

GNSS RFI Source Localization using Flight Track Data and support from GNSS Providers

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And in context of support for ICAO Navigation Systems Panel

UN ICG-12 WG-S GNSS Compatibility and Spectrum

IDM Standards and Information Exchange, Agenda Item 1b)

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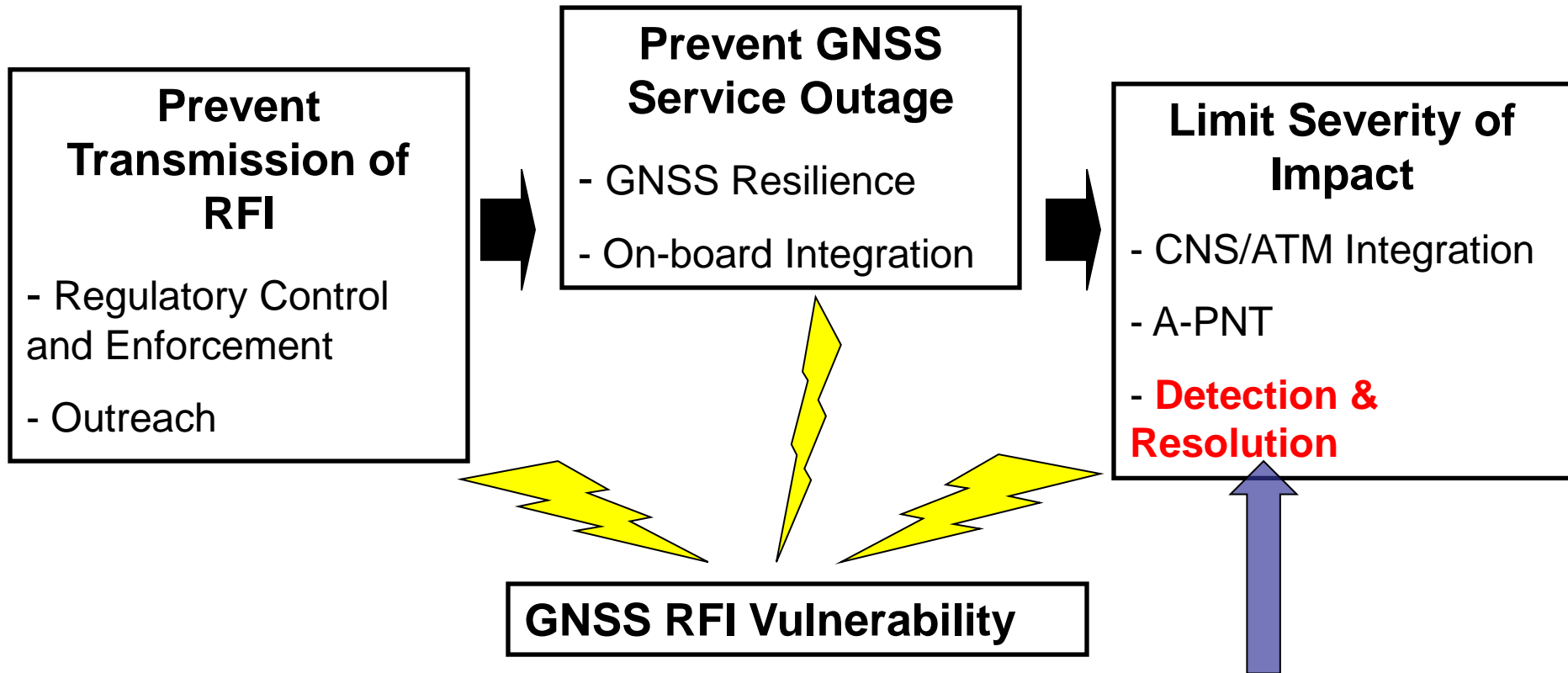
Objective in Context of UN ICG

