Supporting European Aviation

EUROCONTROL

ADS-B Spectrum Issues: RF Interference to GNSS

ADS-B Webinar, ICAO EUR/MID

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FOUNDING MEMBER SESAR JOINT UNDERTAKING

NETWORK MANAGER

Some History of Using ADS-B to Detect GNSS RFI

- 2014: Preparation for EU PBN Implementing Rule:
  - ATC Human in the Loop Impact Studies for regulatory impact assessment including GPS Loss
  - Budapest simulation, high level of “GPS-only for PBN” traffic (20%)
  - ATCO Statement: **“I can deal with GPS RFI, just tell me when it starts, how many sectors are affected, and when it ends”**
- Started to look at feasibility of using ADS-B data gaps as a GPS RFI Monitor
  - Using open source providers has a variety of challenges (filtering, coverage)
  - Initial ADS-B versions (0, 1) had a variety of anomalies
  - Often had either ADS-B data OR confirmed RFI source location and time, but not BOTH
- By now, concept is mature and includes geolocation capabilities
  - Presented to EUROCAE / RTCA CSC in 2018
  - RTCA SC159 / EUROCAE WG62 including RFI detection in next generation GNSS standards
  - ICAO NSP agreed job card to work on “GNSS RFI Status Downlink”
  - **Basic capability enabled by current ADS-B, would like to improve it further**

Envisioned Next Generation RFI Mitigation Function

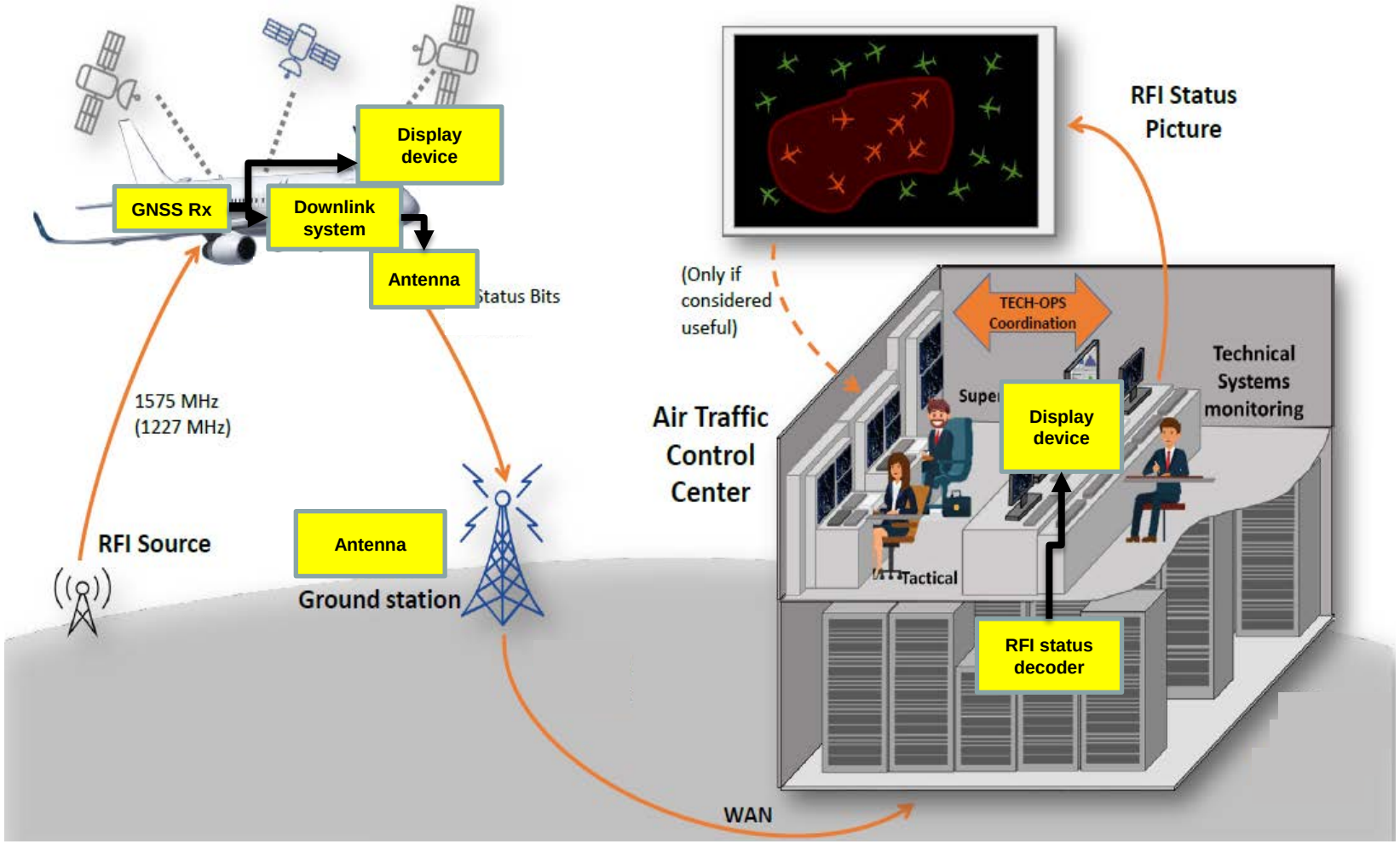
Functional architecture (Single Frequency Model)

