Supporting
European
Aviation

EUROCONTROL

ICAO DOC 8071
Manual on Testing of Radio Navigation Aids
Volume II: GNSS
and current GNSS Operational Issues

ICAO Webinar on *Flight Inspection*

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FOUNDING MEMBER SESAR JOINT UNDERTAKING

NETWORK MANAGER

Update of Volume 2 on GNSS

- With removal of flight validation, GNSS Volume is becoming thin
  - GNSS Signal in Space analysis is best done with data collection receivers (or network of receivers) on ground
  - Nature of “testing” evolving toward engineering data analysis
  - Main content in terms of size will be GBAS
  - Maintaining two volumes to minimize editorial efforts
    - Doc 8071 often used in contract specifications

- Sometimes boundary between flight inspection and flight validation can be argued
  - In particular with landing systems reference path as it is the reference for guidance signals
- Sometimes people forget that Doc 8071 is GROUND and flight test
  - Thorough ground preparation prevents wasting resources using flight hours (both in inspection and validation)
  - Improved guidance on flight path alignment verification

Volume 2 Revised Structure

1. General: GNSS-specifics only, no more duplication of chapter 1 in Vol I

2. ABAS for NPA becomes GNSS Core Constellations and ABAS
   - Link to new material in Doc 9849, GNSS Manual, on Performance Monitoring

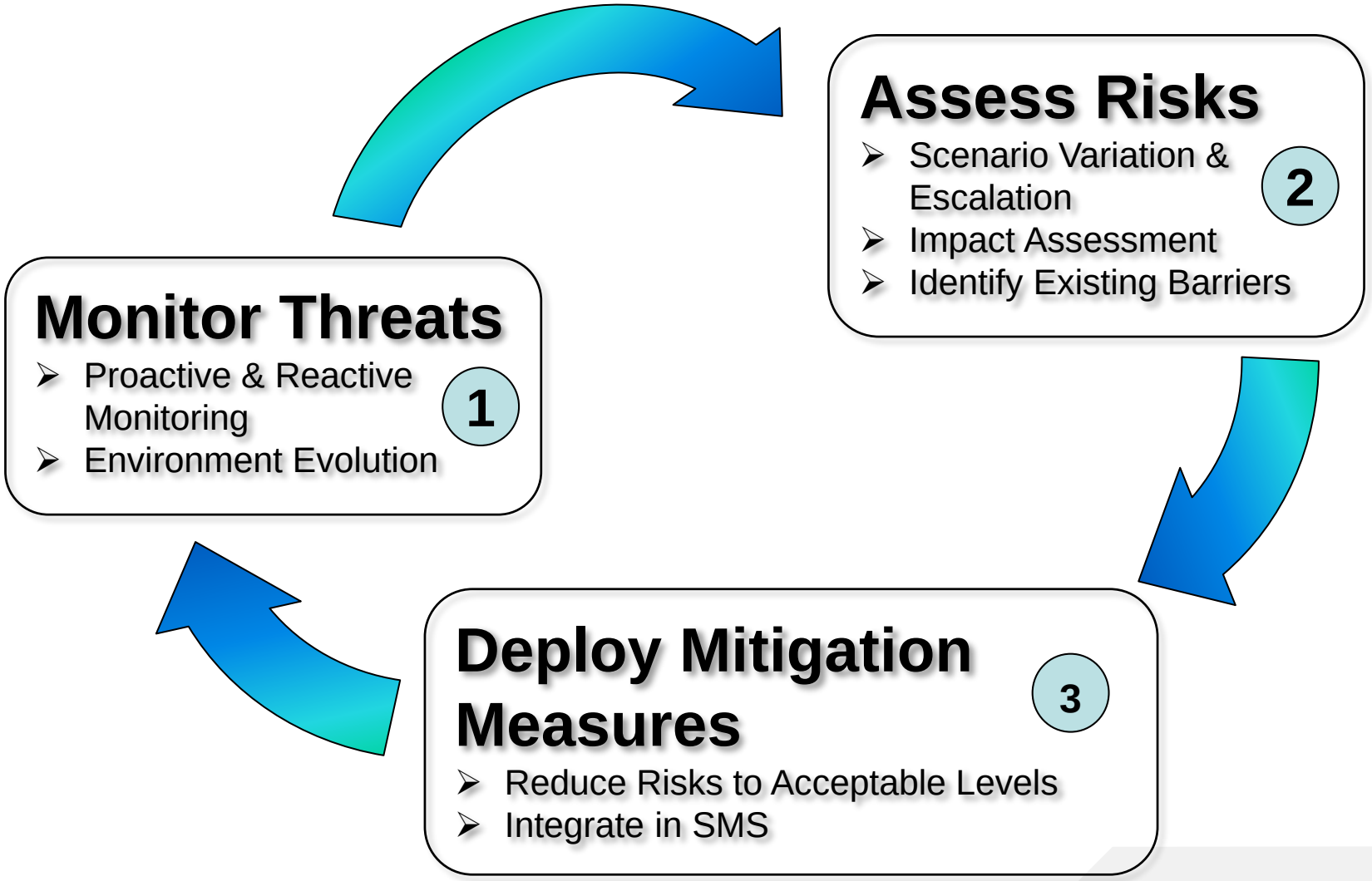
3. SBAS: Testing relevant to SBAS service provider, TBD?

