Supporting
European
Aviation

EUROCONTROL

Use of Satellite-Based Communication, Navigation and Surveillance (CNS) by Aviation

ITU Webinar on *Interference to Satellite Systems*

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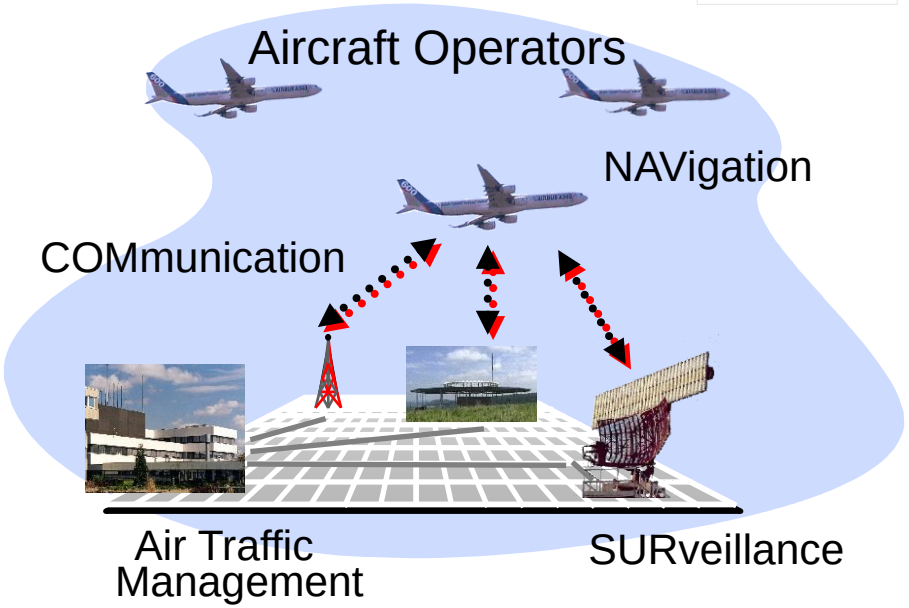
FOUNDING MEMBER SESAR JOINT UNDERTAKING

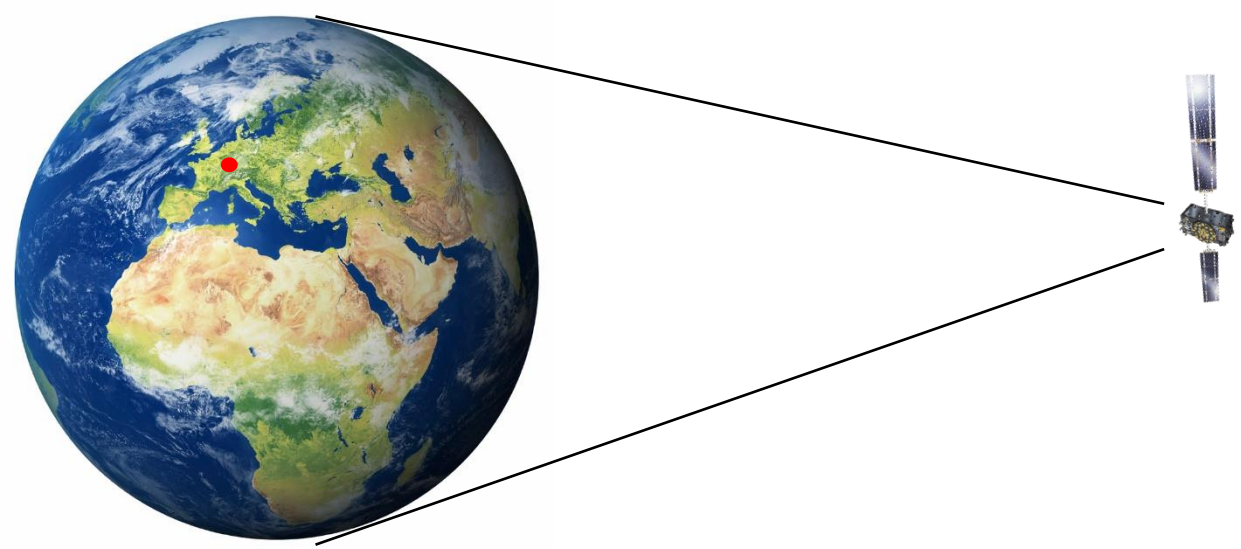
NETWORK MANAGER

CNS Enables Air Traffic Management (ATM)



- No RF Spectrum = No CNS = No ATM
  - Indispensable ingredient for safe and efficient aviation operations
- Provision of CNS: Sovereign State responsibility under Article 28 of the Chicago Convention, Int. Civil Aviation Organization (ICAO)
  - Delegated to Air Navigation Service Provider (ANSP)
  - ANSP typically funded through route charges (passenger tickets)
- **Pressures** on aviation: (safety/security), cost, environment; spectrum?