Steps

1. GNSS Receiver **detects RFI** and **reports** it to the **ground**
2. Ground stations **process RFI status** and allow generating an integrated RFI status picture for multiple aircraft
3. TECH services coordinate with OPS on impacted areas and launch **operational mitigation measures**
4. Report to the **radio regulator**

➔ ***Detail CONOPS still needs further refinement***

➔ ***Can already be implemented with current ADS-B***



OPS Requirement and ICAO Context

Validated OPS Requirement through EUROCONTROL NETOPS

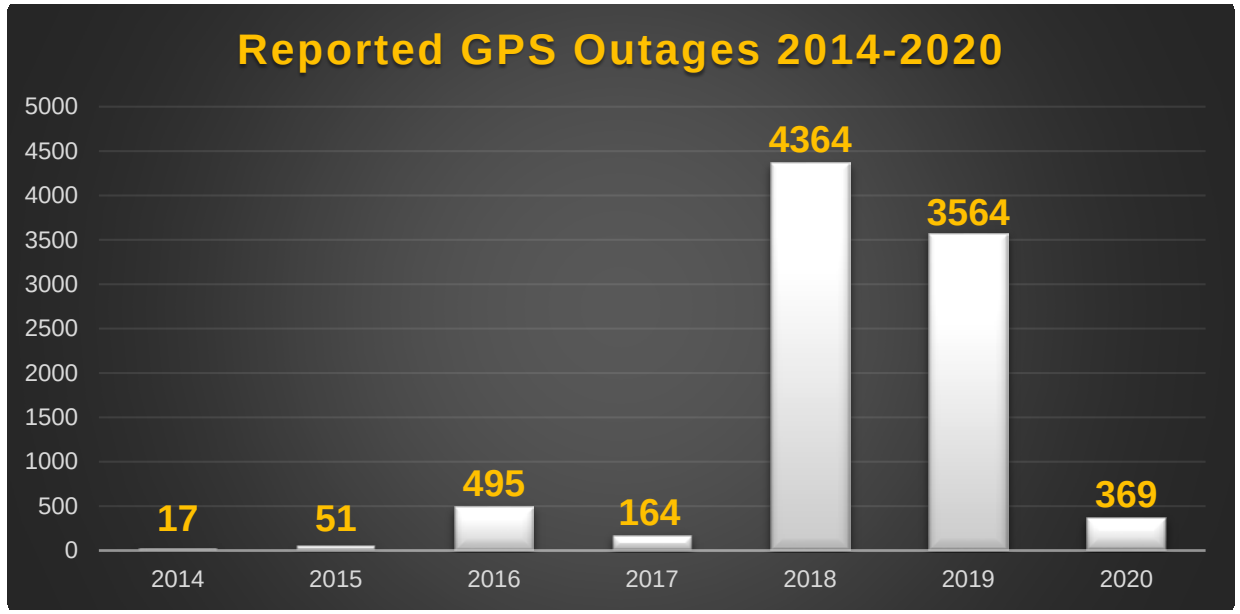
- **NETOPS Conclusion 23/10:** NETOPS agreed the following recommendations:
- *b)* With reference to paragraph 3.2: *confirm the Operational need to be aware of the geographic area of GPS outages and that they (ATC) intend to use this information in the context of contingency operations.*

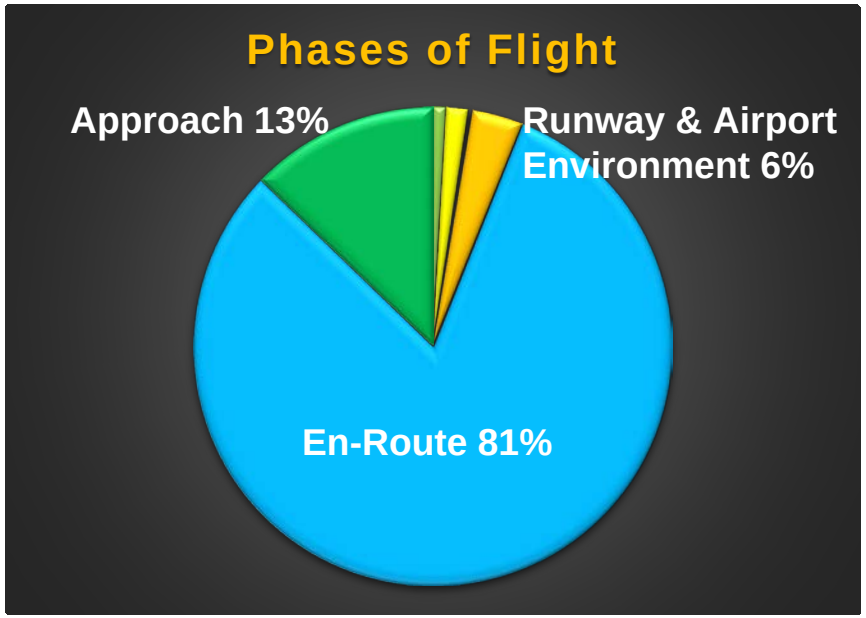
Summary Report Twenty-third Meeting (NETOPS/23) Brussels, 28 Feb - 1 March 2019, NETOPS/24 WP02

