GNSS Jamming/Spoofing and Continued Operational Safety

International Committee on GNSS Interference Detection & Mitigation Workshop

15 April 2024

Christina Clausnitzer
Management and Program Analyst
Office of Safety Standards
and
Ken Alexander
Chief Scientist and Technical Advisor for
Satellite Navigation Systems
Office of Senior Technical Experts

Federal Aviation Administration

EASA/IATA PNT Resiliency Workshop

Jan 25, 2024

Goals

- Assess safety threats
- Develop mitigation strategies
- Unified European Aviation PNT strategy

Discussion

- Risk identification
- Collaborative Assessment
- Short-Term Solutions
- Long-Term Solutions

EASA/IATA PNT Resiliency Workshop

Jan 25, 2024

Participants

- Airlines
- Manufacturers
- System Suppliers
- Air Navigation Service Providers
- Institutions

Why is civil GNSS vulnerable?

- Signals are extremely weak and easily overpowered
- Public GNSS signals have no security protocols
  - Unencrypted and unauthenticated digital data messages
- Easily imitated (open public standards)
- Most devices “blindly” trust signals they receive
- Unlike computers/routers, GNSS has no firewall or virus protection
- Spoofing, tactics & techniques-widely available on the internet
- Low-cost devices have large area effect

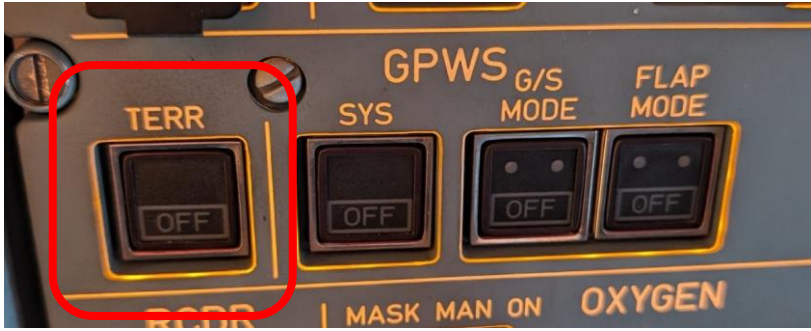
GNSS can be trusted, but how do you know what you’re using is from GNSS?

Aircraft and ATC GNSS Dependencies

- **Comm:** Datacom, SATCOM, Networks
- **Nav:** RNAV, RNP & LPV
- **Surveillance:** ADS–B and ADS-C
- **Safety:** GNSS enables Terrain Awareness and Warning System (TAWS) forward-looking function
- **Automation & Aircraft Specific Functions**
- **Support Equipment:** Elec Flt Bag, Survey, etc.
- **FAA ATC & Industry Infrastructure**

May not be able to identify or "deselect" erroneous GNSS signal inputs

False Alerts & Warnings



Two fundamental principles:

1. **Trust Your Instruments**
2. **Follow Standard Operating Procedures**

Pilot must either:

1. Ignore alerts/warnings; or
2. Follow required checklists & execute mandatory evasive maneuvers

Representative Audio:

Spoofing can result in repeating TAWS alerts and other alerts

- Aural Warnings <u>cannot</u> be muted or turned down

Increased pilot workload and desensitization can contribute to, or directly result in an accident

FAA Jamming / Spoofing Activities

- SAFO (25 Jan 24) provides information and guidance to operators and manufacturers for operations in a disrupted environment
- Performance Based Navigation (PBN) Aviation Rulemaking Committee (PARC) GPS/GNSS Disruption Action Team coordinating with stakeholders to ensure safe and efficient continuity and recovery of aircraft
- Leveraging industry and international partners and RTCA to identify and implement both operational & technical mitigations
- Developing integrated FAA/Industry “Playbooks” for future events
- FAA working with RTCA to improve DME PBN Navigation capability
- Evaluating situational awareness tools for display and decision making
- FAA researching jam and spoof resistant antennas for civil aircraft

ICAO Europe/North Atlantic/Middle East Radio Navigation Symposium (February 6-8, 2024)

- Theme ”**Towards Safe, Reliable and Resilient Air Navigation**”
  - Included experts from States, Organizations & Aviation industry

Symposium Objectives Included:

- Provide updates on ICAO activities and plans at Regional and Global levels as well as guidance on rationalization of conventional Navigation aids and their evolving solutions
- Provide updates on GNSS and augmentations, identify & address emerging challenges including GNSS vulnerabilities a
- Discuss GNSS vulnerabilities management plan & possible GNSS jamming/spoofing monitoring solutions

Complementary Positioning: Architecture Change?