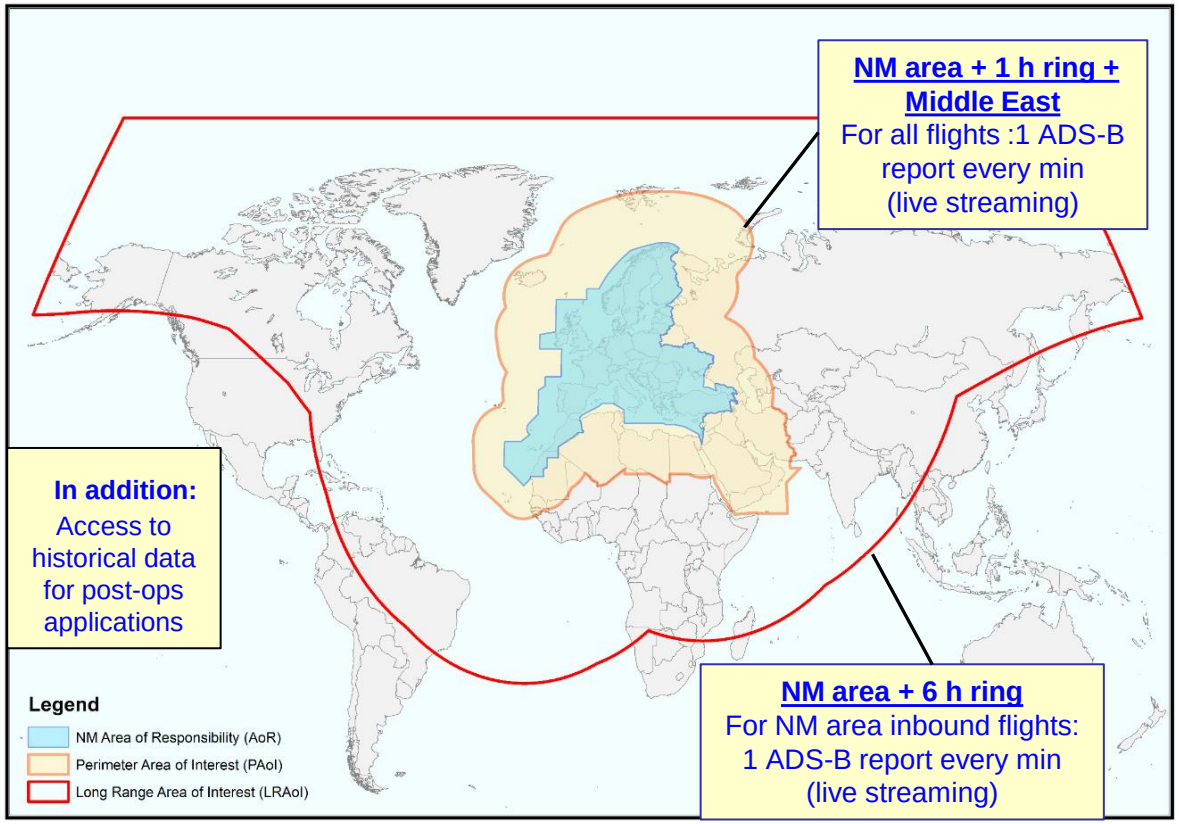
Hard to beat the coverage of satellites…



- Global COM: Full transoceanic & remote area connectivity
- Global NAV: GNSS for Performance Based Navigation & Free Routes
- Global SUR: ADS-B complementing RADAR, Global Flight Tracking?
- Need to meet aviation target level of safety (TLS)
  - No more than 5 x 10^{-9} fatal accidents per flight hour
  - Sets stringent CNS system design & operational requirements on integrity, continuity, accuracy, availability and other quality of service parameters
- Tricky new element: normally SHARED systems, multi-sector

Space-based ADS-B

EUROCONTROL agreement with Aireon to support the Network Management (NM) Function



Use cases:

Air Traffic Flow Management (ATFM)
Crisis management
Contingency situations
Performance monitoring
Safety assessments
Post-ops analyses etc.