4. GBAS: Most significant update including GAST D

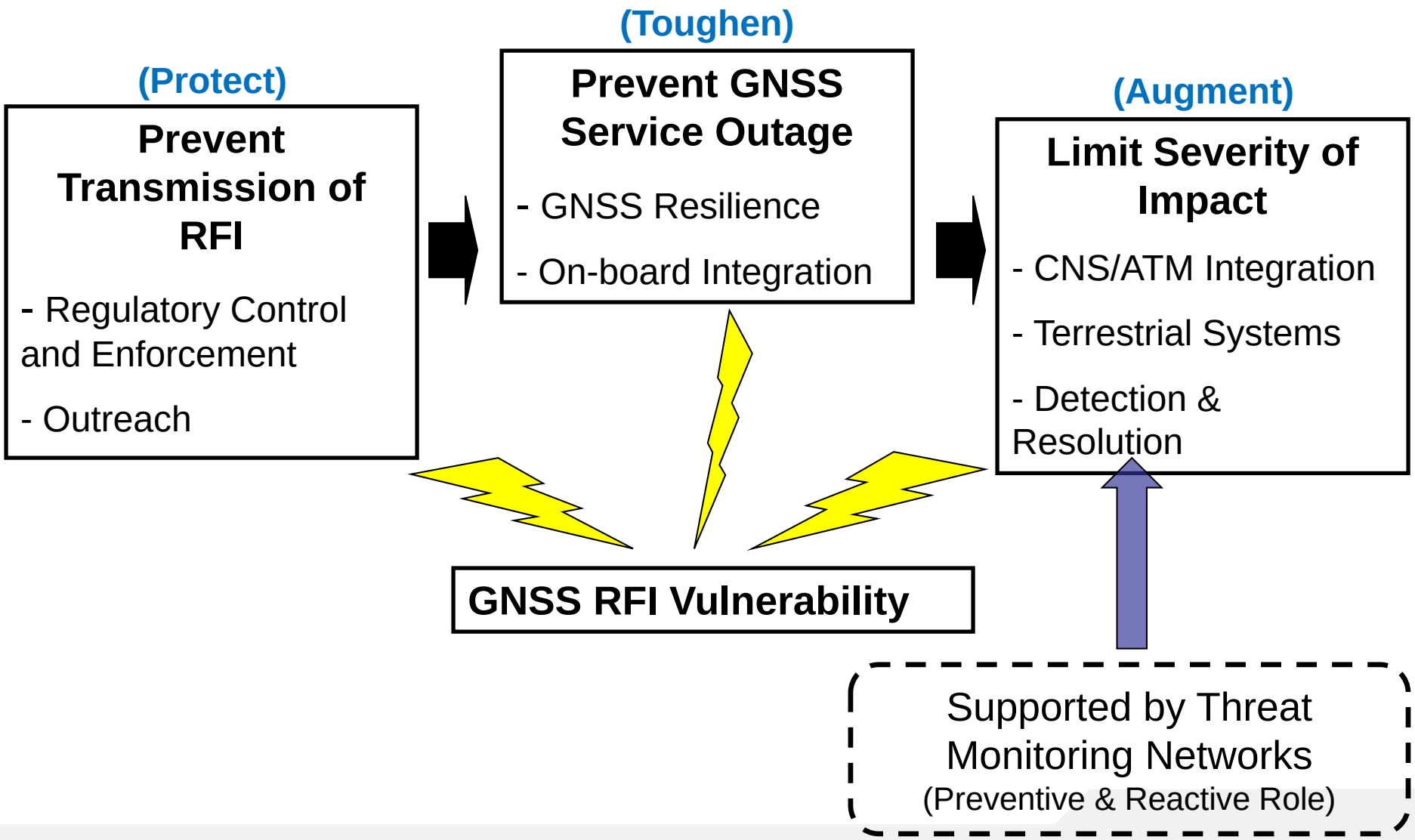
5. Flight Validation becomes **new GNSS RFI measurement chapter**
   - Building on attachment 3 to chapter 1

