to excessive complexity

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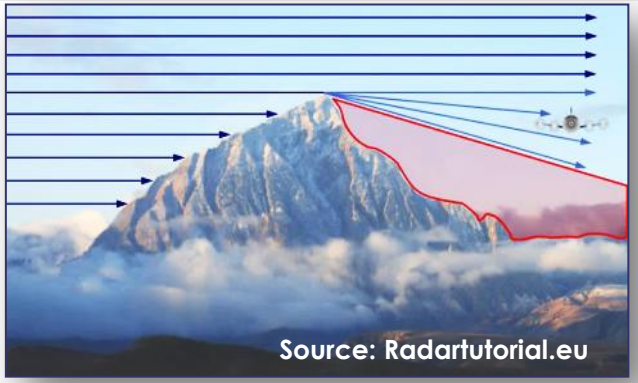
Real World Constraints

Quasioptical Propagation @1090 MHz

- Not much diffraction (good)
- Obstruction
- Multipath



Nutzung des Kanals durch andere Systeme

- SSR, ACAS/TCAS, IFF, ADS-B
- Hohe Funkfeldbelastung – Einschränkung der Empfangswahrscheinlichkeit
- Unkoordinierter Kanalzugriff („Aloha“)

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Effects and Anomalies

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Main Reasons for good or bad Performance

Centralized Sensors (Radar, ADS-B, …):

- Equipment characteristics
- Algorithms applied
- Chosen antenna pattern

Distributed Sensors (WAM, PAM, MLAT, …):

- Equipment characteristics (Ground Stations)
- Algorithms applied (Central Processing Station, CPS)
- Chosen antenna patterns
- Synchronisation Methods
- Number and constellation of ground station sites
  - Minimum: 3 Stations for 2D, 4 Stations fsr 3D Position

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Comparison ADS-B vs Multilateration

Criterion	ADS-B	Multilateration
Ground Equipment	Single Ground Station for coverage	Multiple Ground Stations for coverage
Position Source	Dependent Surveillance: Onboard Navigation Position via Datalink, usually based on GPS	Independent Surveillance: Own Measurement of Position
Operational Principle	Passive	Passive/Active (e.g. Baro Altitude)
Equipage	Needs ADS-B – capable Mode S transponder	Needs Mode S or Mode A/C transponder, also supports ADS-B
Coverage	As defined by ground station antenna and terrain	Tailored by ground station deployment
Ground Communication Network is needed to each Ground Station		

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Operational Ground Station Equipment Characteristics (1/2)

Reception:

- High Sensitivity – long detection range
- Superb de-garbling – good performance even in high density airspace

Transmission:

- Dual Channel 1030 and 1090 MHz
- Power Controlled up to 1000W
- Multirole Transmitter: interrogation, system synchronization backup, test target

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Operational Ground Station Equipment Characteristics (2/2)

Ground Station Interfacing:

- Low bandwidth requirements
- Dual raw data, dual independent Asterix Cat 21 output per channel

Ground Station Maintenance

- Maintenance-free equipment
- Full remote access via network
- Remote diagnostics via BITE, internal oscilloscope and spectrum analyzer
- Dual SW, FW, OS, Configuration partitions for easy upload during operation
- Failsafe remote update

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Ground Stations Configurations

- Single or dual Sector
- Local redundant or spacially redundant
- Receive-only (GSR) or Receive-Transmit (GST)

Subrack

Indoor Cabinets

Outdoor Cabinet

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Operational System Characteristics

System Synchronization for TOA Time Stamping

- Distributed Timing (independent time stamping to UTC in each ground station)
- Dual independent synchronization capability – not depending on GPS alone

System Interfacing:

- Asterix Cat 19, 20, 21, 23, 25, 247 – and also Cat 34, 48 (radar-like) in pseudo rotation
- Multiple independent output streams configurable

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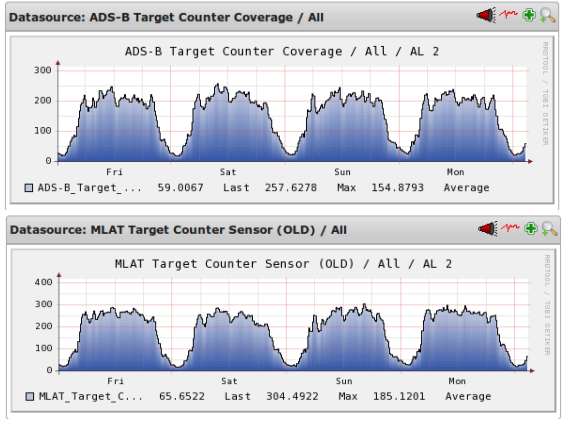
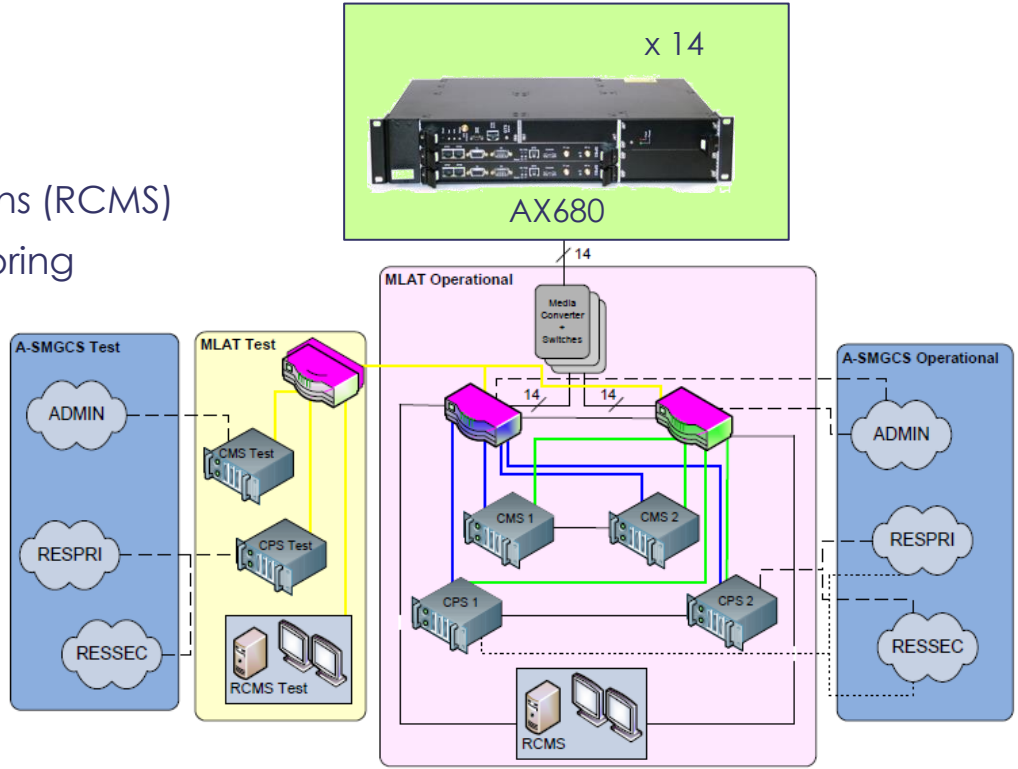
Redundant Central Site Architecture

Centralised Control and Monitoring System

Central Processing System

- Fully redundant Master-Slave Setup
- Any number of remote control positions (RCMS)
- Real time system performance monitoring
- Full data logging and replay





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How to build a good WAM System

Excellent Equipment Performance ✓

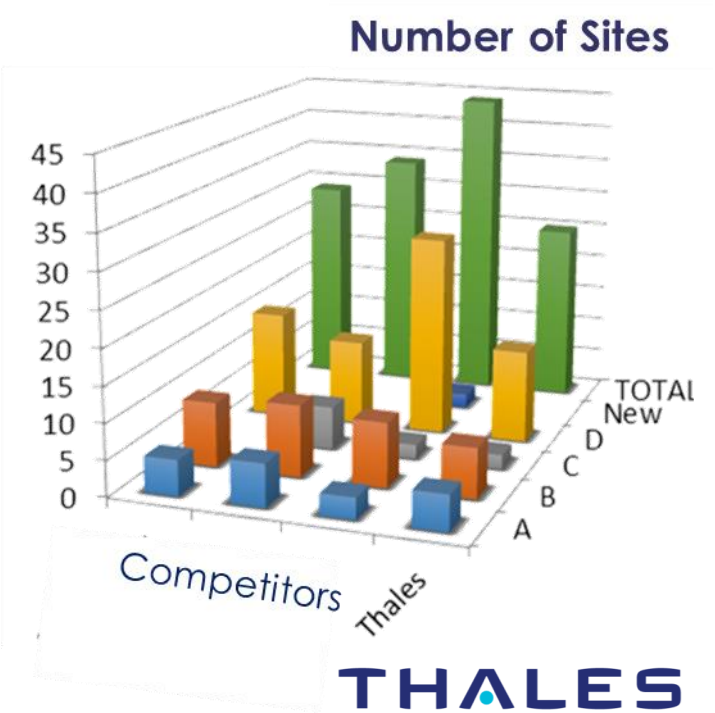
Versatile Algorithms tuned as needed ✓

- Accuracy, output rate
- Probability of Detection, interrogations
- Coverage Volume

Good Site Selection Process ✓

- Performance
- Coverage
- Operating Cost (number of sites to maintain)