ICAO State Letter 2020/89, AN 7/5-20/89, 28 August 2020

- Based on 40th Assembly papers from Europe, Saudi Arabia, and IFATCA/IFALPA/IATA
- **Action required:** Note the criticality of the issue and the importance of action by States to address it by making use of the ICAO guidance provided in Doc 9849, *Global Navigation Satellite System (GNSS) Manual* and by taking any other measures as appropriate
- *Various recommendations including*: cooperate for **design, development and realization of Ground and on-board mitigation techniques of GNSS loss of service**

EVAIR: Collecting Pilot Reports of “GPS Problems”





- EUROCONTROL Voluntary ATM Incident Reporting (EVAIR)
- 250 Participating Aircraft Operators
  - Coverage: Europe, Middle East, Northern Africa
  - Detail reports subject to confidentiality
- 2018 / 2019 trend: average of 10 GPS reports DAILY!
  - 2020 decrease due to reduced flights (COVID) and reporting

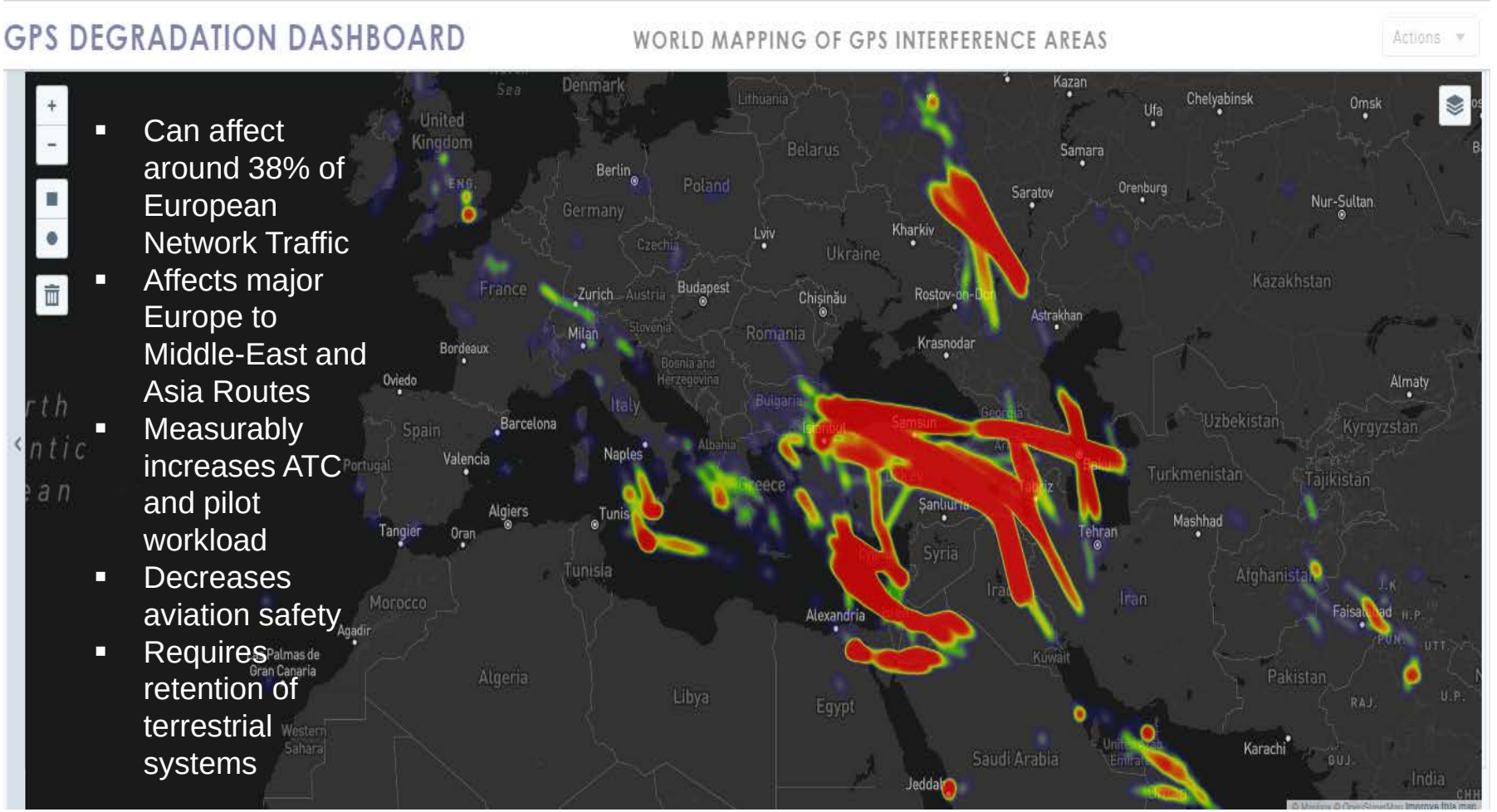
<u>Report Analysis</u>
RFI most probable cause in absence of GNSS constellation or solar issues, especially if multiple aircraft are affected in a region

