Supporting
European
Aviation

EUROCONTROL

GNSS Vulnerabilities and Emerging Threats

Radio Navigation Workshop for NAM and SAM Regions

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Important Notice

- Information in these slides is NOT INTENDED FOR THE GENERAL PUBLIC
- Goal of this sharing of sensitive information is to help aviation maintain safe operations
- Workshop Particpants are requested to use the material with the necessary discretion, for aviation-internal SAFETY purposes ONLY

The GOOD NEWS FIRST

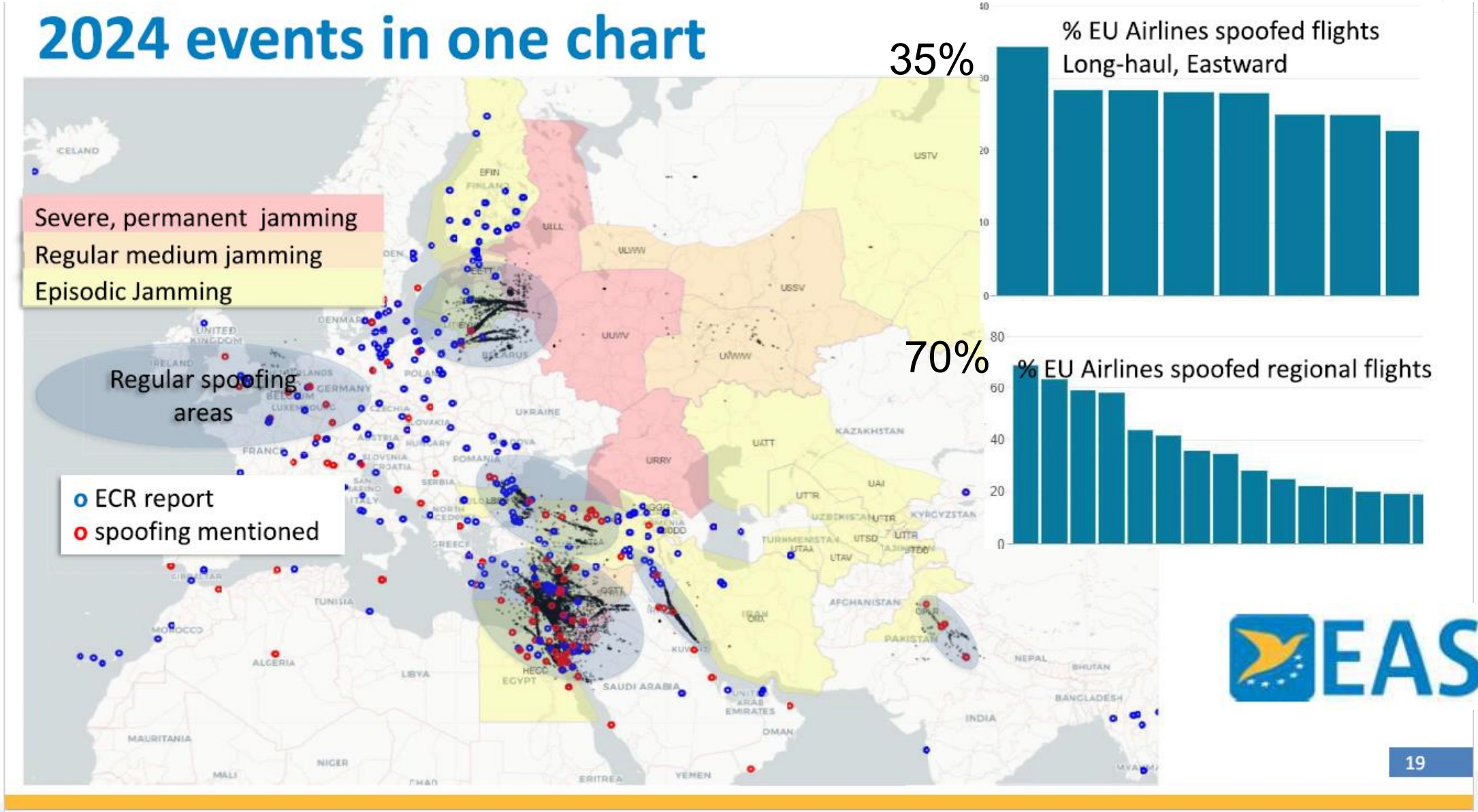
- Core Satellite Constellation Internal Faults
- Mitigated by over 2 decades of Augmentation System Design

- Constellation Weakness (not enough satellites with good geometry)
- GPS operating well above minimum constellation (24SV)
- DFMC will have plenty satellites

- Space / Solar Weather and Ionospheric Effects
- Occasional issues in SBAS during solar peaks
- DFMC will fix all first order effects

- Radio Frequency Interference (RFI)
- 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)

GNSS Interference Summary from EASA



EUROCONTROL Voluntary ATM Incident Reporting

- EVAIR Reports confirm EASA Reports
- EVAIR Totals for 2024:
  - GNSS Reports: **3115** out of 7453 (rough average 10 per day)
  - Spoofing cases: **550** (rough average 2 per day)