System has to be managed centrally ✓



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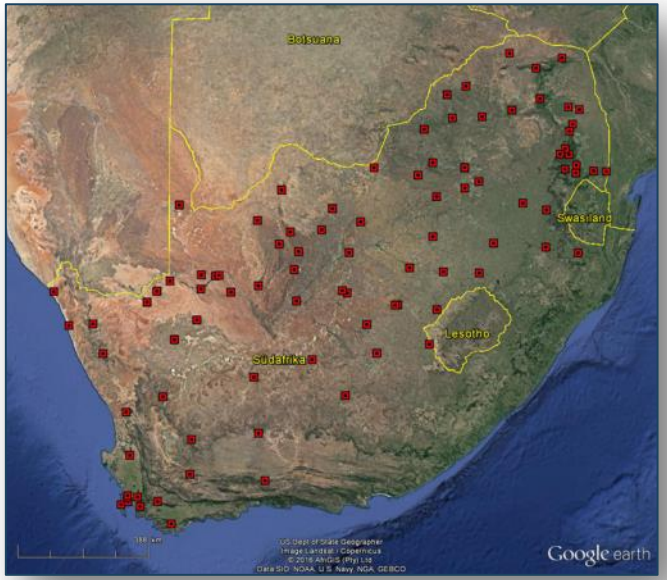
Managing Large Systems

- **Multilateration Systems are fully remote operated / remote controlled**
- **Maintenance-free**
- **Larger, more complex systems can be built**
- **Availability becomes an issue – main reasons :**
  - communication network issues,
  - power loss
- **System Resilience is required**



South Africa:
Operational WAM Implementation
(approx. 100 Ground Stations)

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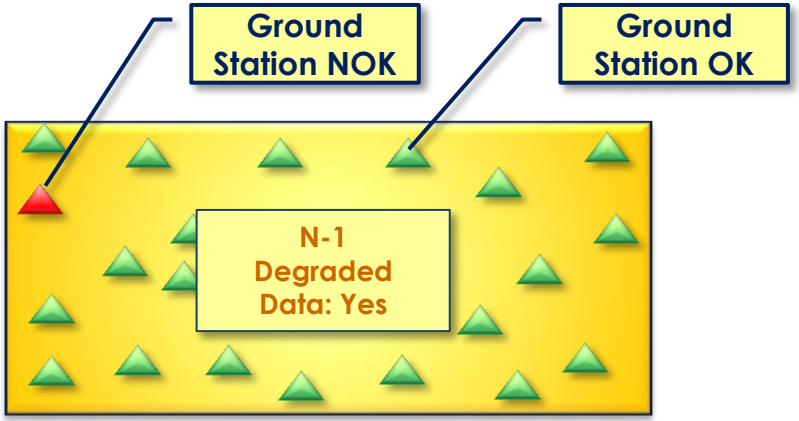
Multilateration System Resilience (1/2)

Classical N-1 System Concept

System State: **Normal**



System State: **Degraded**

System State: **NOGO**

System State: **NOGO**

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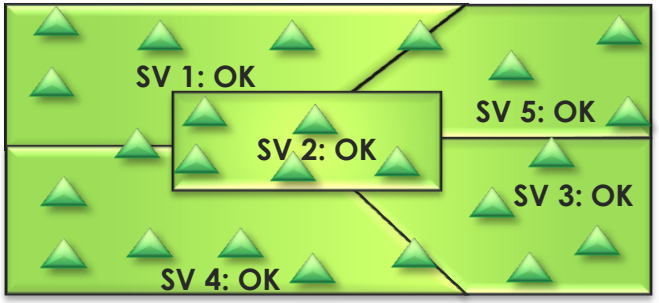
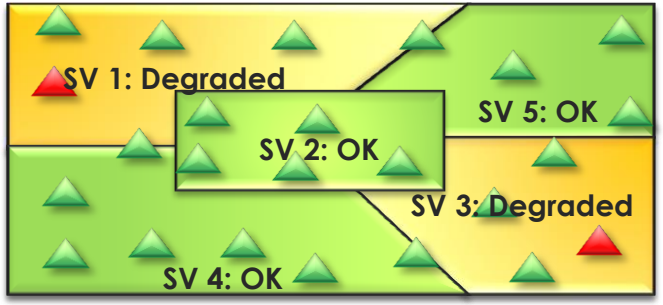
Multilateration System Resilience (2/2)

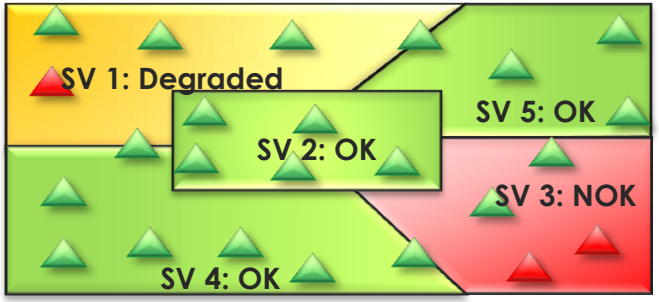
Solution for improved Availability – Virtual WAM



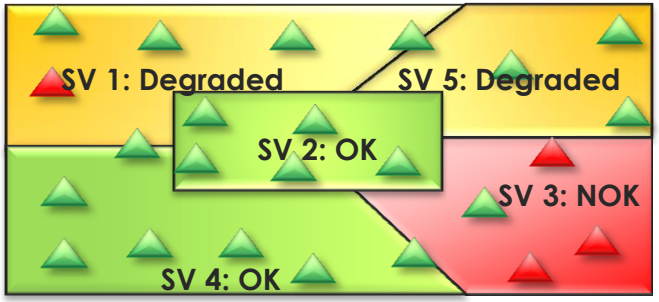
System State: **Normal**



System State: **Degraded**



System State: **Degraded**



System State: **Degraded**

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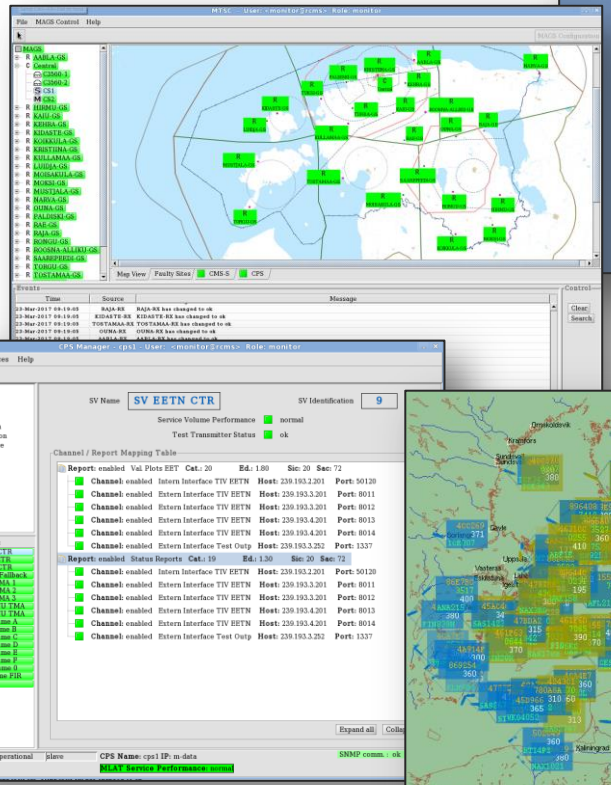
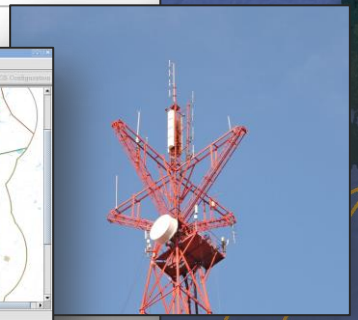
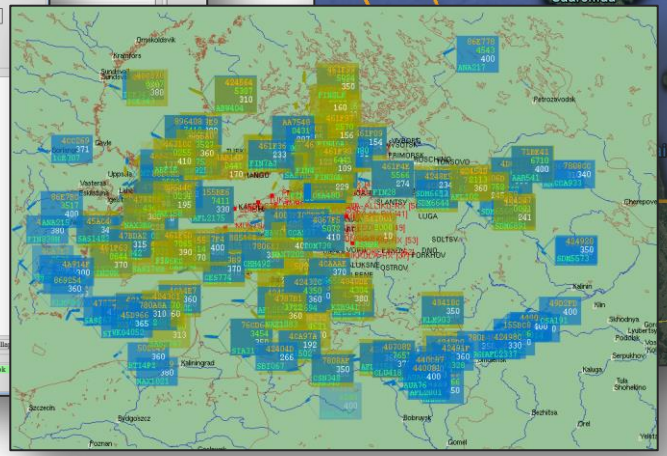
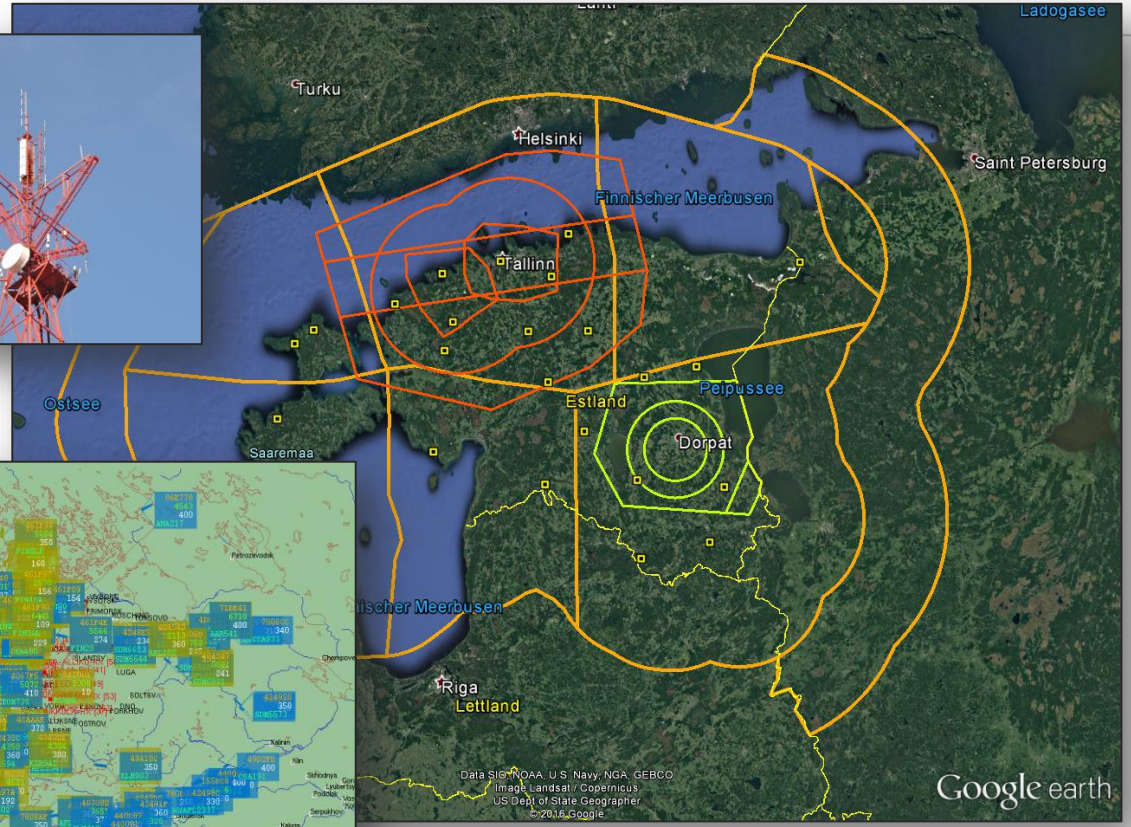
WAM Estonia with Virtual WAM Service Volumes