Benefits:

Predictability improvements especially at the borders of the European airspace

ATFM delay reduction

Efficiency improvements, environmental benefits, improved crisis and contingency management etc.

ADS-B: Automatic Dependent Surveillance – Broadcast; cooperative surveillance, aircraft transmits GPS position and other data

Focus on Satellite Navigation

- GNSS: Global Navigation Satellite System
  - Core satellite constellation (GPS, GLONASS, Galileo, Beidou) combined with
  - Augmentation: Aircraft-Based, Space-Based, Ground-Based
  - ABAS / SBAS / GBAS designed to aviation requirements for a phase of flight
- Short History
  - Letter of commitment to ICAO: United States (1994), Russian Federation (1996)
  - Publication of GNSS in ICAO Standards & Recommended Practices (2001)
  - 2020: Almost all aircraft equipped with *at least* GPS L1 ABAS receiver
  - Ongoing: Inclusion of Galileo & Beidou, updates and expansion to L5
  - Operating under ITU RNSS Allocation, aviation use is safety use
  - GNSS being integrated into many aircraft & ground CNS systems
- BUT: What about GNSS vulnerabilities?
  - System provider errors / malfunctions ➔ Augmentation service design
  - Multipath, Ionosphere & Troposphere propagation ➔ Models & filters OK
  - RF Interference ➔ most significant vulnerability, physics of space based systems

L1 = 1559 - 1610 MHz, L5 = 1151 – 1214 MHz

Moving from Vulnerability to Mitigation

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

Monitor Threats (1)

- Proactive & Reactive Monitoring
- Environment Evolution

Assess Risks (2)

- Scenario Variation & Escalation
- Impact Assessment
- Identify Existing Barriers

Deploy Mitigation Measures (3)

- Reduce Risks to Acceptable Levels
- Integrate in SMS

Implementing Mitigation Barriers

(Protect)

Prevent Transmission of RFI

- Regulatory Control and Enforcement
- Outreach

(Toughen)

Prevent GNSS Service Outage

- GNSS Resilience
- On-board Integration

(Augment)

Limit Severity of Impact

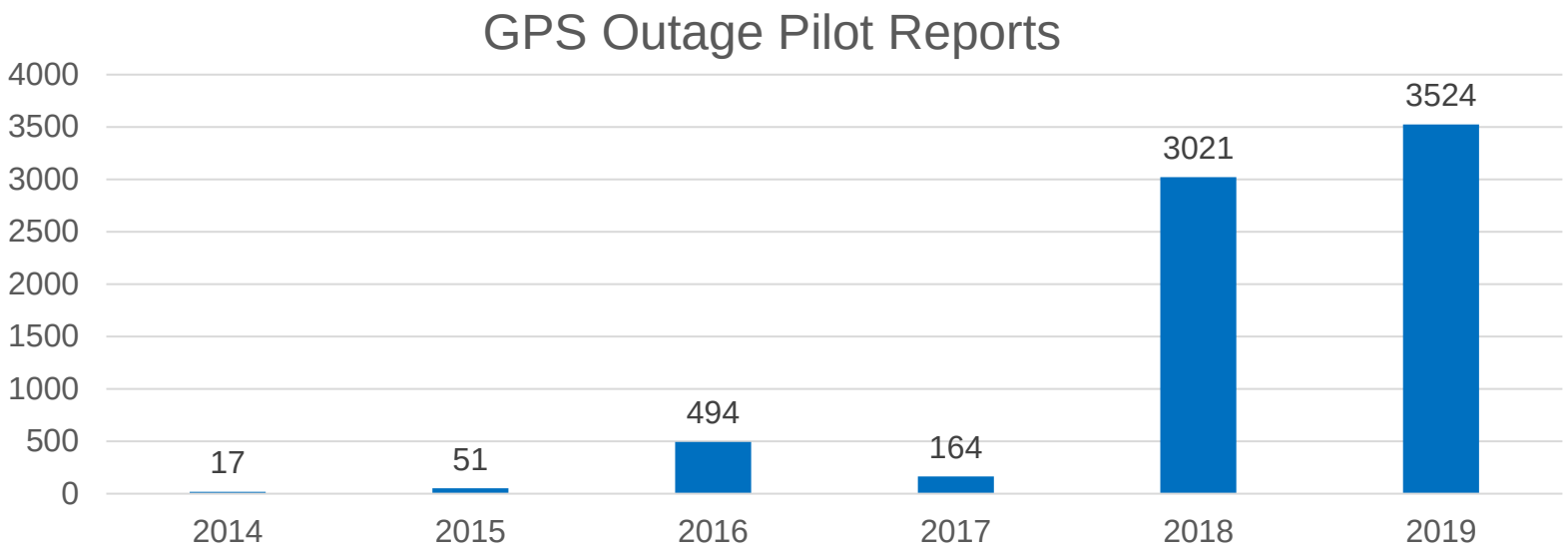
- CNS/ATM Integration
- Terrestrial Systems
- Detection & Resolution

