GNSS RFI Status Downlink

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Introduction

- Baska 2018
  - First introduction to aircraft-data based RFI mitigation concept using ADS-B
  - Including approximate airborne RFI source geo-location to enable efficient ground-based radio regulatory enforcement intervention
  - Much can be done with current (serendipitous) capabilities, but also proposing improvements for tailor-made function in next generation aviation equipment
  - Presentation focus on further developments, work in progress, coordination EUROCAE/RTCA, ICAO, EU/US WG-C, etc. ongoing

- One of many GNSS RFI mitigation efforts by EUROCONTROL
  - Extended conflict zone management of CNS issues
  - Operational contingency management
  - Increase preventive outreach against jammers (PPD) – arguments for consideration attached at end
  - Improvement of GNSS RFI “testing” guidance

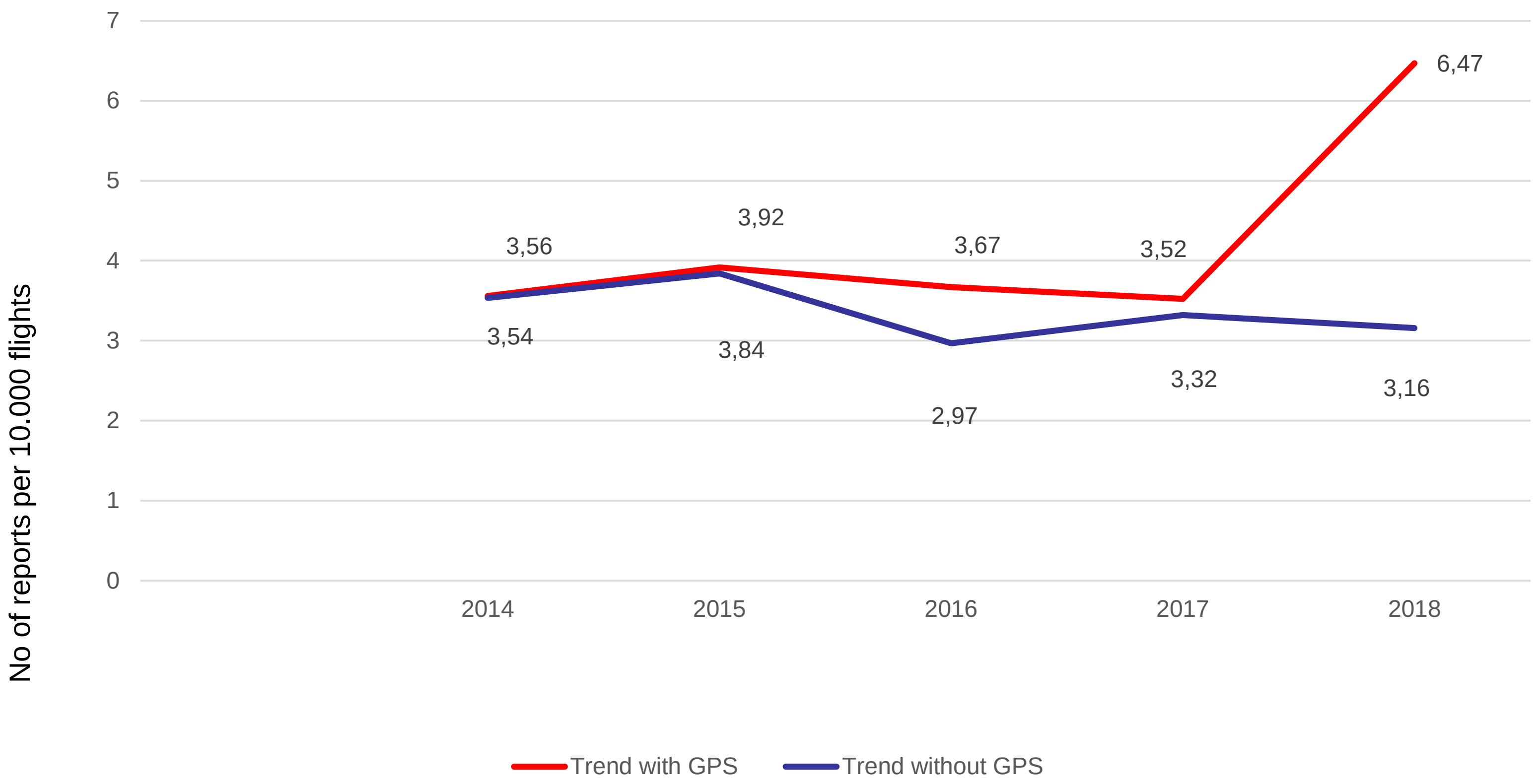
Confidentiality of next 2 Slides

- Traffic Light Protocol (TLP) Classification: Green

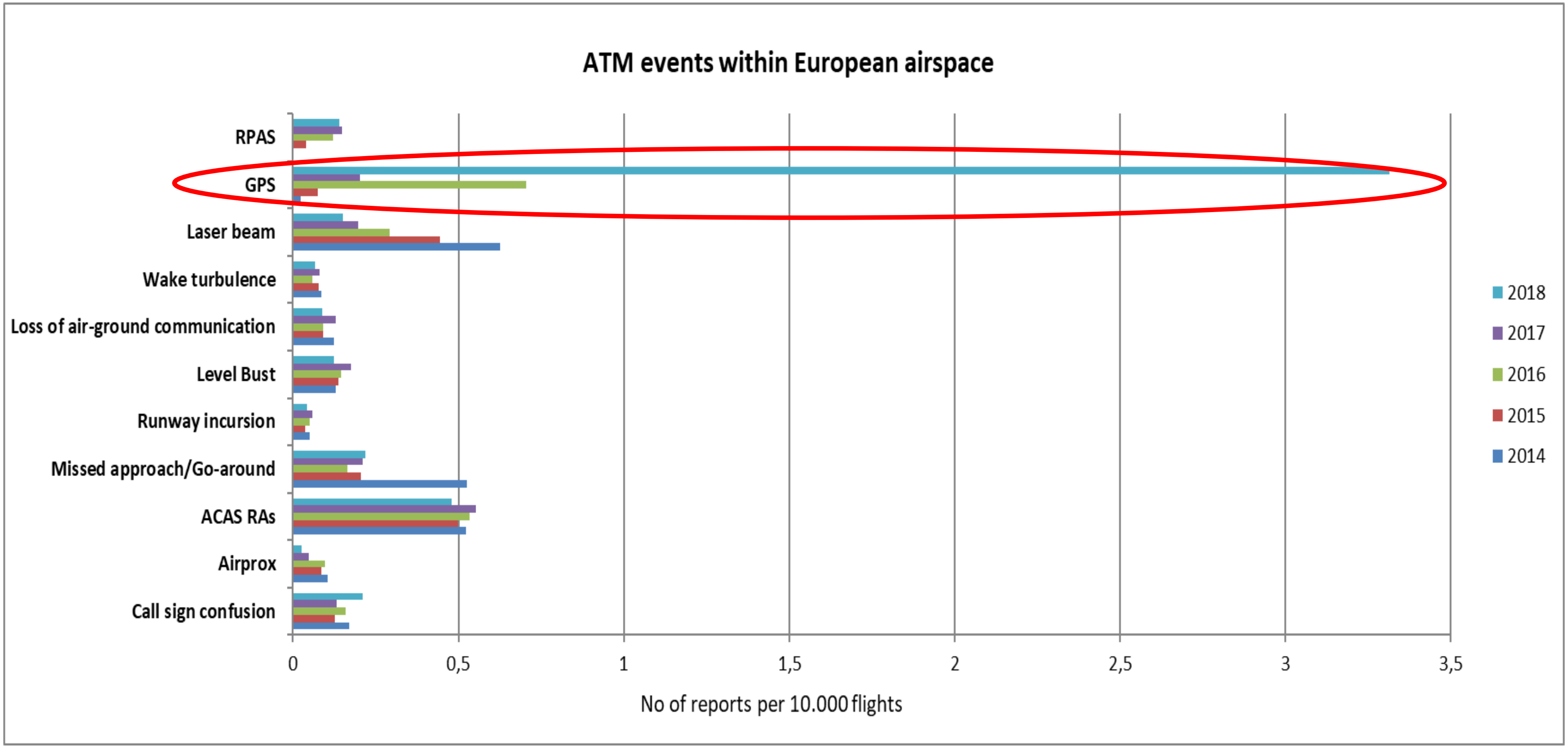
- *Limited disclosure, restricted to the aviation community*

- *Distribution Statement: Recipients may share TLP:GREEN information with peers and partner organizations within their sector or community, but not via publicly accessible channels. Information in this category can be circulated widely within a particular community. TLP:GREEN information may not be released outside of the community.*