Remote Control Screens



Coverage and Service Volumes (24 Ground Stations)

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Virtual WAM also for Airport MLAT?

Separate Areas can be identified

- Runways systems
- Aprons
- Approach areas

Even Airport MLAT can benefit from virtual WAM principle

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MAGS

- WAM, TMA, Airport surface, as well as, airport Precision Approach Monitoring
- Great flexibility and scalability to tailor performances to customer needs
- Highly efficient and safe
  (high accuracy, high refresh rate, dual synchronisation, AL4/ED109)
- In operational use e.g. by DFS (sole means of separation in Frankfurt approach) and French DGAC (MLAT Lyon, Nice) in complex operational environments
- Simultaneous Multilateration and ADS-B surveillance
  (includes full ADS-B processing)
- Multiple outputs (including virtual-radar cat 48) to ease interface to ATM system
- MAGS performance exceeds ED129, ED117 & ED142 requirements

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WAM, PAM, MLAT
Example Implementations

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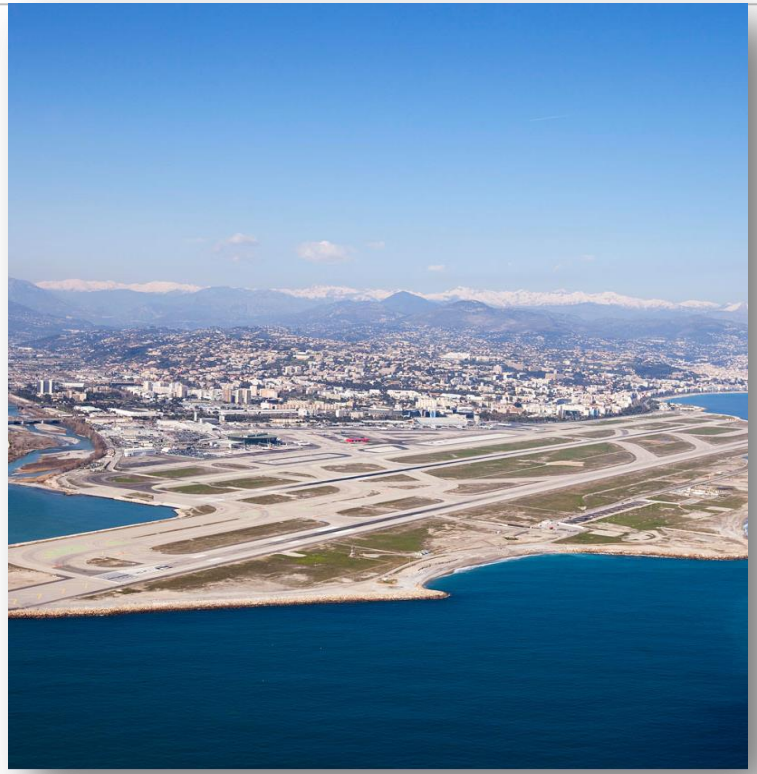
NICE – Aéroport Côte d'Azur, France

- France's 3rd largest airport
- Approx.160,000 movements/year
- Approx. 11million passengers/year
- Serving both domestic and international destinations
- Significant share on general aviation and helicopter traffic serving Monaco, Cannes, and the entire Côte d'Azur
- DTI contract awarded to Thales to supply MAGS airport multilateration system (plus a WAM option)



MAGS – Multilateration and ADS-B Ground Surveillance System

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Ground Station Sites on Airport

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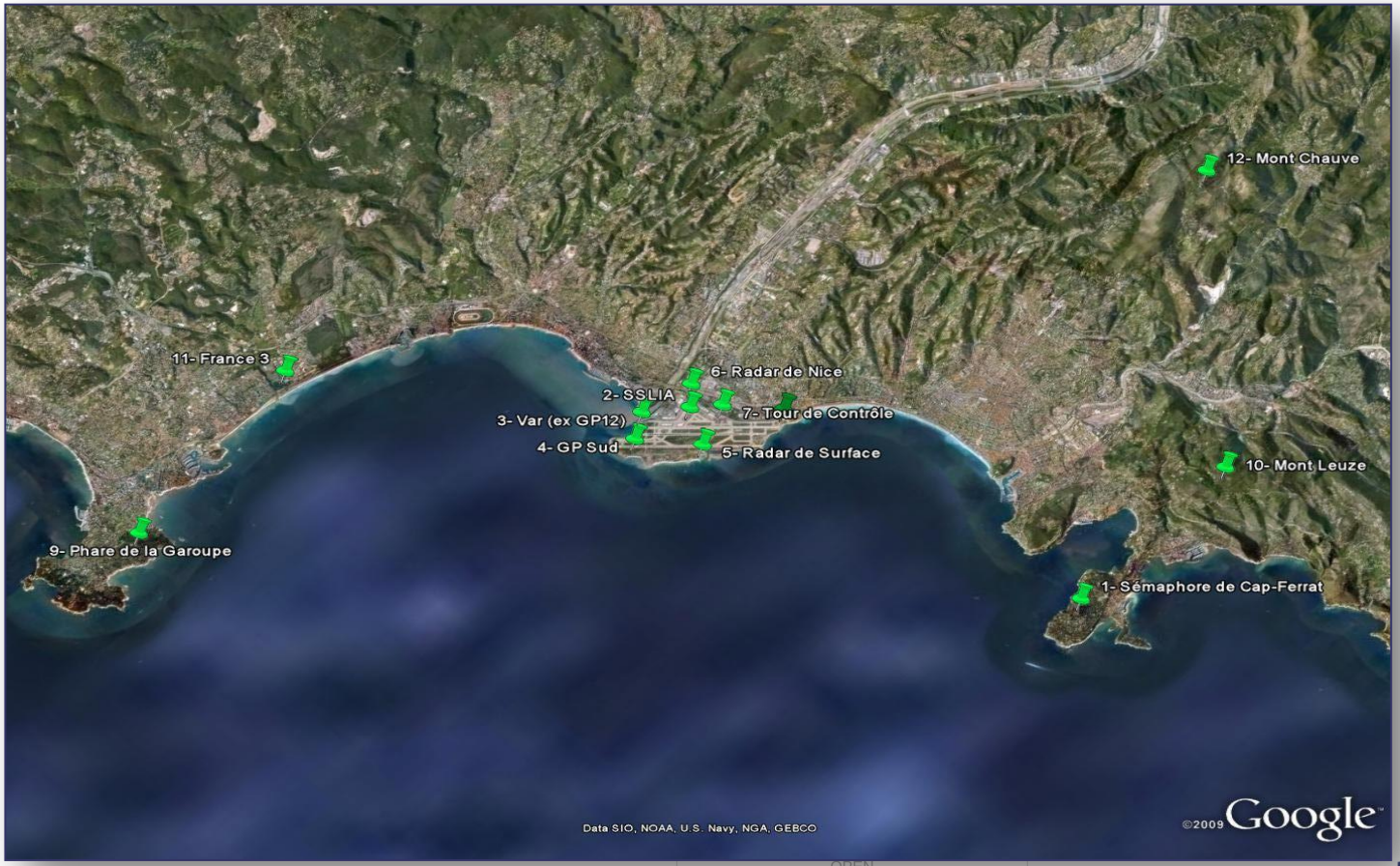
Ground Station Sites outside Airport



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Some Sites on the NICE MLAT System