The most frequent problems reported by pilots in EVAIR GPS outage reports

- Failure of one or both GPS boxes
- Disagreement between GPS positions and NAV FMSs
- Terrain warnings, sometimes with pull up requests
  - (In the majority of cases pull up warnings were disregarded by pilots or function switched off)
- Unable to fly RNP and request for radar vectoring
- In a few cases lack of situational awareness and requests for the assistance of radar vectoring to reach the destination
- Wind and ground speed wrong presentations
- Lost ADS-B L/R, wind shear, terrain and surface functionalities
- Aircraft clocks L or R or both failed or began to count backwards
- EICAS Transponder L/R

GNSS RFI as detected by Airbus Aircraft

- Post-OPS Monitoring from participating aircraft operators
- 1 JAN 2021 to 3 SEP 2021
- **RFI continues despite reduced pilot reports**
- Provided by Airbus through Skywise



This picture matches EVAIR Pilot Reports and has been "stable" since 2018!

Could Military Jamming Power be LIMITED?

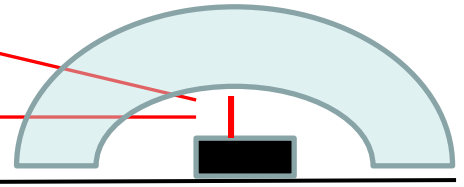
Jammer Power	Impact Radius on Aircraft at FL350[1]	Maximum Outage Duration at ENR Speed[2]	"Protection" against military GPS system near ground[3]
10W	77NM	20min	20km
100W	230NM	1h	60km

Air Transport Aircraft
at En-Route Altitude
(no anti-jam capability)

1: Assuming -6dB antenna gain and 15dB tracking margin
2: ENR speed assumed 450 knots
3: Assuming a +20dB J/S capability (very modest!)

"so far as possible, take measures to prevent harmful interference" – ITU Constitution Article 48 No. 203, on freedom with regard to military radio installations