ATM trends as reported by AOs 2014-2018



European ATM events
2014-2018



GPS reports in 2018 made 68% of EVAIR AOs' ATM reports

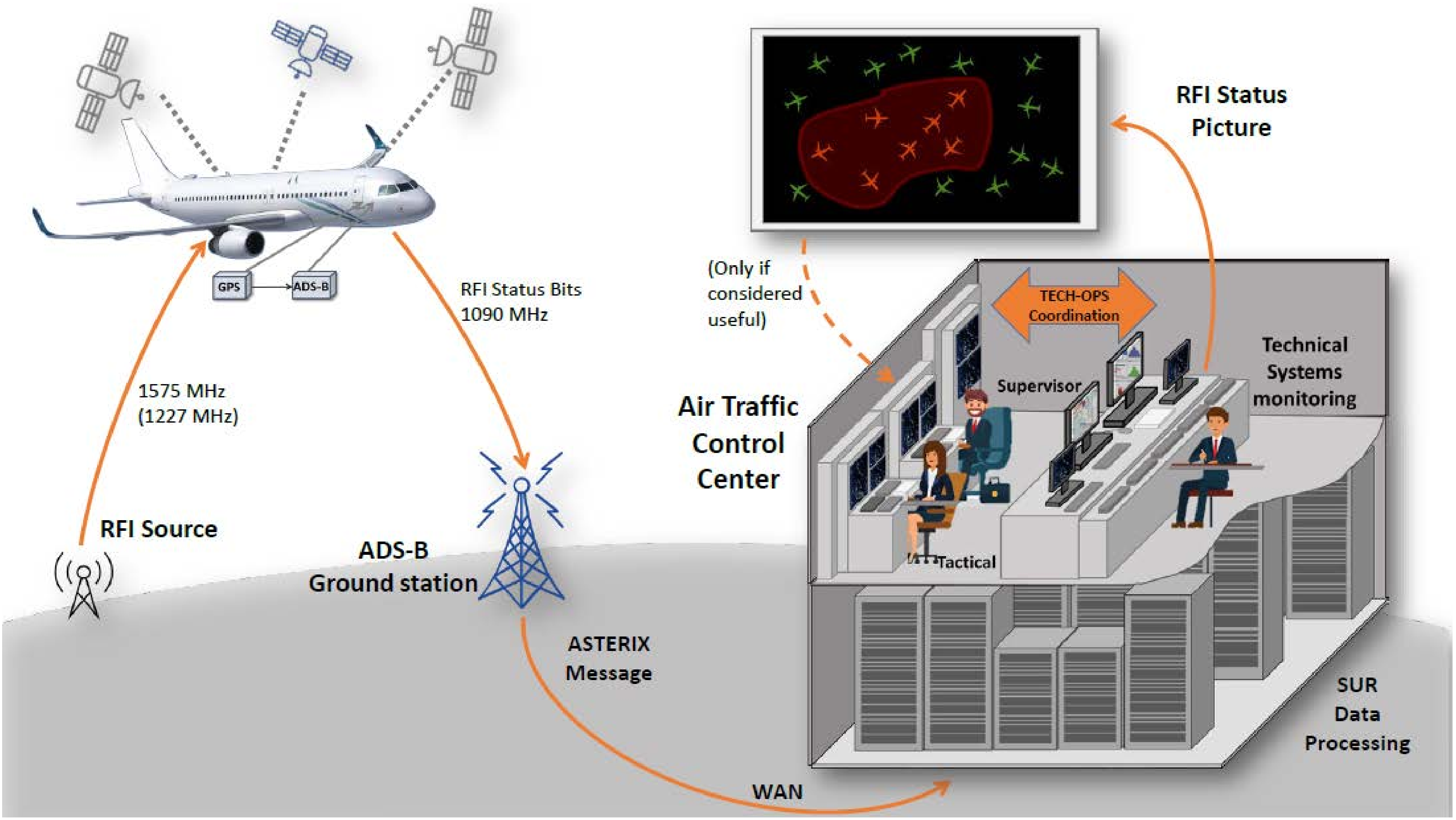
Envisioned Next Generation RFI Mitigation Function

1. GNSS Receiver detects RFI and reports it to ADS-B avionics
2. ADS-B avionics downlinks RFI status on 1090 MHz
3. ADS-B ground stations process RFI status and allow generating an integrated RFI status picture for multiple aircraft
4. Technical services can coordinate with ATCO on impacted areas and launch mitigation measures
5. ADS-B also provides confirmation when event is finished

Objectives:

- Operational mitigation management (duration and size of event)
- Effective technical intervention capability to eliminate RFI source

Functional Picture



- Still TBD if downlink should be on ADS-B

Potential Benefits Summary

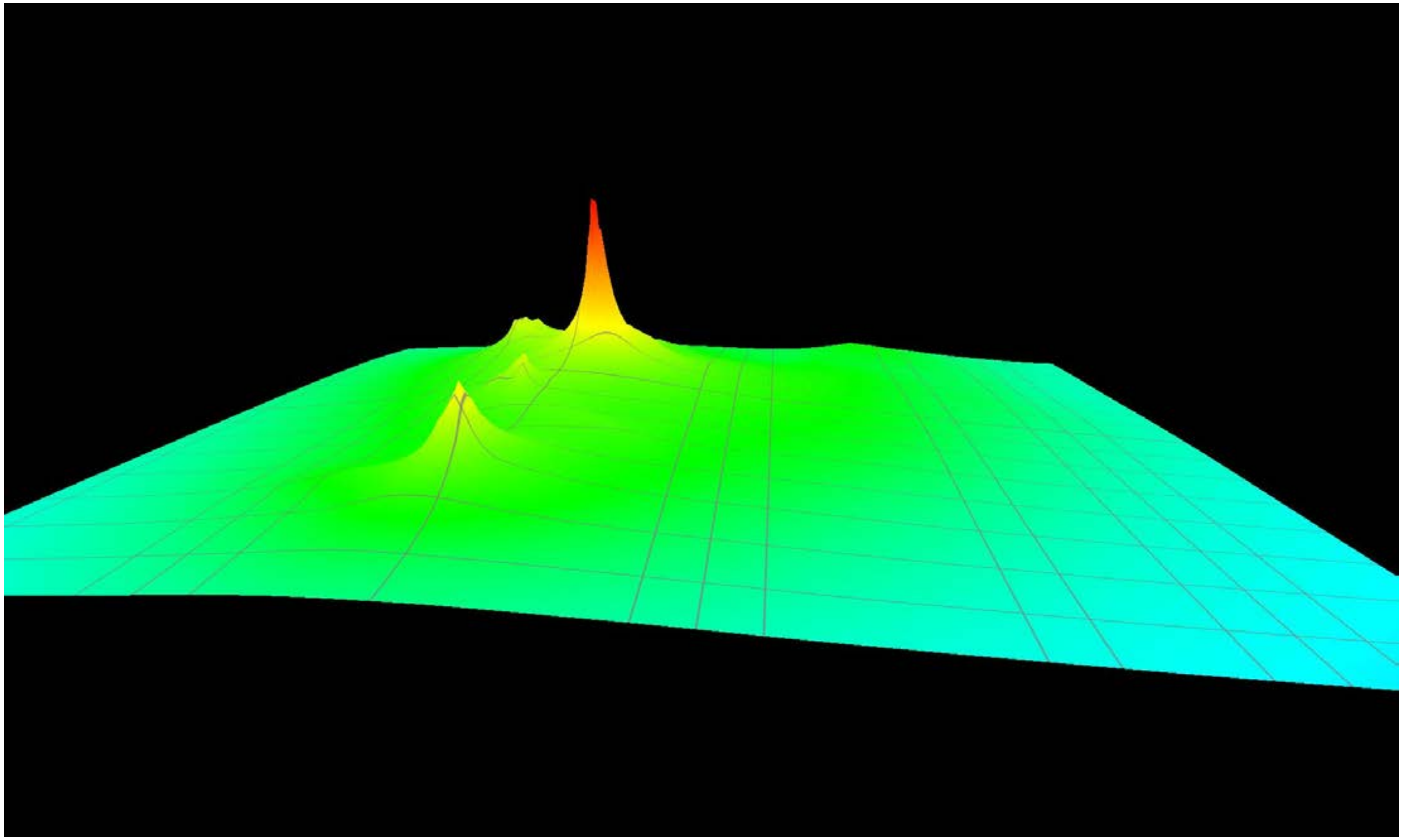
- Operational Mitigation Management
  - ATC gets immediate picture of impact area, not dependent on pilot report
  - Likely to remain with technical ANSP services, with advisories to ATCO staff
  - Objective to keep airspace open safely as long as possible