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WAM Afghanistan

COUNTRYWIDE AND MAZAR-E-SHARIF TMA

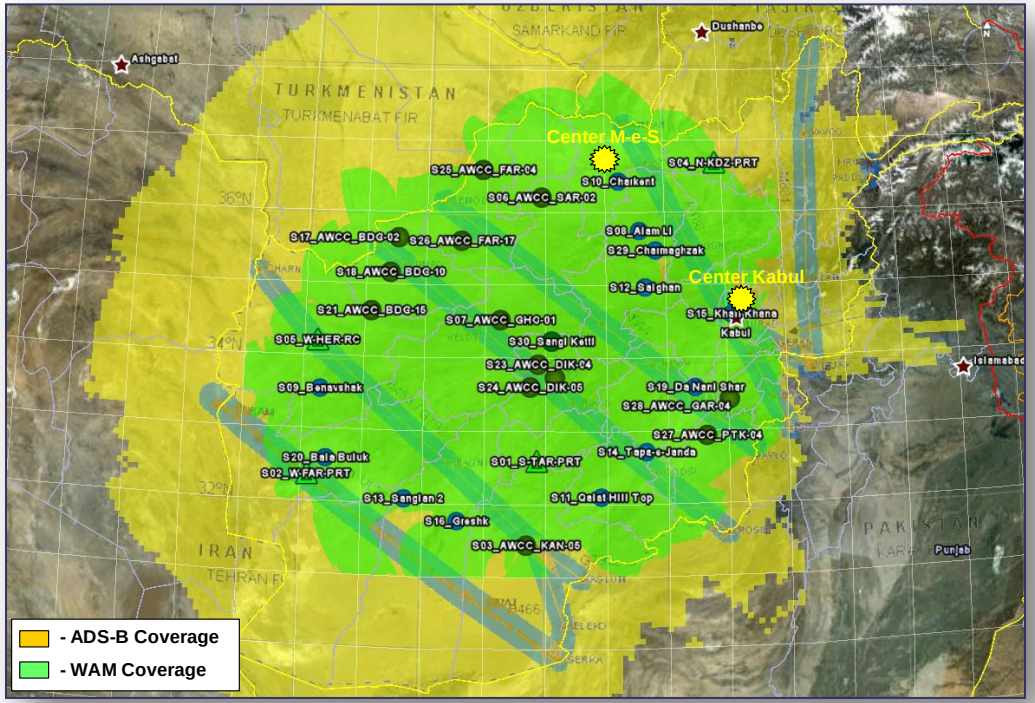
OPEN

Country-wide WAM Implementations

Afghanistan country-wide WAM

- System operational
- WAM + ADS-B 1090 ES
- Operation via VSAT
- Difficult Environment

Fortified Ground Station Site



ADS-B and WAM Coverage in Afghanistan

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Local Constraints

- extreme climatic conditions
- earth quake area
- not much infrastructure
- no safe transport routes
- extreme security risk outsite ISAF camps

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PAM FRA

PRECISION APPROACH MONITOR FRANKFURT

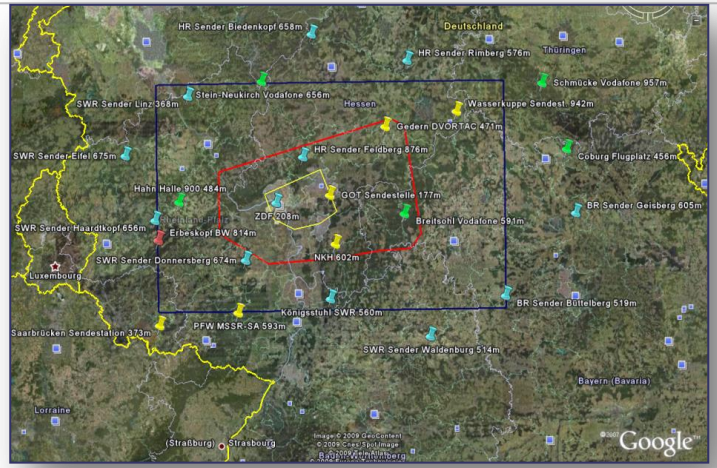
PAM FRA Project

Customer

- DFS
- Main Drivers:
  - High update rate in final approach
  - High accuracy

DFS Deutsche Flugsicherung

DFS Sites
Public-sector Sites
Military Sites
Privately-owned Sites



Main Task

- Provide Multilateration Surveillance within 128 x 80 NM coverage region around Frankfurt International Airport
- Focus on closely parallel approaches
- Primary means of Surveillance in approach sectors

Source: Fraport AG

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PAM FRA required Performance (1/2)

Main Parameters

- Output Probability of Detection: PD ≥ 97%
- Up to 500 targets Mode A/C & S in coverage at any one time (plus > 500 targets outside to be detected to discard)
- Reporting interval: 1 second (Radar: 4.8s, 10s…)
- Direct plot output (no coasting, extrapolation or smoothing)
- Horizontal Position Accuracy: HPA ≤ 50m RMS (ED142: 150 m)
- Probability of Code Detection:
  PCD ≥ 97% (Mode A), ≥ 96% (Mode C)
- Altitude Timeout 1s
- Dual synchronisation required (GPS and RF Time Beacon)
- N-1 redundancy

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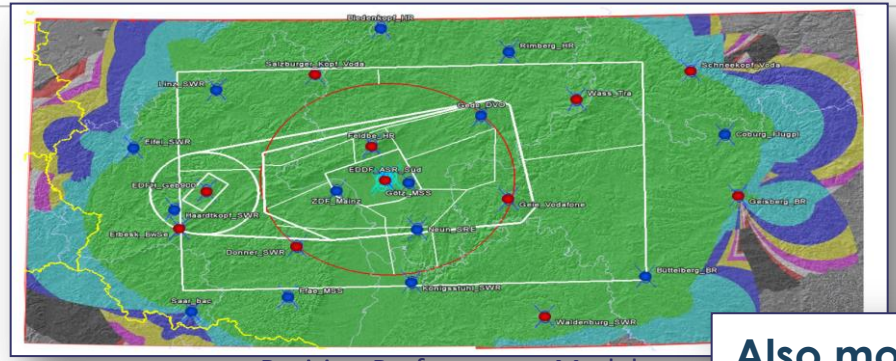
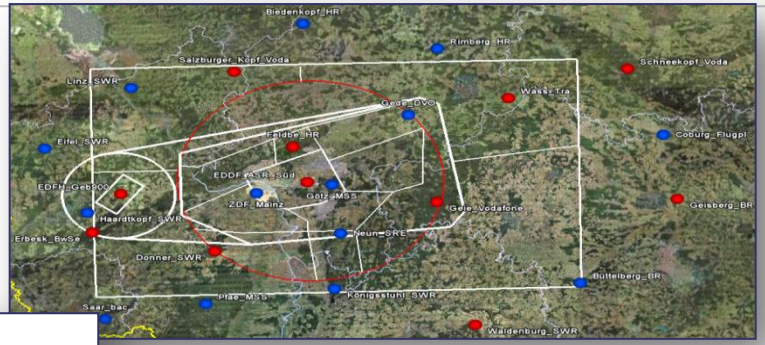
Siting Model



Position Performance Model

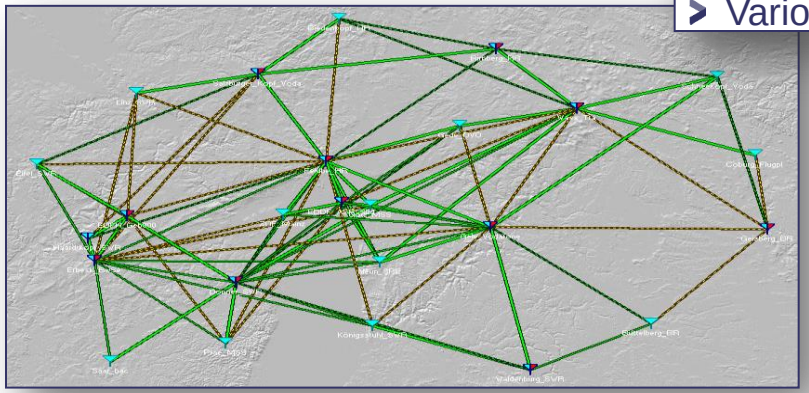


Selected Sites

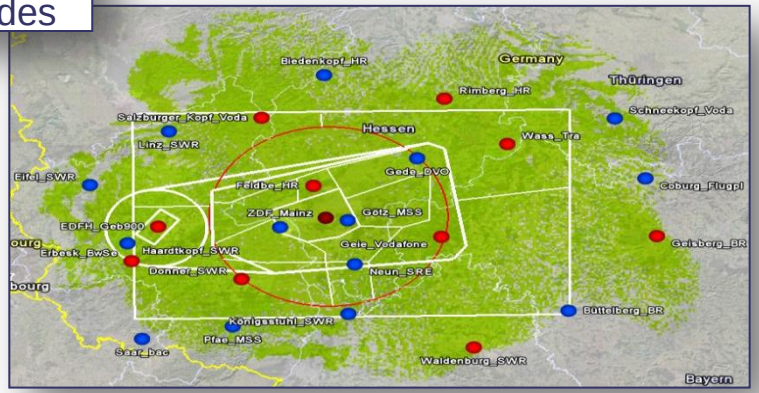
Also modelled:

- all N-1 cases
- all performances
- Various target altitudes

RF Sync Performance Model



Interrogation Performance Model



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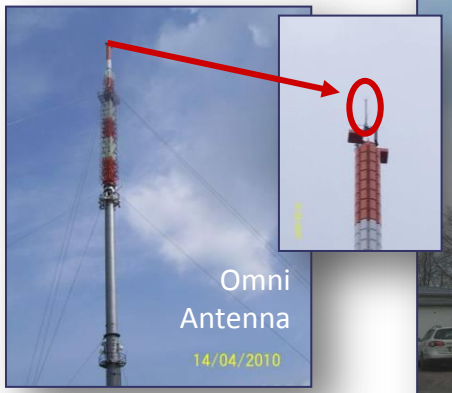
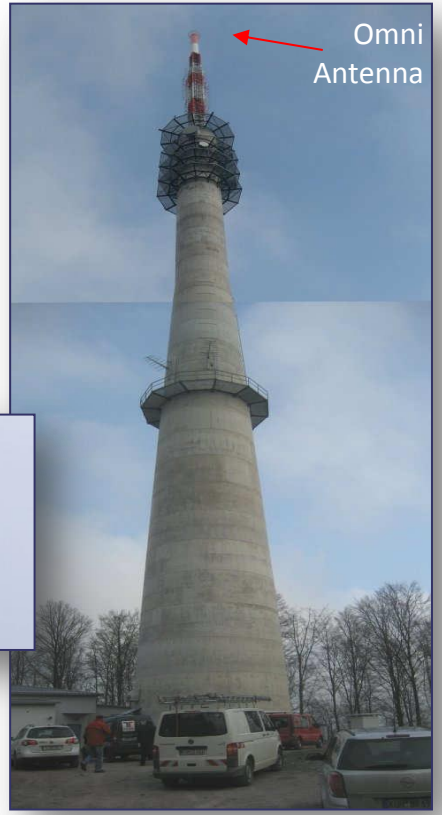
Siting Concept

