

# GNSS Vulnerabilities and Emerging Threats

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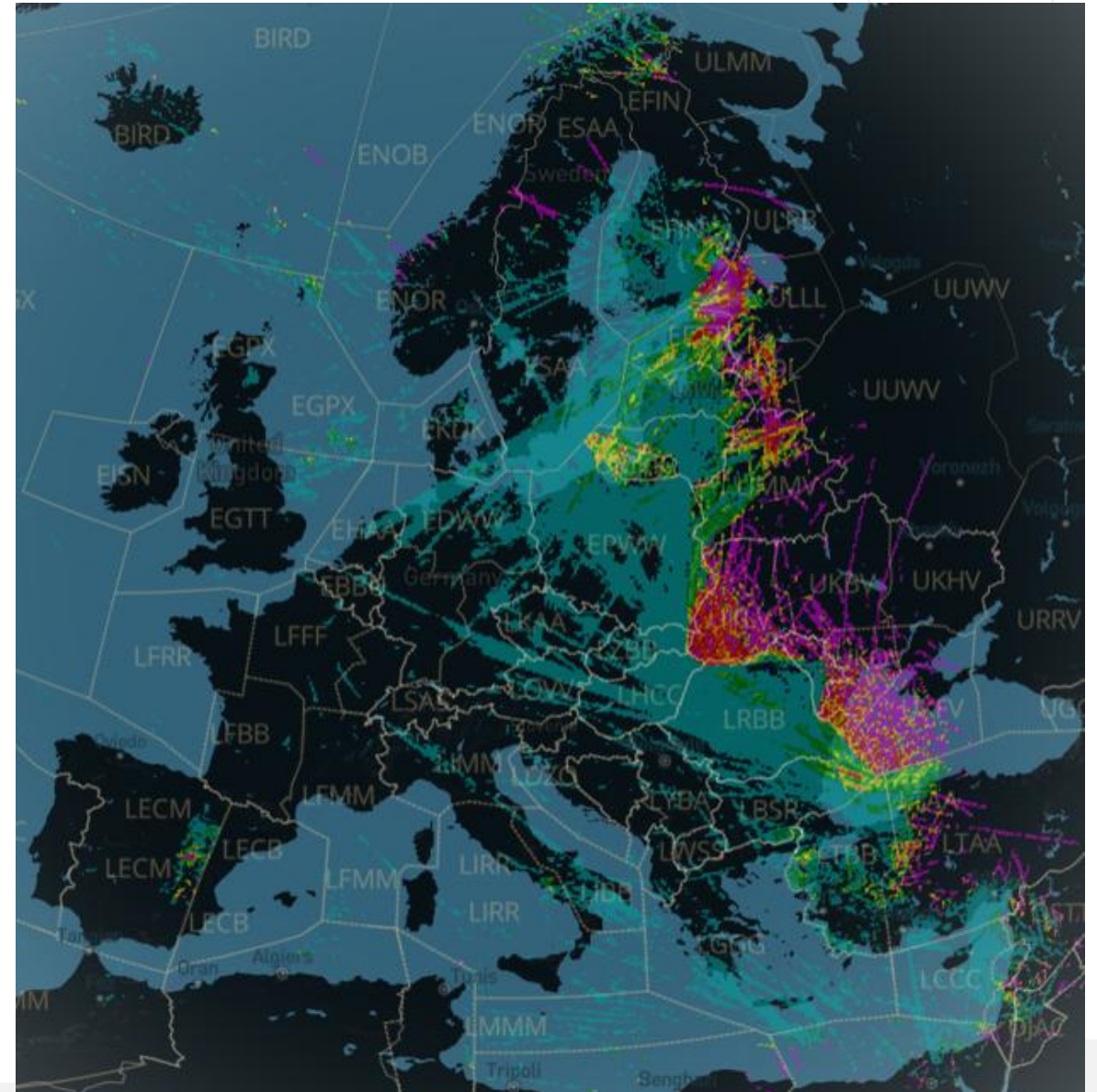
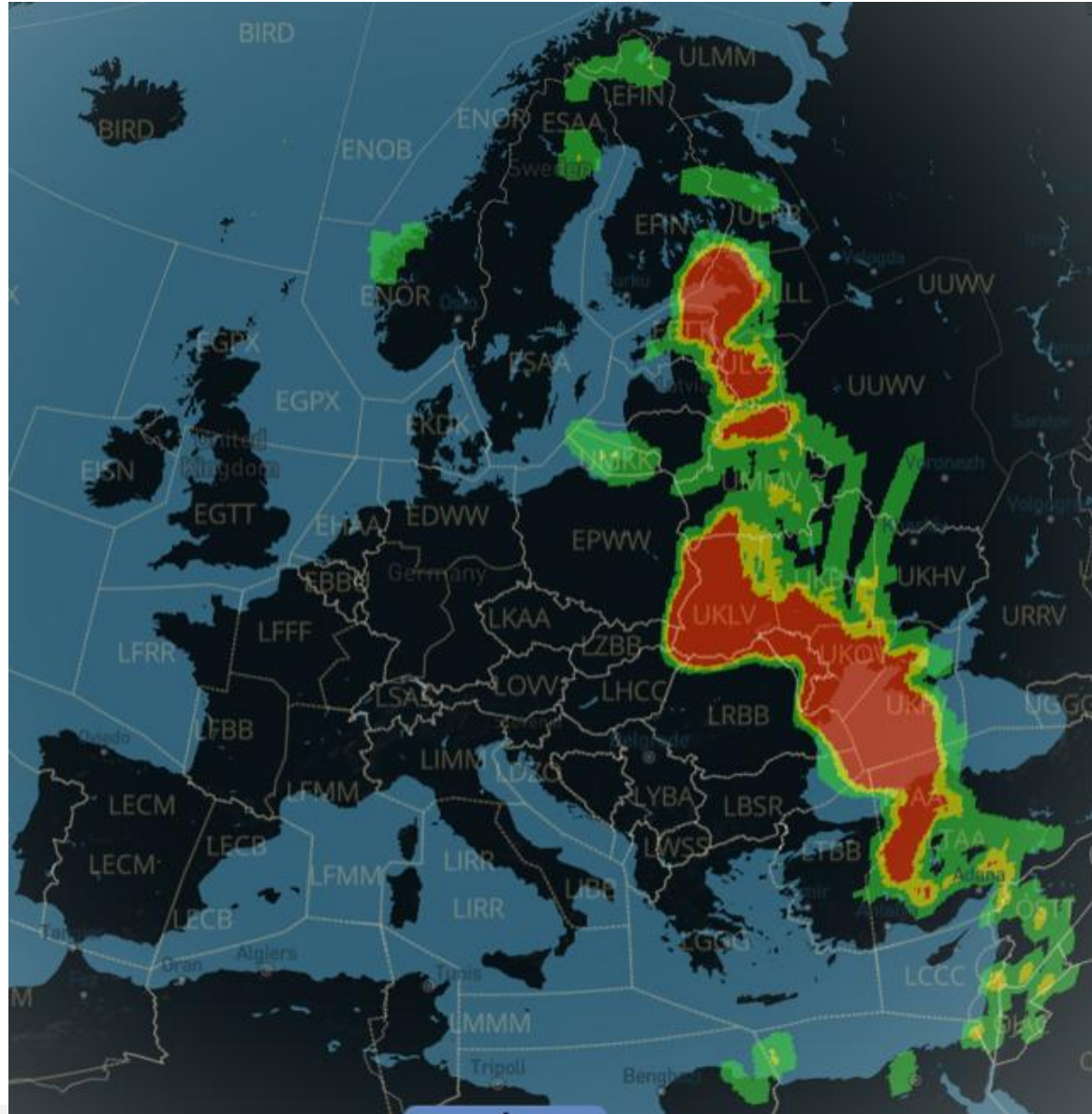
# Important Notice

