

# GNSS RFI Source Localization using Flight Track Data

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UN ICG Interference Detection and Mitigation (IDM) Workshop

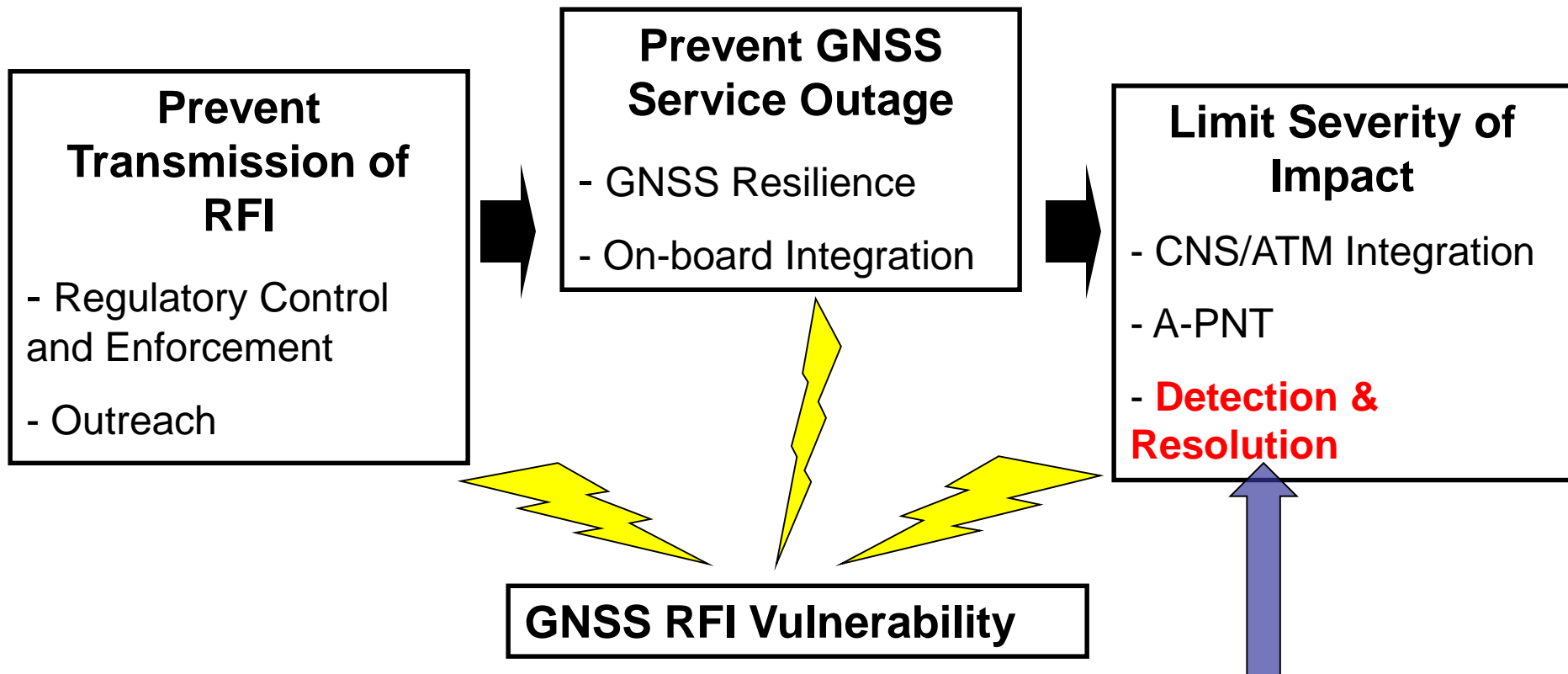
Baska, Croatia, 9 May 2017



# 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”

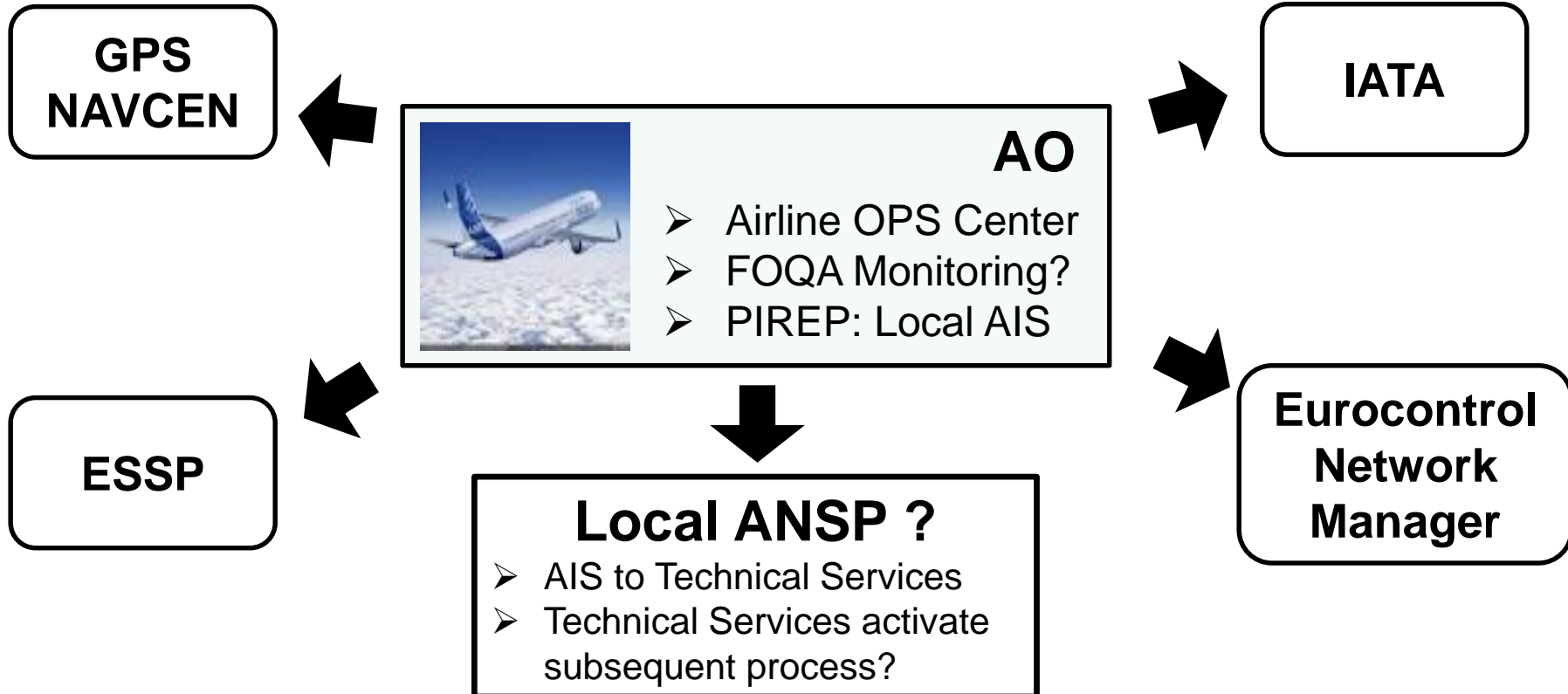
- Budapest GPS Outage Simulations:
  - **“Tell me when event starts, when it ends, and how many sectors are affected”**
  - No simple technical solutions exist today
  - Allows contingency planning through planner ATCO
- **Best to monitor at the impact source: aircraft receiver**
  - Currently, only 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