GNSS RFI Vulnerability

Supported by Threat Monitoring Networks
(Preventive & Reactive Role)

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

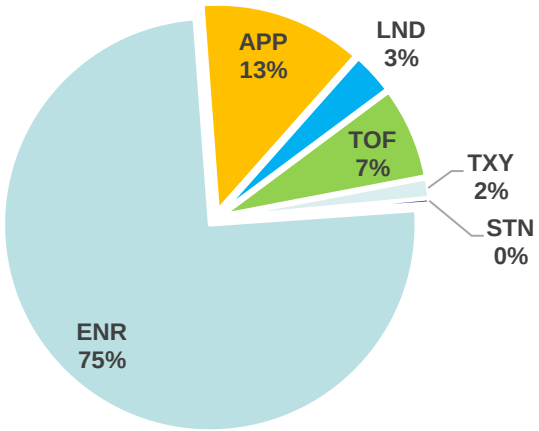
EUROCONTROL Voluntary ATM Incident Reporting (EVAIR)

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

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)

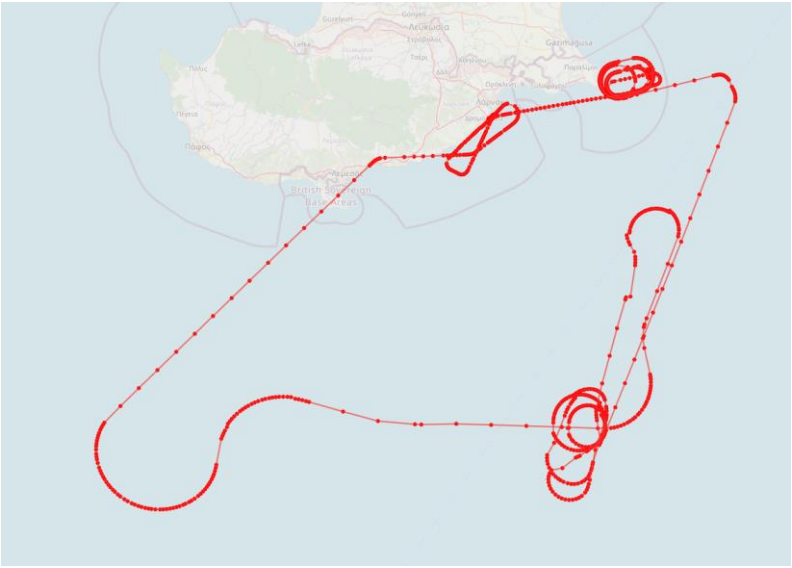
→ Most affected regions:
- Middle East – Europe across the Black Sea / Caspian Sea
- Middle East – Europe via Mediterranean Sea (Cyprus Airspace, Malta)
- Middle East – Canada and USA via cross polar routes

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

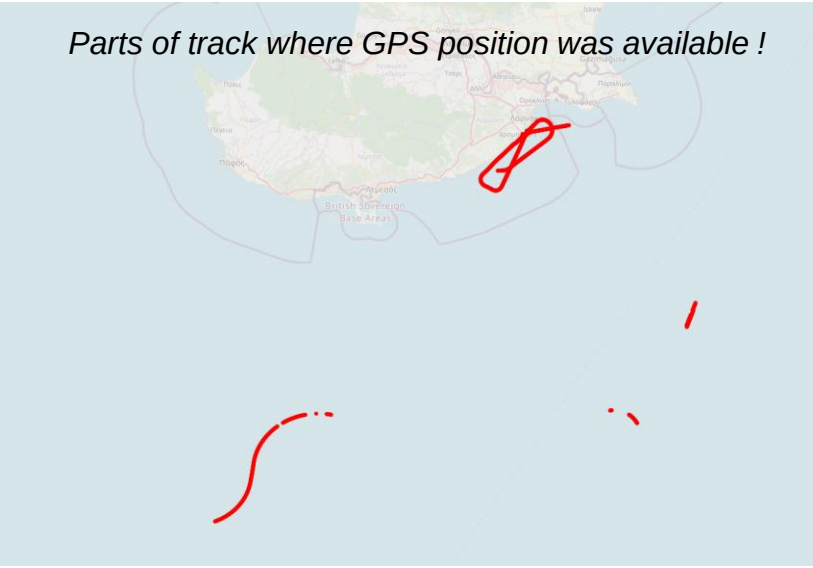
→ Significant number of events in a specific area leads to further investigation: Cyprus example (Nicosia FIR)