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- Goal of this sharing of sensitive information is to help aviation maintain safe operations
- Workshop Participants are requested to use the material with the necessary discretion, for aviation-internal SAFETY purposes ONLY

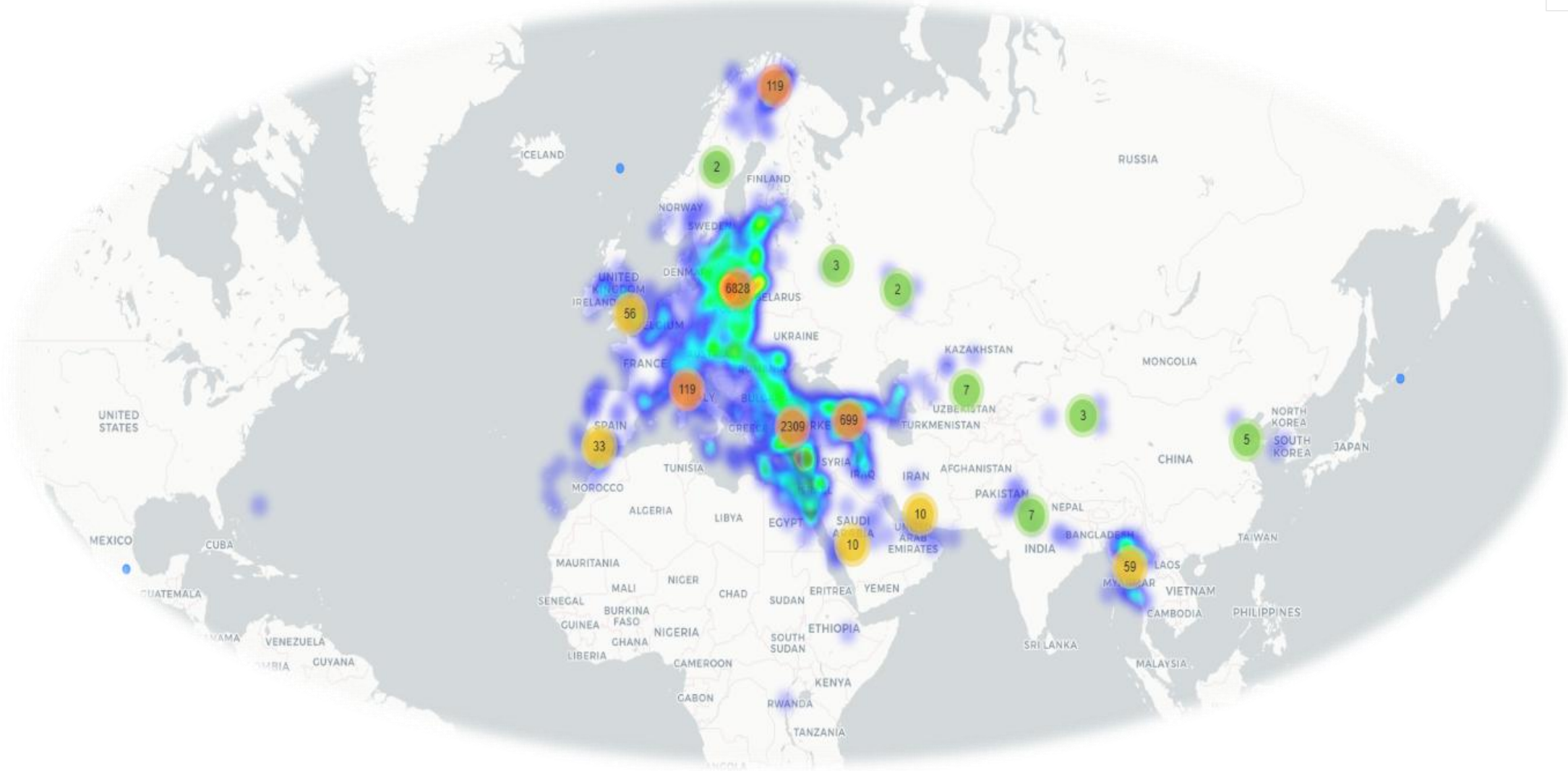
# The GOOD NEWS FIRST

- Core Satellite Constellation Internal Faults
- Constellation Weakness (not enough satellites with good geometry)
- Space / Solar Weather and Ionospheric Effects
- Radio Frequency Interference (RFI)
- Mitigated by over 2 decades of Augmentation System Design
- GPS operating well above minimum constellation (24SV)
- DFMC will have plenty satellites
- Occasional issues in SBAS during solar peaks
- DFMC will fix all first order effects
- Current multi-sensor and independent CNS capabilities provide significant robustness (especially INS)
- DFMC: L5/E5 signal is stronger, ARAIM will have redundant Single Frequency Modes (+other stuff)