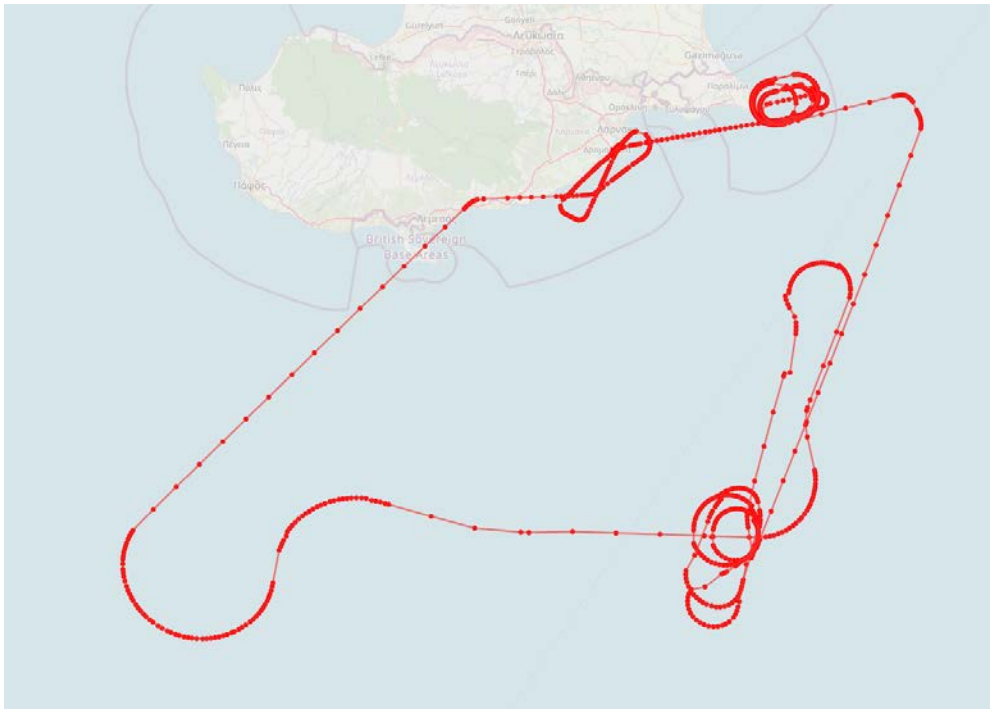
Drone with Anti-Jam Capability

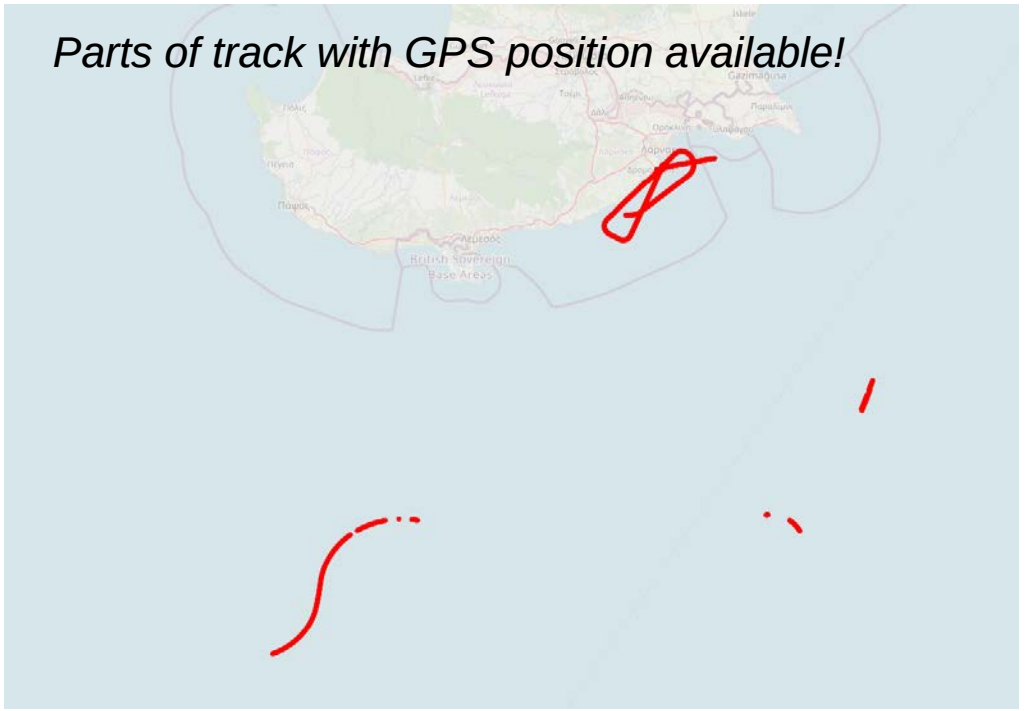


Jammer Antenna

DLR Airbus A320 Test Flight in Cyprus Airspace

13 FEB 2020 Flight Track





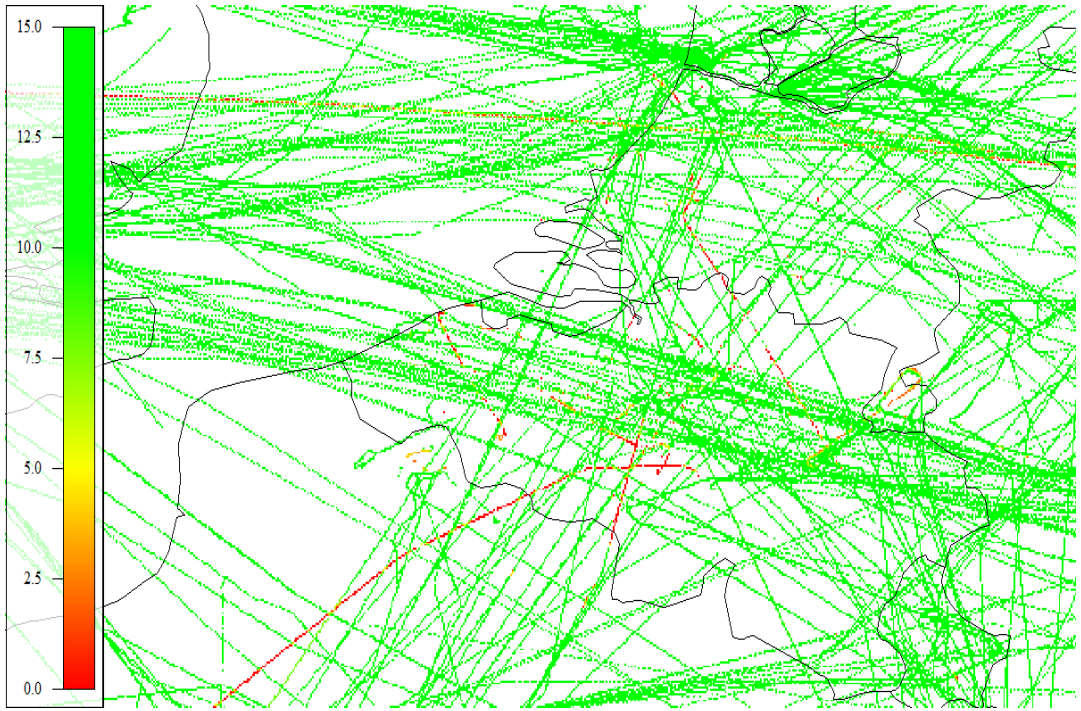
- DLR: German Aerospace Research Center
- Flight conducted in an area about 250km (east-west) x 170km (north-south) between 10’000 – 30’000 ft altitude

- GNSS signal reception heavily affected for most part of the flight, confirmed by RF measurement
- Multiple GPS-related alerts in cockpit (GPS 1 Fault, GPS 2 Fault, GPS Primary Lost)

Observations from a Recent RFI Case

- End March 2021, 40W Anti-Paparazzi Drone Jammer on a Private Yacht
  - Jammer accidentally turned on by maintenance personnel, Southwest NL
  - Impacting air traffic in Netherlands, Belgium, France and MUAC for a few hours
- Core European airspace with climbing and descending traffic from some major airports
  - Info on affected flights **could be quite critical**, while large majority of flights **sees no impact**