Moving from Vulnerability to Mitigation

GNSS RFI Mitigation Plan published in ICAO Doc 9849, GNSS Manual

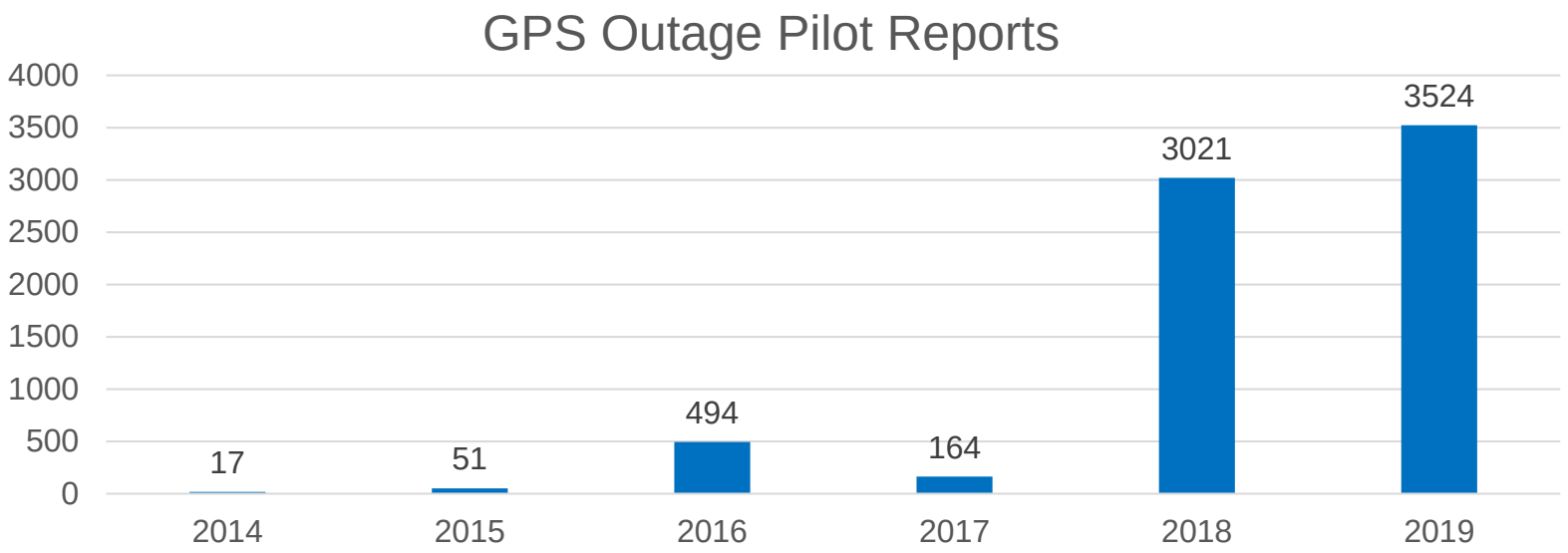


Implementing Mitigation Barriers



First Step: Visibility!

EUROCONTROL Voluntary ATM Incident Reporting (EVAIR)



- 250 Participating Aircraft Operators
  - Coverage: Europe, Middle East, Northern Africa
  - Detail reports subject to confidentiality (just culture reporting)
- RFI most probable cause in absence of rx, constellation or solar issues
- 2018/2019 trend continues: average of 10 GPS reports DAILY!
  - 2020 decrease due to reduced flights (COVID), RFI persists in many locations

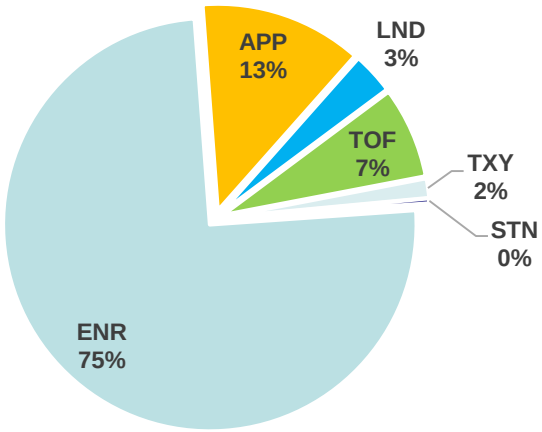
EUROCONTROL Voluntary ATM Incident Reporting (EVAIR)

Reported failures:

- Failure of one or both GPS units
- Disagreement between GPS positions and Flight Management System
- 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 GNSS procedure and request for radar vectoring
- Wind and ground speed wrong presentations
- Lost ADS-B, wind shear, terrain and surface functionalities
- Aircraft clock irregularities

- Many aircraft manufacturers are publishing more detailed guidance on GNSS RFI impact on avionics for their operators
- **Flight inspection system (FIS) operators should also assess the vulnerability of the FIS to GNSS RFI and resulting operational impact**

EUROCONTROL Voluntary ATM Incident Reporting (EVAIR)



ENR = En-Route
APP = Approach
LND = Landing
TOF = Take Off
TXY = Taxi
STN = At Gate / Stand

→ 35 Flight Information Regions FIR affected
→ Several measurements clearly confirm narrowband RFI on L1 at significant distances (300+ km) and altitudes (10km)

→ Most affected regions:

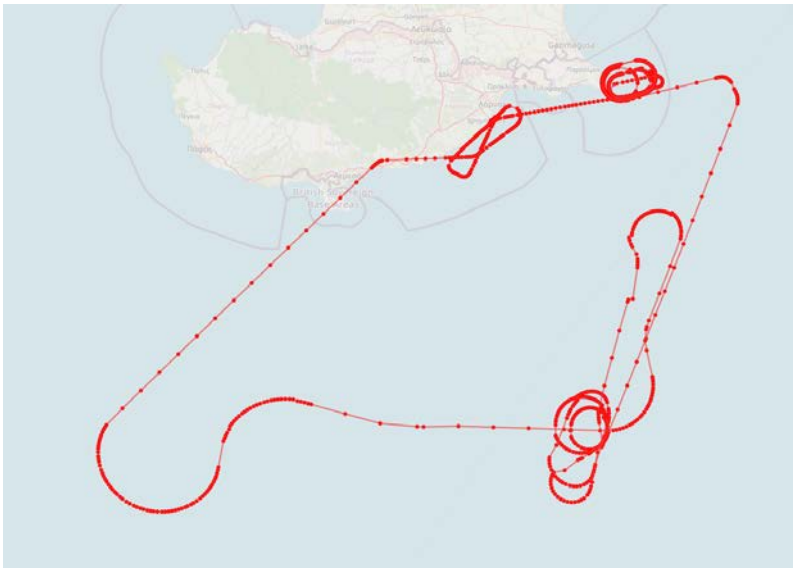
- Middle East – Europe across the Black Sea / Caspian Sea
- Middle East – Europe via Mediterranean Sea (Cyprus Airspace, Malta)
- Middle East – Canada and USA via cross polar routes

→ Several events also in West European Terminal areas (airports)

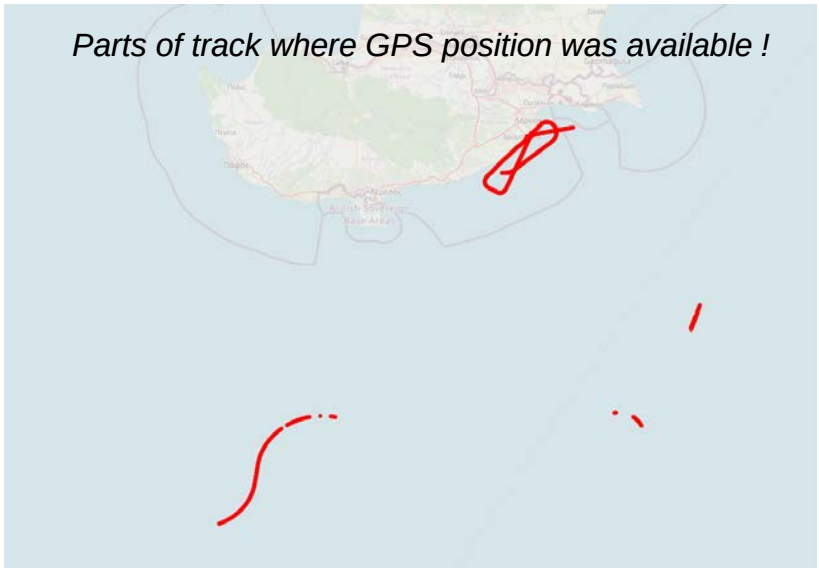
→ Significant number of events in a specific area leads to further investigation: Cyprus example (Nicosia FIR)

DLR Airbus A320 Test Flight in Cyprus Airspace

13 FEB 2020 Flight Track



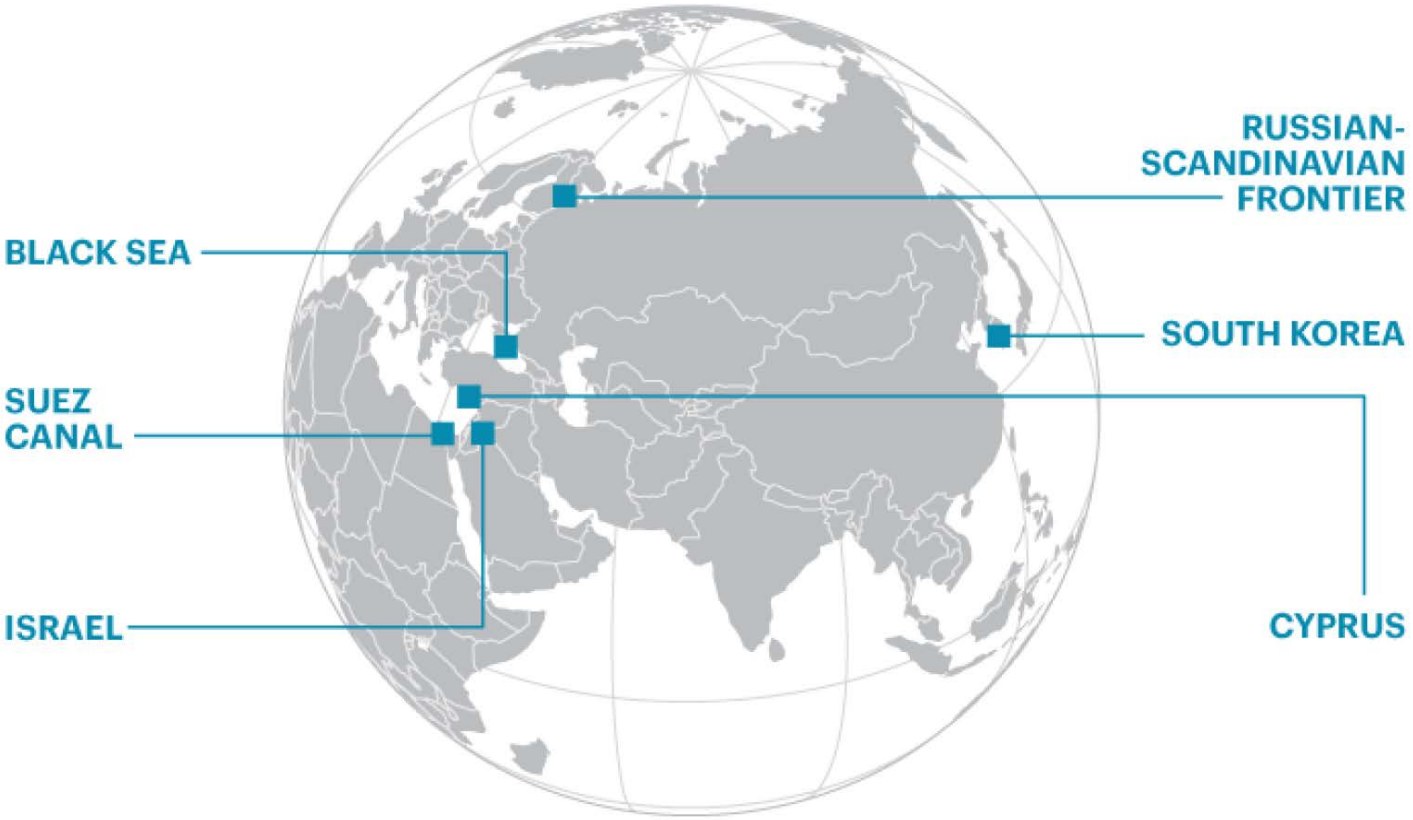
Parts of track where GPS position was available !