# GPS OUT Reporting Streams Today

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

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

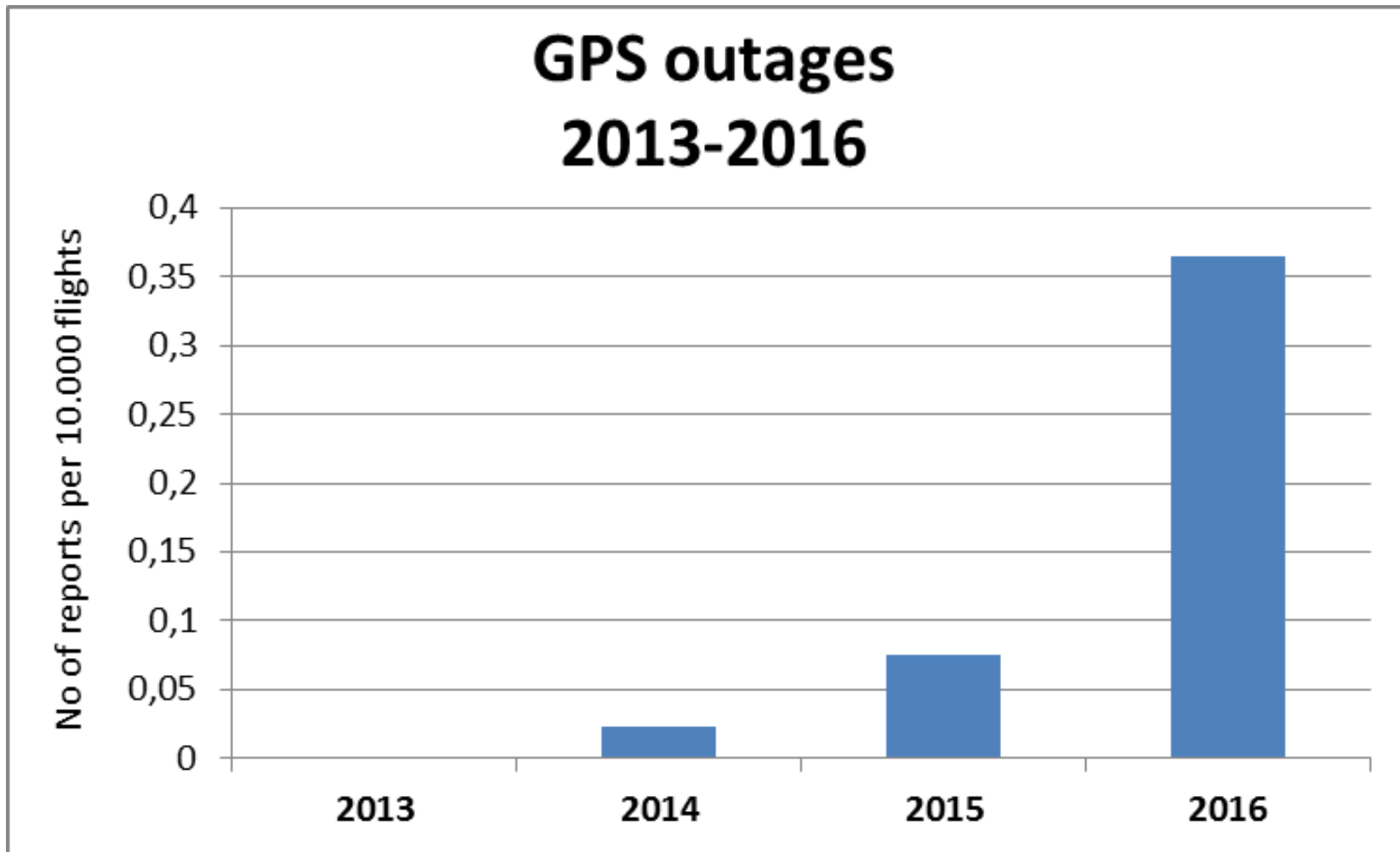


**No aggregate vision of events → Incomplete threat picture**  
**Resolution depends on awareness of many individuals**

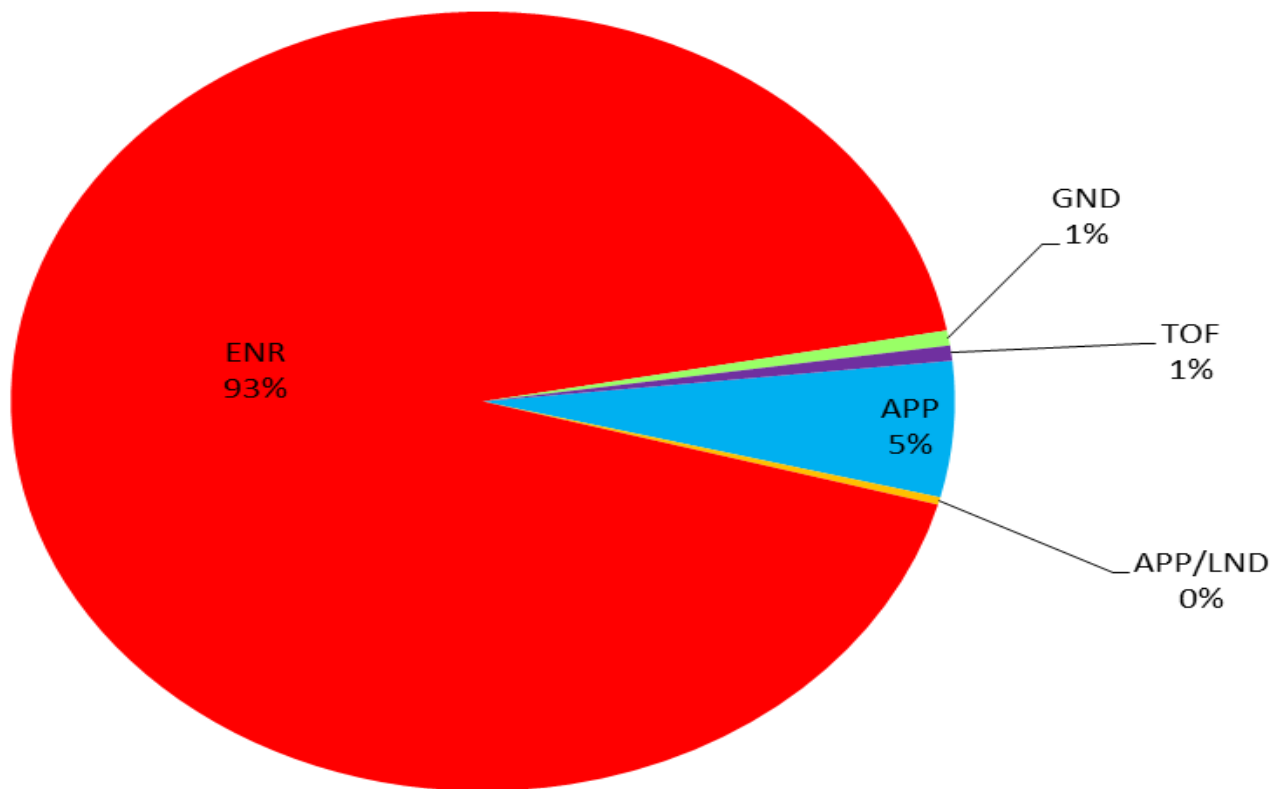
# Implemented: GNSS in EVAIR

- 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
  - Part of Network Manager Functions
- Info Bulletin sent beginning 2015 and mid-2016
  - Initial wave of reports received covering 2013/2014
  - Additional reports coming in every few weeks
  - GNSS Outage one issue among many
  - Simple to set up because it is an existing process / framework
  - Sending further awareness materials to aircraft operators

## GPS outages 2013-2016



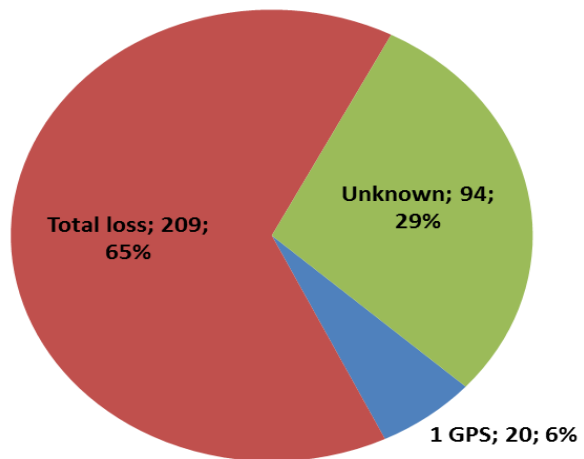
### GPS Outages - Phases of flights 2013-2016