ADS-B Gaps: 93 aircraft impacted,
Multiple aircraft per sector



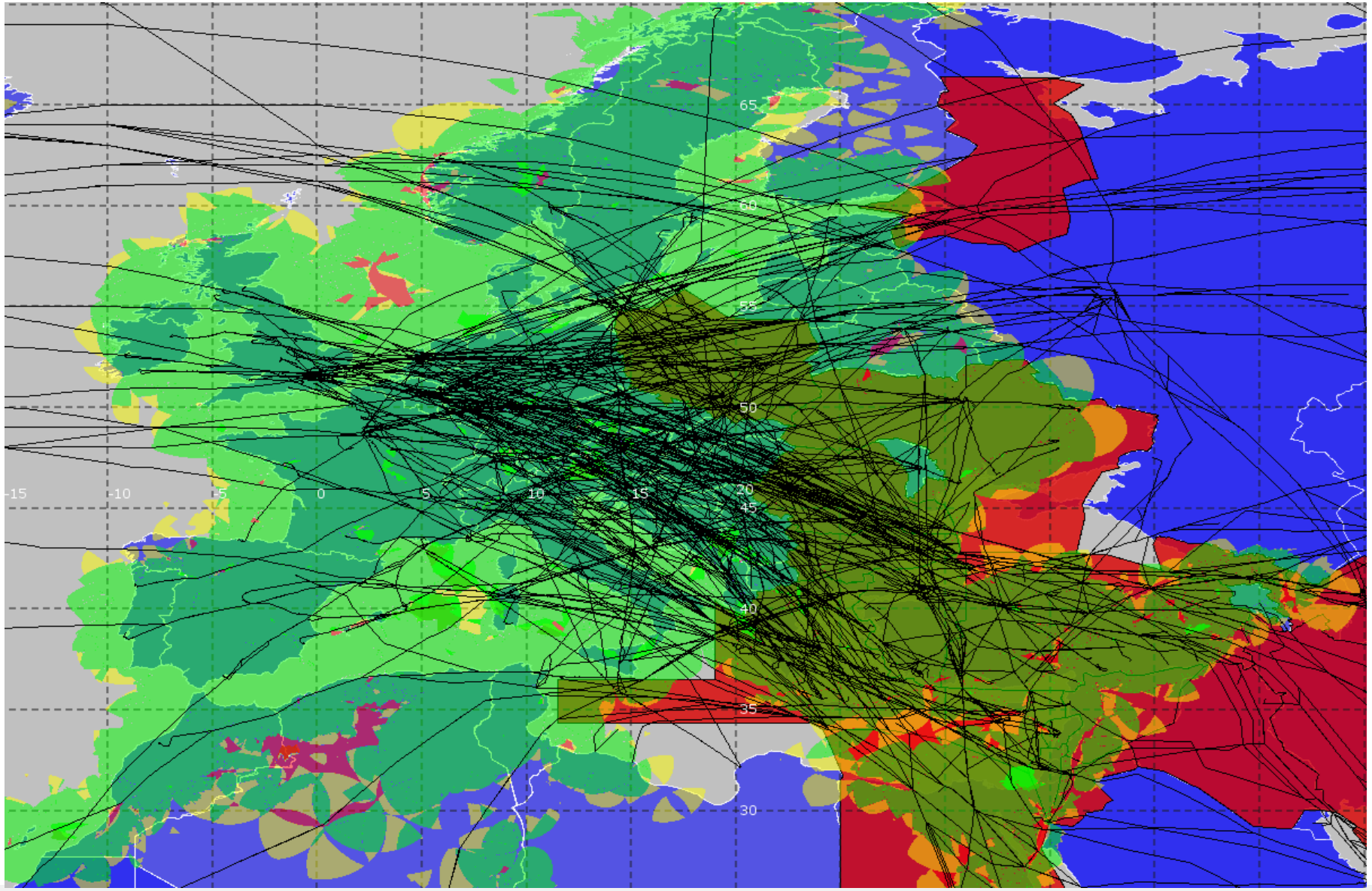
ADS-B PIC, All Flights during event

Developing Solutions: Real Time ADS-B Monitoring

- Lack of ADS-B Position Reporting by multiple aircraft is a reliable indicator of GNSS RFI
  - Can be combined with ADS-B Position Quality Indicators
  - Serendipitous capability: current ADS-B not specifically designed for RFI monitoring

- Monitoring Objectives
  - **Operational Risk Management**: ensure traffic sectors can remain at nominal capacity safely as long as possible
    - Depends on other available CNS capabilities: alternate navigation (DME/DME, IRS, VOR/DME) and SUR infrastructure (SSR Mode S, PSR)
    - Depends on aircraft equipage: especially medium to long-haul air transport traffic normally well-equipped with multi-sensor navigation
    - Slight ATC & pilot workload increase as long as only few aircraft are affected
  - **Technical Intervention**
    - Determine RFI Source Location if possible
    - Report incident to radio regulator for resolution