- 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
- Multiple GPS-related alerts in cockpit (GPS 1 Fault, GPS 2 Fault, GPS Primary Lost)

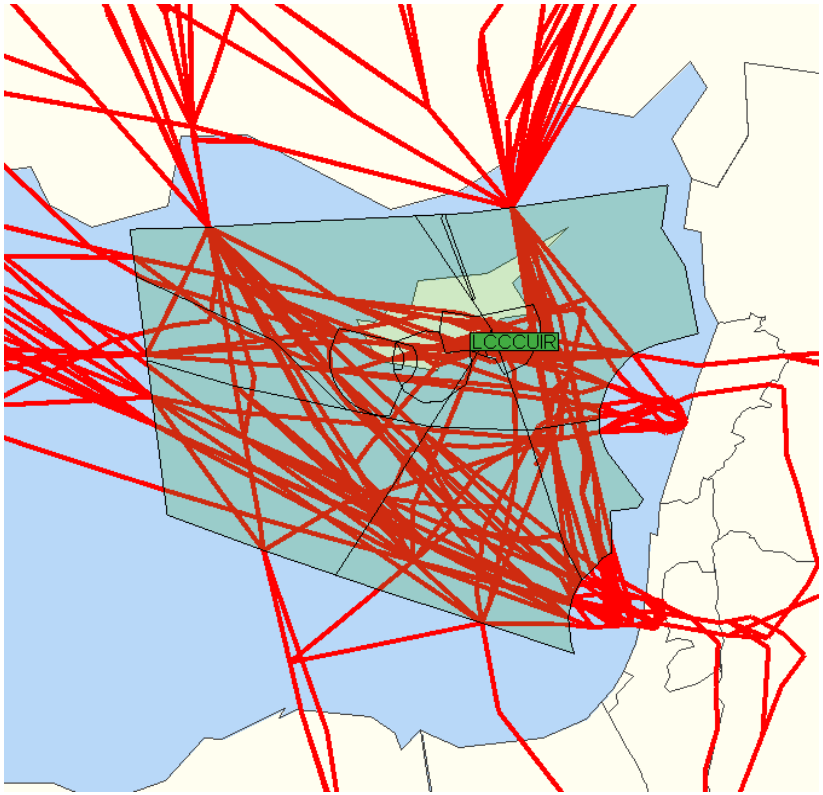
GNSS RFI Impact on Maritime Sector



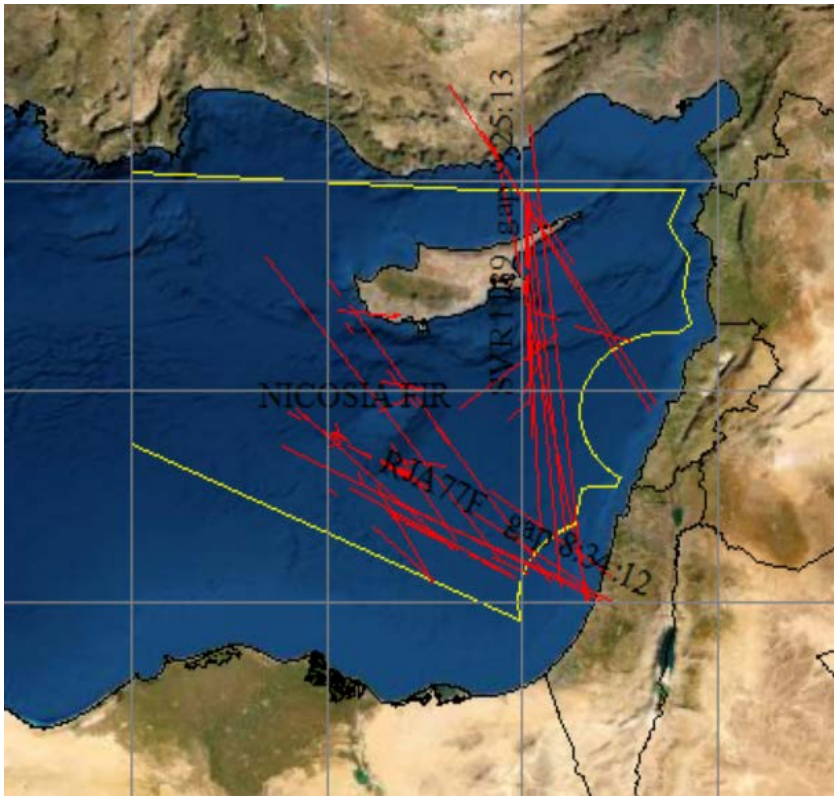
- Catherine Dunn, Fortune Magazine, “Mysterious GPS outages are wracking the shipping industry”, 22 January 2020

What can we do with detected GPS Outages?