- Technical RFI Source Localization Support
  - Directly actionable RFI report: reduces guesswork
  - Facilitates link to radio regulator
  - Allows distinction of issues on either 1575 or 1090 MHz
    - *(Current ADS-B development is still single frequency GPS)*
  - Augments ground enforcement with aircraft as sensors
  - Improves heat map granularity of probable source location
    - *(Details TBQuantified)*

Operational Work

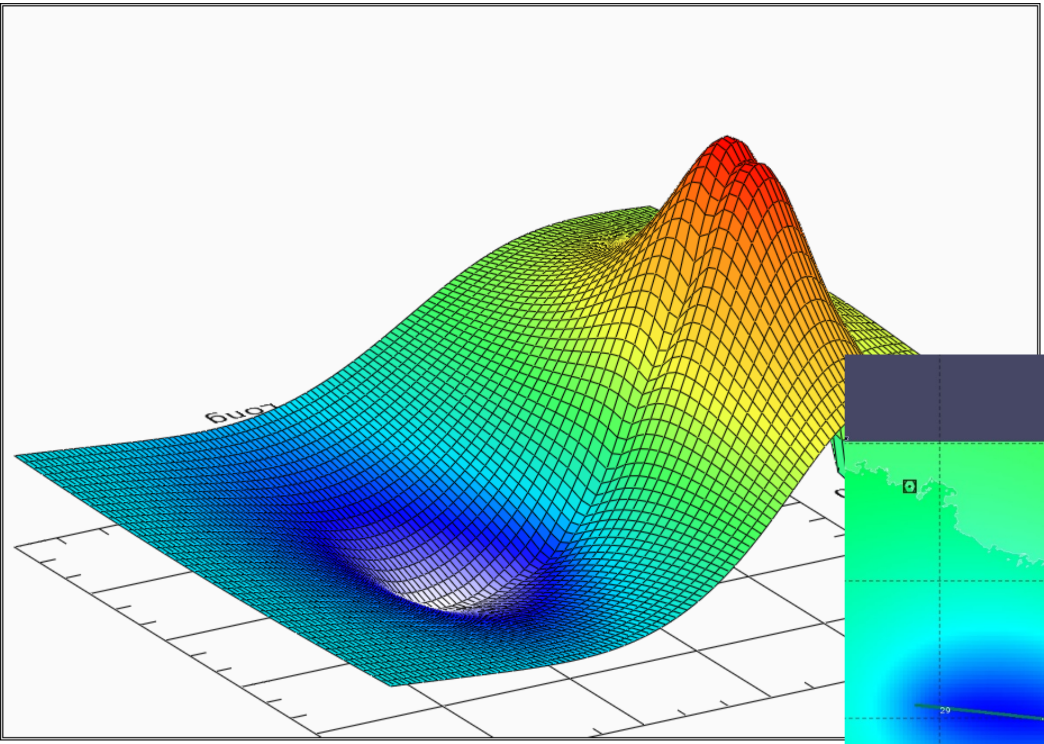
- Ops Requirement endorsed by EUROCONTROL Network Operations Team
  - YES ATC wants to know when RFI starts / stops and the area of impact if possible
- EUROCONTROL experience with RFI OPS impact
  - Interviewing all relevant actors (ANSP, aircraft operators) for feedback from significant cases
- GNSS Contingency / Reversion
  - Preparation of guidance material underway
  - Links to need for residual conventional infrastructure
  - Motivated by EASA PBN Implementing Rule
  - GNSS Reversion workshop June 2019