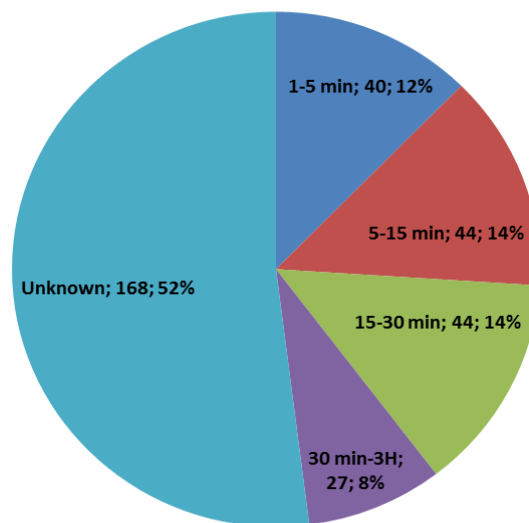




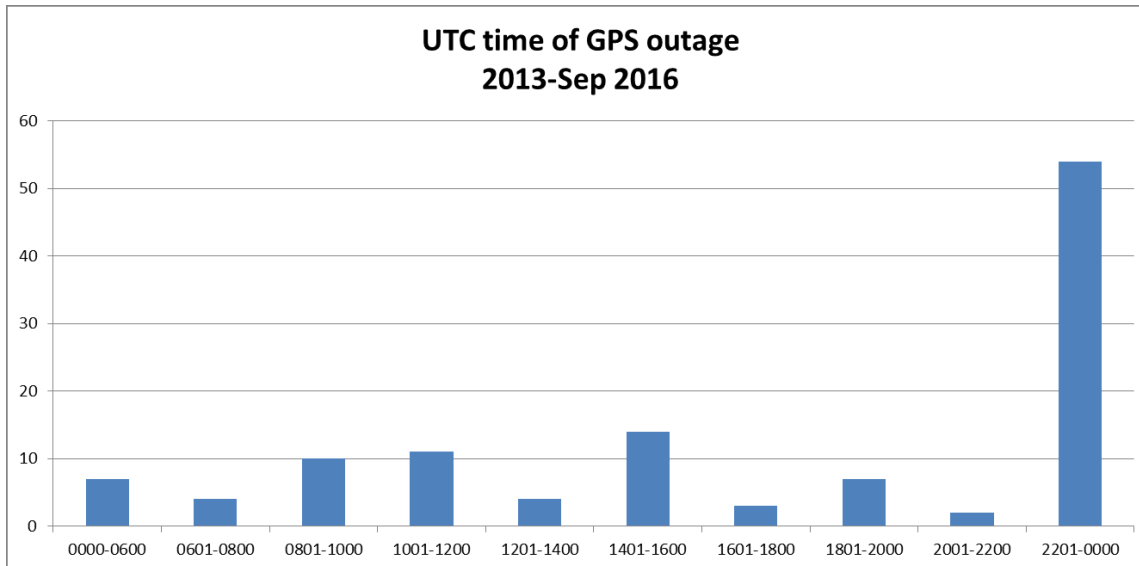
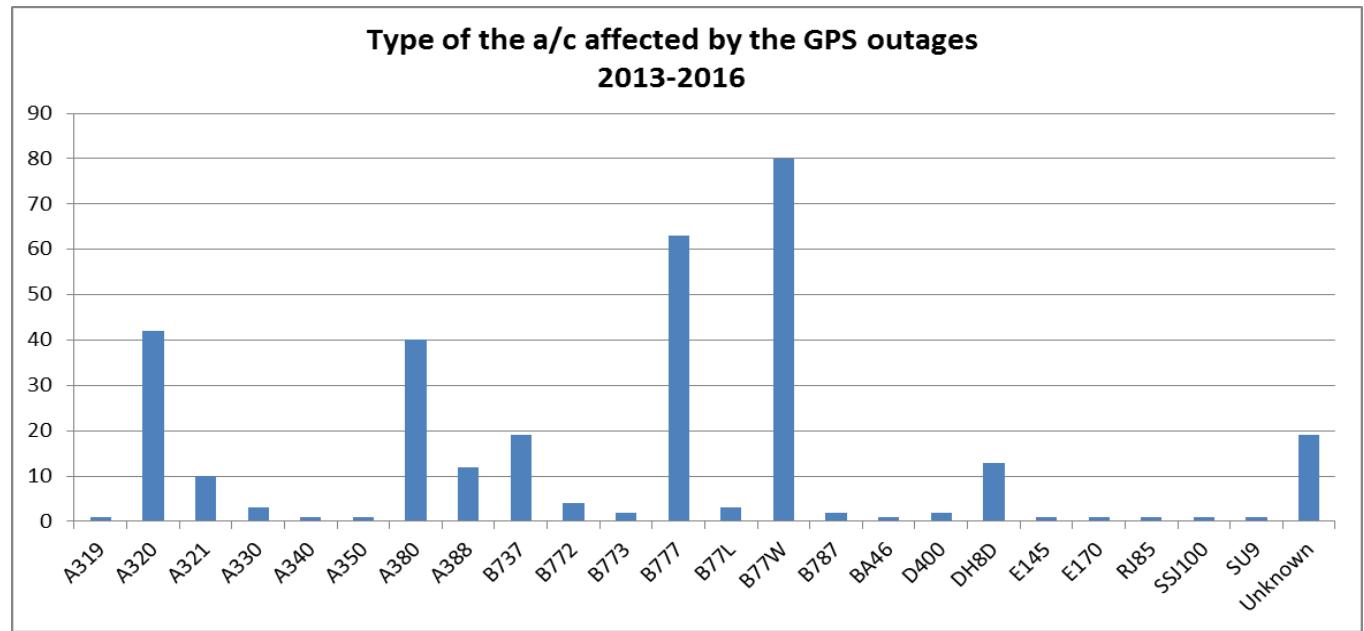
**GPS failure  
2013-2016**



**Duration of GPS failure  
2013-2016**

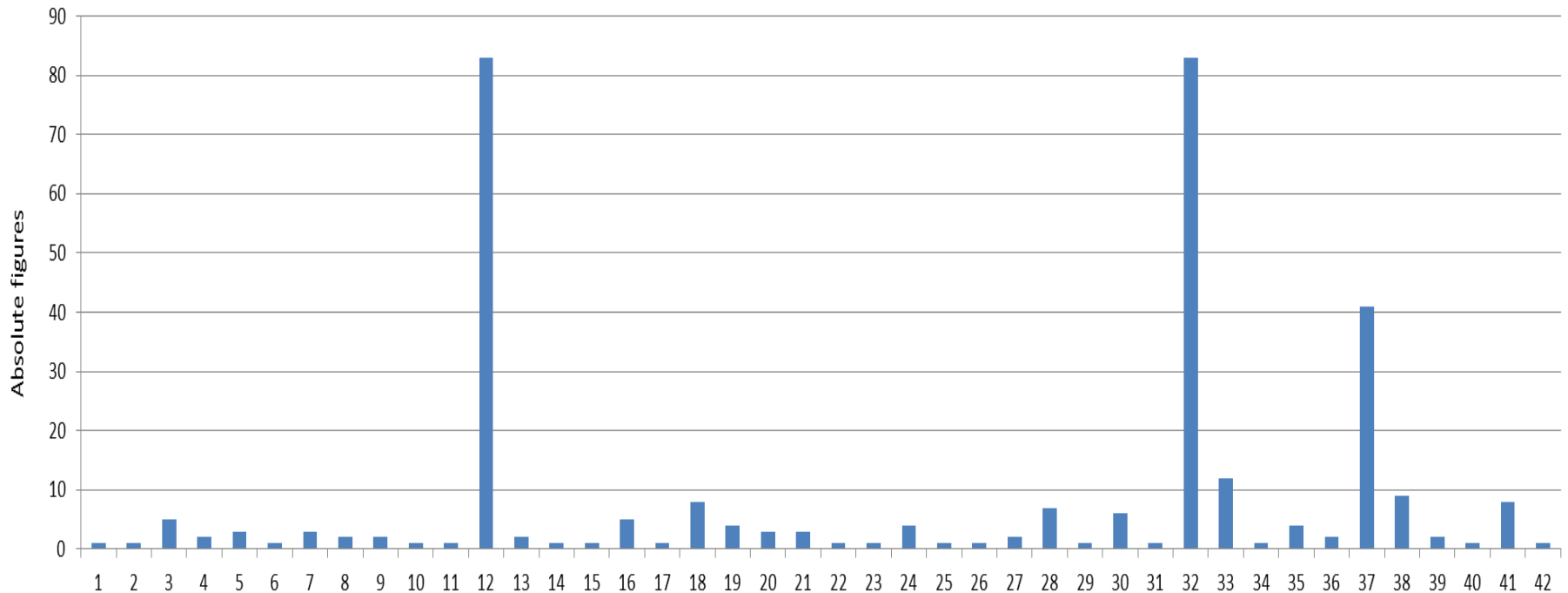


B777 is most flown type in areas most affected



Most Events Occur at Night!