3h slot – FL>290 – VIA LCCCUIR – reported by ADS-B stations (179 Flights)



Traffic



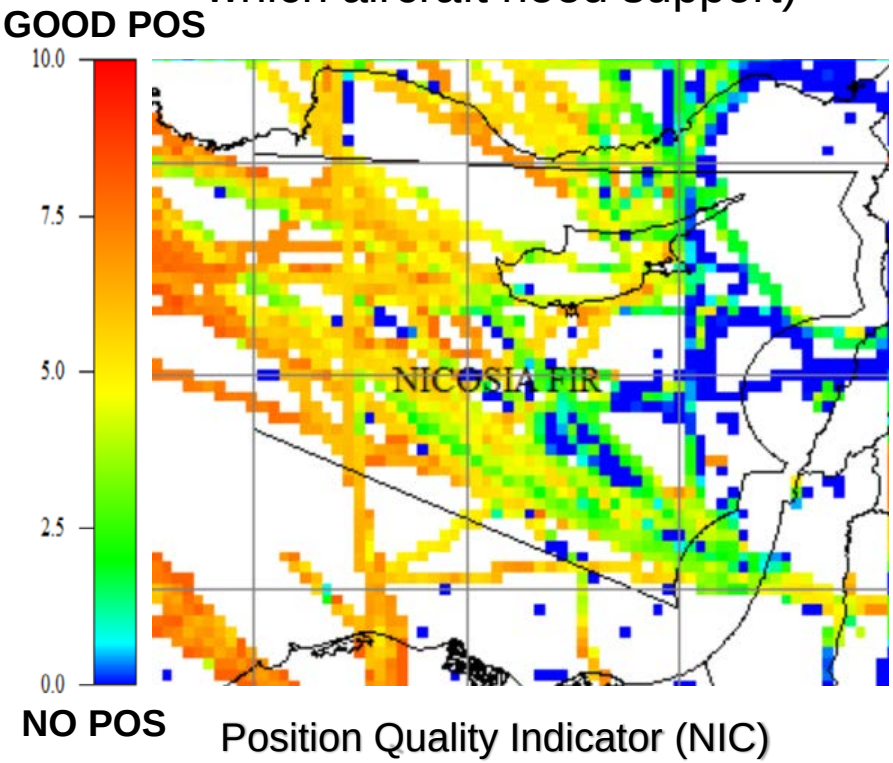
ADS-B gaps

21% of flights crossing Nicosia FIR are impacted
(Over 50% impacted flights if considering adjacent areas!)

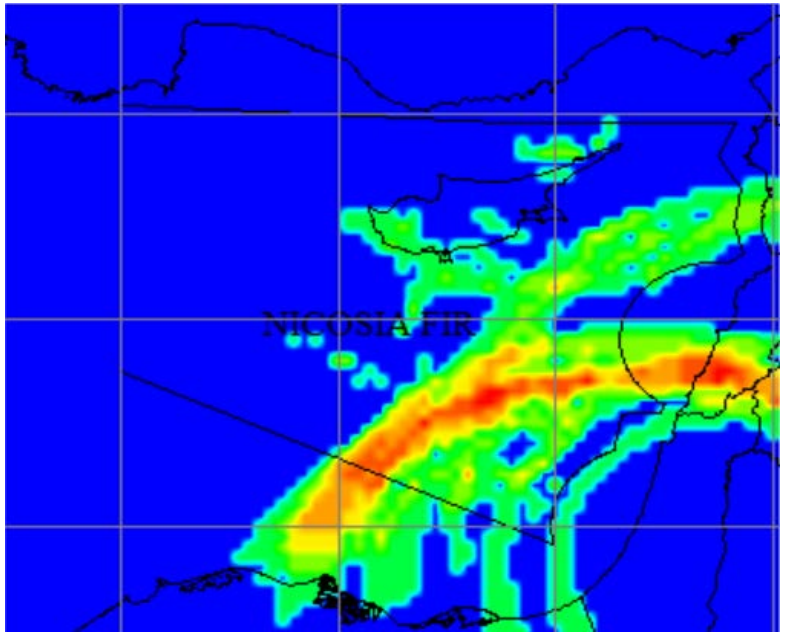
ADS-B Data Analysis

1st Priority: Manage Operational Impact (Air Traffic can identify which aircraft need support)

2nd Priority: Identify Probable RFI Source: Geolocation to **Stop** RFI Source!?