Tech Work: 3D Probability Contours

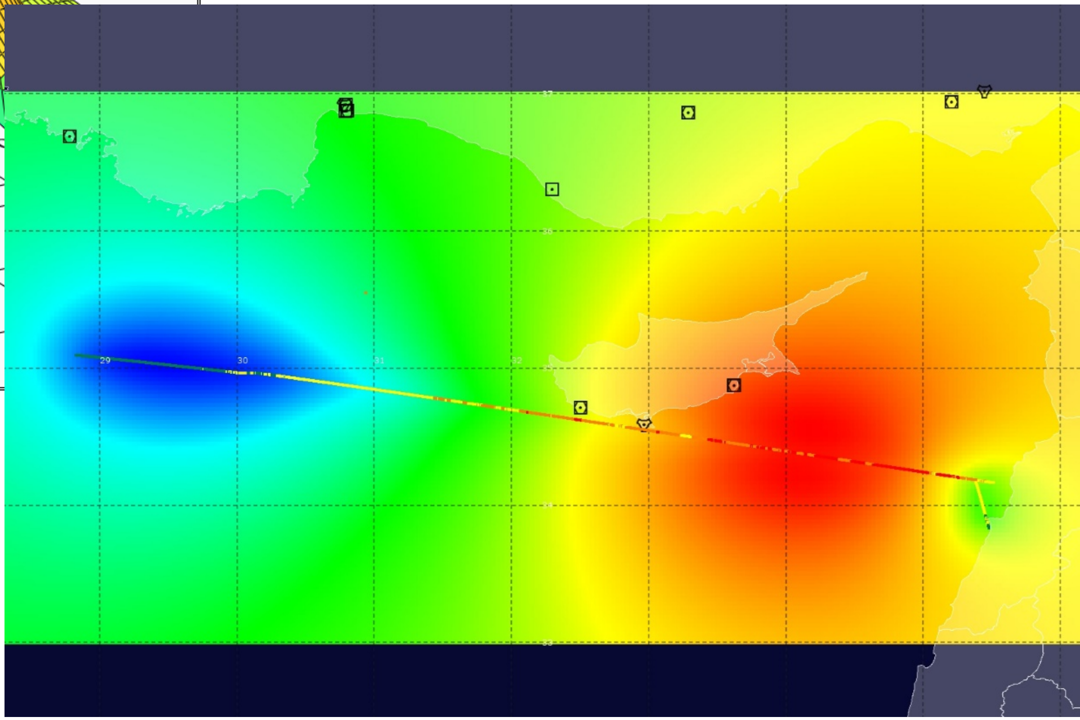


Probability density “heat map” example generated by real case of ADS-B track gaps due to RFI
(Method developed by Valeriu Vitan, EUROCONTROL)