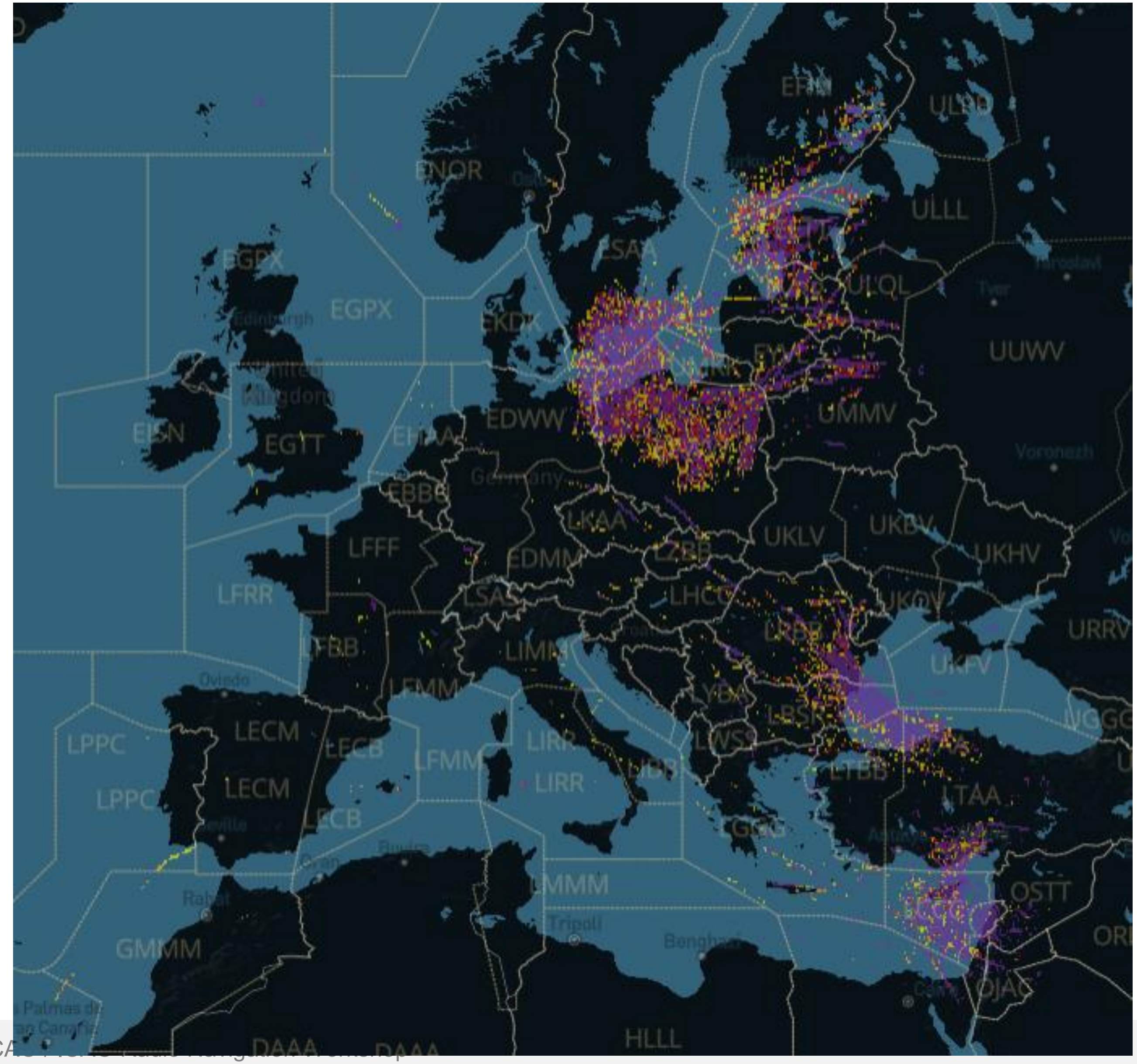
- GNSS RFI Reporting has become *a significant burden* for many operators and some ANSP
- Difficult to read trends out of "human reporting"
- Reports scale with traffic levels
- **Estonia study with ADS-B and MLAT based detection: Reporting rate varies between 2 and 10%**

02. – 08. of September

Date	Reports by pilots in EETT	System EETT Only first anomaly per aircraft	Reporting rate
2	8	176	4.5 %
3	16	152	10.5 %
4	10	163	6 %
5	13	170	7.6 %
6	10	165	6.1 %
7	5	161	3.1 %
8	4	172	2.3 %

EANS, M. Haug, Warsaw Workshop SEP 2024

EUROCONTROL GNSS RFI Monitoring using ADS-B



ADS-B Low PIC Map, Week 8, 2024
Using dedicated 1090 MHz monitoring network, SHERLOCK Platform

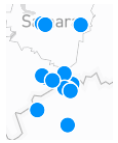
2018 – 2022: GNSS RFI becoming part of daily OPS in some regions, no longer just a “contingency” – it is “normal” operation.

2023 – 2024: Escalation to collateral spoofing, impact can get significant including no recovery of GPS until arrival destination. Some diversions!