Position Quality Indicator (NIC)



RFI Source Heatmap

Clearly confirms multiple aircraft impact: given calm ionosphere, highly likely due to RFI

Using Power Difference of Arrival (PDOA) approach: multiple RFI sources, possibly moving!

Recommendations of ICAO State Letter 2020/89

AN 7/5-20/89, 28 August 2020

- **Subject:** Strengthening of communications, navigation, and surveillance (CNS) systems resilience and mitigation of interference to global navigation satellite system (GNSS)

- **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

- Doc 9849 Appendix F, 8.2 **Reactive measure checklist** (items a, b, c, g):
  - measurement capabilities exist for all potentially required monitoring tasks ;
  - where supported by a corresponding risk analysis, airports perform monitoring for RFI at critical points within or near airport perimeter ;
  - **capabilities to detect, locate and identify RFI sources are in place**
  - all involved personnel is trained to recognize and deal with RFI events as appropriate

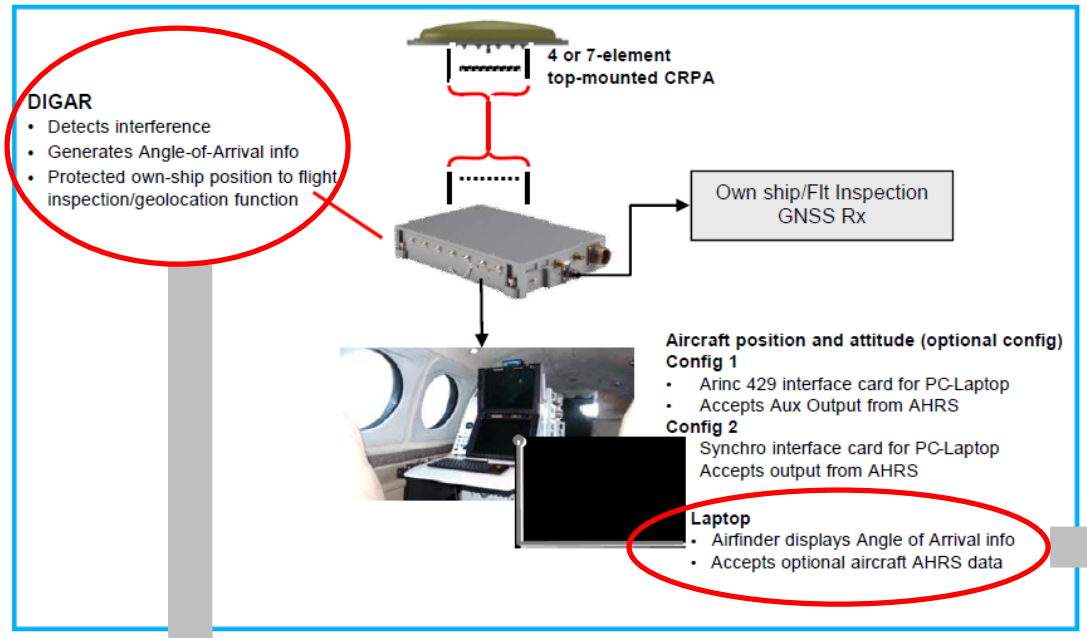
Complementary Capabilities

- Advantage of Pilot reports and ADS-B analysis is evidence of operational impact
  - Disadvantage: No solid proof or RFI
  - Such proof is highly desirable for suitable radio regulatory action

- Ground vs. Airborne Measurement Capabilities
  - Ground receiver often will not “see” RFI impacting aircraft at altitude
    - But can record continuously
  - Aircraft can’t stay in the air forever
    - If successful at confirmation and geolocation, can reduce search space for efficient deployment of ground resources

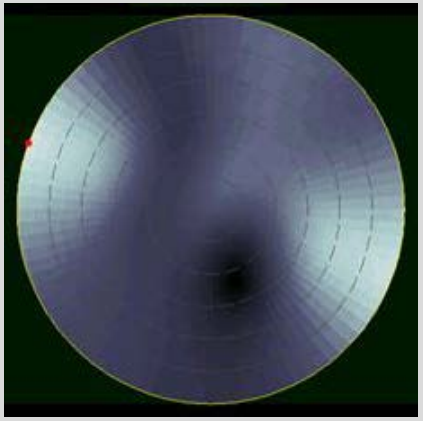
- FI / FV Providers should do whatever possible to increase GNSS RFI detection capabilities
  - Many measurement quality GNSS receivers have RFI detection features
  - Suitable RF signal capture recommended with access to GPS antenna
  - Best is direction finding capability

Use of CRPA for In-flight RFI LOC? (2016 ION)