Current Work: 3D Probability Contours

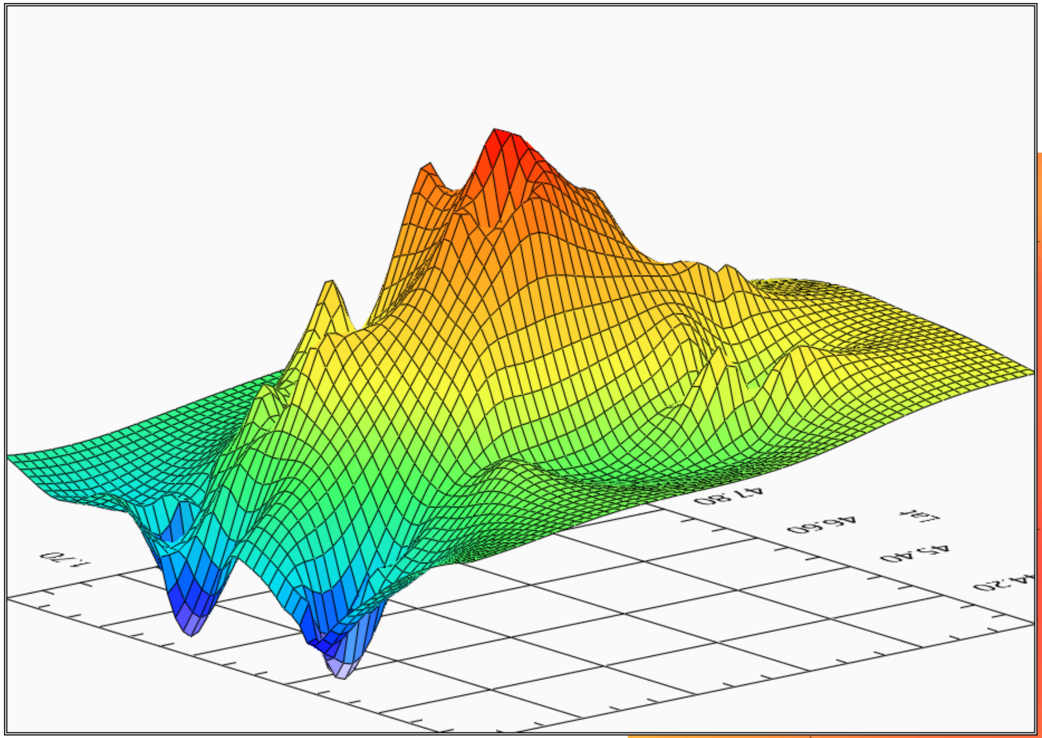


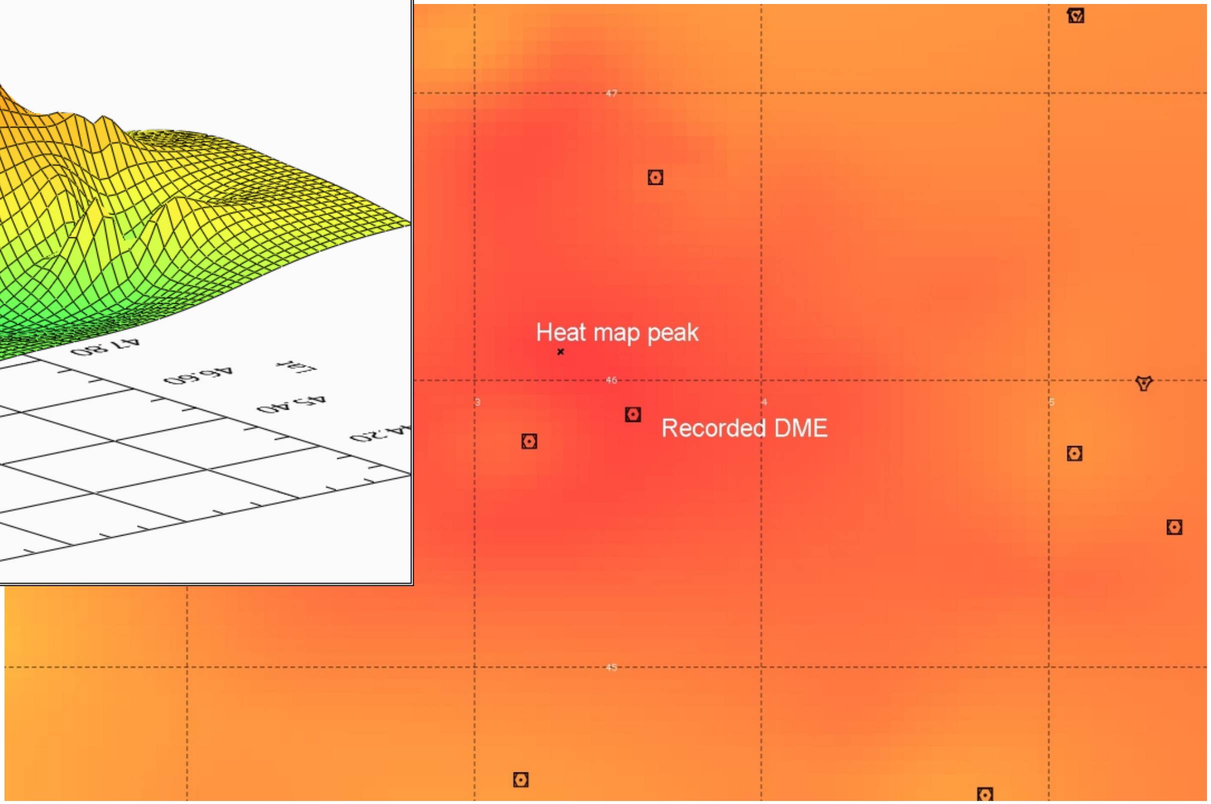
Probability density “heat map” generated by real case of in flight RFI measurements



Data provided courtesy of DSNA/DTI Flight Inspection (with C/N0 levels)

Current Work: 3D Probability Contours





Probability density “heat map” example generated by real case of DME peak level recordings (validation)