# 2025 RFI Situation – Sherlock / GRID Tool

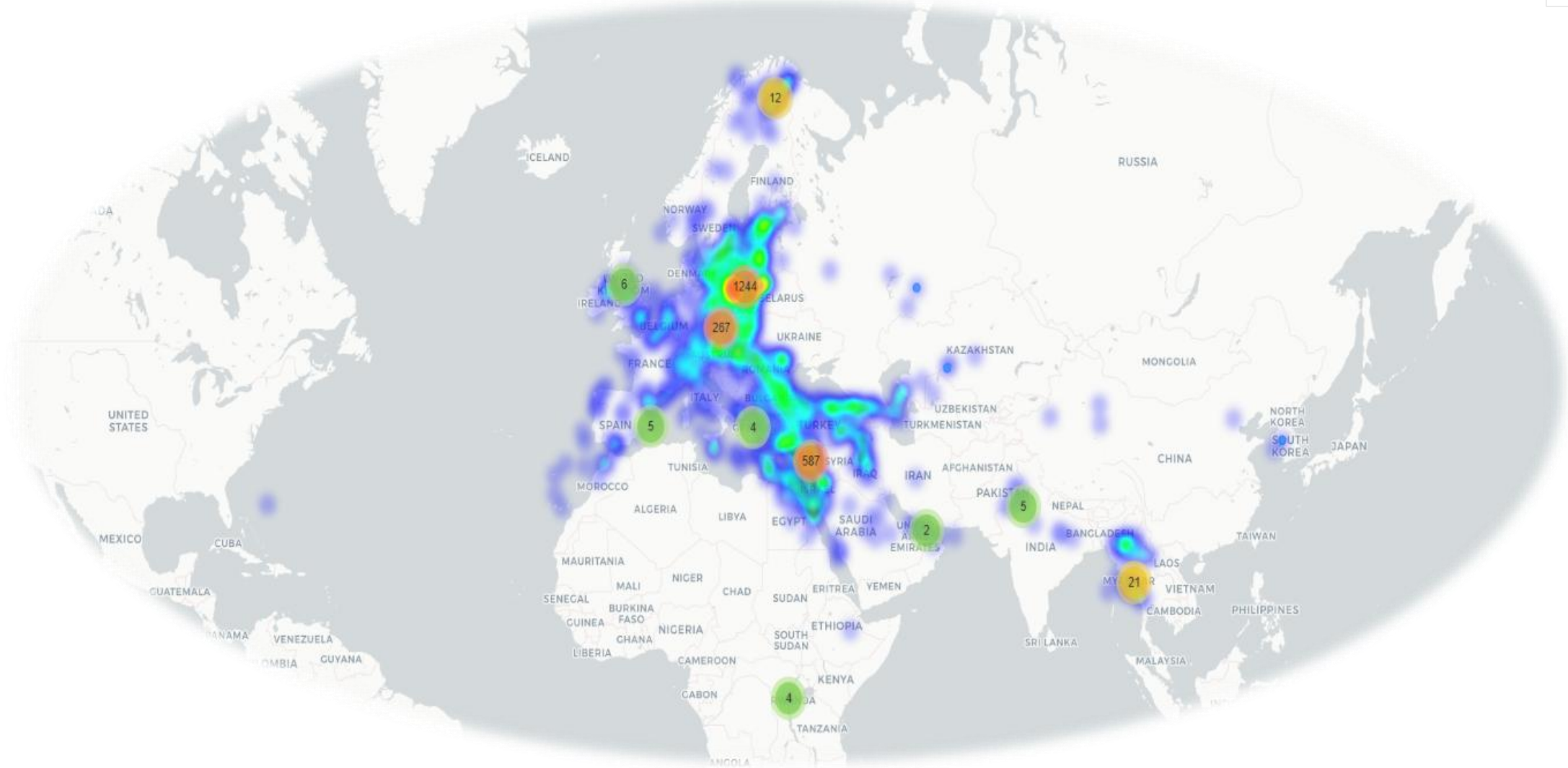


# 2024-2025 GNSS Jamming: Pilot Reports to EVAIR



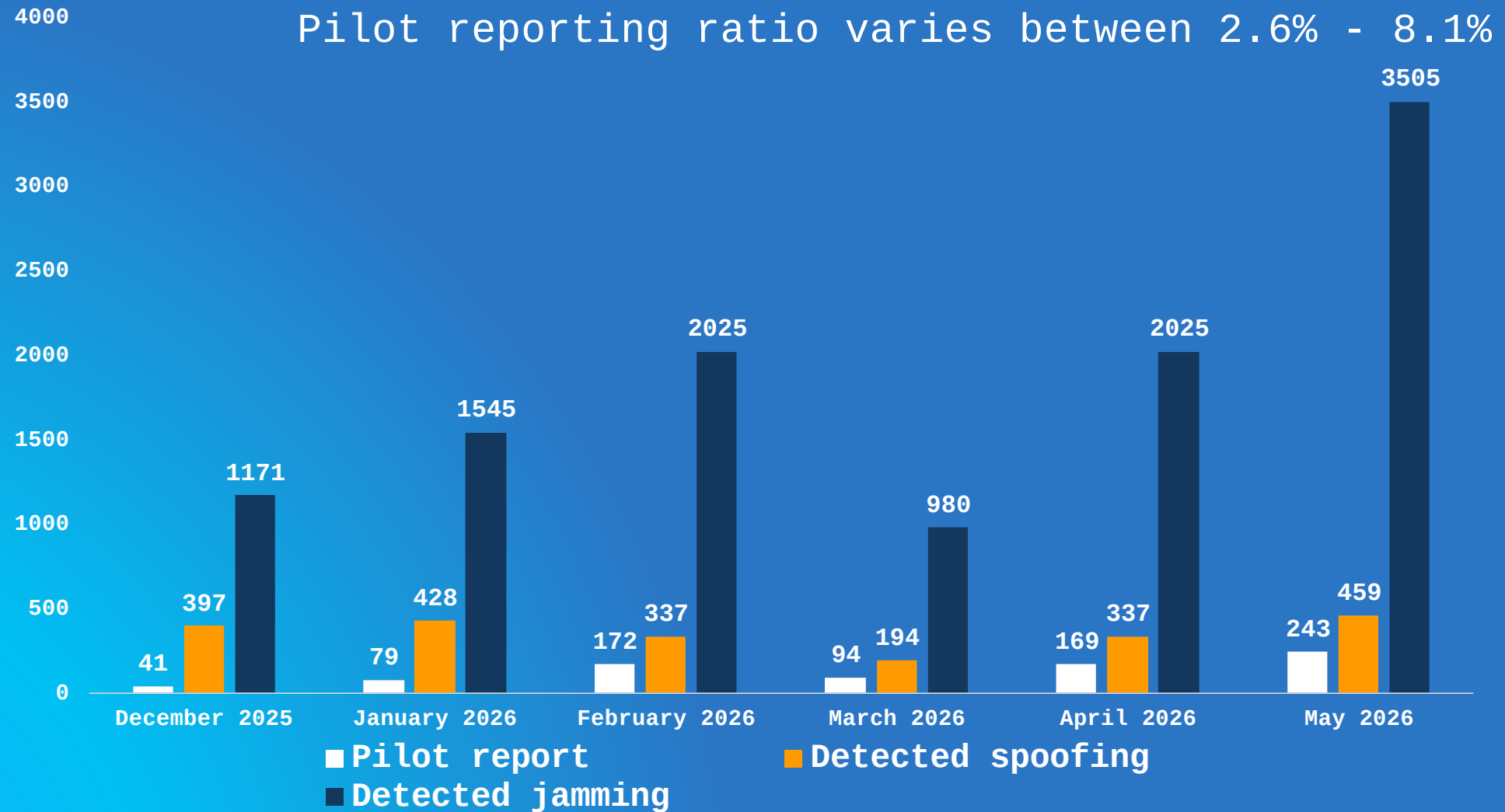
*EVAIR = EUROCONTROL Voluntary ATM Incident Reporting System*