Proposed Principle of Operations

- Rockwell Collins DIGAR: Digital GNSS Anti-jam Receiver
- Algorithms able to detect wide range of RFI sources (Continuous Wave (CW), swept CW, Broadband, …)
- AHRS and Direct Geolocation Processing NOT YET implemented / investigated

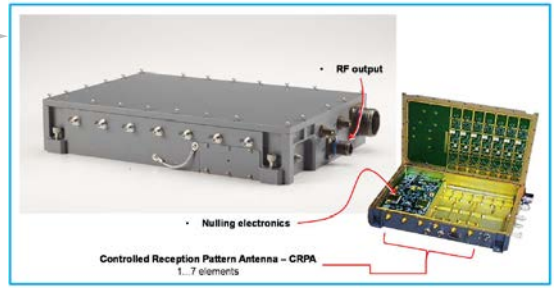


- **White area: possible RFI direction**
- **Red dot: received power above specified threshold**

Jammer Direction Finder Display

Installed system includes:

- CRPA
- Antenna & interface cabling
- DIGAR with GNSS Baseband Processing
- Laptop with DF Software



DIGAR

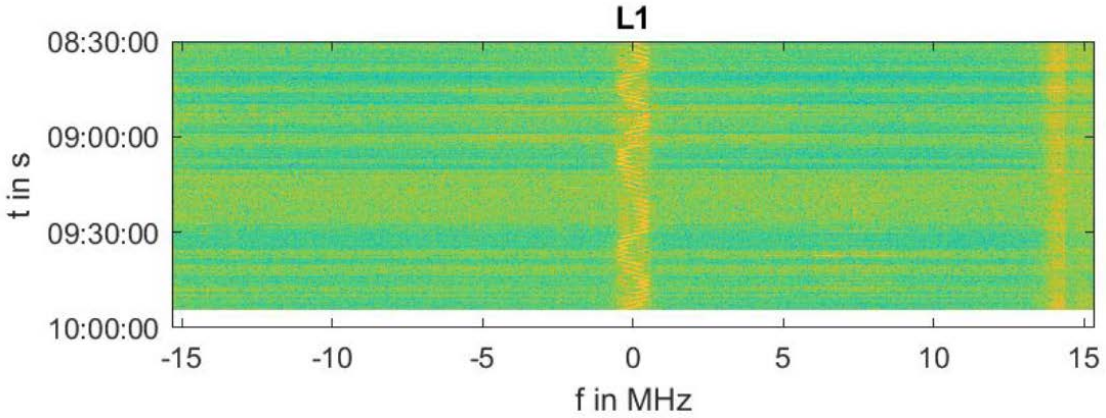
Conclusions

- Efficient Aviation Operations are enabled by GNSS (PBN, ADS-B)
  - For both capacity and reduced environmental impact
  - INS, DME/DME and ILS are the main alternative navigation capabilities today, VOR/DME is complementary (but VOR can be reduced)
    - Keep them going! (See Doc 8071 Volume I)
- Most significant GNSS Operational issue today is RFI
  - Hard to beat an airborne spectrum measurement, if available
    - Keep it on during ferry flight!
    - Consider recording on other aerial work aircraft
      - Example: Helicopter Emergency Medical Service HEMS
    - Even a very basic GNSS receiver can provide MUCH more detail than a pilot
  - Especially near conflict zones, an independent measurement can be very valuable
  - Future aviation GNSS receivers may detect and downlink RFI information
- Variety of projects ongoing to help establish best practice
  - Need continued exchange of experiences
  - ***Need to develop balanced & complementary capabilities***
  - Technology, Procedures, Human Factors

Thanks & Questions ???

- Data Processing and Analysis by Hamdi Nasser, Valeriu Vitan, EUROCONTROL
- EVAIR Manager: Dragica Stankovic, EUROCONTROL
- DLR Cyprus Flight: Dr. Okuary Osechas, Dr. Michael Felux, DLR
- ADS-B Data provided by Air Traffic Control of Cyprus and Malta
- Further data provided by French Flight Inspection Service, DSNA/DTI

Aircraft bottom mounted direction-finding array (multiple frequency bands), French Flight Inspection



"Waterfall" Spectrum Measurement at 1575,42 MHz by DLR near Cyprus

Further Reading and Links

- EUROCONTROL EVAIR: https://www.eurocontrol.int/service/eurocontrol-voluntary-atm-incident-reporting
- EUROCONTROL CNS Dashboard: https://www.eurocontrol.int/communications-navigation-and-surveillance
- GNSS Reversion Handbook on ePBN Portal: https://pbnportal.eu/epbn/main/Using-PBN/GNSS-Reversion/GNSS-Reversion.html?queryStr=GNSS%20Reversion%20Handbook
- GNSS Spoofing and Aviation: An Evolving Relationship: https://insidegnss.com/gnss-spoofing-and-aviation-an-evolving-relationship/
- Interference Localization using a Controlled Radiation Pattern Antenna, Berz et al, ION GNSS Portland USA September 2016
  - Also in FEB 2017 GPS World, “Tracking RFI: Interference Localization using a CRPA”