Locations with the GPS outages  
2013-2016

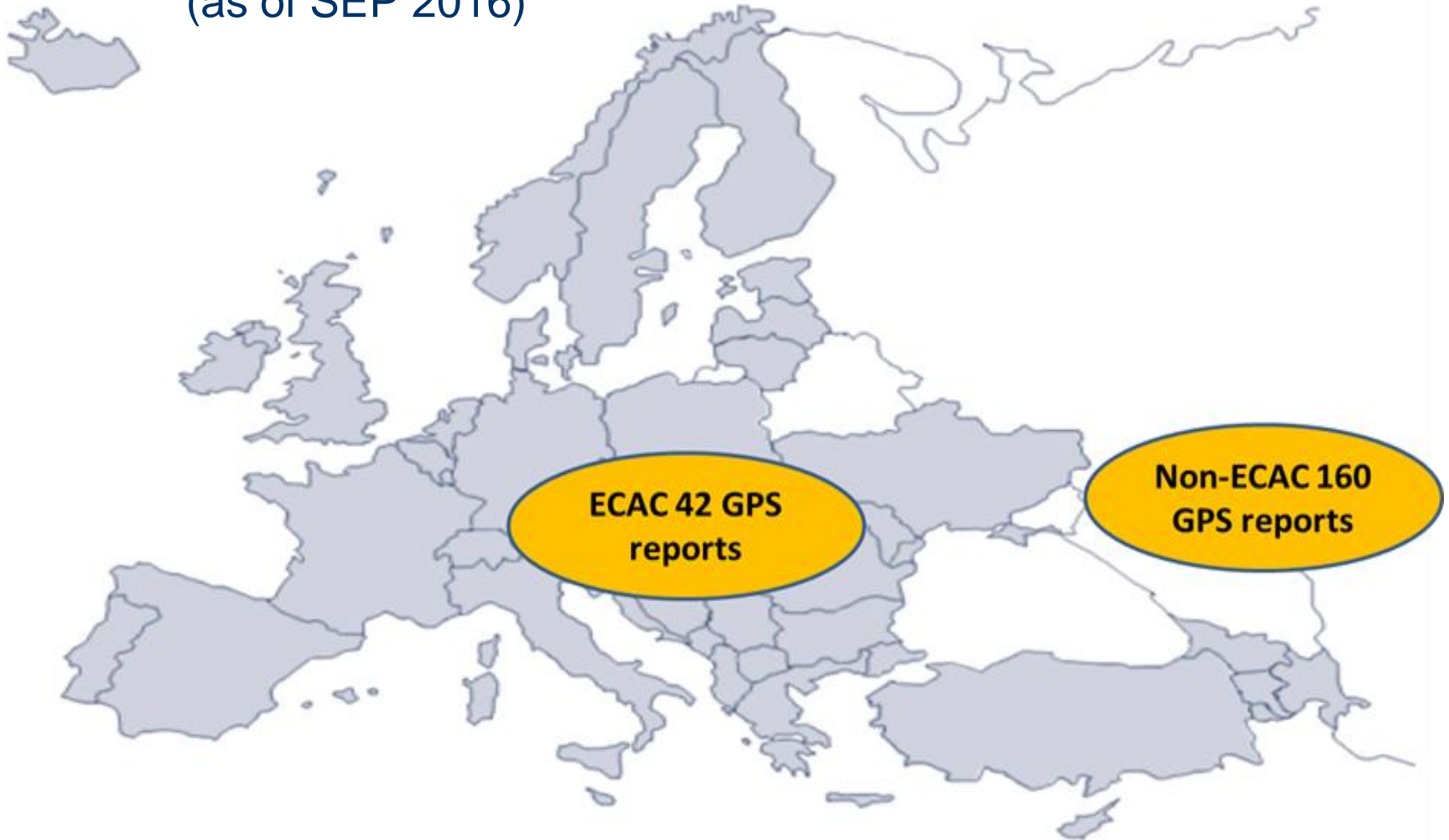


**Specific Actions already facilitated by EVAIR:**

- *Information Bulletin* sent to Airspace Operators in Black Sea / Caspian Sea Region
- NOTAM Issued by Turkey's DHMI (Ankara Region)