EUROCONTROL Airspace Risk Assessment



Dark RED: FIR affected by GNSS RFI

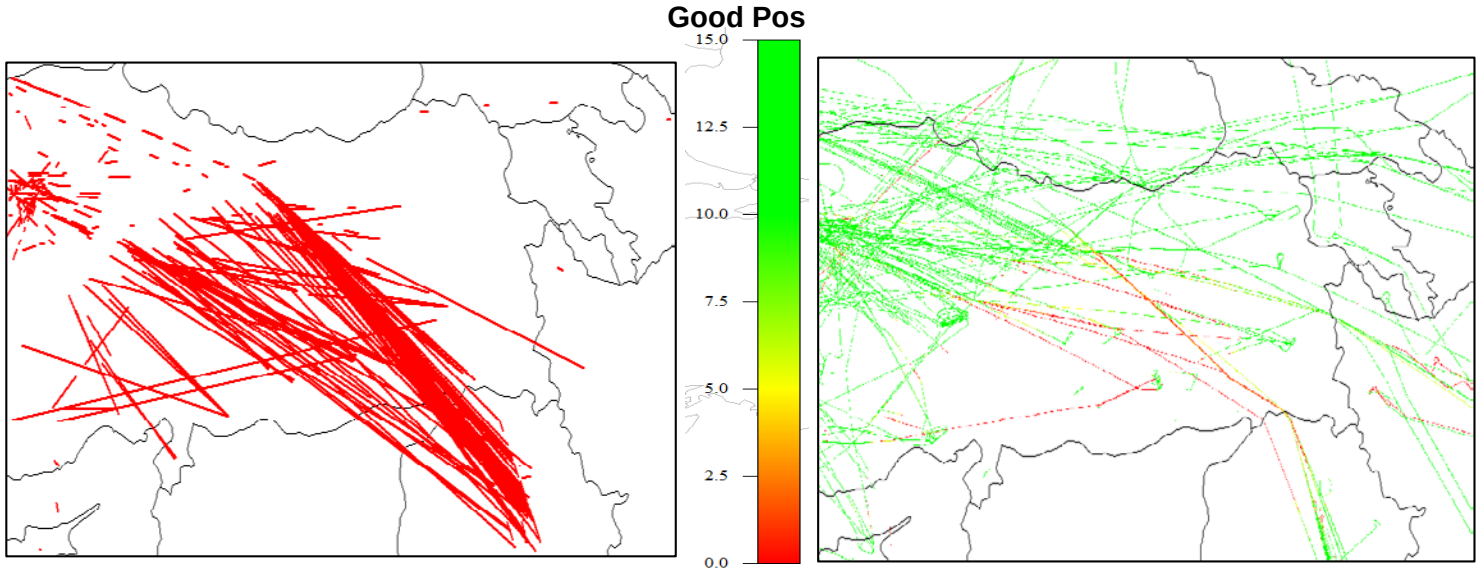
Black: Flights crossing affected FIRs

Green: Alternative DME/DME RNAV Coverage Available

Yellow/orange: DME/DME RNAV Coverage Available but no redundancy

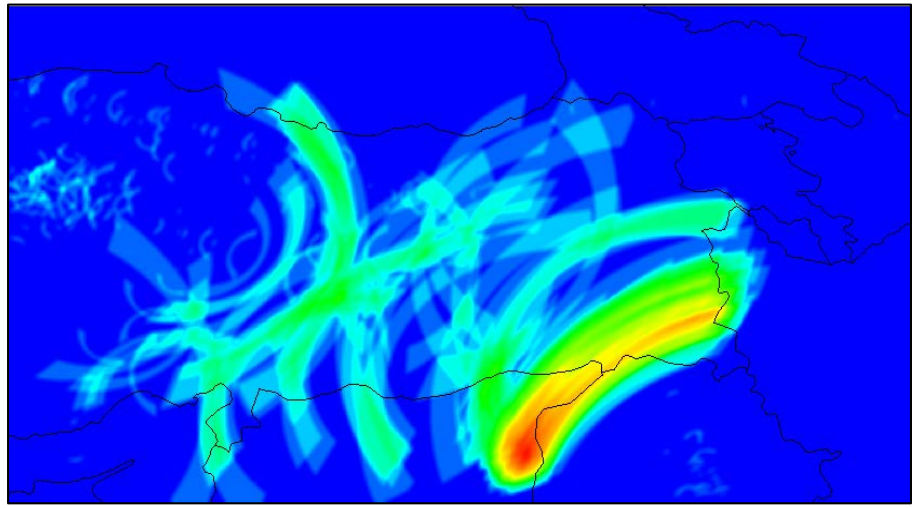
Light red: No DME/DME RNAV Coverage

Detection & Geolocation of GNSS RFI using ADS-B



ADS-B gaps (Loss of GNSS)