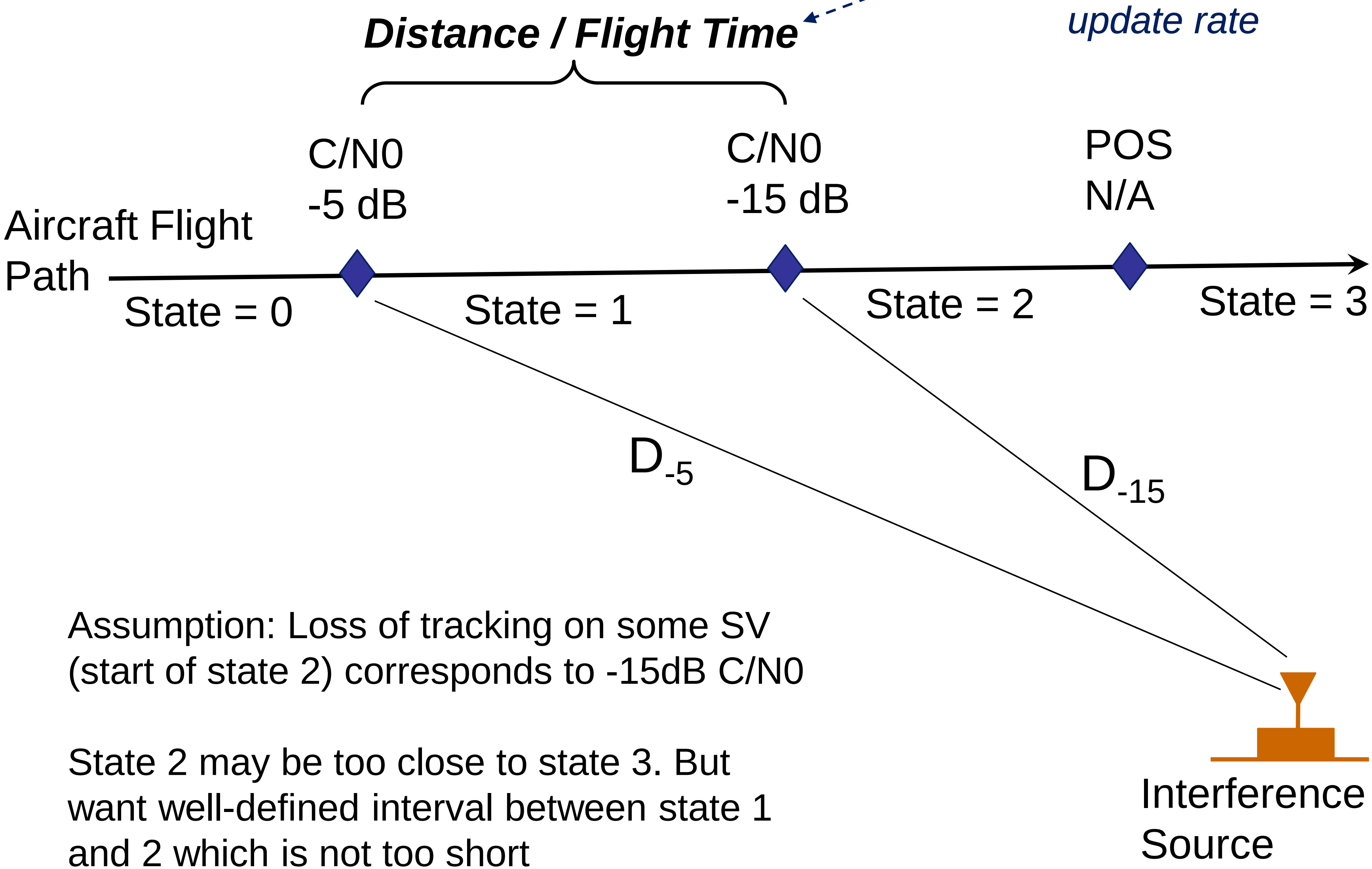
GNSS Receiver Function & Downlink

- GNSS Receiver to report 2-bit RFI Status
  - State 0 = normal tracking
  - State 1 = C/N0 reduced by 5dB on at least 4 SV
  - State 2 = Loss of tracking on at least 4 SV (-15dB)
  - State 3 = Loss of GPS Position
  - *Proposal limited to 2bits to limit BW impact and recognizing that differences exist between receivers (not an exact measurement receiver)*

- Question: what is a useful update rate?
  - Update rate too slow: intermediate states not seen, direct transition from normal tracking to loss of position
  - Update rate too fast: excessive data overhead
  - ADS-B Community to advise on which messages could accommodate 2 RFI bits

Operational Scenario

Estimate for a variety of jammer scenarios used to derive a useful update rate



Assumption: Loss of tracking on some SV (start of state 2) corresponds to -15dB C/N0

State 2 may be too close to state 3. But want well-defined interval between state 1 and 2 which is not too short

Update Rate Derivation