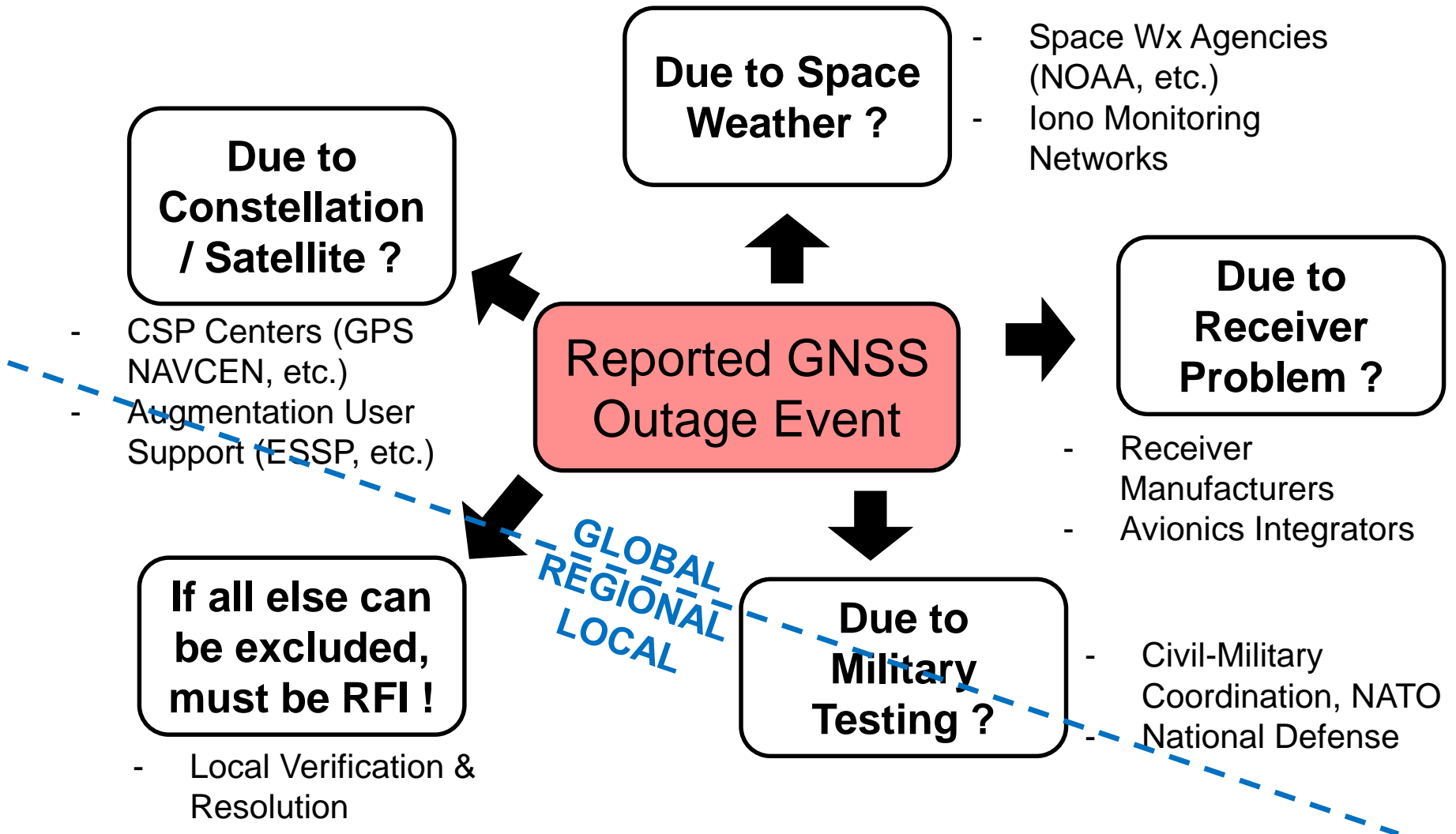
# Geographic Distribution of Events

(as of SEP 2016)