- Many of TODAY's Aircraft, FMS NAV Integration is an "**availability switch**"
  - IF GPS/GNSS is available, THEN use GPS
  - IF GPS/GNSS is not available, THEN use INS or RADIONAV
    - Unless forced through an outage, RADIONAV position gets ignored
    - Systems today are trimmed to deliver high availability / continuity
- TOMORROW's Aircraft Flight Management System NAV Integration: "**improved consideration of all sources**"
  - (Operators are) Not interested in carrying another aircraft system just in case the other one does not work
  - Service provision: Need to push for DME network to provide GNSS-like navigation service

EUROCONTROL Voluntary Pilot/ATC Incident Reporting (EVAIR)

(Events per 10,000 flights - 2016 to 2020)

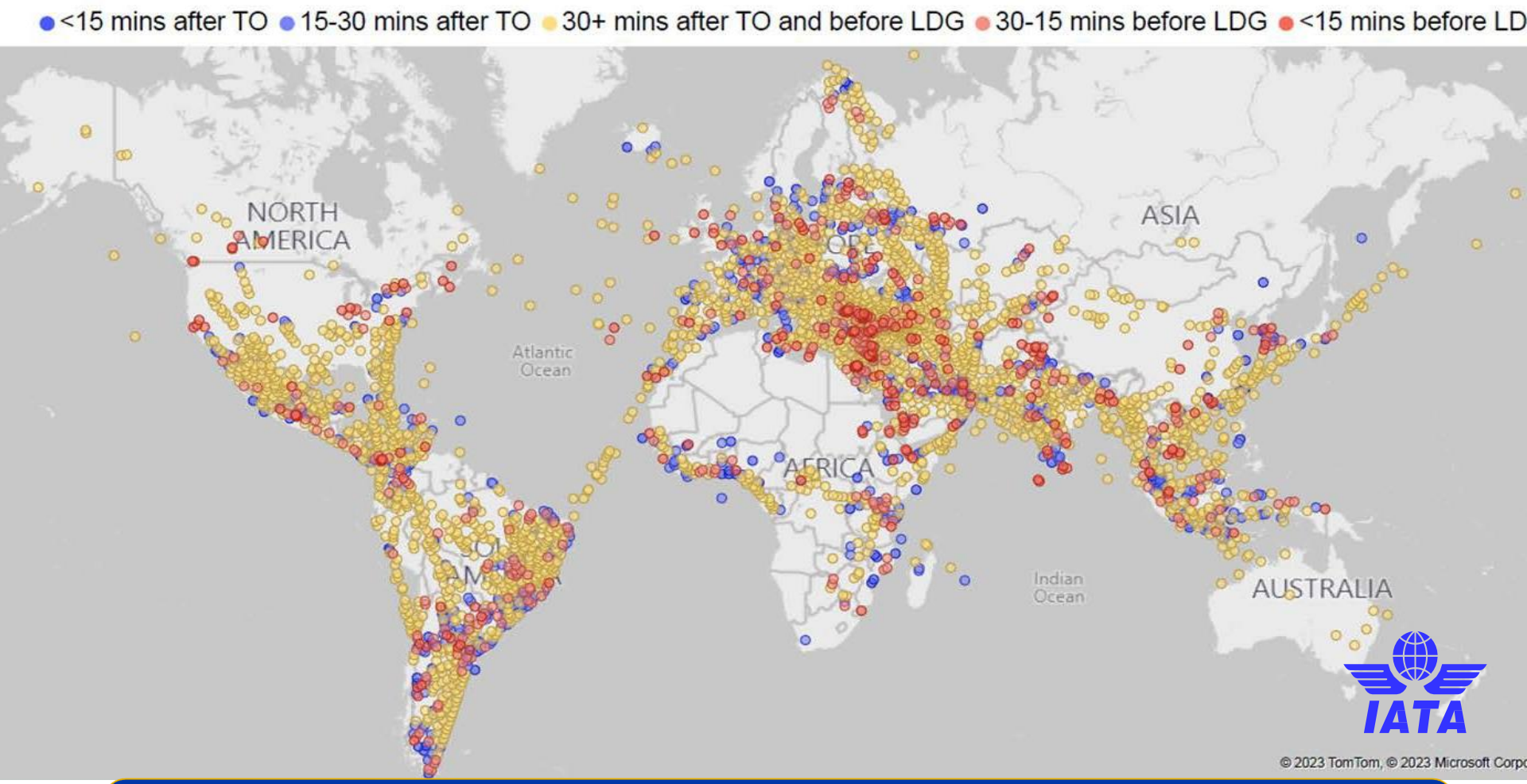
2018 GPS Jamming & Spoofing Safety Reports (Green)