# 2024-2025 GNSS Spoofing: Pilot Reports to EVAIR

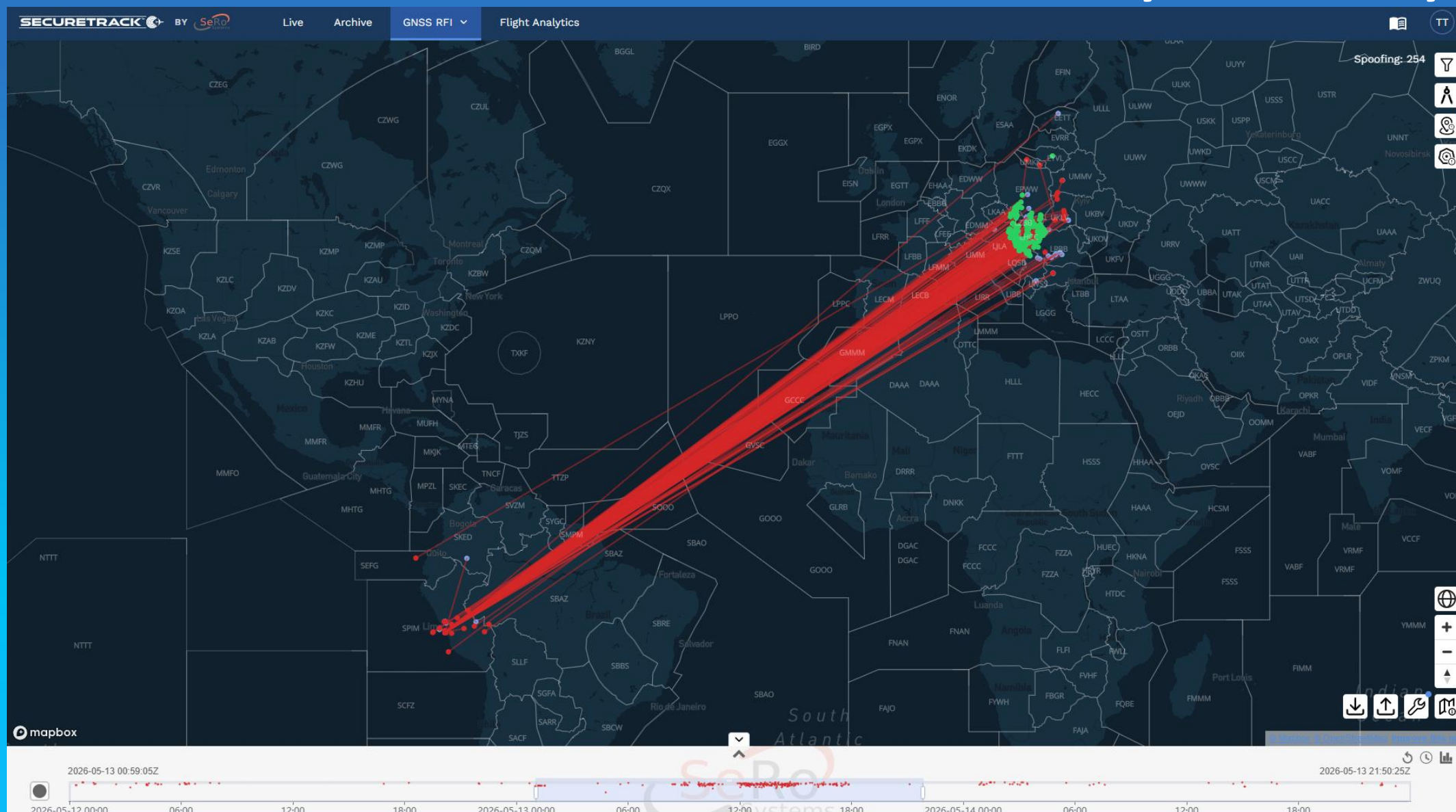


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# GNSS RFI event reporting ratio

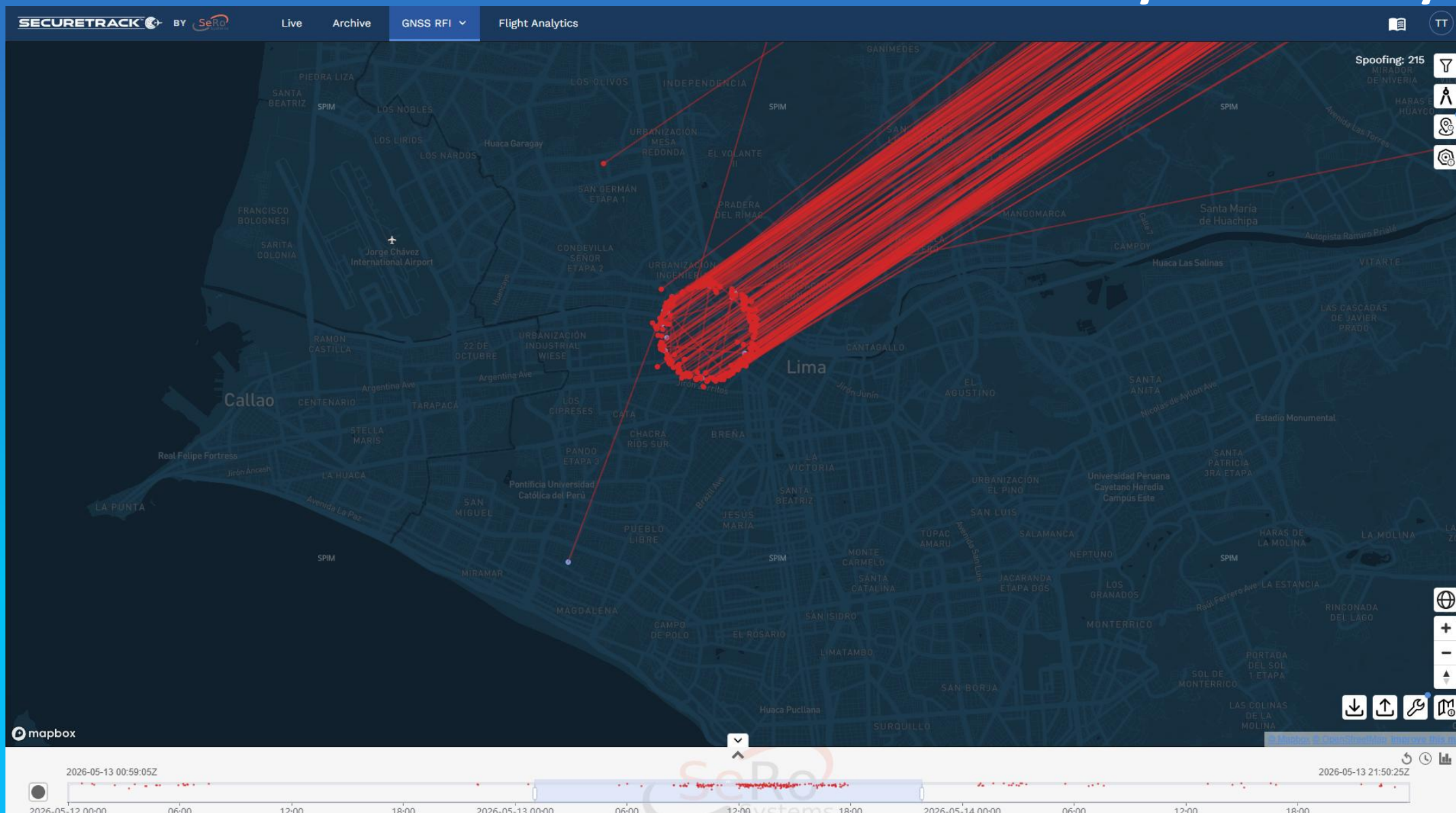


# Post-event analysis: 13. May 2026



Source: SecureTrack developed by SERO GmbH.

# Post-event analysis: 13. May 2026



Source: SecureTrack developed by SERO GmbH.