- WG-S Agenda Item: Interface between Aviation Authorities and GNSS Service Providers to Analyse Possible RFI Incidents
- Aviation is only one but unique user of GNSS (altitude)
 - Can suffer collateral RFI not directed at aviation
- ICAO RFI Mitigation Plan (Presentation at UN ICG-11 Sochi)
 - Published in ICAO GNSS Manual Doc 9849 (3rd Ed. 2017)
 - Implementing barriers to mitigate severity of impact
 - Preventive & reactive measures: once RFI event happens, vulnerability is limited by being able to localize and stop RFI source as fast as possible
- **Effective coordination arrangements necessary to help eliminate RFI**

Overview

- Detecting GNSS Outages
 - From passive threat monitoring to active intervention in case of relevant events
- Determination of Probable Cause
 - Elimination of Non-RFI Causes
- Localization and Elimination of RFI Source
 - Supporting the chain of detection (Operator / ANSP) to confirmation, characterization and localization (radio regulator) to elimination (law enforcement)

Implementing Mitigation Barriers



Note: Limiting “success probability” of intentional RFI limits likelihood of events (exposure to detection)

Supported by Threat Monitoring Networks
(Preventive & Reactive Role)

Meeting “Stated ATCO Requirement”

- Budapest GPS Outage Simulations:
 - **“Tell me when event starts, when it ends, and how many sectors are affected”**
 - No simple technical solutions exist today
 - Allows contingency planning through planner ATCO
- **Best to monitor at the impact source: aircraft receiver**
 - Currently, only pilot can observe receiver outage
 - Subsequent reporting requires support at regional and global level to determine probable cause (only RFI is local problem)
 - Provides essential risk assessment link on operational impact
 - **Try to get as much information from the air as possible before starting search on ground: *cooperative approach for efficiency***

ATCO = Air Traffic Control Officer

Pilot Reporting Streams Today

***GNSS Multi-Modal
Aviation one User among
many***

***Aviation Specific
GNSS Out One Issue
among many***

**GPS
NAVCEN**



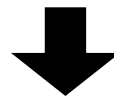
AO

- Airline OPS Center
- FOQA Monitoring?
- PIREP: Local AIS



IATA

ESSP



Local ANSP ?

- AIS to Technical Services
- Technical Services activate subsequent process?



**Eurocontrol
Network
Manager**

***No aggregate vision of events → Incomplete threat picture
Resolution depends on awareness of many individuals***

Update: GNSS in EVAIR

- EVAIR = Eurocontrol Voluntary ATM Incident Reporting
 - Established Safety Process (Confidentiality, Anonymity)
 - 250 Participating Aircraft Operators
 - Coverage: Europe, Middle East, Northern Africa
 - Close cooperation with IATA (Int. Air Transport Association)
 - Part of Network Manager Functions
 - Covers ALL safety issues, not just GNSS outages
- Informal Channel to send operationally relevant messages to aircraft operators
 - Less formal than a State issuing a NOTAM (Notice to Airmen) through its ANSP (Air Navigation Service Provider)
 - Sending regular awareness messages through bulletins

EVAIR GPS Outage Reports by Pilots

- Strong increase in 2016 not continued so far
 - Turkey event causing a lot of reports has been resolved
- But likely to also include “reporting fatigue” and operators getting used to experiencing events in other regions



Not shown: Many Flight Information Regions with NO events

Pilot Reports usually not precise enough to enable determination of probable origin of suspected RFI source

- Multiple EVAIR Pilot Reports used as trigger to launch more detailed investigation

Step 1: Issue Warning to Operators

- Allows preparation and contingency planning
- Two warning mechanisms
 - Official NOTAM by ANSP DHMI Turkey

A4757/16 NOTAMN

Q) LTAA/QGWXX/IV/NBO/E/0/999/3856N03709E423

A) LTAA B) 1610261245 C) 1612262359 EST

E) RECENTLY, GPS SIGNAL OUTAGES HAVE BEEN REPORTED BY THE PILOTS OF THE AIRCRAFT OPERATING WITHIN SOME PARTS OF ANKARA FIR. AIRCRAFT OPERATORS OPERATING WITHIN ANKARA FIR ARE ADVISED TO BE CAUTIOUS ABOUT GPS OUTAGES.