GPS Problems spreading towards Western Europe?
Likely linked to GPS Receiver getting locked up (and recovering late) due to spoofing when flying over East MED, Black Sea & Baltic Hotspots

GNSS RFI Monitoring using Open Source ADS-B

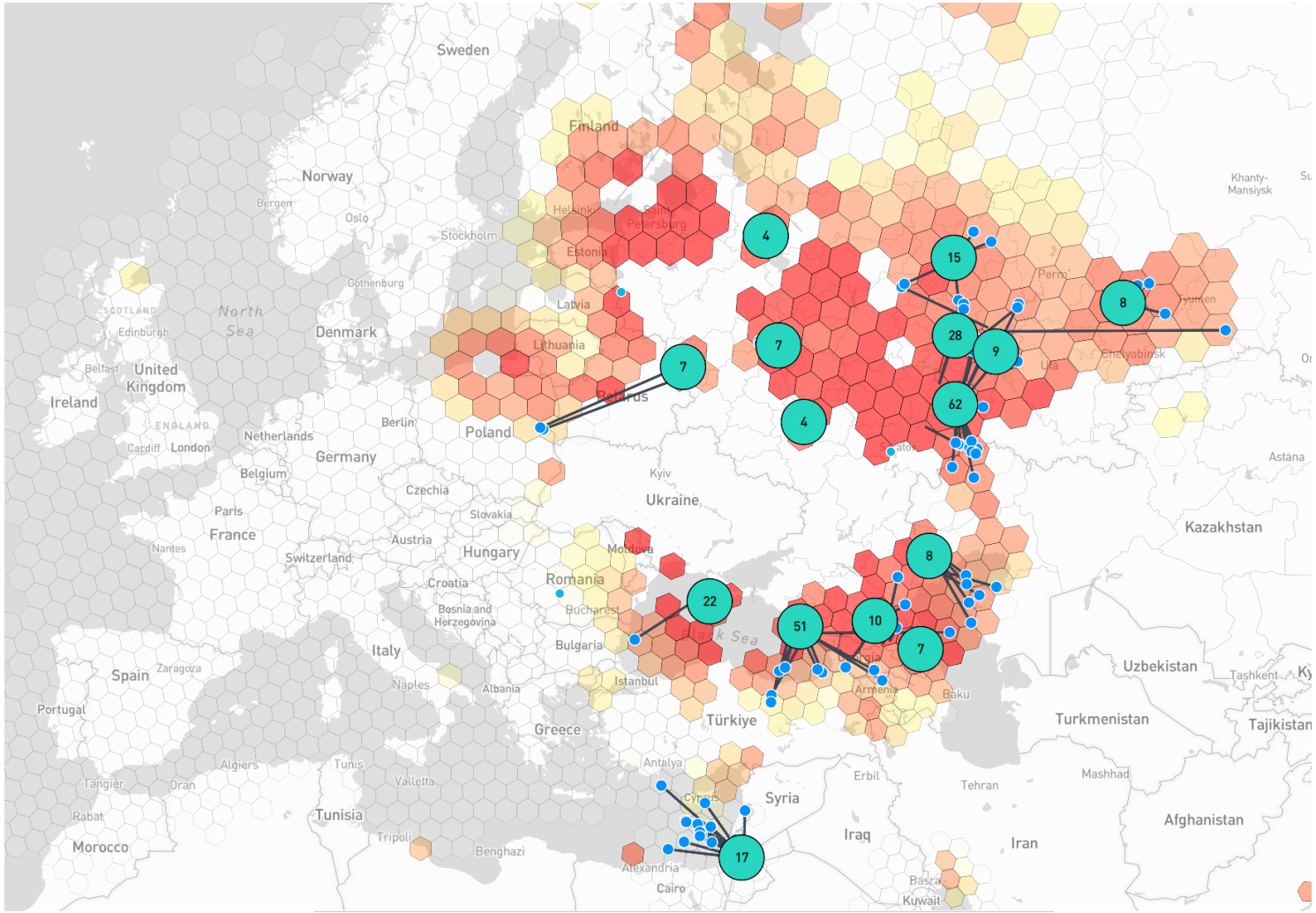
Jamming & Spoofing
07/02/2025 (24 H)