DLR Airbus A320 Test Flight in Cyprus Airspace

13 FEB 2020 Flight Track



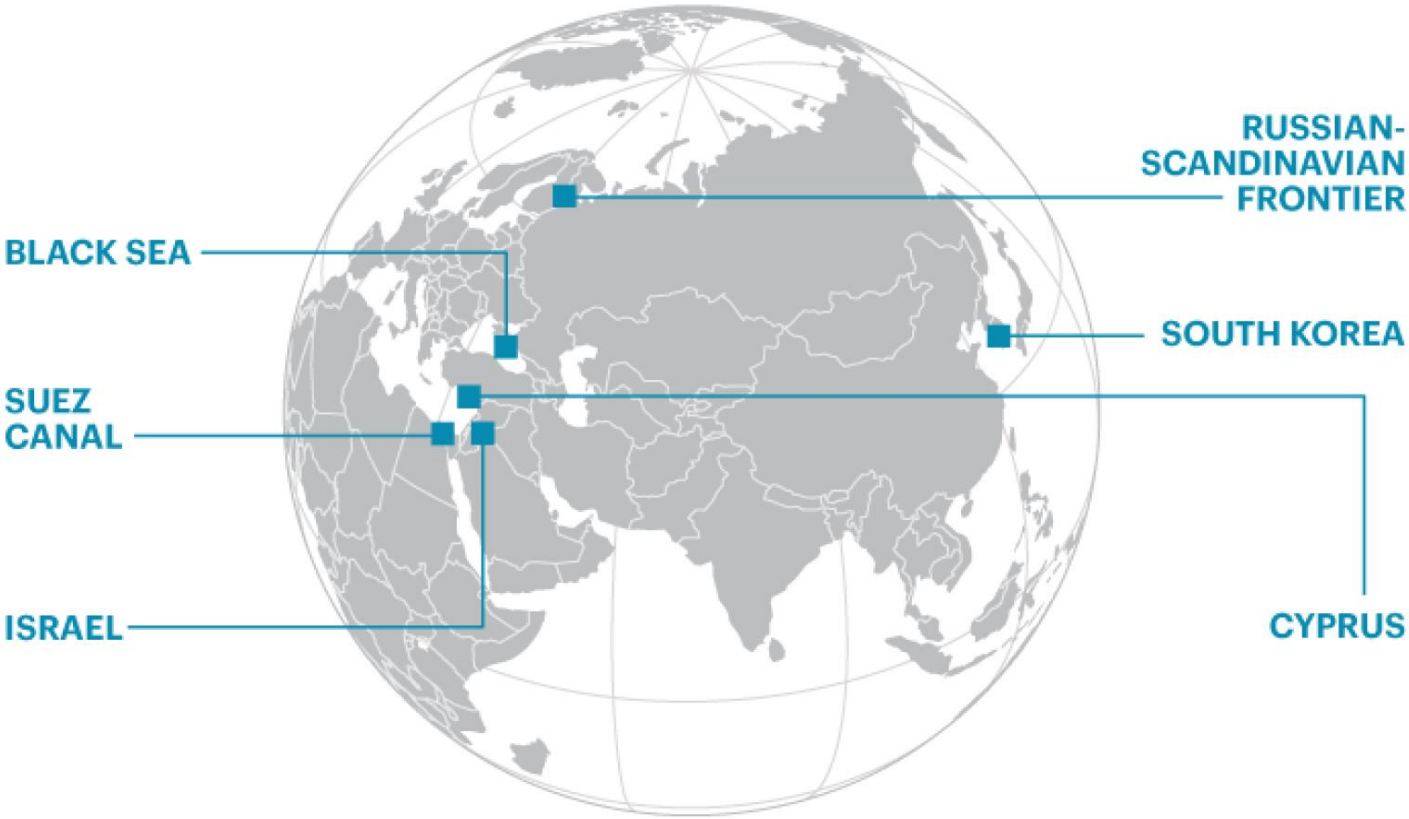
Parts of track where GPS position was available !