~ Three times all other categories combined

1st two months of 2024 are 3 times 2023

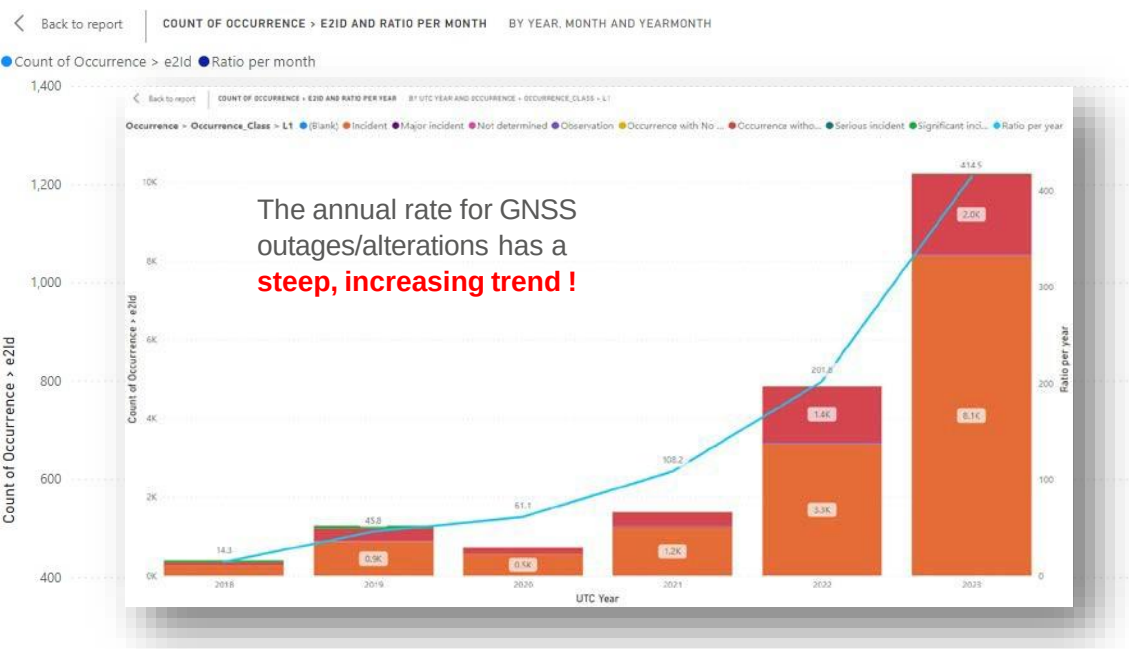
2023 rate **2024 rate**

GPS Signal Loss Occurrence by Phase of Flight



From June 2022-June 2023: 209 Airlines recorded ~150,000 Loss of GPS Events n ~5 million flight operations

GNSS outage (ECR data), mitigations



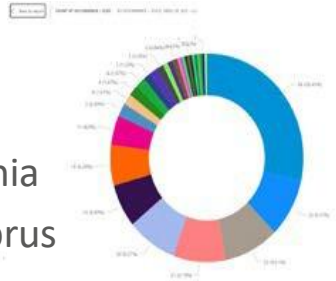
19.73K

Count of Occurrence > e2...