- DFS concluded a comprehensive initial site survey presenting a selection of more than 80 sites for tenderers to choose from
- Thales identified 34 sites (12 of these for airport GND alone) and their respective role
  - Main driver: low level visibility, rather than power budget
  - Re-use existing sites as far as practial
  - Requires system adaptability: antenna types, EMC, communication, packaging, lightning protection, etc.
  - Confirmed findings in final site survey





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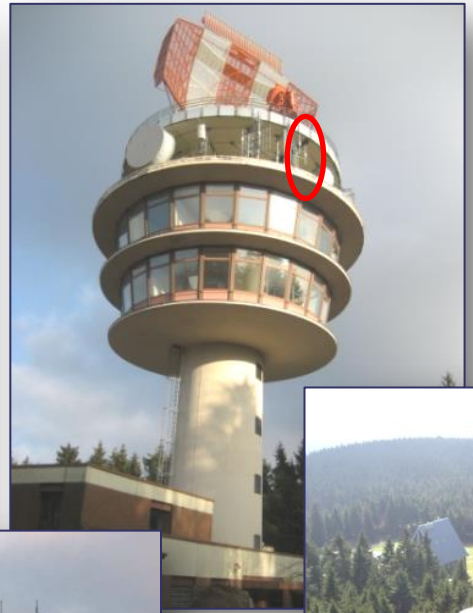
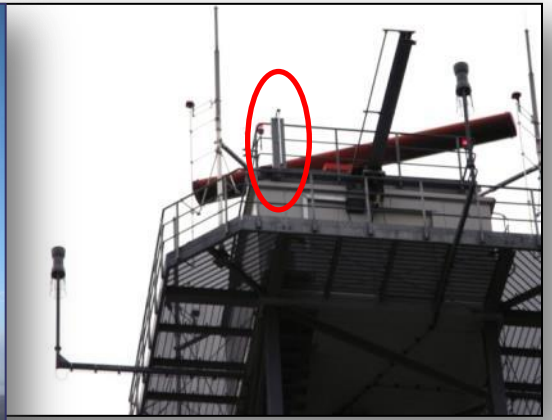
Typical PAM FRA Ground Station Sites





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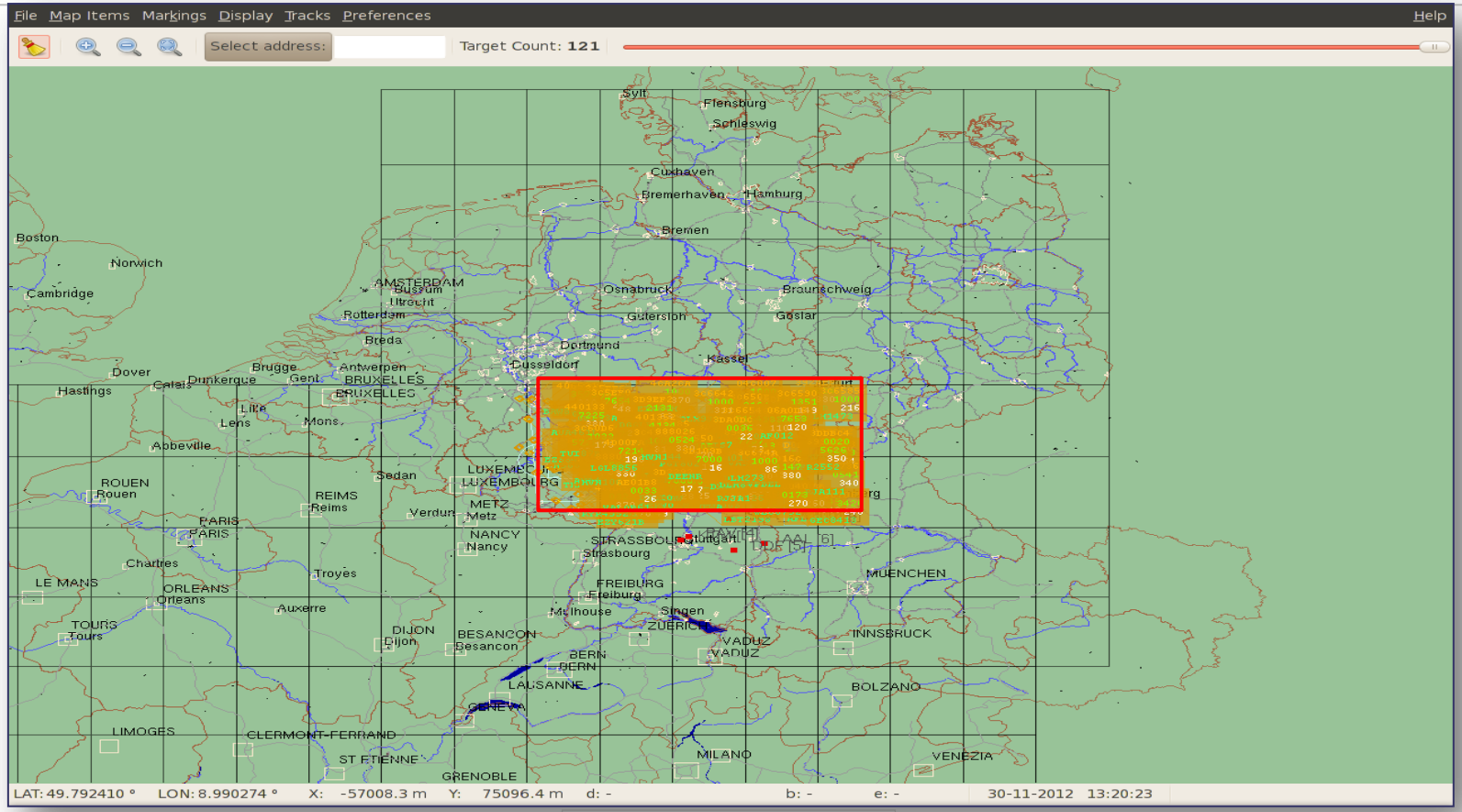
Operational WAM Coverage



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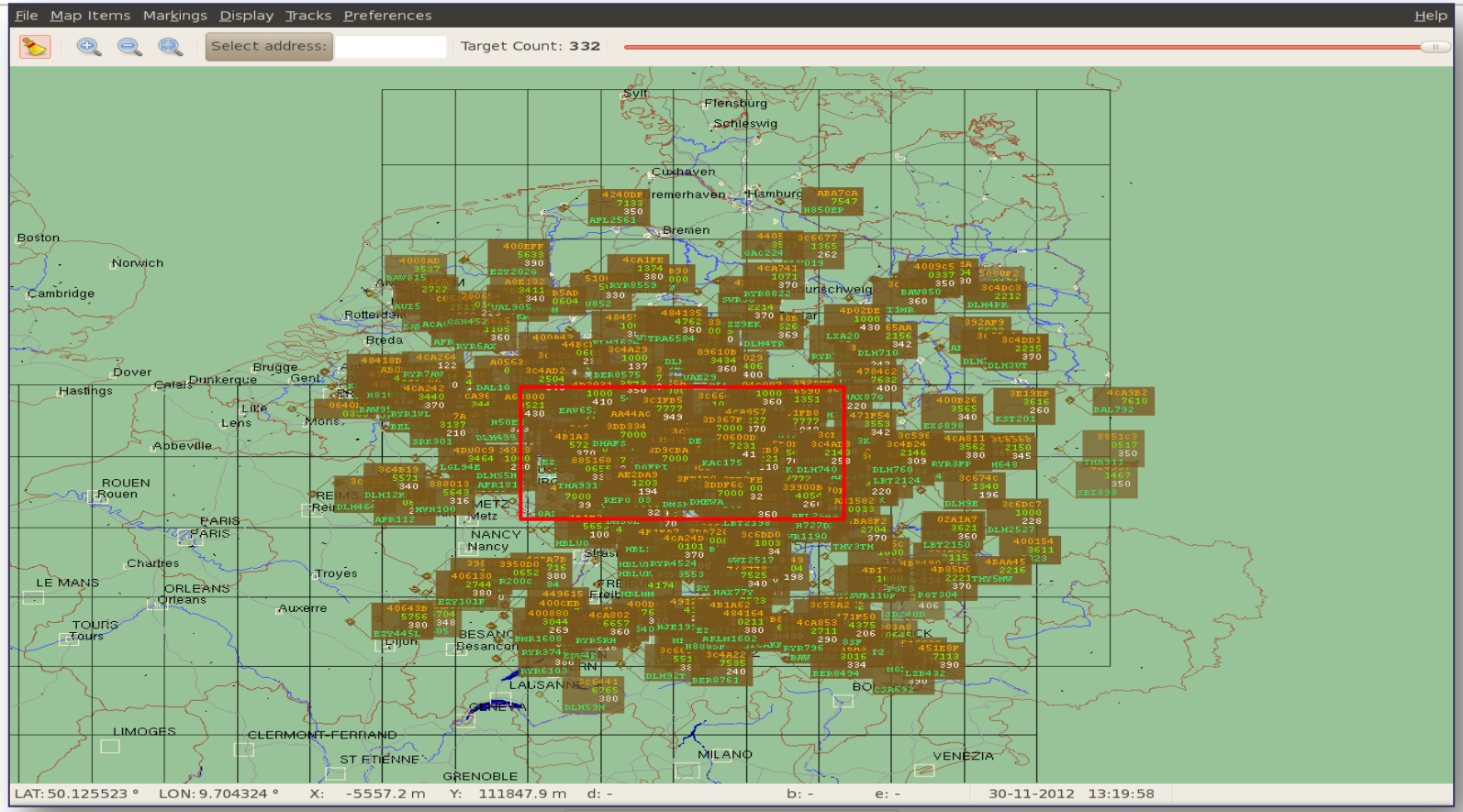
Physical WAM Coverage