- 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)

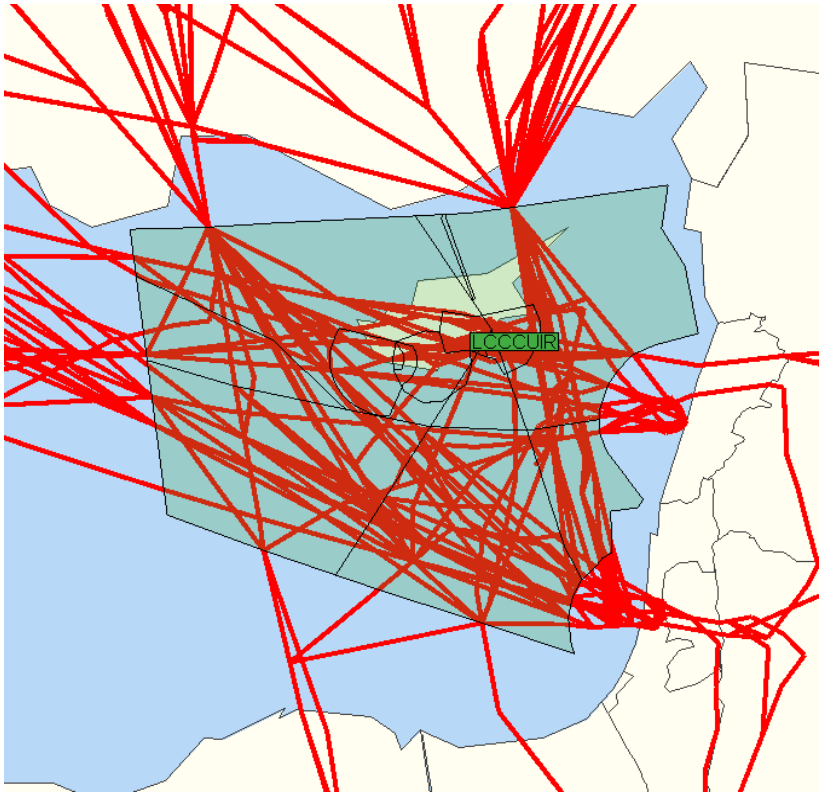
GNSS RFI Impact on Maritime Sector



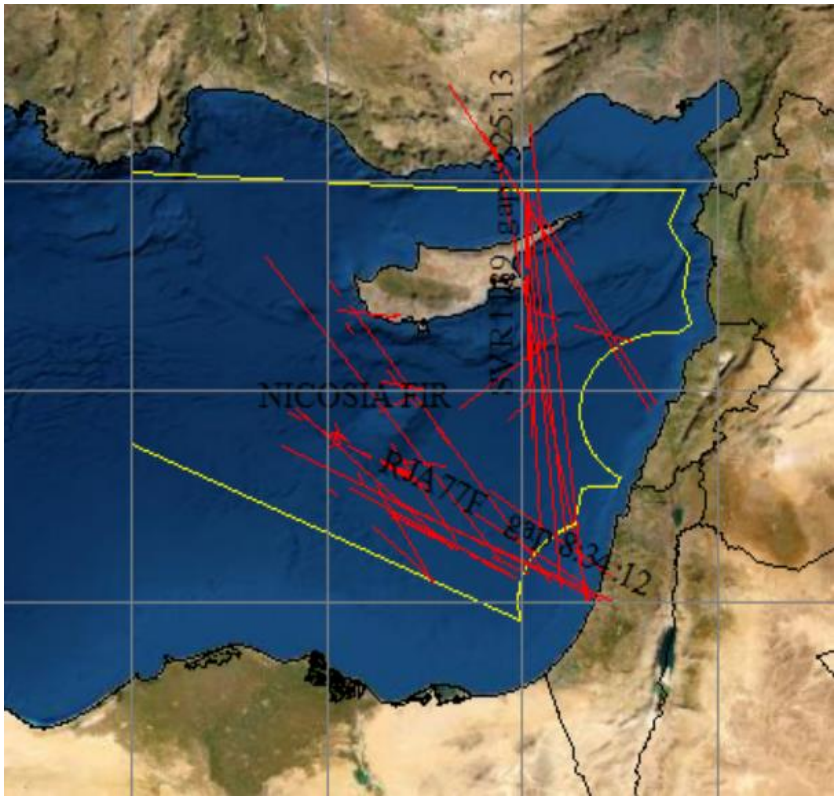
- Catherine Dunn, Fortune Magazine, “Mysterious GPS outages are wracking the shipping industry”, 22 January 2020
- Report to US GPS NAVCEN User Support: No GPS on complete voyage from Nicosia to Beirut (R. Hamilton)