# Typical workday snapshot



# Persistent Impact of GPS Spoofing on Aircraft Navigation



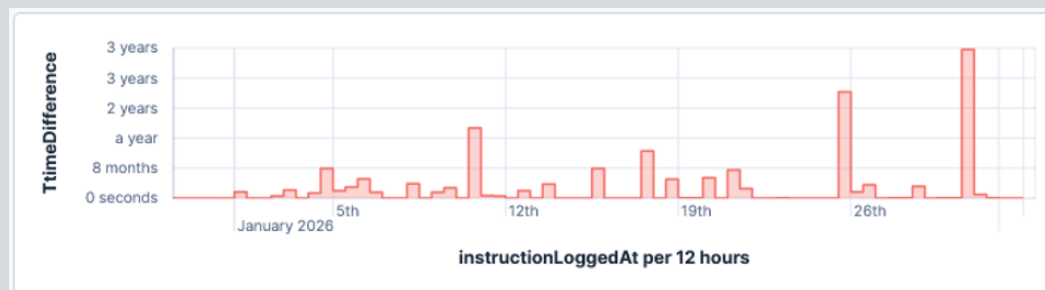
SKAI  
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**Analysis of 397 transatlantic flights initially spoofed over the Black Sea:**  
≈74% broadcast a NIC  $\geq 7$  once they exited the jamming / spoofing area  
≈10% were still broadcasting a NIC = 0 as they entered the Oceanic airspace  
Remaining flights regained NIC  $\geq 7$  at various points over Europe  
*Provided by Skai Data Services (NSP JWG/13 IP15)*

CPDLC Clock Shift Data:



# Taking it to the individual Cockpit level:

## Example of a report from a small business jet

During the arrival, when passing FL130, the aircraft experienced **total loss of GNSS navigation** due to GPS jamming. This affected multiple systems, such as **attitude and horizontal reference system (AHRS affected)**, **loss of obstacle and terrain awareness (TAWS inop)**, **loss of awareness aid synthetic vision (SVS inop)**, **loss of ADSB-OUT**, **loss of horizontal and vertical navigation capabilities (absence of VORs in the region, aircraft with no DME-DME navigation capability, limited inertial navigation capability)**.

ATC was advised and in the **aircraft was vectored** by the ATC until establishing the localiser. The GPS signal was restored once at low altitude (6000 ft).

# GNSS Interference Impact on Aircraft and Operations

- GPS Receiver **fail**, FMS position **fail**, Clock **fail**: may remain
- GPWS **failure**
- Weather Radar **failure**
- Position reporting **failure** (ADS-C)
- Comms **failures** (CPDLC, SatCom)
- Head Up Display (HUD) **failure**
- Synthetic Vision System (SVS) **failure**
- Runway Protection Systems **failure** (RAAS, ROPS)
- Emergency Locator (ELT) reporting incorrect
- Wind Display (ND) **failure**
- ADS-B-out **failure**, ADS-B-in **failure**
- Transponder **failure**, Navaid tuning **failure**
- Unable to navigate normally (may need radar vectors to destination)
- No longer RNP capable (cannot cross North Atlantic RNP4)
- EGPWS false alerts, EGPWS system switched off
- Go-Arounds in unexpected positions
- Cascading system failures, complex and high workload approaches
- Weather Radar: unable to detect thunderstorms (CB's)
- Loss of comms: CPDLC, SatCom
- GPS receiver contamination possible
- Unable to de-select GPS input to aircraft systems
- Aircraft may be grounded pending hard reset of GPS receiver

*Summary from OPSGROUP*

# Why are civil aircraft so exposed to interference?

Air Transport Aircraft  
at En-Route Altitude  
(no anti-jam capability)



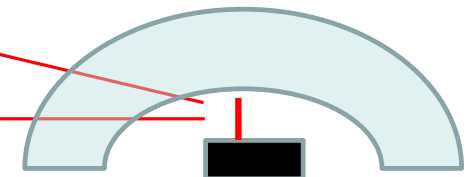
| Jammer Power | Impact Radius on Aircraft at FL350 <sup>1</sup> | Maximum Outage Duration at ENR Speed <sup>2</sup> | “Protection” against military GPS system near ground <sup>3</sup> |
|--------------|-------------------------------------------------|---------------------------------------------------|-------------------------------------------------------------------|
| 10W          | 77NM                                            | 20min                                             | 20km                                                              |
| 100W         | 230NM                                           | 1h                                                | 60km                                                              |

1: Assuming -6dB antenna gain and 15dB tracking margin

2: ENR speed assumed 450 knots

3: Assuming a +20dB J/S capability (very modest!)

Drone with Anti-Jam Capability



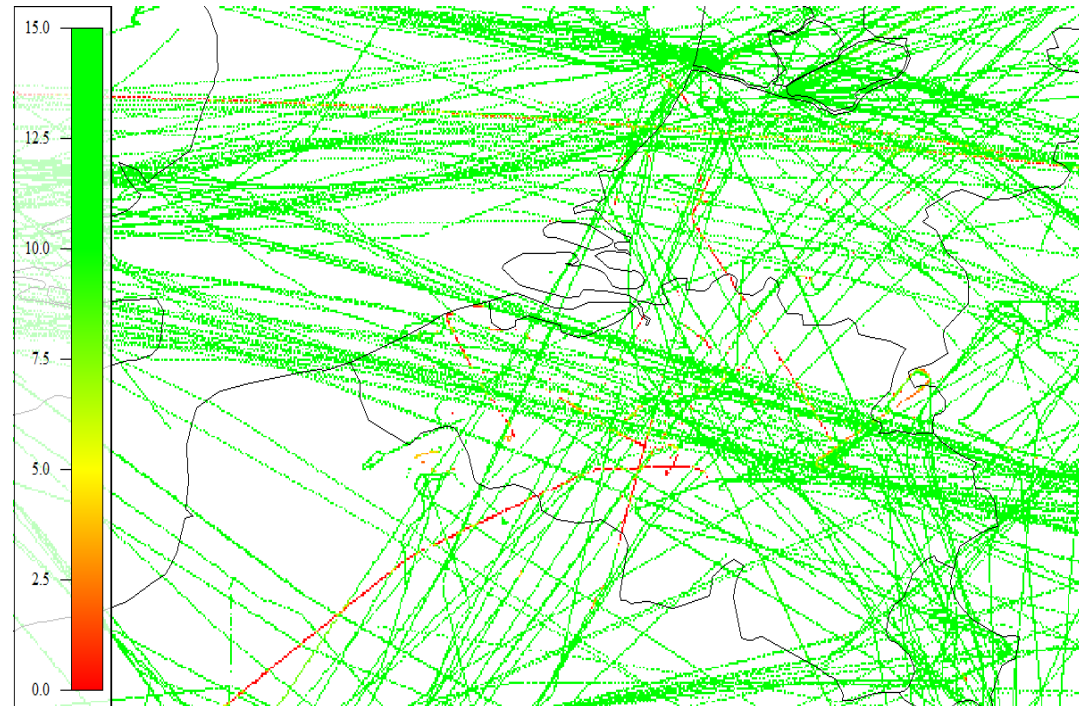
Jammer Antenna

# RFI May Not Be Limited to Conflict Zones Only...

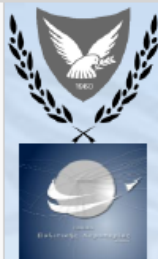
- End March 2021, 40W Anti-Paparazzi Drone Jammer on a Private Yacht
  - Jammer accidentally turned on by maintenance personnel, Southwest NL
  - Impacting air traffic in Netherlands, Belgium, France and MUAC for a few hours
- Core European airspace with climbing and descending traffic from some major airports
  - Info on affected flights **could be quite critical**, while large majority of flights **sees no impact**