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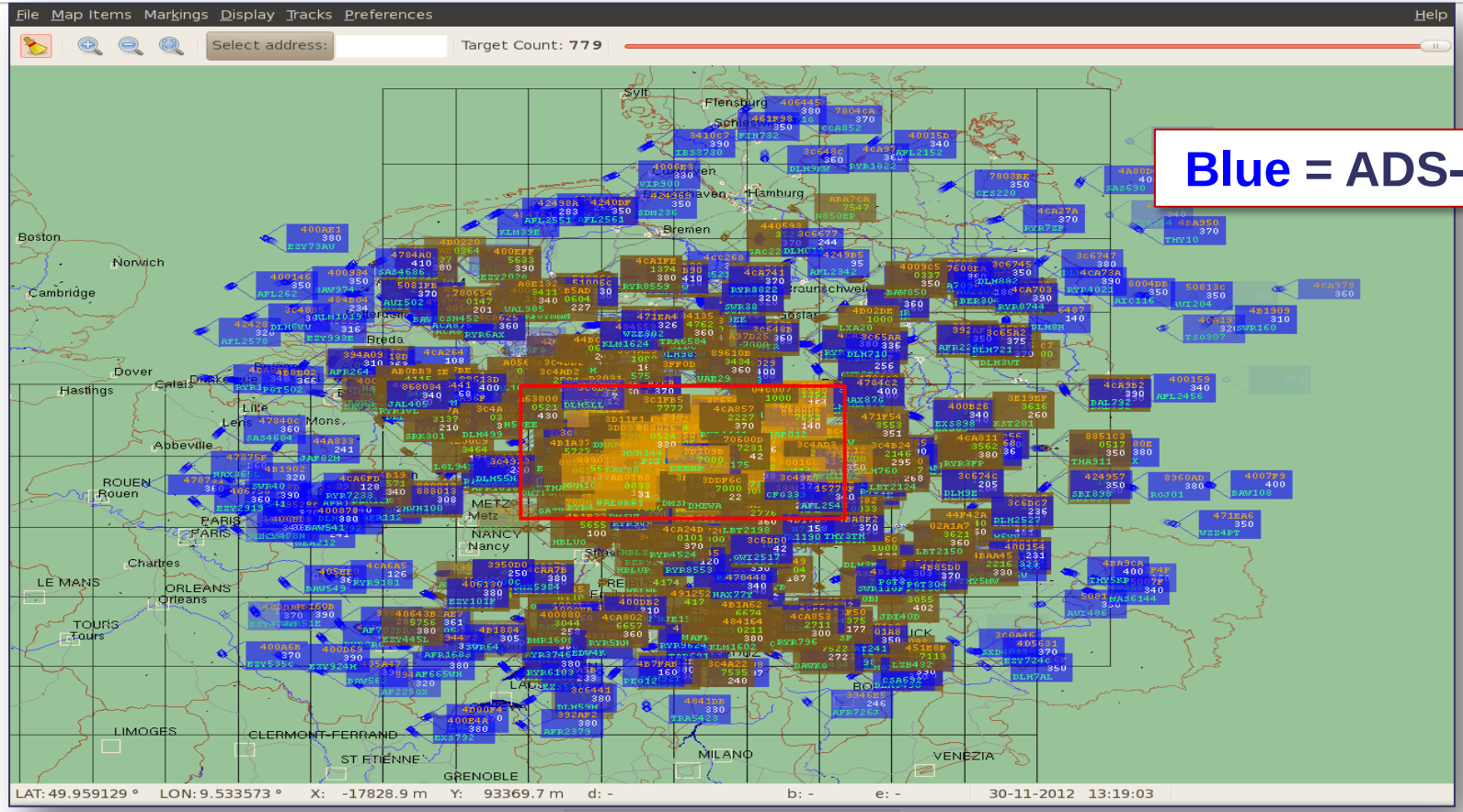
WAM and ADS-B Coverage



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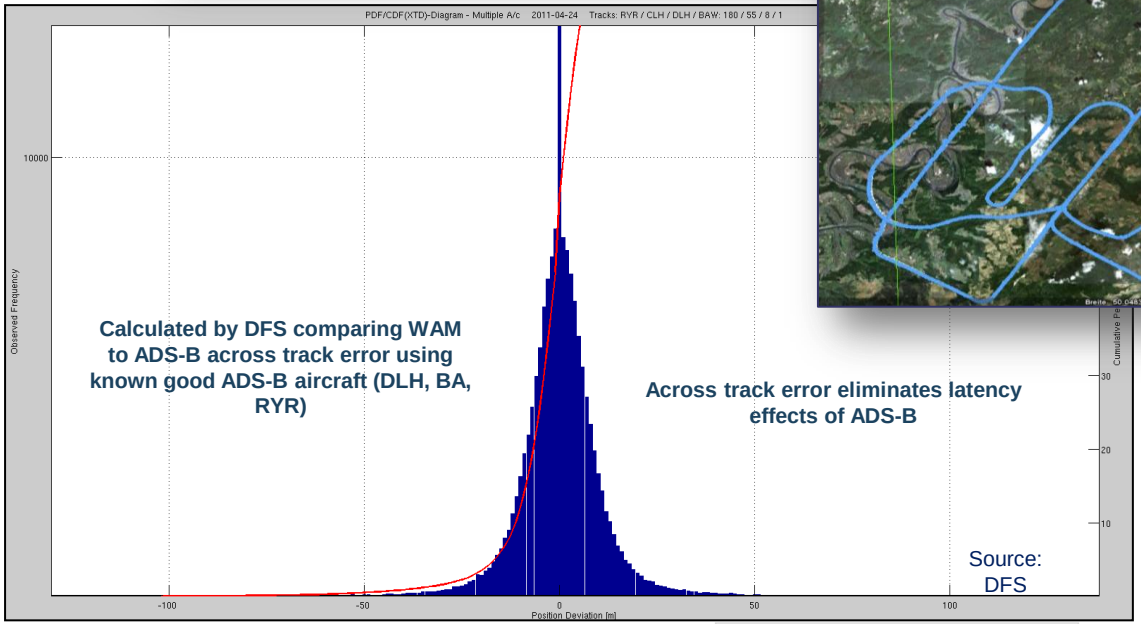
Accuracy PAM FRA

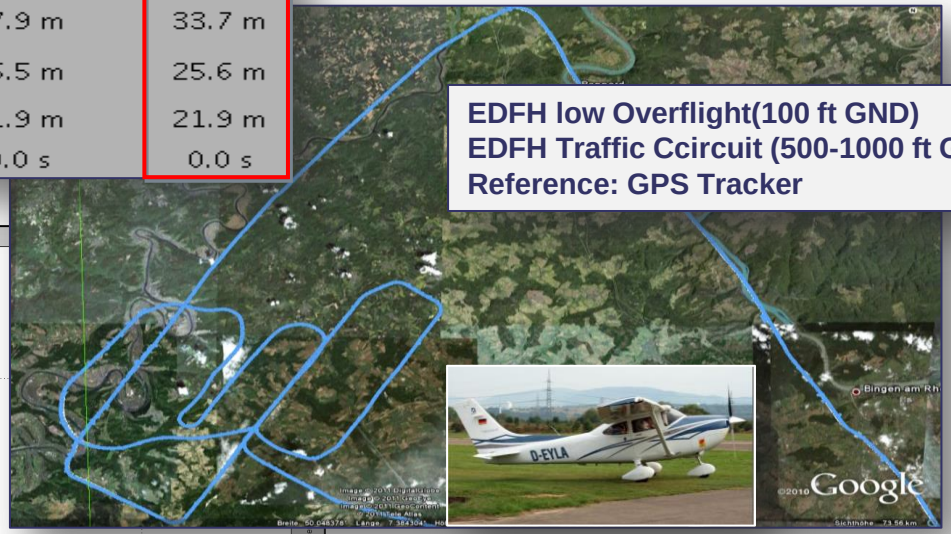
	Mean:	SD:	RMS:
Total Deviation:	18.9 m	27.9 m	33.7 m
Across Track Deviation:	2.5 m	25.5 m	25.6 m
Along Track Deviation:	−0.4 m	21.9 m	21.9 m
Latency:	0.0 s	0.0 s	0.0 s



Calculated by DFS comparing WAM to ADS-B across track error using known good ADS-B aircraft (DLH, BA, RYR)

Across track error eliminates latency effects of ADS-B

Source: DFS



EDFH low Overflight(100 ft GND)
EDFH Traffic Ccircuit (500-1000 ft GND)
Reference: GPS Tracker