Spoofing Locations

Spoofed-to Position

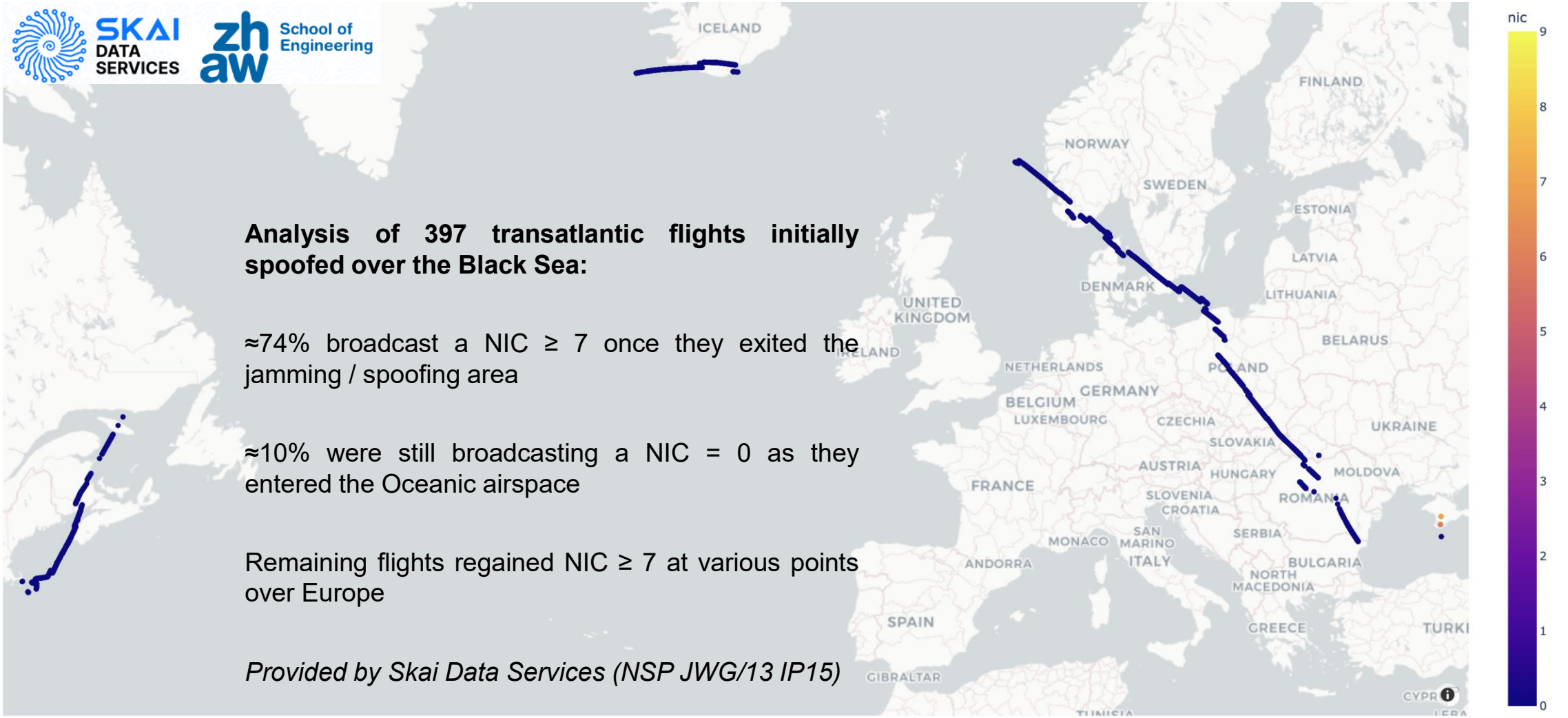
Jamming Locations



SKAI DATA SERVICES

Live GPS Spoofing and Jamming Tracker Map

Persistent Impact of GPS Spoofing on Aircraft Navigation



Analysis of 397 transatlantic flights initially spoofed over the Black Sea:

≈74% broadcast a NIC ≥ 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 ≥ 7 at various points over Europe

Provided by Skai Data Services (NSP JWG/13 IP15)

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

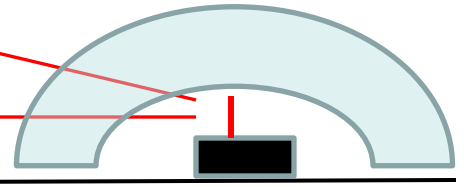
Why are civil aircraft so exposed to interference?

Jammer Power	Impact Radius on Aircraft at FL350[1]	Maximum Outage Duration at ENR Speed[2]	"Protection" against military GPS system near ground[3]
10W	77NM	20min	20km
100W	230NM	1h	60km

