ADS-B over Satellite
Global Air Traffic Surveillance from Space

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➤ Overview on ADS-B

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Air Traffic Surveillance today …

- Continental Airspace with Surveillance Infrastructure
  - Ground based Surveillance:
    - Radar: PSR, SSR, Mode S
    - ADS-B 1090ES
    - MLAT (Gnd), WAM (en-route)
    - Multiple Coverage
    - Radar Data Networks

- Extensive and continuous Air Traffic Surveillance

- Transoceanic Routes, underdeveloped Regions:
  - Non-Radar Airspace (NRA)
  - Procedural: Pilot’s Position Reports via Voice Radio (1~2 hours)
  - ADS-C: Automatic position reporting via data link (~15min)
  - ATN or FANS1/A ("ACARS"), Satcom / Inmarsat or HFDL

- No continuous Air Traffic Surveillance available
... and the Consequences for transatlantic Routes:

- Ample Separation Distances, non-efficient Use of Airspace
- Expensive and time-consuming SAR Measures
- Example: Crash of AF447 on 1.06.2009 at Flight from Rio de Janeiro to Paris
  - 700 km from Brazilian Coast, 170 km after last voice contact
  - Discovery of crash debris on 6.06.2009
  - Discovery of Black Box after ~ 2 Years
  - Costs of search and recovery of black box: 100 Mio € (Bloomberg, 15.03.2014)
Remedy: Satellite based Reception of 1090ES ADS-B

- Worldwide Reception of 1090ES (1090 MHz Extended Squitter)
  - Mode S Data Format DF17

- Technical Solution:
  - ADS-B Receivers on a Fleet of LEO Satellites
  - Satellite Network for world-wide Coverage
  - Communication Network

- Benefits:
  - Global and seamless Air Traffic Surveillance
    also in Regions, where ground based surveillance is impossible
  - Improved Safety
  - Increased Efficiency:
    - Optimized Separation => Increase of Air space Capacity in todays NRA
    - Optimized and more flexible flight routes
  - Increased efficiency of search and rescue activities
  - No Changes required for Aircraft Equipment
    (European ADS-B-Mandate: Forward Fit until 2015, Retrofit until 2018, Operational 2020
    FAA's NextGen ADS-B Final Implementation Rule: All Airliners equipped from 2020 on)
Overview on ADS-B

Automatic Self-triggered Transmission of Position, without Interrogation
Dependent Surveillance (on Ground) depends on Data derived from Onboard
Surveillance Provision of Surveillance Service
Broadcast Broadcasted Information can be picked up by any Receiver

- Concurrent Technologies:
  - 1090ES (Extended Squitter), DF17 Format on 1090 MHz Mode S Downlink mode most common (European ADS-B-Mandate, FAA’s ADS-B Final Implementation Rule)
  - UAT
  - VDL Mode 4

- Information transmitted:
  - Airborne Position (CPR encoded Latitude, Longitude)
  - Heading and Speed
  - Identity and Category
  - Airborne Velocity
  - Barometric Altitude
  - Call Sign, …
Challenges with Satellite based ADS-B Surveillance:

- **Coverage**
  - 1090MHz Mode S formats not intended for reception of weak signals (<-90dBm) due to poor signal correlation properties
  - Distance between aircraft and LEO satellite ≈ 800 km (≈ 444 NM)
  - „Normal“ coverage of 1090ES ADS-B: 50 NM A/A, 150 NM A/G

- **Modulation Scheme**
  - Pulse Position Modulation not suitable for decoding of signals near to noise level

- **Garbling**
  - Huge coverage because of high receiver position
  - plus stochastic channel access
  - => overlap of ADS-B reports
  - Remedy through use of beam antennas: Spatial selectivity + antenna gain

- **Cone of Silence**
  - Recess in vertical antenna diagram of aircraft transponder antennas
System Architecture of Satellite based ADS-B Surveillance

[Diagram showing the system architecture with sections for Satellite Fleet, Space Segment, Airspace Segment, and Ground Segment, highlighting the flow of data and communication between satellites, aircraft, and ground stations.]
Project “ADS-B over Satellite” by German Aerospace Center (DLR)

- **Objectives:**
  - Proof of Concept: Feasibility of satellite-based ADS-B Surveillance
  - In-Orbit Demonstration on ESA-Satellite PROBA-V
  - Identification of Key parameters like Probability of Target Acquisition, Probability of Detection and Prob. of Identification

- **Project Duration:** 1\(^{st}\) Q. 2011 until End of 2\(^{nd}\) Q. 2014

- **Cooperation:**
  - Institute of Space Systems (RY) in Bremen, Germany
  - Institute for Flight Guidance (FL) in Braunschweig, Germany

- **Contributions:**
  - Institute RY: Development and Assembly of a space-qualified ADS-B Receiver and Antennas
  - Flight Calibration Services: Development of ADS-B receiver
  - Institute FL: Verification Concept and Evaluation of ADS-B Data

- **Further Cooperation:** RY with SES-ASTRA / ESA: Provision of Data Server
ESA PROBA-V-Mission

- ESA Small Satellite Mission PROBA-V
- Prime Contractor QinetiQ Space nv
- Launch Mass: ~140 kg
- Launcher: VEGA Rocket
- Launch Date: 7 May 2013 from French Guiana
- Orbit: Sun-synchronous Polar Orbit, 820 km Altitude, 98.73° Inclination
- Satellite Control and Communication via Ground Station Redu in Belgium.
- Main Mission: Vegetation Scanner
- Hosted Payloads: ADS-B, Energetic Particle Sensor, Gallium Nitride X-band Power Amplifier
ADS-B Payload Test and Integration on PROBA-V
PROBA-V on VESPA Adapter, on VEGA in Launch Tower and in Space
ADS-B over Satellite: Technology Demonstrator vs. future Operational System

**PROBA-V In-Orbit Demonstration:**
- **Constellation:** Single Satellite
- **Main Mission:** Vegetation Scanner
- **Hosted Payload:** ADS-B-Receiver of DLR Project

**Operational System:**
- **Constellation:** Satellite Network
- **Main Mission:** Multichannel ADS-B- Receivers and Multiple Antennas
- **Hosted Payload(s):** Other
Aircraft Tracks detected during a Satellite Pass
3D Histogram of all received Messages in Footprint: The Effect of the Cone of Silence

Radiation Pattern of Satellite Antenna

Radiation Pattern of Aircraft Antenna

K. J. Keeping, J.C. Sureau: Scale model Pattern Measurements of Aircraft L-Band Beacon Antennas, Project Report ATC-74, Lincoln Laboratory, MIT, April 1975
Distribution of decoded Position Messages vs. Grazing Angle
Example Trajectory of Aircraft taking off from Lijiang Airport, South China
Trajectory of the Aircraft taking off in Lijiang in the Footprint
Performance Parameters of ADS-B over Satellite

PTA: Probability of Target Acquisition
POD: Probability of Detection

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Receiver Technology: SSR Bandpass Raw Data from IF (1)

- Receiver Dynamic Range between -90dBm and -104dBm
- The ADS-B receiver can downlink raw data samples of full Mode S telegram length at 105MSPS/s / 16 Bit
- Raw data samples are beneficial for feeding new receivers and correlators during development phase
Summary

The technical Feasibility of Satellite based Air Traffic Surveillance with 1090ES ADS-B was proven by the PROBA-V In-Orbit Demonstration.
Thank you for your Attention!

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