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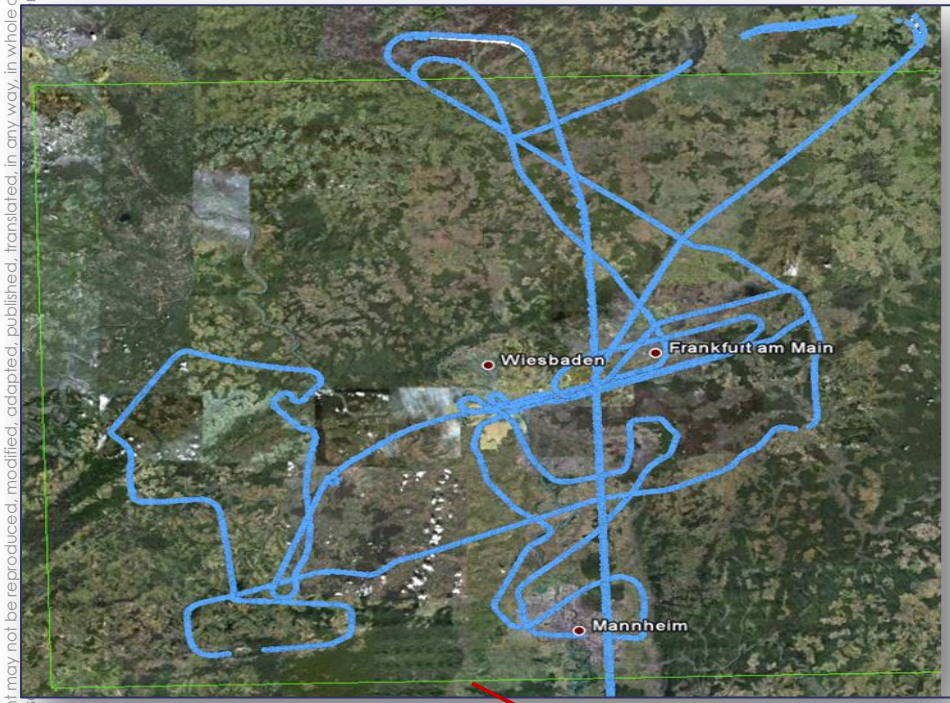
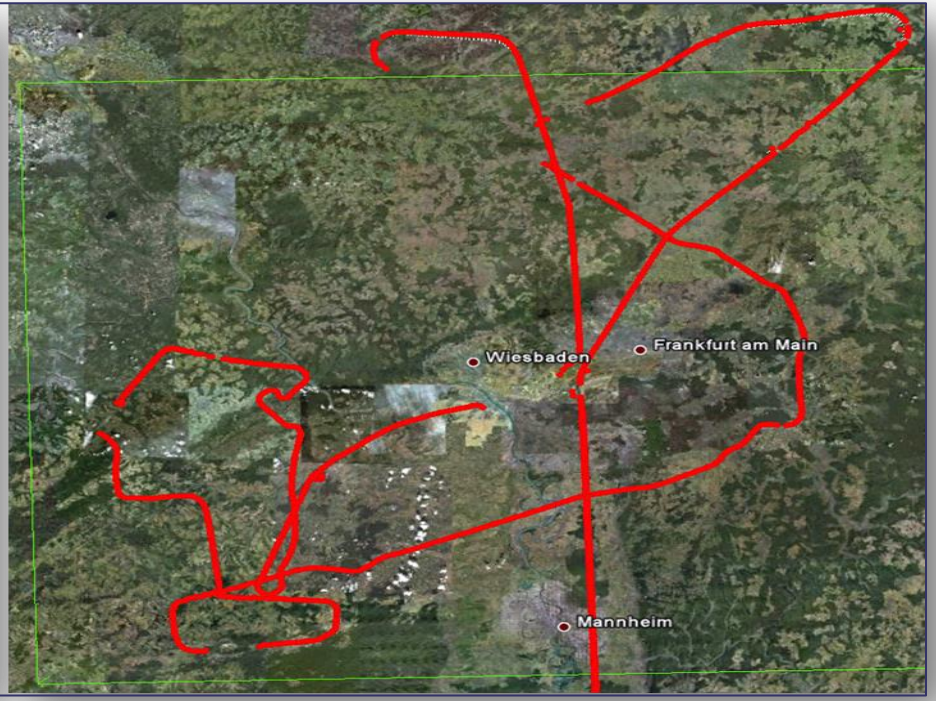
Comparison of Low Altitude Coverage

PAM FRA



MSSR Radar



PAMFRA
Coverage boundary

Source: DFS

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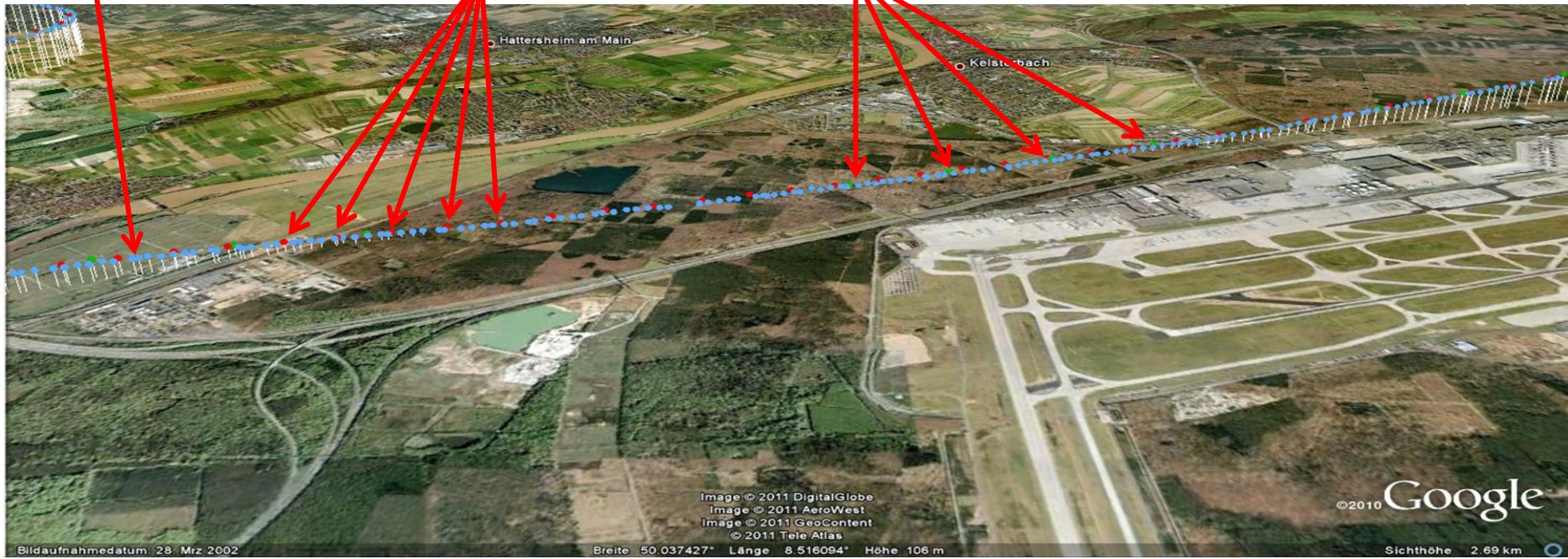
Comparison of Update Rates PAMFRA – ASR – MSSR

PAM FRA WAM (1s) ASR Radar (4,8s) MSSR Radar (10s)



(Testflight: New Runway North – Frankfurt Airport)

Source: DFS

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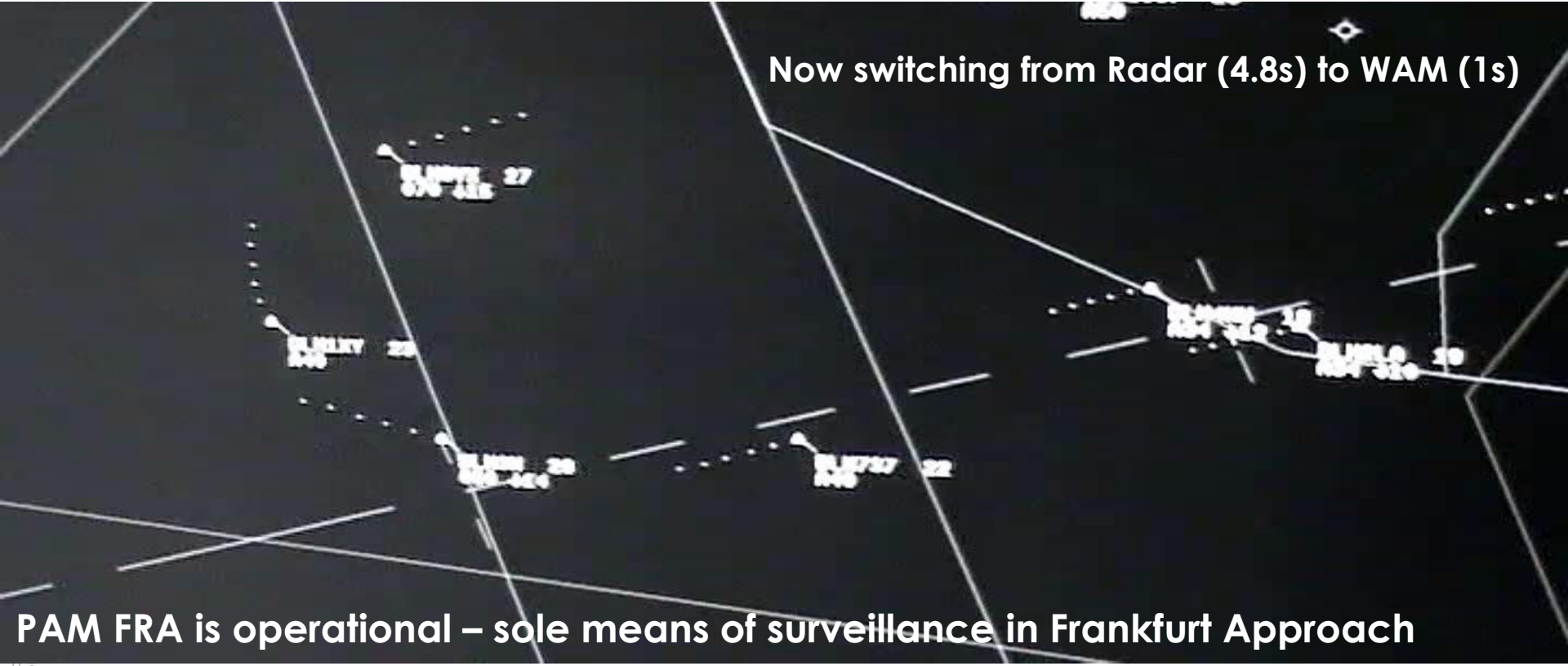
Screen Capture Movie: Comparison of Update Rate at ATC Display