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

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

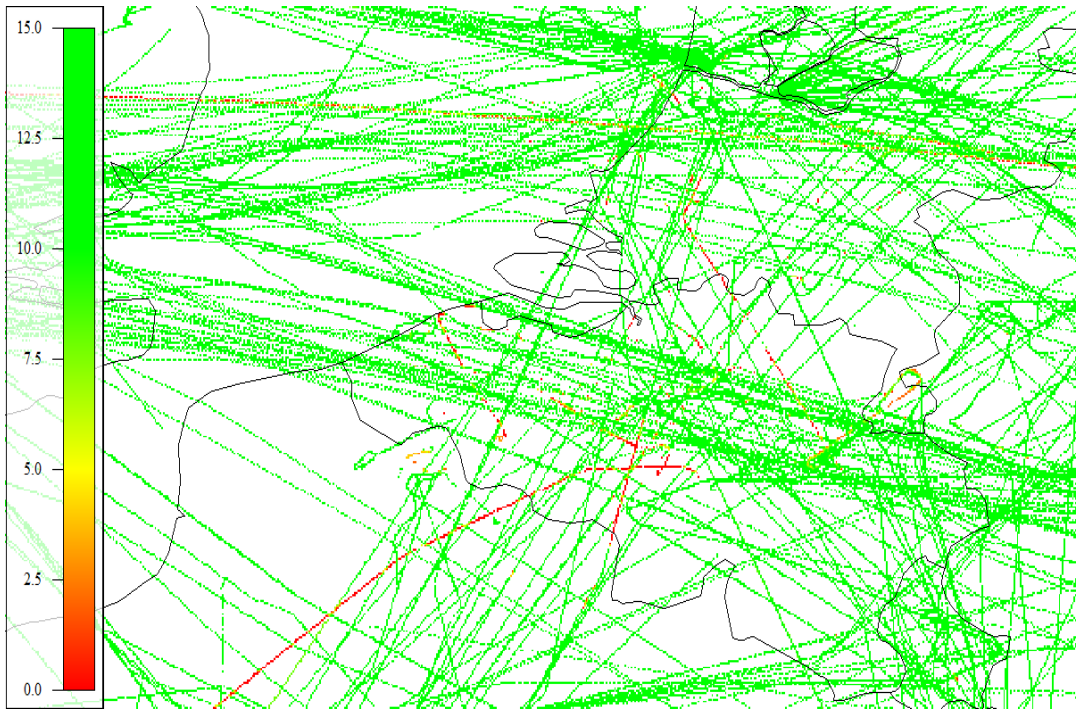


Jammer Antenna

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