Position integrity Category



RFI Source Heatmap

Using Power Difference of Arrival (PDOA) approach

Operational Impact
Identify impacted area / routes / flights

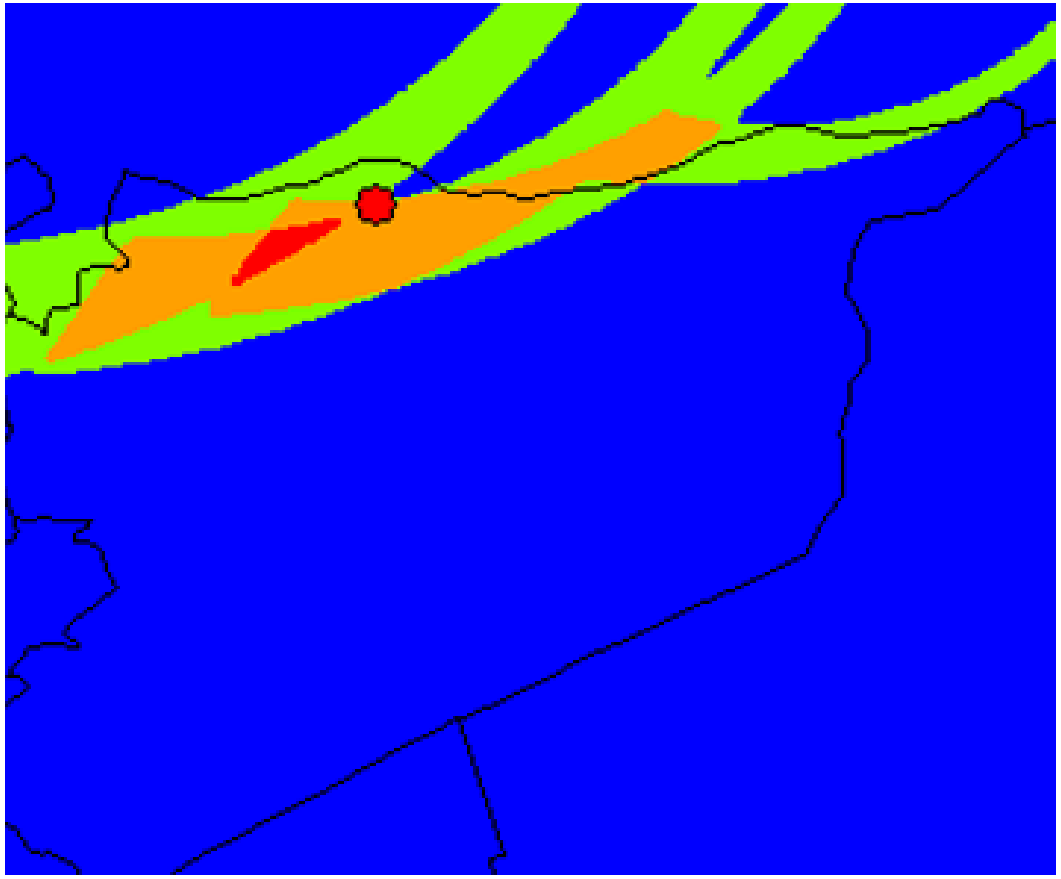
Estimate RFI source location

Using ADS-B Data, EUROCONTROL has detected multiple GNSS RFI sources in the most affected regions, sometimes moving, sometimes in international water

Example of Successful RFI Geolocation

- Successful match using two completely independent methods
  - Experimental LEO RF Detection by HawkEye360 (round dot)
  - ADS-B geolocation (triangle) based on scarce data (few flights)

- Positive confirmation of RFI and **source origin location essential** for radio regulatory resolution procedures
  - “Simplest” cases are within State boundaries
  - Cases with a neighbour State depend on relationship between States
  - Cases over international water very difficult, even if an ANSP remains responsible for providing safe traffic services
  - Cases with non-ground origin most difficult



Summary

- Exploit multi-mode strengths to mitigate multi-mode weaknesses
  - ADS-B provides indirect monitor of GNSS RFI – already today
  - ADS-B enables a rough geolocation of the RFI source
  - Limitations exist depending on available ADS-B track density and geometry
  - Additional aircraft, ground and space capabilities can provide independent confirmation
  - Developing capabilities to move from post-ops statistics to near real time visibility
  - Need to frame CONOPS of RFI Detection and Downlink functions accordingly
  - Requires interdisciplinary discussion especially on link options

- Need to reverse the trend in PBN & ADS-B to go “GPS ONLY”
  - Had good reasons at the time, but need to return to robust multi-sensor positioning including NextGen GNSS, INS and DME/DME
  - NAV working on providing integrity with DME (EUROCAE WG107 / RTCA SC227)
  - Even if it currently simplifies estimation of impacted aircraft using flight plan information
  - Do not want to stand in the way of avionics OEM developing robust positioning in future

Further reading & watching

- Technical Webinar on GNSS RFI: https://www.eurocontrol.int/event/eurocontrol-stakeholder-forum-gnss
- GNSS RFI risk assessment: EUROCONTROL Think Paper #9 https://www.eurocontrol.int/publication/eurocontrol-think-paper-9-radio-frequency-interference-satellite-navigation-active
- GNSS RFI Mitigation Plan: GNSS Manual, ICAO Doc 9849
- GNSS RFI reporting: https://www.eurocontrol.int/service/eurocontrol-voluntary-atm-incident-reporting
- GNSS contingency procedures: https://www.eurocontrol.int/publication/european-gnss-contingency-reversion-handbook-pbn-operations
- Aviation and Spoofing? https://insidegnss.com/gnss-spoofing-and-aviation-an-evolving-relationship/
- EUROCONTROL Guideline on GNSS Interference Testing (enables coordination for those willing to coordinate) https://www.eurocontrol.int/publication/eurocontrol-guidelines-process-civil-military-gnss-interference-testing