What can we do with detected GPS Outages?

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



Traffic



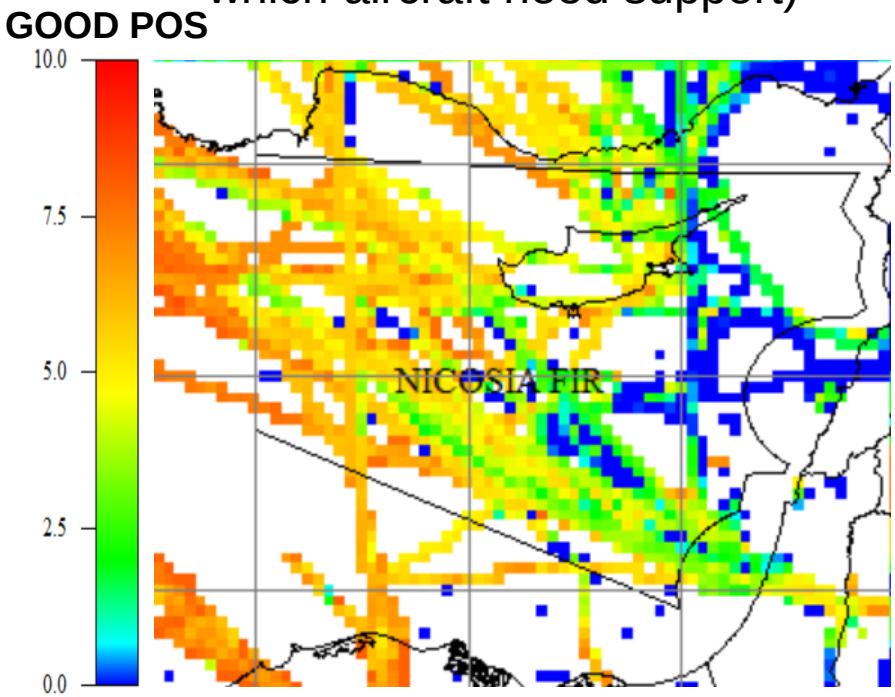
ADS-B gaps

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

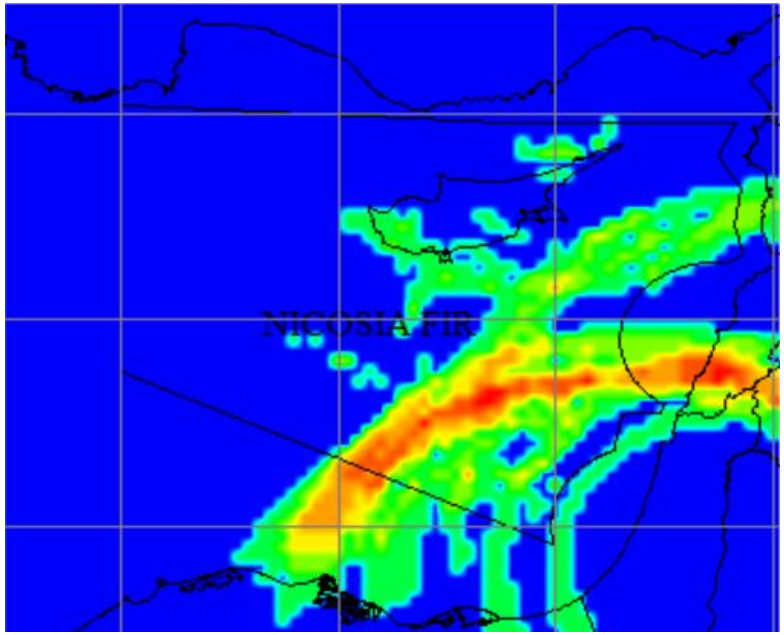
ADS-B Data Analysis

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
- Excerpt of European recommendations:
  - apply necessary measures to **avoid the commercialisation** / proliferation and the use **of illegal** transmitters such as **jammers** which may impact satellite-based CNS systems;
  - ensure, considering that the use of radio frequency spectrum by aeronautical safety services requires special measures, **close collaboration between aviation authorities, service providers, radio regulatory and spectrum enforcement authorities** to ensure that this spectrum is free from harmful interference;
  - reinforce **civil-military collaboration** regarding global navigation satellite system (GNSS) testing and other activities, which may impact satellite-based CNS systems, with the air navigation services provider (ANSP) responsible for the affected airspace; and
  - consider, when assessing the interference risks associated with conflict zones, that the use of satellite-based CNS systems can potentially be impacted beyond that zone."

Conclusions

- Significant and sustained increase of GPS RFI cases since over 2 years
  - Affecting large areas, significant number of flights on frequent but irregular basis
  - Even if it is Electronic Warfare (EW) in contested regions: **Do you really need to jam GNSS with such high power?**
    - Jammers can be detected and locations can be determined!

- Aircraft Operators and Air Traffic Control are dealing with it…
  - through operational measures and current redundant CNS capabilities BUT:
  - *Operational safety margin reduced over long exposure time* – ***significant risk if ever multiple CNS elements are degraded***