ADS-B Gaps: 93 aircraft impacted,  
Multiple aircraft per sector



ADS-B PIC, All Flights during event



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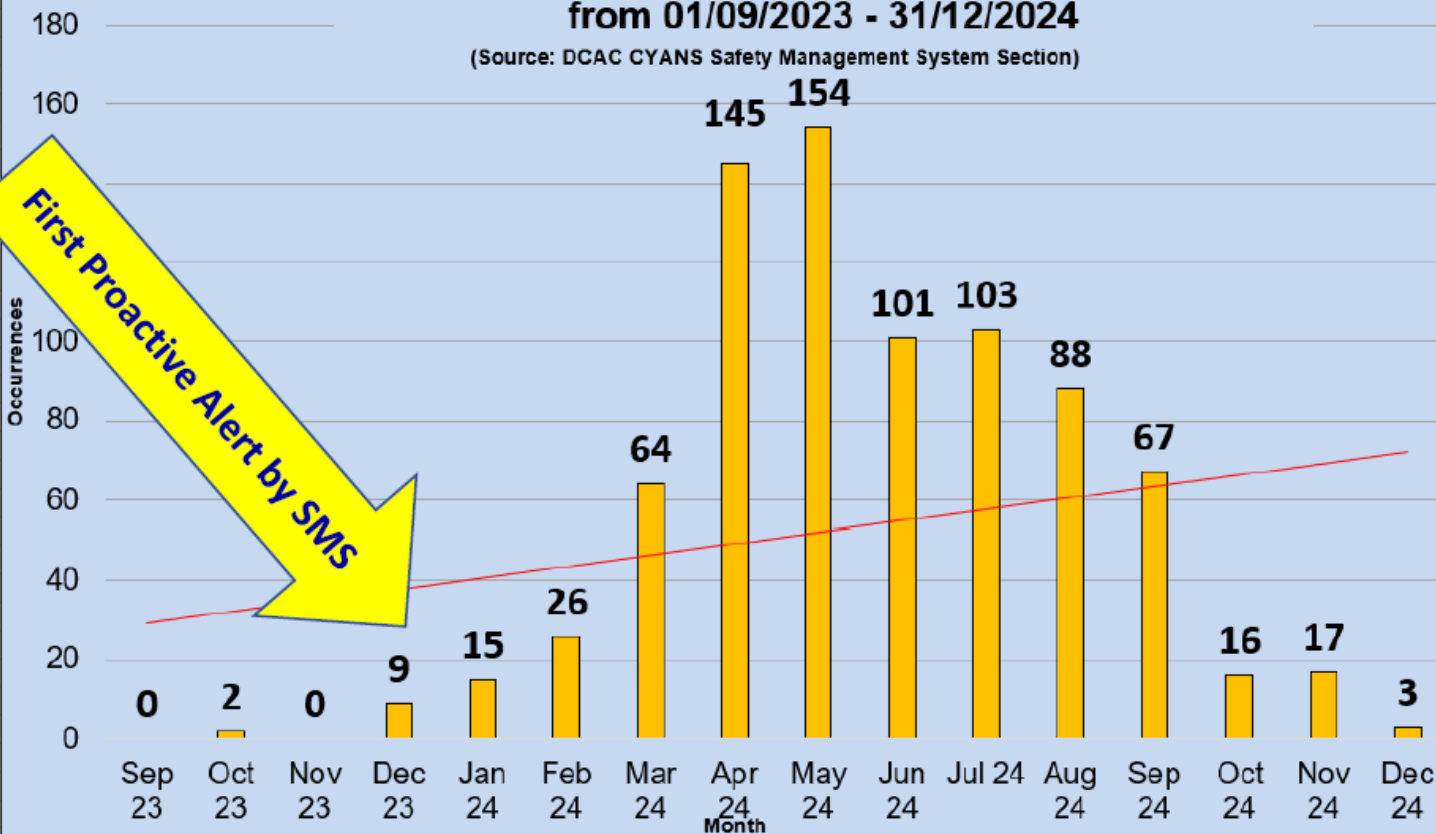


# An exponential increase of GPS Spoofing Occurrence Reports since Dec. 2023

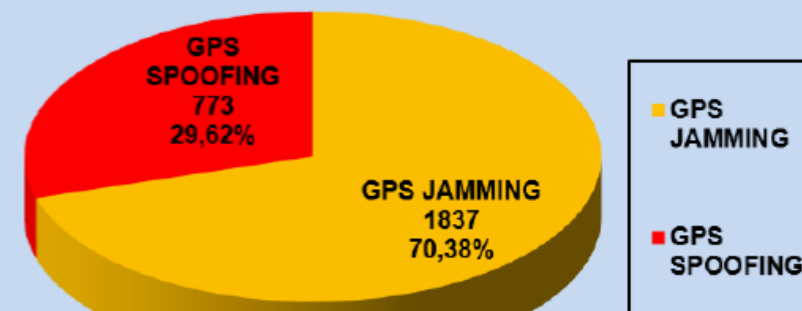
**Figure 4: GPS Spoofing Reports to CYANS per month  
from 01/09/2023 - 31/12/2024**

(Source: DCAC CYANS Safety Management System Section)

**First Proactive Alert by SMS**



**Figure 5: GPS Jamming vs GPS Spoofing occurrences for 2024**

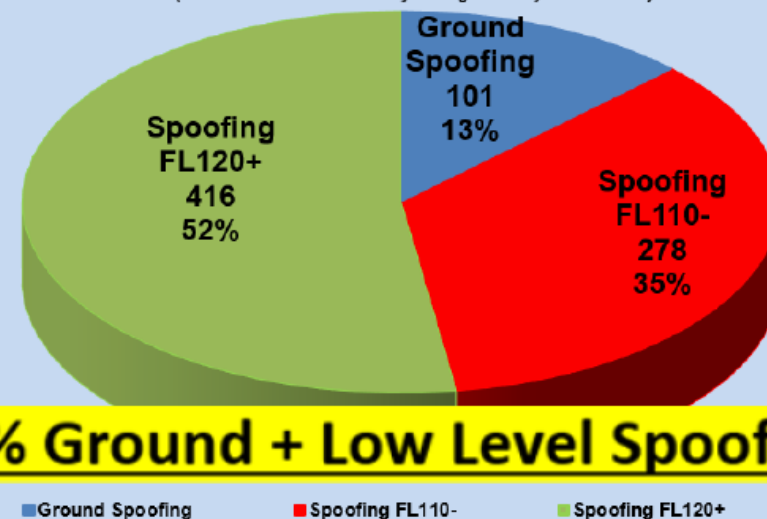


**3:7 Spoofing to Jamming**

Source: DCAC CYANS Safety Management System Section Jan. 2025

**Figure 6: 2024 Ground and Low Level GPS Spoofing up to  
31/12/2024**

(Source DCAC CYANS Safety Management System Section)