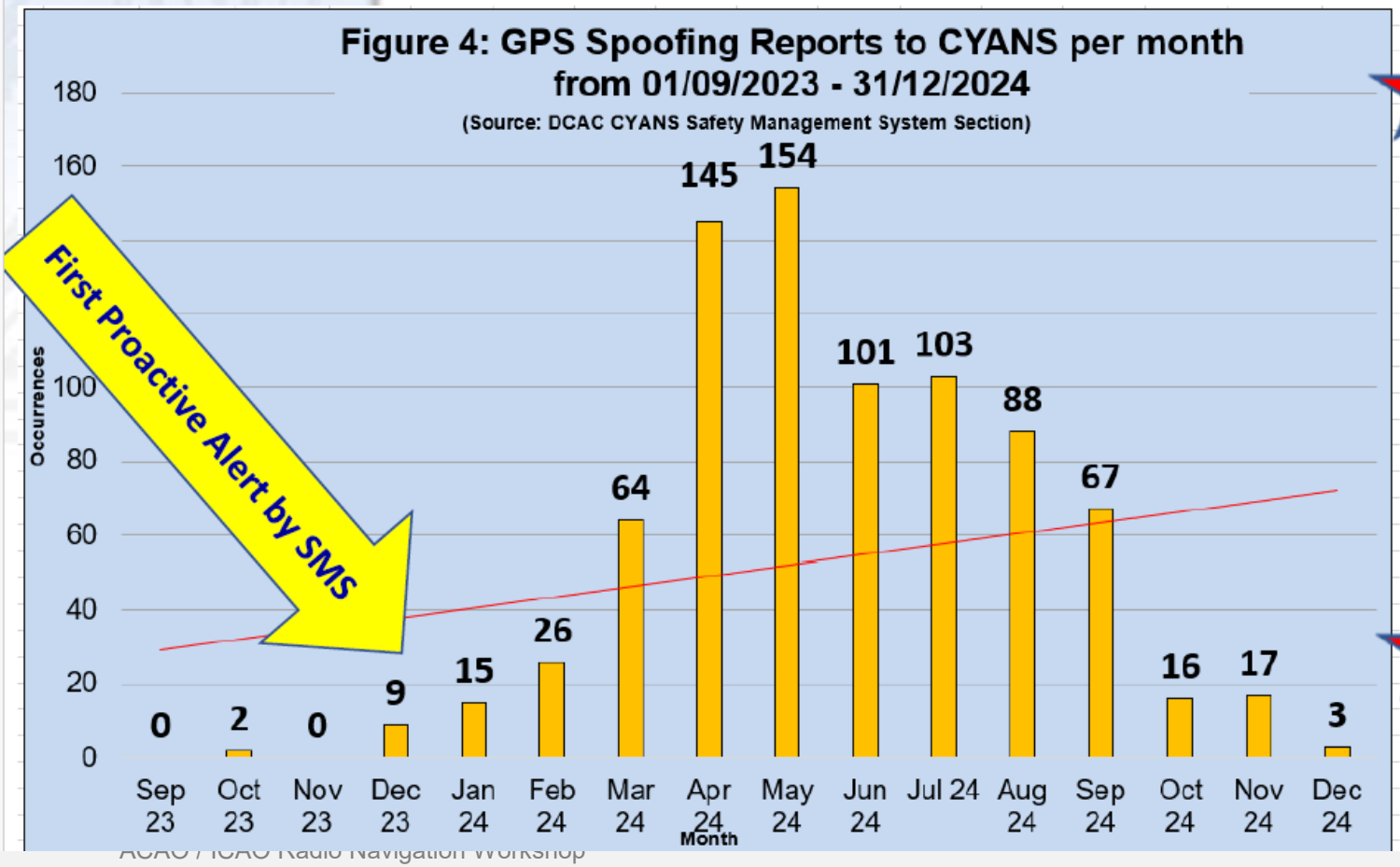
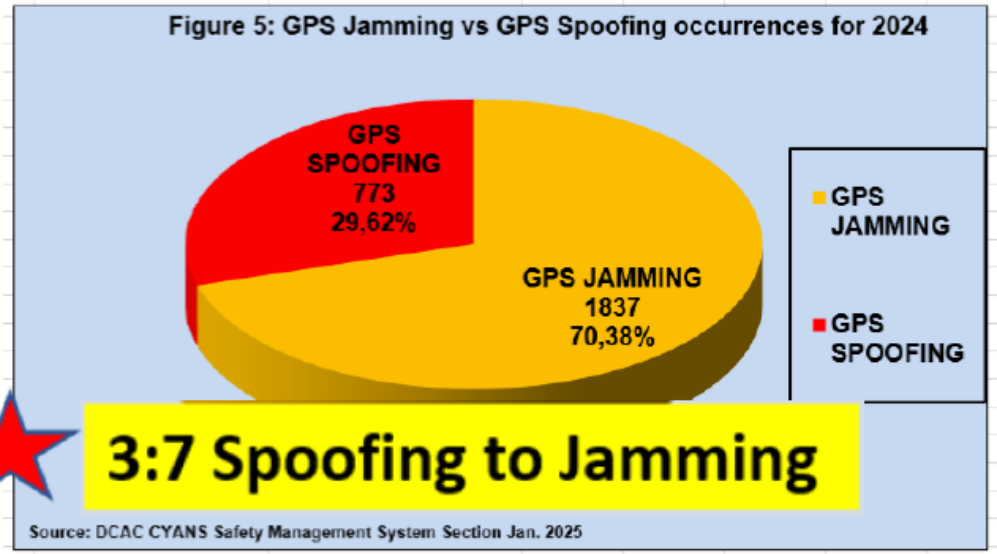
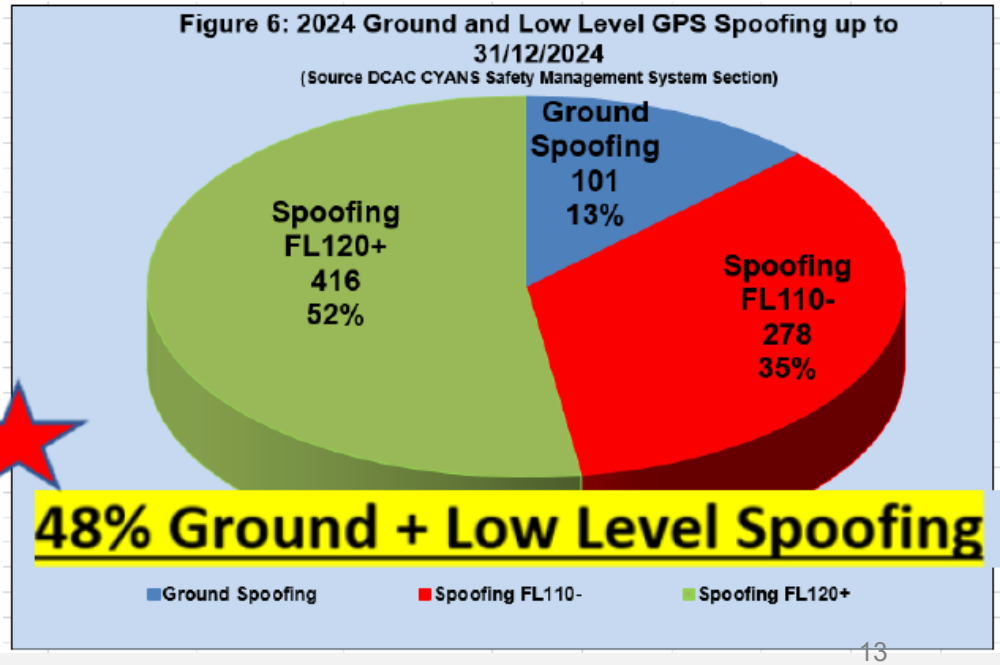
An exponential increase of GPS Spoofing Occurrence Reports since Dec. 2023