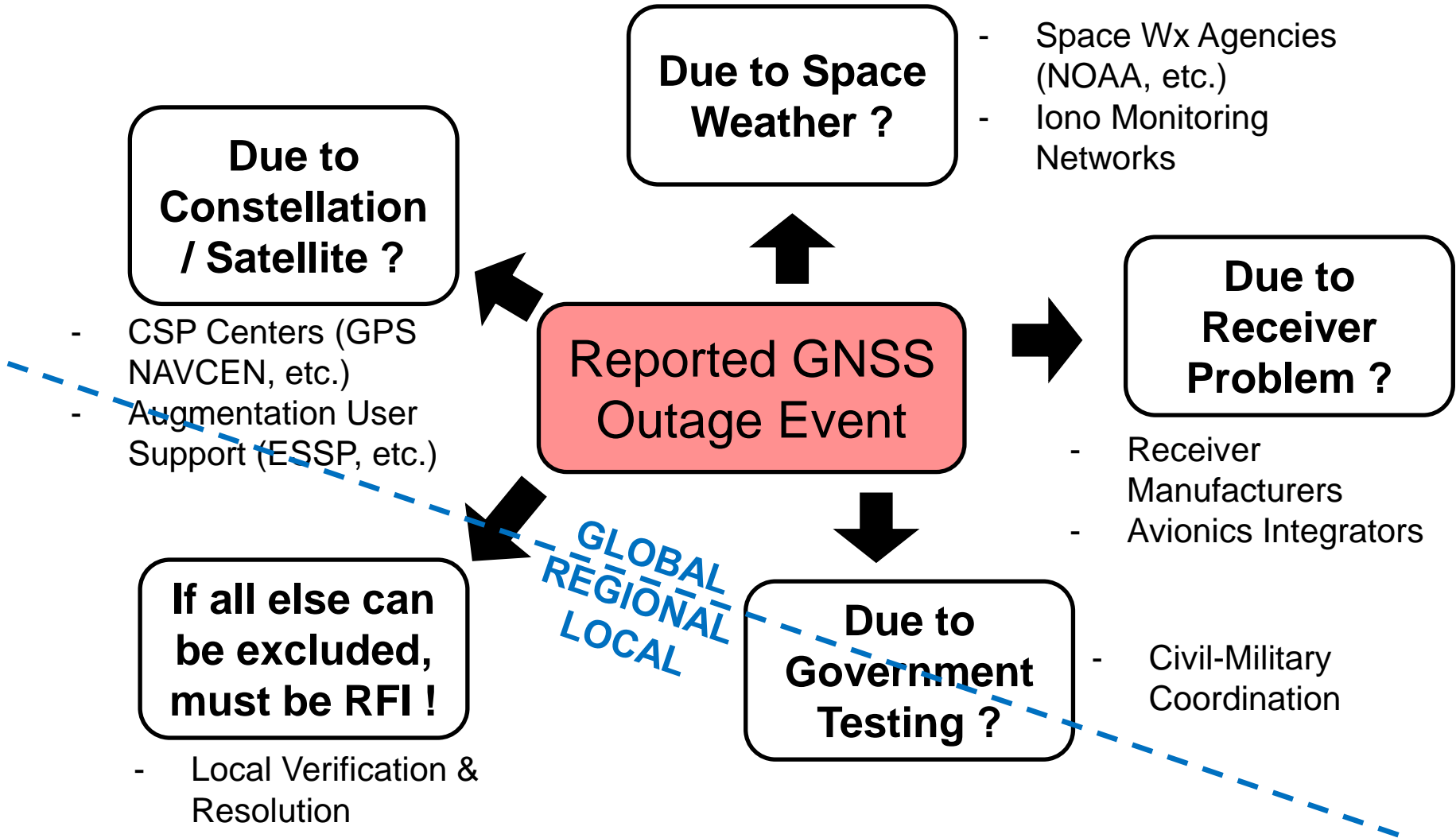
- OR: Direct Message to Operator through EVAIR
used if ANSP not responsive or if many ANSP affected while RFI location is not consistent