  - *Especially* over international water where alternate CNS service is limited
  - Need to know which systems are affected by GNSS and other outages

- Future Developments
  - Every RF link (including broadcast only) should have health status monitoring and associated operational procedures
  - Directly **detect** RFI at the receiver (not pilot's job) and **report** probable location of source to radio regulator using multiple aircraft sources (not ATC's job)
  - **Balanced** mix of terrestrial and space based CNS systems will be required to support aviation for the foreseeable future

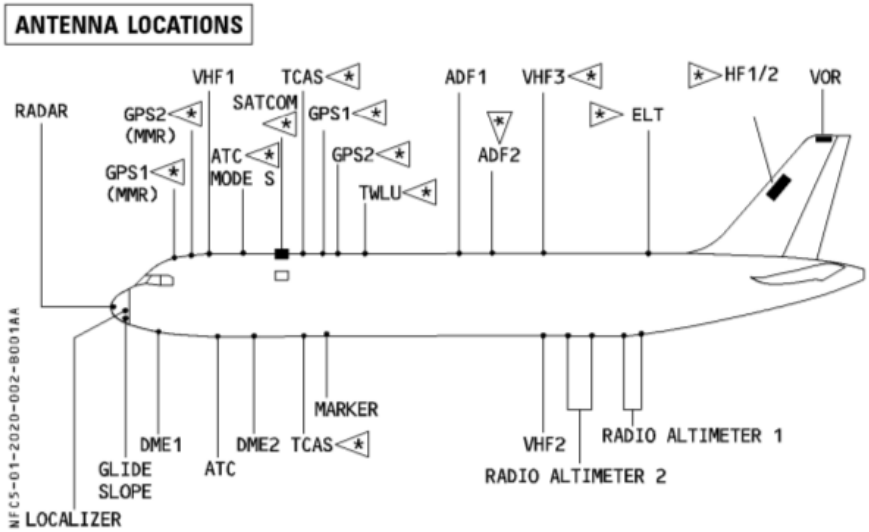
Recommendations

- Escalation procedure per ITU Radio Regulation Article 15 unfortunately not effective in many cases; RFI to Space Systems is
  - Dangerous to human life
  - Costly as it requires retention of redundant systems and hampers the transition from analogue to more spectrum efficient digital CNS systems
  - Devalues the significant investment in space assets by limiting benefits
    - Often involves two parts of the same State…
  - ***Take action on such letters from the ITU Radiocommunications Bureau***

- **IF you operate a GNSS jammer or interfere with any other CNS service used by aviation: *STOP IT!* (or at least tune it down!)**
- Any electronic warfare activity outside a declared zone of conflict is considered a **training exercise** and must be **fully coordinated** with aviation and maritime sectors
- Multi-sector problems require multi-sector solutions supported by ITU
- Pay special attention to compatibility between space systems and terrestrial systems (such as 5G)
- A lot must still be done at local level incl. awareness about illegal (low power) jammers

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



Further Reading and Links

- Impact of COVID-19 on Aviation: www.eurocontrol.int
- 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/