3:7 Spoofing to Jamming



48% Ground + Low Level Spoofing

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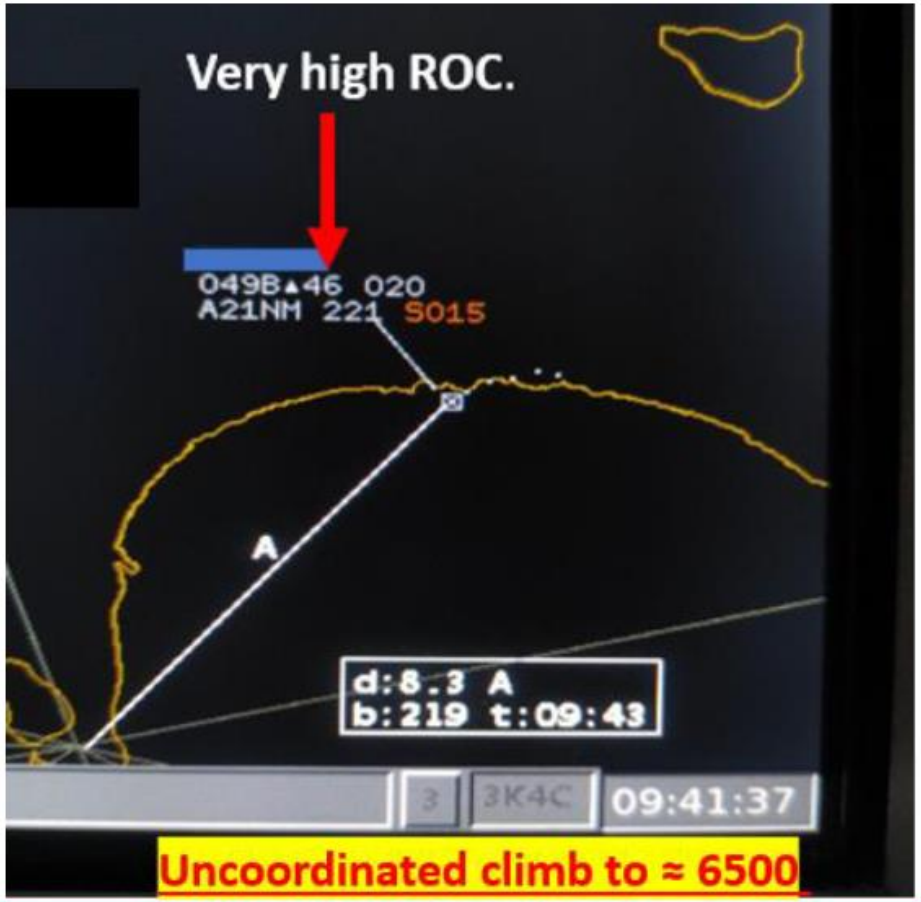
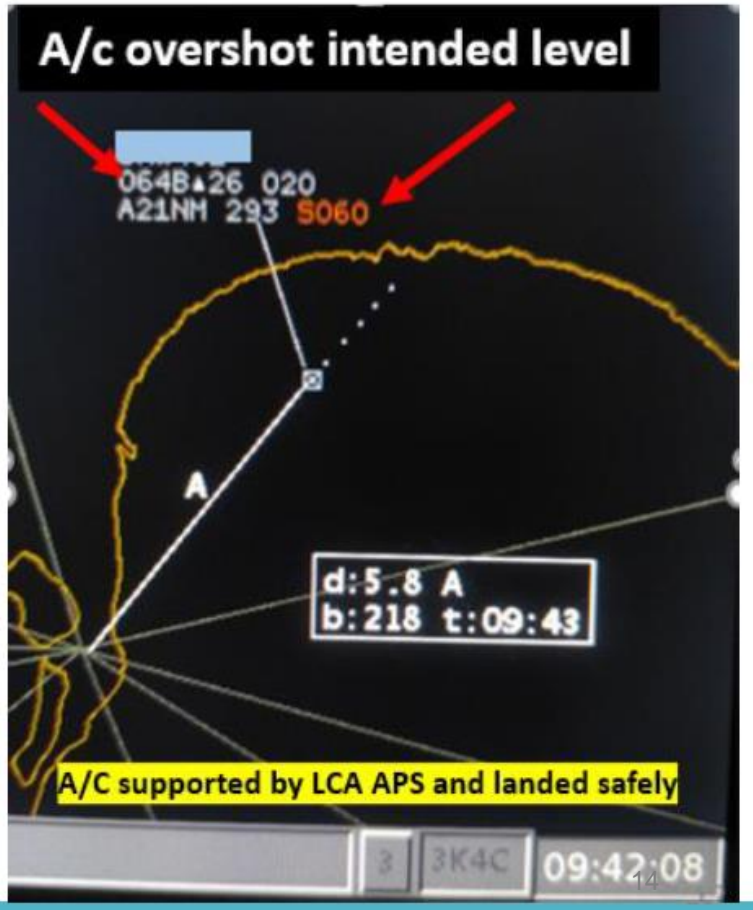
Incident 1: April 2024, CAVOK, A321, under Larnaca TWR procedural control, at 1800 ft, turning to establish on ILS RWY 22, with clearance to land, reported "going-around".

1. Initiated Uncoordinated Climb to ≈ 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 (≈4600ft/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.





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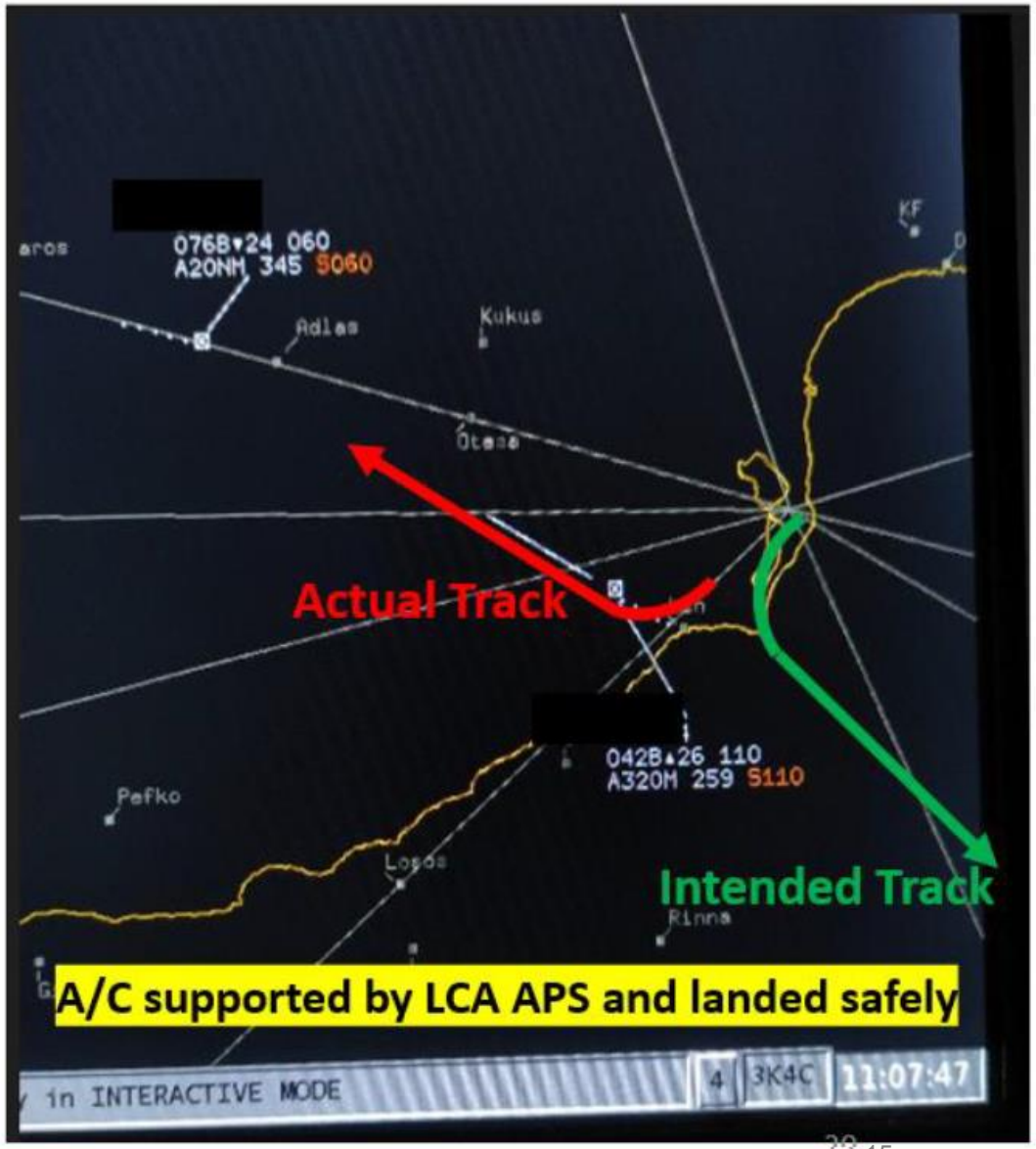
Incidents 6,7: Spoofing on departure, Lateral Deviation from ATC Clearance