EVAIR Message to Aircraft Operators

NOV 2016

- “EVAIR has been recording continuous increase of the GPS outage reports and the expansion of the area affected. According to the reports still the most affected area is about 300 NM around Black Sea – Caspian Sea axis. Within the affected area the lost GPS signal became a daily problem. It could be lost from a few minutes up to three hours.”
- “Practically from all ANSPs who are responsible for the provision of the ATC within the affected area we got the confirmation that the area is radar covered and that there is no problem to provide navigational assistance if requested.”

Step 2: Identification of Probable Cause Through Elimination

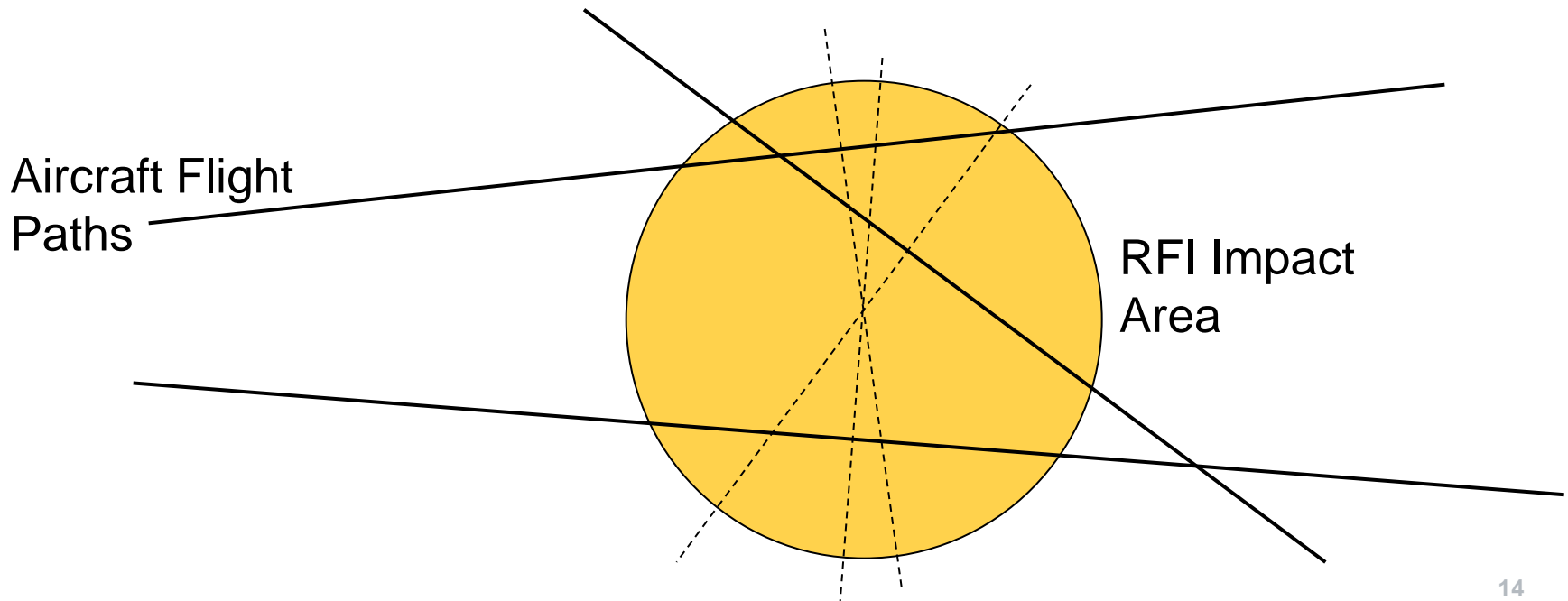


Step 3: RFI Localization Support

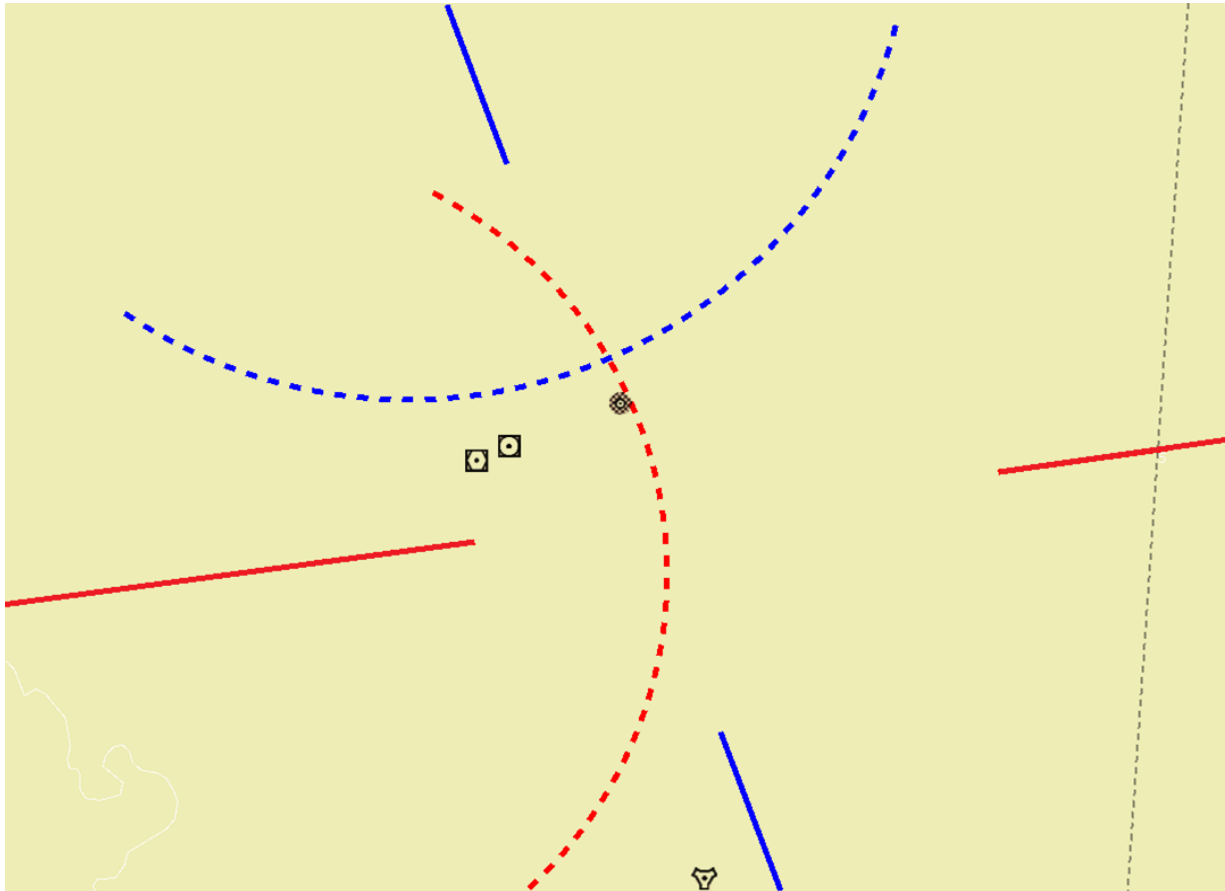
- Primary current method to detect potential RFI is pilot reporting
 - Pilot reporting by nature not precise about location of event
 - Developing process of what to do with reports
 - Evaluating if meaningful localization can be made possible if flight track data is made available
- Prerequisite is that relatively precise lat/lon/ht of GNSS Outage event start and end is available
 - Either through ADS-B or other airline data reporting system
 - Possible for single, omnidirectional and static RFI source only
 - If search inconclusive using this method, could also be a valuable data point to suspect more sophisticated threat
 - **Objective is to reduce RFI source search area for State and reduce associated intervention time**





Flight Track Data Possibilities?