ECAC = European Civil Aviation Conference

# Identification of Probable Cause Through Elimination

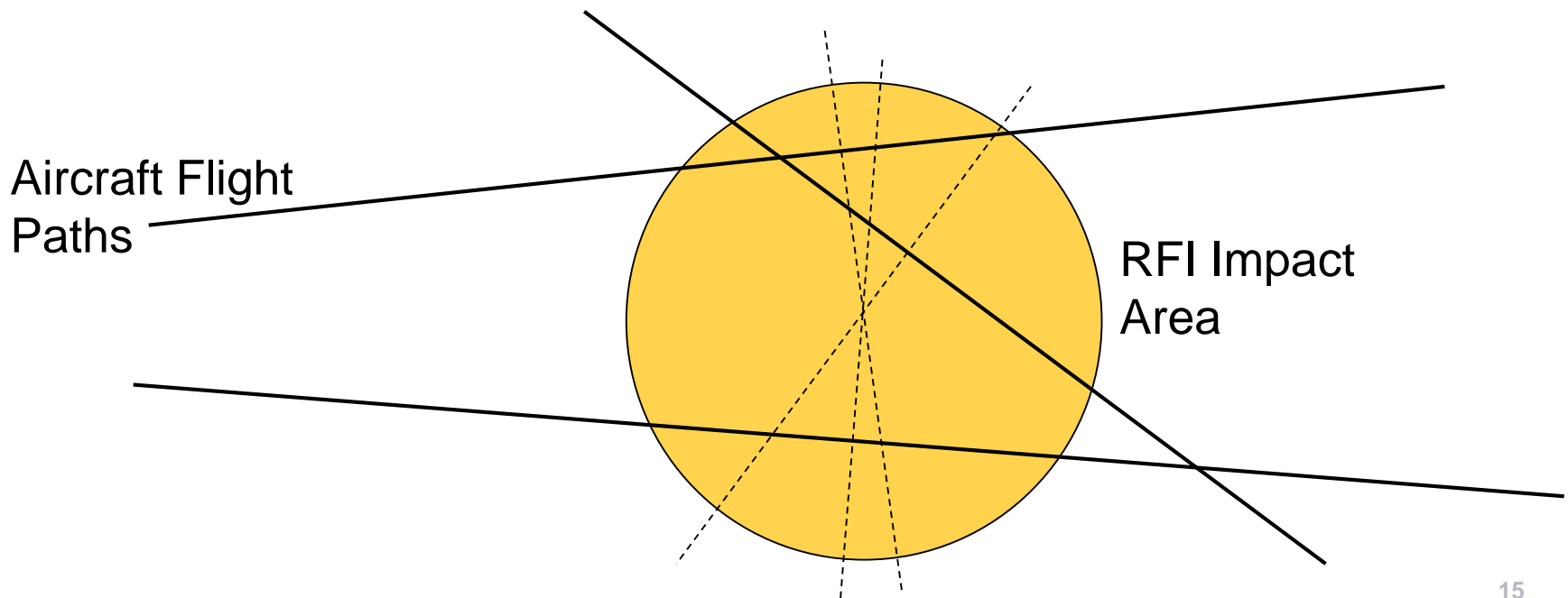


# Moving Towards RFI Localization Support

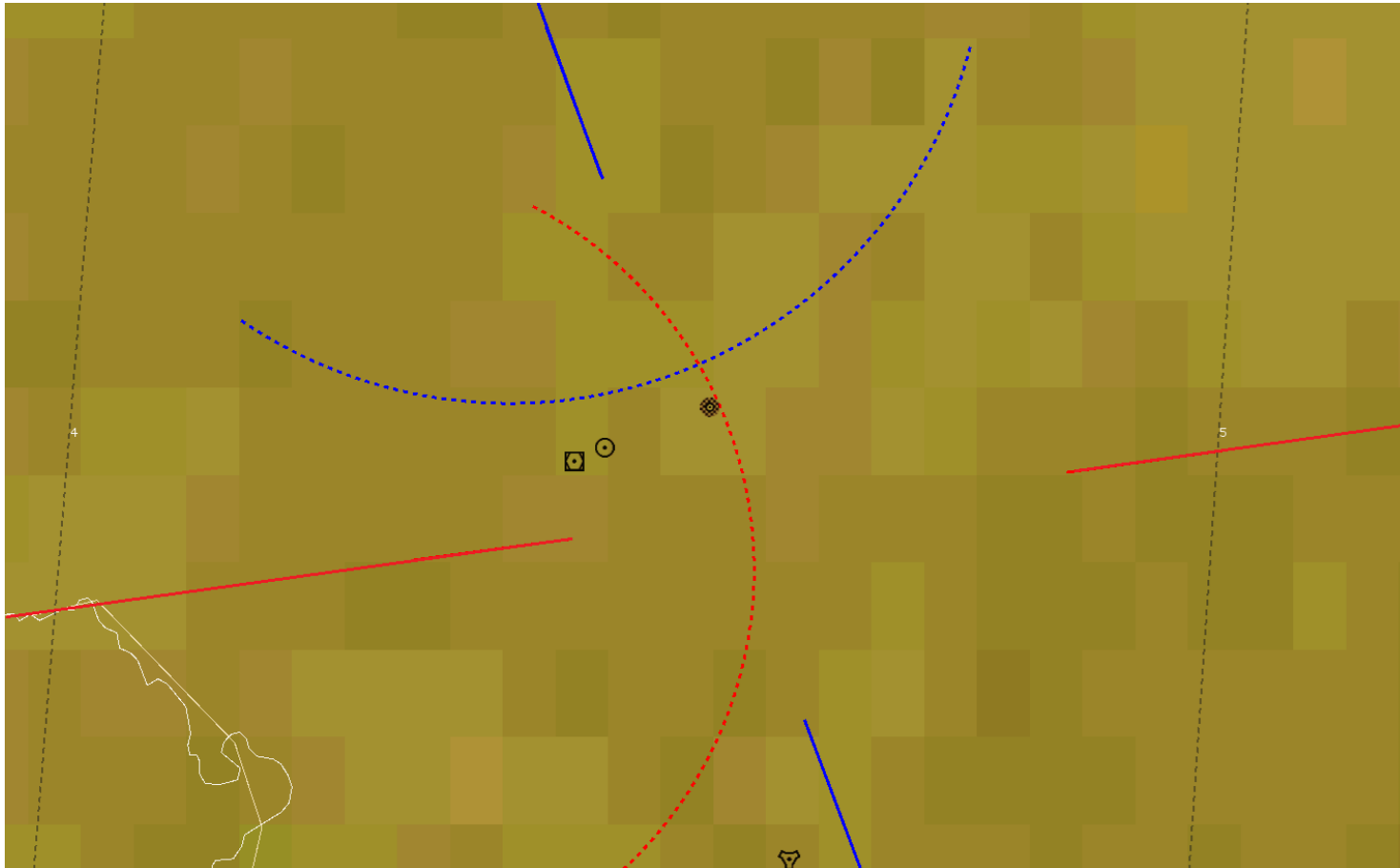
- Primary current method to detect potential RFI is pilot reporting
  - Pilot reporting by nature not precise about location of event