**48% Ground + Low Level Spoofing**

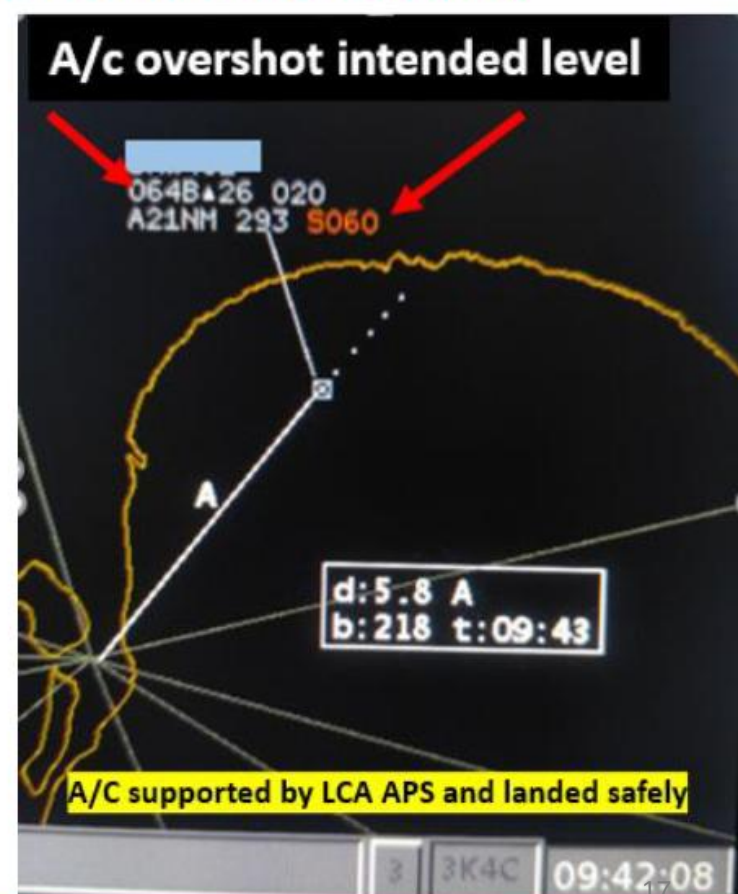
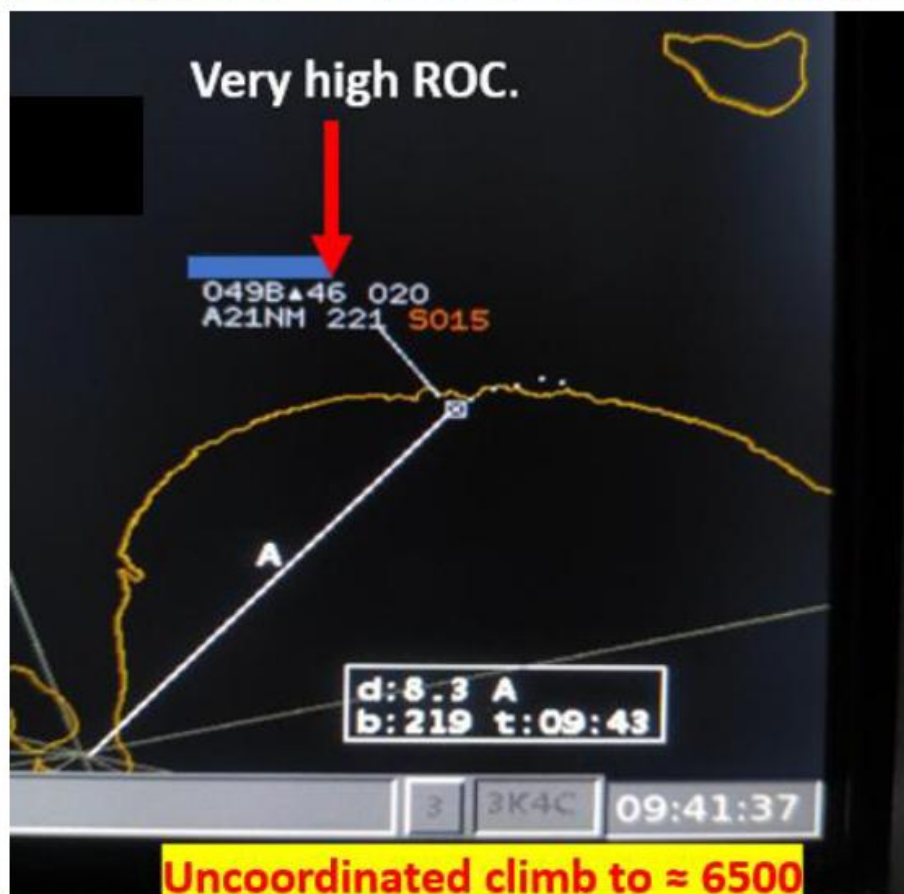


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## Incident 1: April 2024, CAVOK, A321, under Larnaca TWR procedural control, at 1800 ft, turning to establish on ILS RWY 22, with clearance to land, reported “going-around”.

1. Initiated **Uncoordinated Climb** to  $\approx 6500$  due to reported GPWS alert, **Vertical Deviation from ATC Clearance**;
2. Without ATC clearance and without warning to ATC; Luckily no other traffic;
3. High rate of climb ( $\approx 4600\text{ft/min}$ );
4. Climbed to a different level than mode-s indication;
5. Overshot by 500ft the intended level.
6. A321 released to Larnaca Approach Surveillance Service (LCA APS), vectored to final and landed safely.





## Incidents 6,7: Spoofing on departure, Lateral Deviation from ATC Clearance

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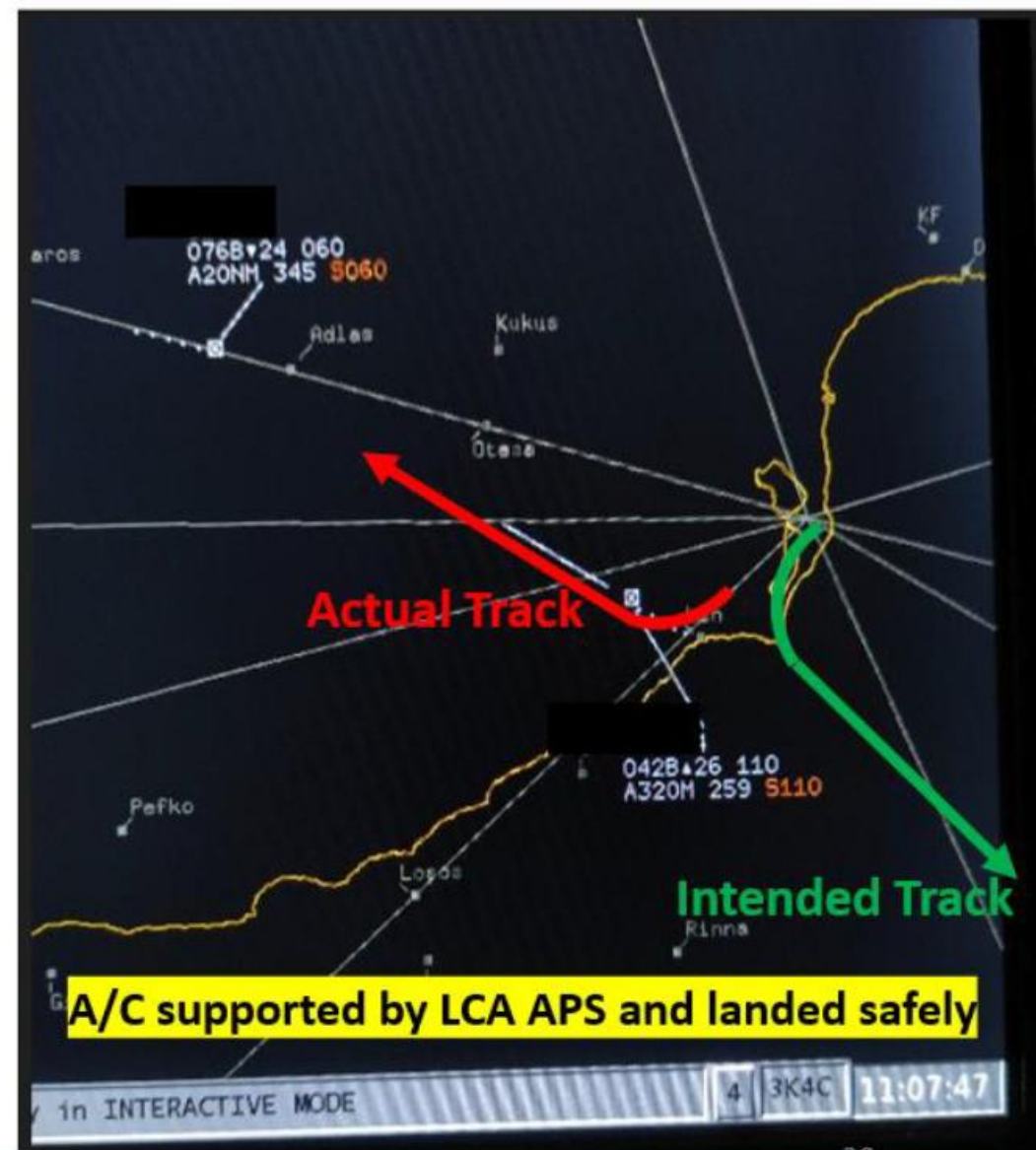
### Incident 6:

1. April 2024, A320; After take-off Larnaca turned to the right instead of left
2. Daytime, CAVOK;
3. A/C reported GPS interference before departure and **requested conventional SID**;
4. **Clearance** for RWY 22 EMEDA 2B DEP **to the left over the sea**;
5. **After take-off, due to GPS Spoofing turned to the right towards DAROS, high terrain and opposite to inbound A320**
6. Conflict immediately resolved by APS (Approach Surveillance Service)

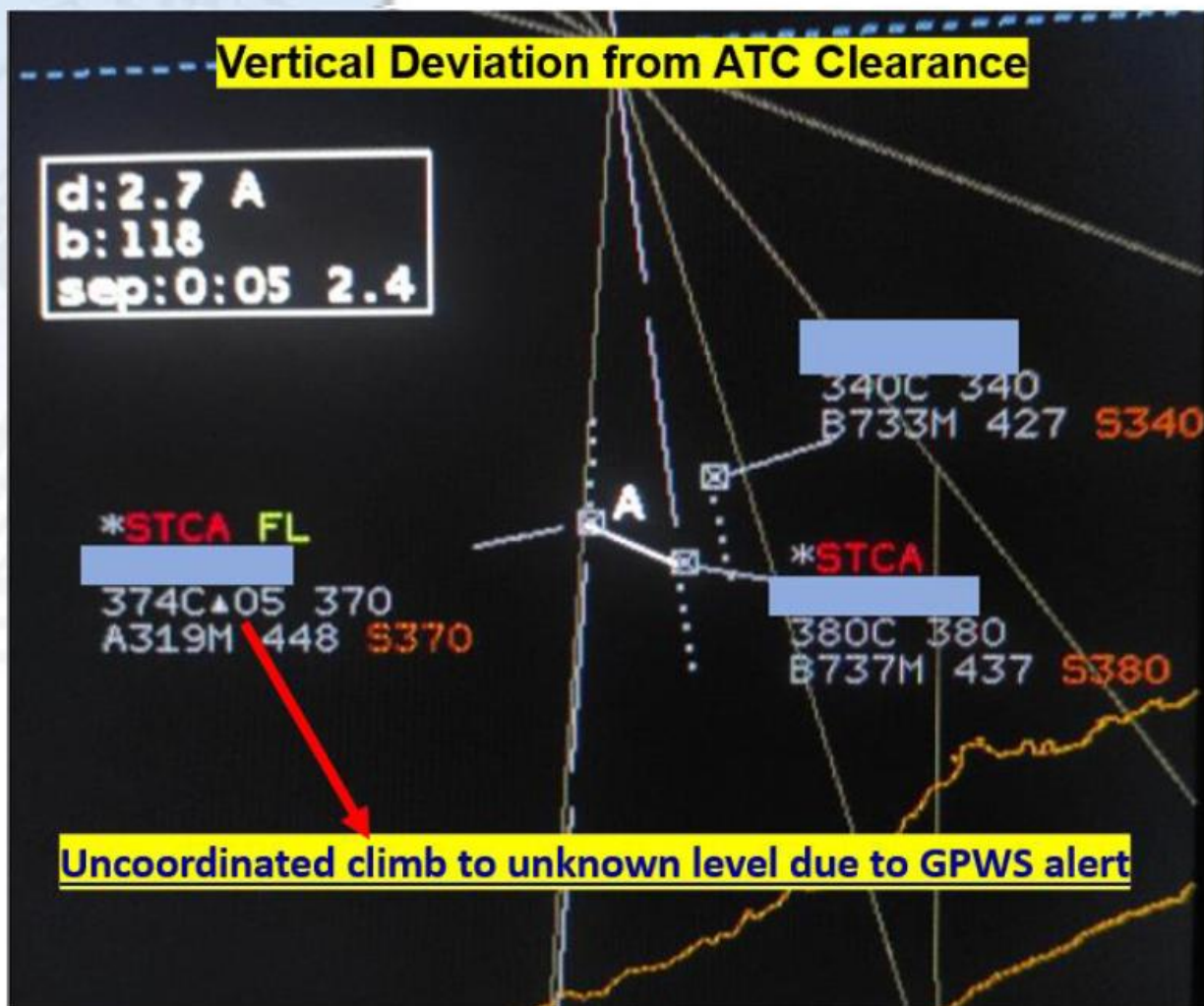
Lateral Deviation from ATC Clearance



Incident 6: April 2024, After departure, a/c reported unable to follow conventional departure, deviated to the west and provided navigational support



## Incident 8: **Separation Minima Infringement (SMI)** in response to GPW at FL370



1. June 2024, 06:31 UTC
2. A319 over VESAR at FL370, Weather not relevant;
3. Responded to a GPW (due to GPS spoofing);
4. Commenced climb without ATC clearance;
5. Opposite direction traffic at FL380;
6. NACC ATC responded by providing essential traffic information to the a/c which climbed up to FL374, before descending back to FL370.

# SUMMARY: GNSS RFI Impact

- Impact on all CNS elements: PBN, ADS-B, CPDLC
  - Plus large variety of cascading effects
  - Difficult to predict actual operational impact
- Most severe threat: Uncoordinated high-rate climb due to **false** Enhanced Ground Proximity Warnings (EGPWS / TAWS)
- Fundamentally undermines today's cockpit safety principles:
  - Trust your instruments
  - Follow Standard Operating Procedure (SOP)
- In some airspaces, operation in presence of compromised GNSS has become NORMAL OPERATIONS!
  - Extended Risk Exposure Time: Requires Independent CNS Elements to ALL WORK!
  - Collateral Impact at extended ranges from zones of conflict