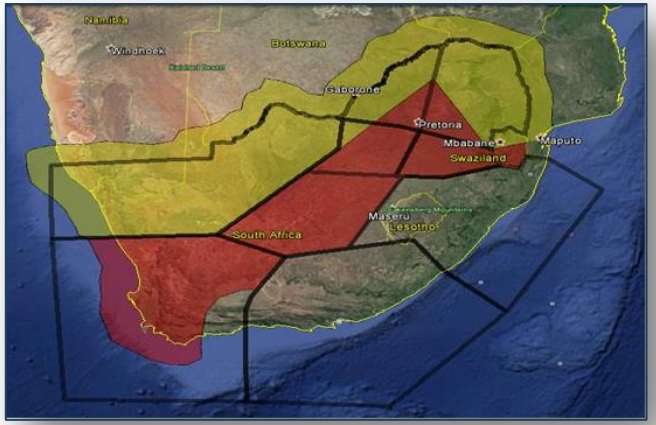


Quelle: DFS

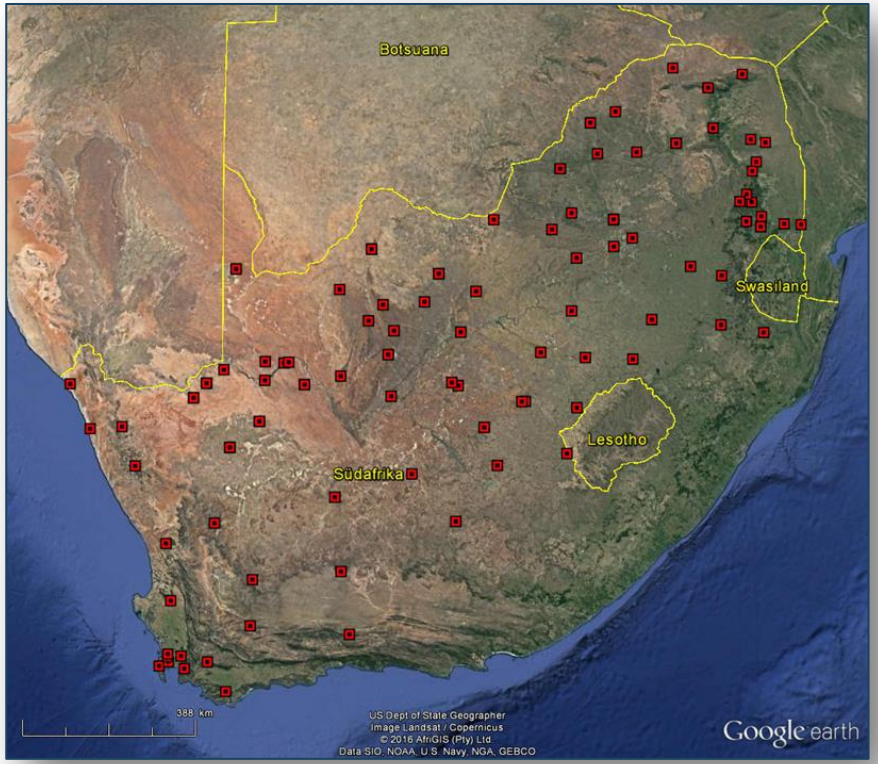
WAM South Africa

World's largest WAM system

- ~100 Ground stations
- Dual Central Processing
- Implemented in two phases



Coverage Area Phase 1 (yellow) and 2 (red))



Operational WAM-Implementation

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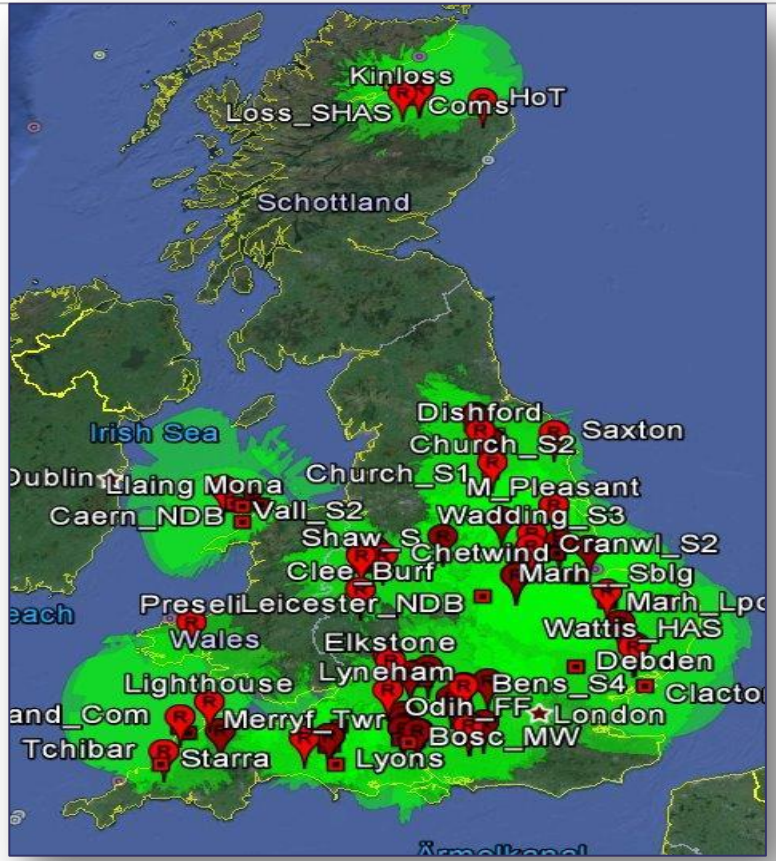
WAM in Marshall project

9 WAM Clusters consisting of

- 112 Ground stations
- 9 Central Processing Locations
- Remote Control and Monitoring
- Engineering Services (Design, FAT, Commissioning), Installation Support and Training
- WAM Project Management

Subcontract to AQUILA, a Joint venture of Thales and NATS



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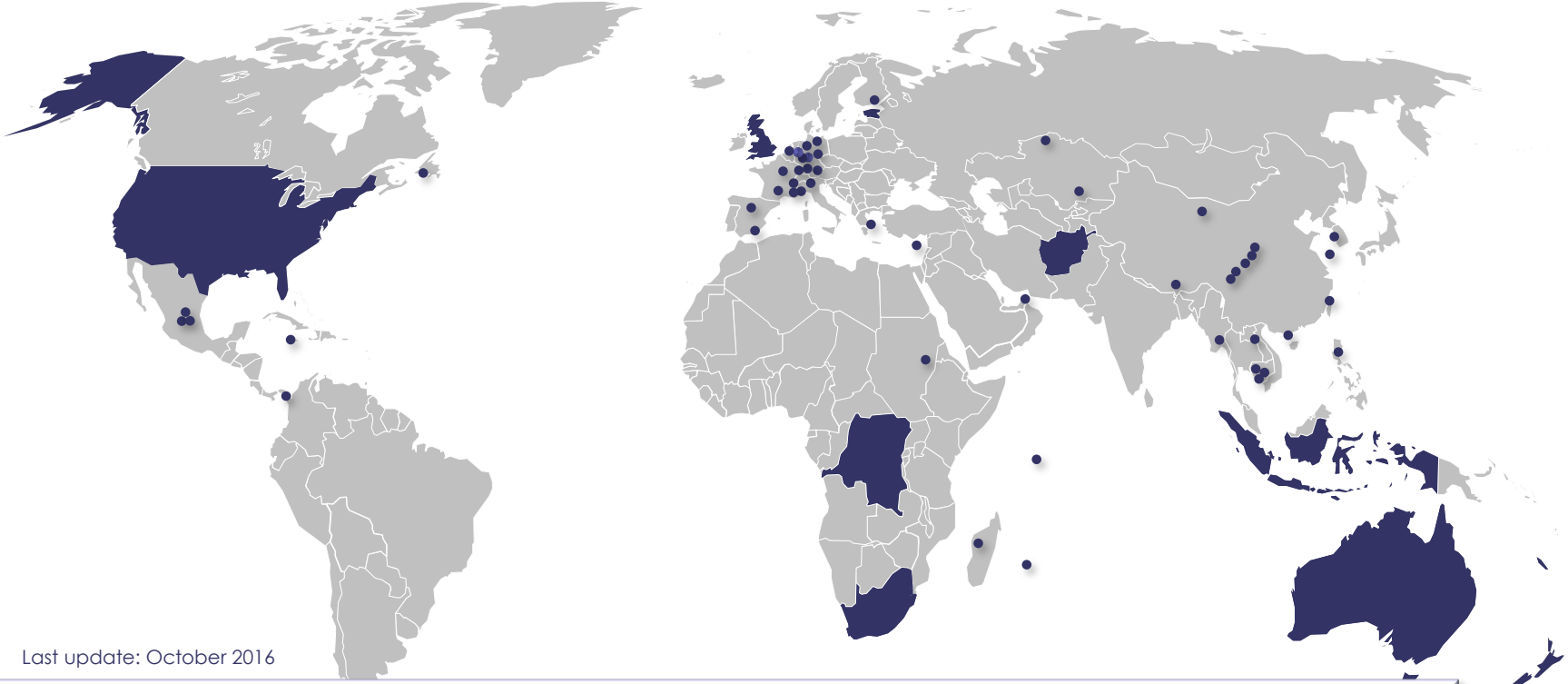
Thales Worldwide Non-Radar Surveillance References



Last update: October 2016

Thales has delivered over 2,000 ADS-B and Multilateration Ground Stations around the World

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Thank you very much!
Happy to answer Questions

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