- Degradation of C/N0 = C/N0 before RFI / C/N0 during RFI
  - $\frac{C/N}{C/(N+I)} = \frac{N+I}{N} = 1 + \frac{I}{N}$
  - For 5 dB degradation, **I = 2,16 N**
  - For 15 dB degradation, **I = 30,6 N**
- Noise power for T = 20deg and BW = 2 MHz
  - N = kTB = -111dBm
- "Target" RFI Power
  - I_{-5dB} = 3,3dB – 111dBm = **-107,7 dBm**
  - I_{-15dB} = 14,8dB – 111dBm = **-96,2 dBm**
- "Target" FSPL and resulting Distance
  - Assumed Jammer Power – FSPL = Target RFI Power
  - $FSPL_{GPS\ L1}$ = 20 log D + 36,4
  - $D = 10\text{^}(\frac{FSPL-36{,}4}{20})$

Jammer Scenarios

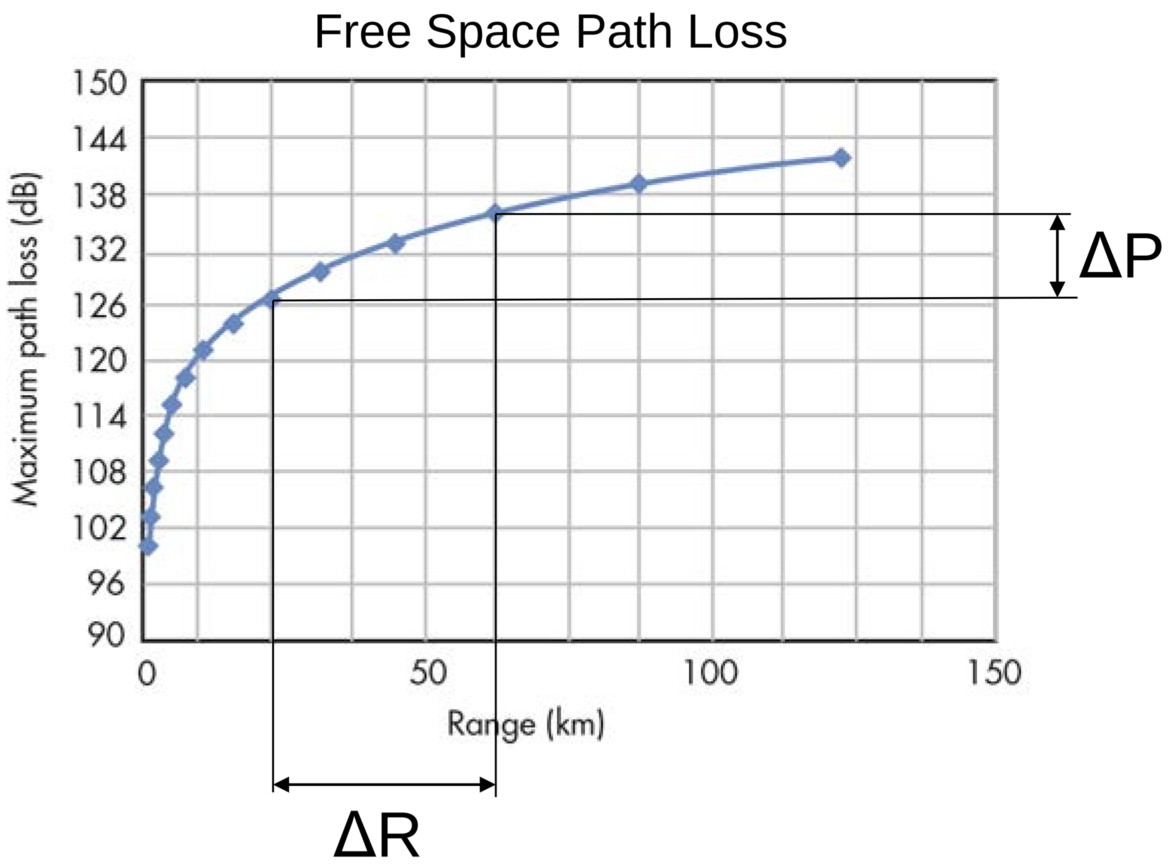
- 10W Jammer
  - 40dBm – FSPL = Target RFI Power
  - D_{-5} = 198 NM
  - D_{-15} = 51 NM
  - ΔD = **147 NM**
  - @500kt = **18 min**
- 1W Jammer
  - D_{-5} = 58 NM
  - D_{-15} = 16 NM
  - ΔD = **42 NM**
  - @350kt = **7 min**
- 0,1W Jammer
  - D_{-5} = 18 NM
  - D_{-15} = 5 NM
  - **ΔD = 13 NM**
  - @250kt = **3 min**
  - **TMA = Limiting scenario**
  - **1/10 to 1/20 resolution =** ***10 – 20 sec update rate***
- 1mW Jammer
  - D_{-5} = 3,4 km
  - D_{-15} = 955 m
  - ΔD = 2,4 km