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)

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



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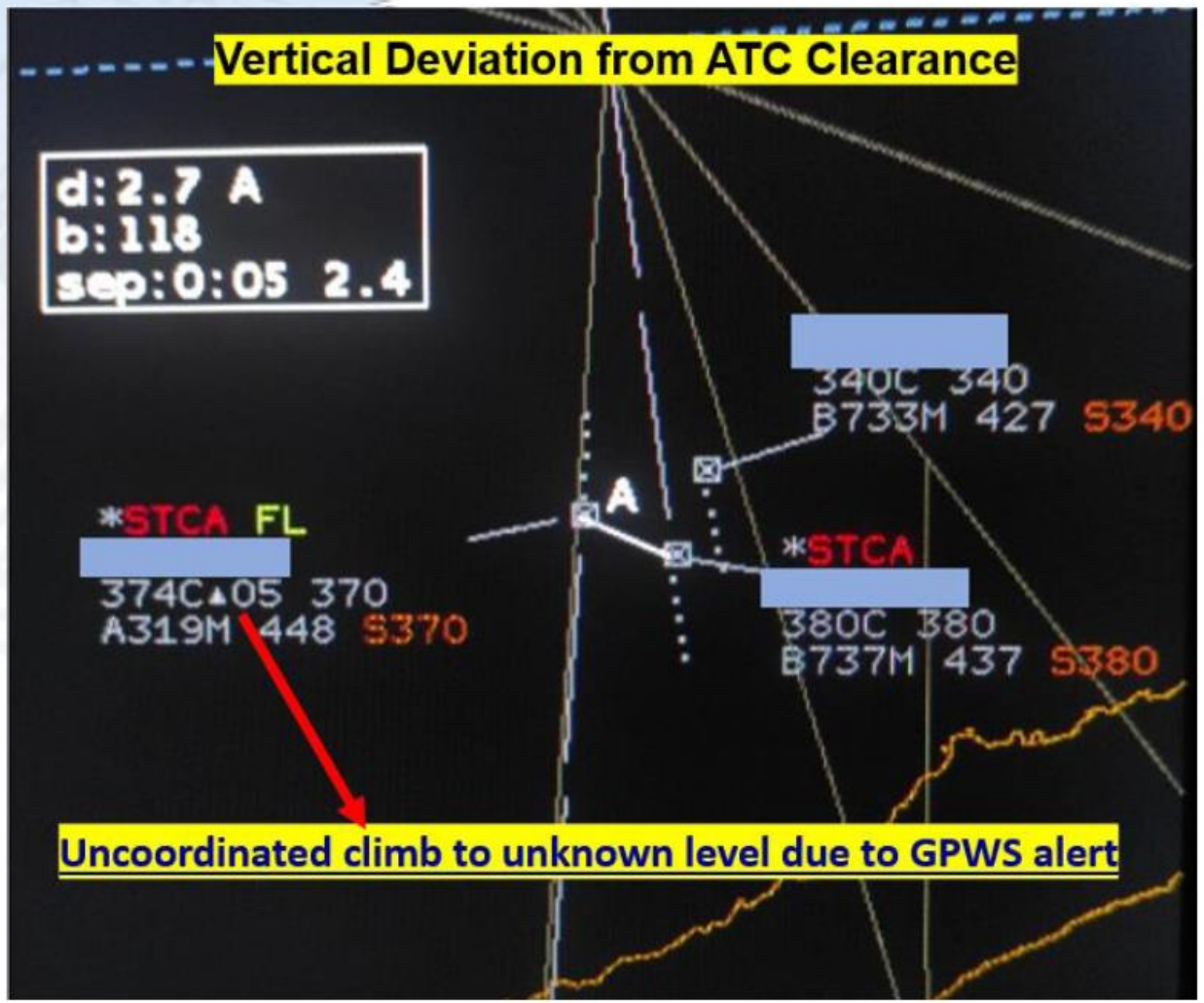
Incident 8: Separation Minima Infringement (SMI) in response to GPW at FL370



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