- If precise report of start and stop coordinate of outage event are known, bisector line of potential RFI source location can be derived
 - Assumes omnidirectional RFI source and constant aircraft altitude
 - Assumes that loss of tracking and reacquisition thresholds are similar
 - Multiple aircraft reports could lead to localization
- Within limits, a minimum power level can also be hypothesized



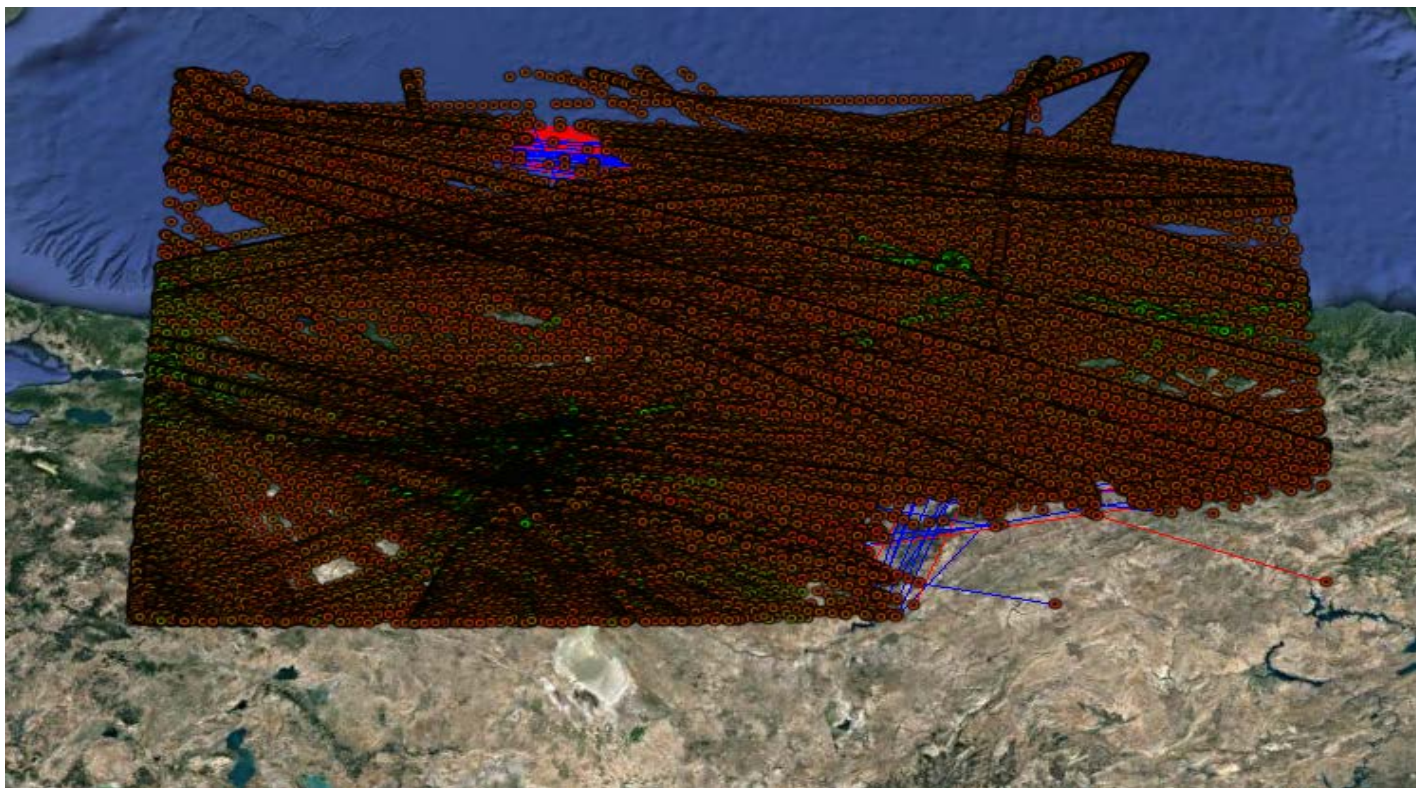
Modelling and Visualisation in DEMETER



- | | | | |
|--|--------------------------|--|-----------------------|
|  | GPS track 1 (eastbound) |  | Possible RFI position |
|  | GPS track 2 (southbound) |  | Possible RFI position |