  - Developing process of what to do with reports
  - Evaluating if meaningful localization can be made possible if flight track data is made available
- Prerequisite 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)
- GPS track 2 (southbound)
- - - Possible RFI position
- - - Possible RFI position



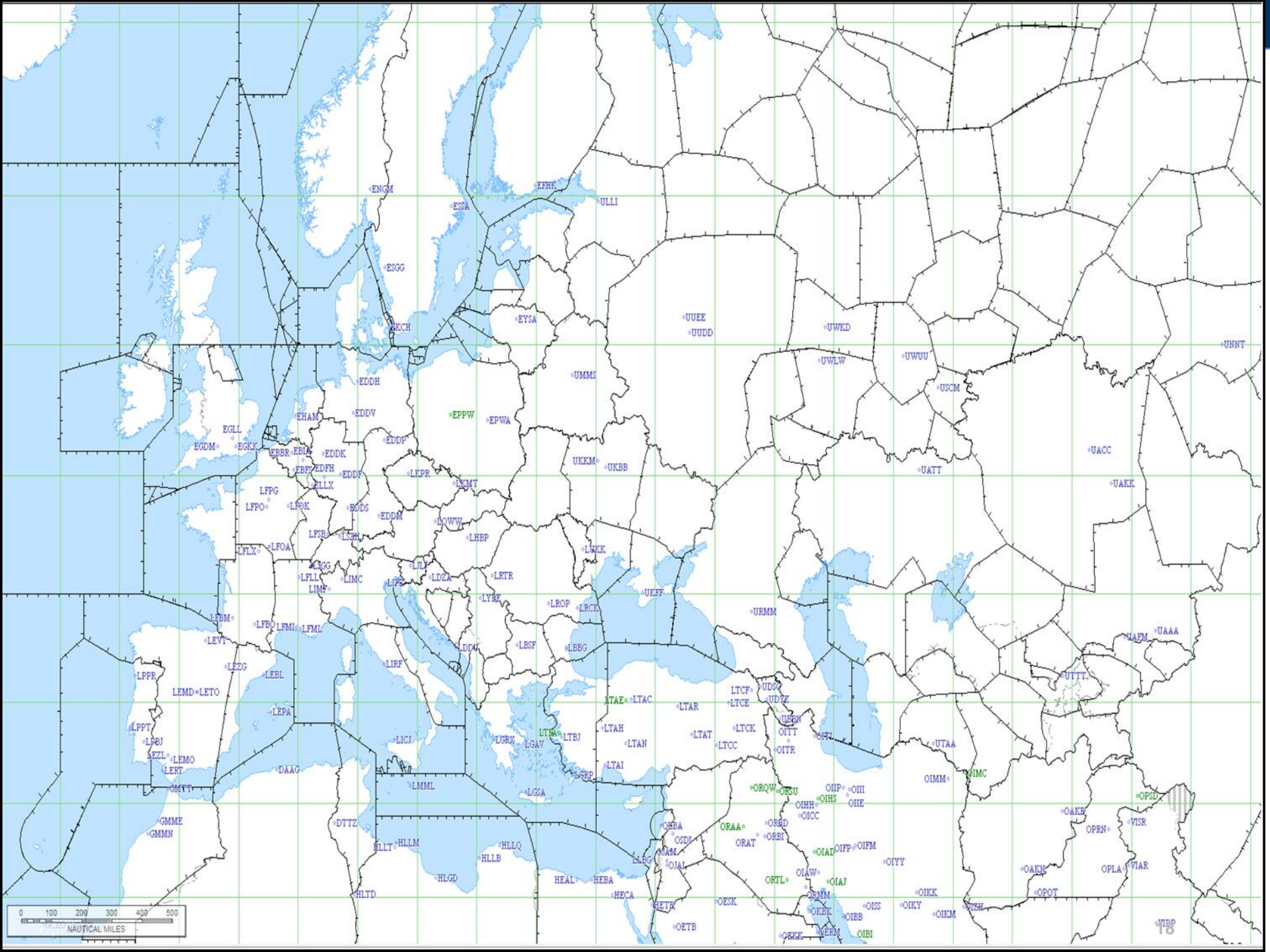
# ADS-B Flight Track Data from Public Internet