Note: Neglecting slant range effect, aircraft altitude variable

Benefits of a relative power measurement?

- Within rough limits, provides some estimate of RFI source power and range

- With multiple measurements, may also infer if RFI source is not omnidirectional (subject to validation)



Questions to GNSS RX Community

Agree?

- C/N0 considered most common and reliable RFI indicator
  - Multipath and iono operating on desired signal, signal strength variation normally limited to few dB's
    Quantify?
  - Note: recognize that C/N0 can't be used as indicator of type of RFI
- C/N0 varies with SV elevation
  - Normalization techniques exist, is this needed?
  - Better to use C/N0 on 4 or more SV or simply average C/N0?
  - Do we need to standardize C/N0 estimator?
  - Can we agree on two "C/N0 reduction values" of -5 and -15dB?
    - What are normal tracking margins in aviation receivers (normal level to loss of track)?
- Method requires that receiver lock back on to GNSS when out of RFI zone
  - Discussing specific recovery / re-acquisition after RFI requirement in receiver standards (MOPS)

Open Issues

- Firm up OPS Concept
- Quantify benefit of PDOA approach vs track gaps only
- GNSS Receiver C/N0 response to different RFI types – or other means of detection?
  - Duplicate same function for L5?
- Use of ADS-B messages on 1090 MHz or other link?
- Security issue of downlink: will it augment capability of hostile, aviation-targeted jammer?
- Development schedule: this is for DFMC GNSS equipment
  - Whatever link is chosen, need to synchronize developments and manage programmatic dependencies in all relevant communities (avionics, ANSP, etc.)

Summary

- Considering GNSS RFI status downlink a significant future capability to ensure safety and keep airspace open as long as possible
  - Significant coordination effort
  - Multi-dimensional CNS/ATM issue
  - Many open issues remain: biggest hurdle is obtaining good test data for validation of concepts
- Various aspects / principles may be relevant for other sectors also
  - Maritime / AIS?
  - Smartphone Crowdsourcing
- Welcome continued exchange!

Coordination Effort Summary ‘18/19

- Initiated at Spring EU/US WG-C & EUROCONTROL Surveillance Modernization SG
- Bilateral EUROCONTROL / FAA Coordination at ICAO NSP
  - Short concept paper
- RTCA SC-159 Plenary May: Agreed to form ad-hoc group to prepare for more significant discussion at October meeting
- Combined Surveillance Committee (CSC), Brussels, June
  - Groups RTCA SC186 / 209 and EUROCAE WG49 / 51
  - WP09-12 describing concept and requesting feedback on feasibility of providing RFI status bits on 1090 link
- EUROCAE WG62 June: Consultation on GNSS receiver aspects
- RTCA SC-159 October: more background on operational motivation; need for OPS concept, agreed to continue
- ICAO NSP/5: Added topic to RFI Mitigation Job Card but decided to remain more high level
  - New element is downlink and ANSP processing
- EU/GSA STRIKE/3 Project: Support for some RX assumptions
- ICAO Surveillance Panel, ASWG / TSG08 – initiated coordination

Arguments for Jammer Prevention

- Ensure implementation of suitable location privacy laws and awareness to help limit motivation of private citizens and employees to purchase jamming devices
- Consider outreach to ensure that / to:
  - help citizens and employees understand that location privacy laws are in place to protect them
    - Operating a jammer in a company vehicle is a valid reason to fire someone, tracking an employee is not!
  - information is available in local and relevant foreign languages about jammers being illegal (internet searches) and the significant fines in place when caught
  - alert to the risks they can pose to infrastructure and services (without too detailed explanations)
  - explain that operating a jammer may lead to being tracked by law enforcement as a suspect of illegal activities