Verification of ADS-B Coverage

(Requires ADS-B Ground Recorder AND Aircraft Reporting)



- Can be difficult to get to raw data or historical data
- Many commercial providers close reporting gaps by extrapolation, need to check source (ADS-B, not MLAT for example)



“Spaghetti Analysis” of Track Gaps

Verification: RFI Eliminated! But is there a new problem?

- RFI Source which led to NOTAM was stopped
- Unfortunately, Radio Agency did not provide information on location of interference
- Difficult to validate concept and mature processes without feedback

Actual station coverage always needs to be verified

- No more track gaps in original area
- New gaps are due to a change in operational ground stations; a single reporting station outage can also look like an RFI problem (but isn't)!

RFI Localization Process

- Pilot Reports serve as a trigger for further investigation
 - First check to eliminate non-RFI causes as much as possible
 - Currently few constellation or space weather issues, but will still profit from exchange with GNSS service providers
- Currently relying on public domain ADS-B sources
 - Manage coverage and data quality issues
 - Limitations on data history
 - Limitations on track distribution (due to route network)
- Options to be investigated:
 - Framework agreement with ADS-B data providers?
 - Direct data feed from ANSP? Requires Pan-European Approach
 - Further development of RFI source localization methods
 - Future Alternatives: Next Generation GNSS Receivers which downlink GNSS quality indicators directly to ANSP for a real-time network picture?

Summary

- GNSS RFI Mitigation continues to be an exercise in setting up interfaces
 - Developing “GNSS Information Concept” to know what to make available to aircrews and how (NOTAM or alternate channels)
- Focus on short-term implementable options that approach stated ATCO requirement (“tell me which sectors are affected”)
- **Most current significant events are suspected to be of military origin**
 - Difficult to confirm, or even to act upon if confirmed
 - Especially in the case of training exercises, ***States are reminded of obligation to coordinate with aviation***
 - Even more so if GNSS outages impact neighbouring States (Norway)

GNSS RFI Source Localization using Flight Track Data

A representative from Eurocontrol reported on efforts to set up interfaces for mitigation of GNSS RFI in States, supported by sector-specific Regional Organizations (Aviation in Europe in the case of Eurocontrol). Information / process presented:

Detecting GNSS Outages

From passive threat monitoring to active intervention during relevant events

- Eurocontrol is collecting GPS Outage Reports by pilots through standard aviation safety processes and is encouraging other regions / sectors to do the same

Determination of Probable Cause

Elimination of Non-RFI Causes (Constellation issues, space weather, etc.)

Localization and Elimination of RFI Source

Supporting the chain of detection (Operator / ANSP) to confirmation, characterization and localization (radio regulator) to elimination (law enforcement)

- Eurocontrol is actively investigating the use of aircraft ADS-B position reports to support localization of RFI sources

Requests to UN ICG IDM Workshop

The representative had some specific requests for the workshop attendees:

- Support information exchange for aviation with GNSS system operators
 - For both threat monitoring and significant event mitigation
 - Help to identify non-RFI causes (space weather, receiver issues if aware)
- Forward aviation relevant reports to relevant entities (States, Regional Organizations)
 - Eurocontrol has active projects and services to support European States, in line with guidance from ICAO (GNSS Manual)
 - Eurocontrol encourages other regions to set up similar processes

It is recommended that ICG members determine the entities involved and process used to forward reports of Aviation RFI within their countries and discuss findings at the next WG-S Compatibility Subgroup meeting.