[only showing one day and region identified by EVAIR]

Figure removed. Work ongoing to obtain agreement from ANSP to show location of outages.

[ Confidentiality vs. Anonymity: Position Data is never anonymous ]

Actual cases will always be coordinated with the ANSP responsible for the affected airspace.



# FlightAware Coverage

PlanePlotter  FlightFeeder  PiAware  Radarcape





# FlightAware Coverage

ADS-B  MLAT  Radar  Oceanic  Projected



# RFI Localization Process

- EVAIR Reports serve as a trigger for further investigation
  - First check to eliminate non-RFI causes as much as possible
- Then need to rely on public domain ADS-B sources
  - Manage coverage and data quality issues
  - Limitations on data history
  - Limitations on track distribution (due to route network)
  - Recall earlier findings (CNS Team, Avionics White List)
- Options to be investigated:
  - Framework agreement with ADS-B data providers?
  - Publication on Network Manager Operations Portal Nconnect
  - Further investigation of aircraft installed GNSS Rx tracking and acquisition thresholds as a function of ground based RFI type and main airframe type?
  - Future Alternatives: GNSS RX Data, Global Flight Tracking?

# Summary

- GNSS RFI Mitigation continues to be an exercise in setting up interfaces
  - Current effort on ADS-B track data providers
  - Other venues to be developed: GNSS providers, multi-modal projects (EC), Aircraft OEM's, Airline FOQA Systems, NATO?
  - Developing “GNSS Information Concept” to know what to make available to aircrews and how (NOTAM or alternate channels)
  - *Happy to consider any data source incl. ground monitors!*
- Focus on short-term implementable options that approach stated ATCO requirement (“tell me which sectors are affected”)
- AOB: Related IFIS and ION Paper: RFI Localization using CRPA
  - Published in GPS World Magazine

<http://gpsworld.com/tracking-rfi-interference-localization-using-a-crpa/>

# Requests to UN ICG IDM Workshop

- 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)



# Back-Ups

- ADS-B Details



# Sydney Case: ADS-B Lessons Learned

- ADS-B reports key to identifying probable source location: Aerospace Industrial Park
  - “Search” proved sufficient to terminate 3h event
- Most Ground Monitor Stations didn’t see RFI
  - Some outages on WAM network, but difficult to locate
  - Need to evaluate line of sight
- Lessons Learned
  - Aircraft with INS didn’t lose NAV
  - Contingency procedures worked
  - Some aircraft GPS receivers didn’t recover (even on turnaround!)
  - Air Services Australia recommends recording of GPS status on QAR
  - Ground and aircraft based localization must work in complement
  - Implementation simplest if within existing processes & infrastructure

# ADS-B PIC Use for GNSS Monitoring

- ADS-B:
  - Different versions of the ADS-B Out MOPS in use
    - Different ways to encode integrity
  - Not all aircraft are “proper” ADS-B Out:
    - Version 0 implemented on voluntary basis (along with Mode S mandates, ADS-B only certified on a non-interference basis)
    - Later AMC 20-24 certification only applies to subset of fleet
    - Not necessarily using GNSS as position source
    - Some known avionics issues with version 0
- GNSS:
  - Different levels of performance
    - Limited information about the position source (SA On/Off, SBAS etc.)

# ADS-B based GNSS Monitoring: Issues

- Difficult Capability to Test without significant RFI Event
  - Study tried to correlate ADS-B Position Integrity Category with events:
    - Known RFI Events
    - Predicted RAIM Outages
    - Iono Events
    - None of the investigated events produced reliable correlation
- But learned about use of ADS-B data
  - Careful filtering of reliable data – establish white list?
  - On-board issues usually result in a certain NUCp/NIC behaviour
    - not so common – can be filtered out
  - Most of the fleet has stable quality indicators
  - SPI IR implementation of ADS-B Out version 2 (ED-102A / DO-260B) expected to further improve the picture
- **Still think that method has promise at least for “massive” RFI events**

# Position Integrity Category

- Ground system notation (Asterix) for integrity containment bound encoding

PIC	Integrity Containment Bound	NUCp ED102/DO260	NIC (+ suppl.) DO260A	NIC (+ suppl.'s) ED102A/DO260B		
				NIC	A/B	A/C
15	not defined					
14	< 0.004 NM	9	11	11	-	-
13	< 0.013 NM	8	10	10	-	-
12	< 0.04 NM		9	9	-	-
11	< 0.1 NM	7	8	8	-	-
10	< 0.2 NM	6	7	7	-	-
9	< 0.3 NM	-	-	6	0/1	1/0
8	< 0.5 NM	5	6 (+ 0)	6	0/0	-
7	< 0.6 NM	-	6 (+ 1)	6	1/1	0/1
6	< 1.0 NM	4	5	5	-	-
5	< 2.0 NM	3	4	4	-	-
4	< 4.0 NM	-	3	3	-	-
3	< 8.0 NM	-	2	2	-	-
2	< 10.0 NM	2	-	-	-	-
1	< 20.0 NM	1	1	1	-	-
0	No integrity (or > 20.0 NM)	0	0	0	-	-