Continued increase in GNSS jamming and cases of spoofing resulted in EASA SIB 2022-02R2 being issued in November 2023

Rates are per 1.000.000 flights

Spoofing Reports in ECR



Turkey, Black Sea, Romania

→ Iraq, Egypt, Bulgaria, Cyprus

→ Iran, Georgia, Israel

2022 2023

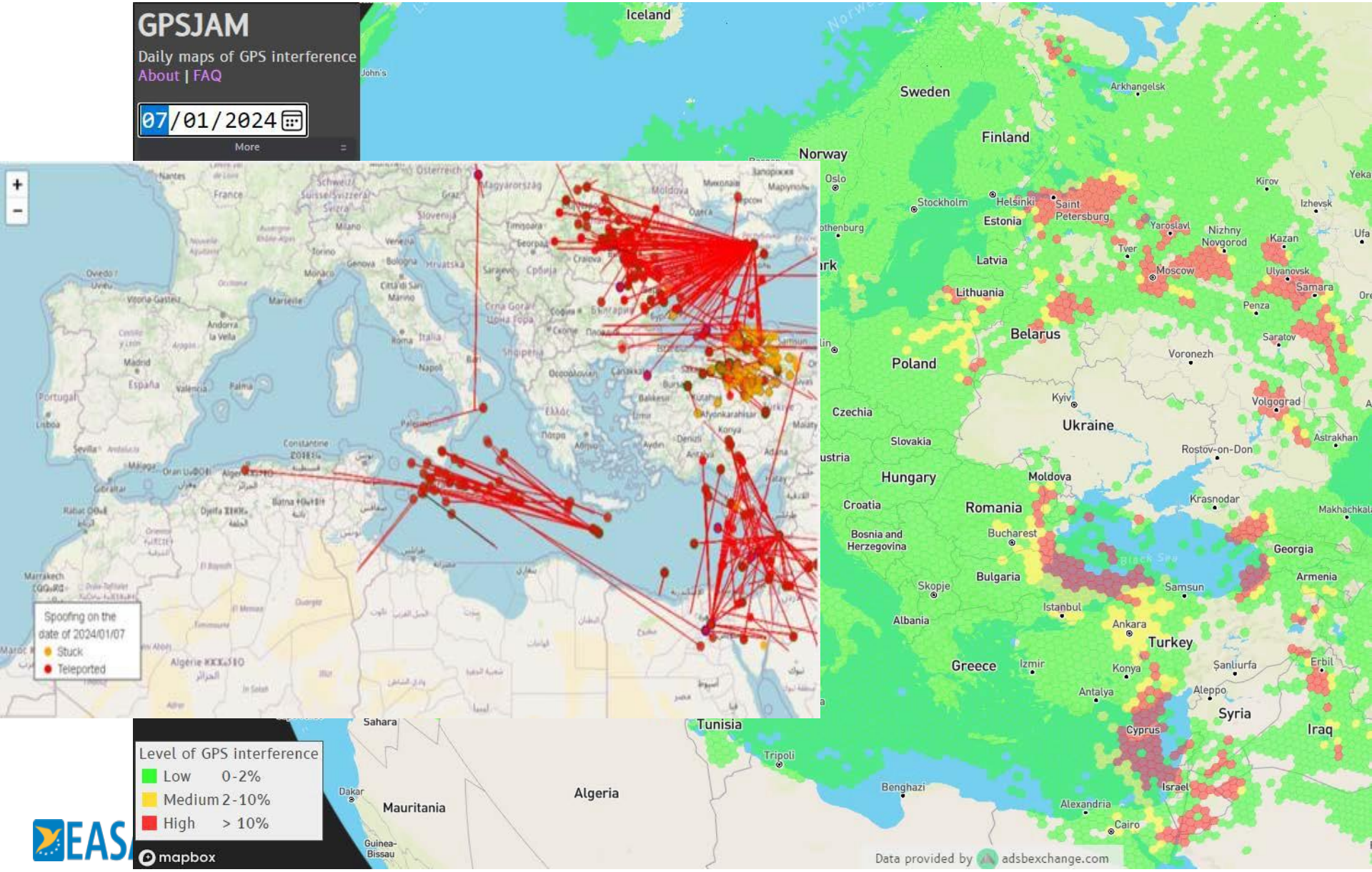
239

Count of Occurrence > e2Id

Rates are per 1.000.000 flights

1-4th Qtr 2023

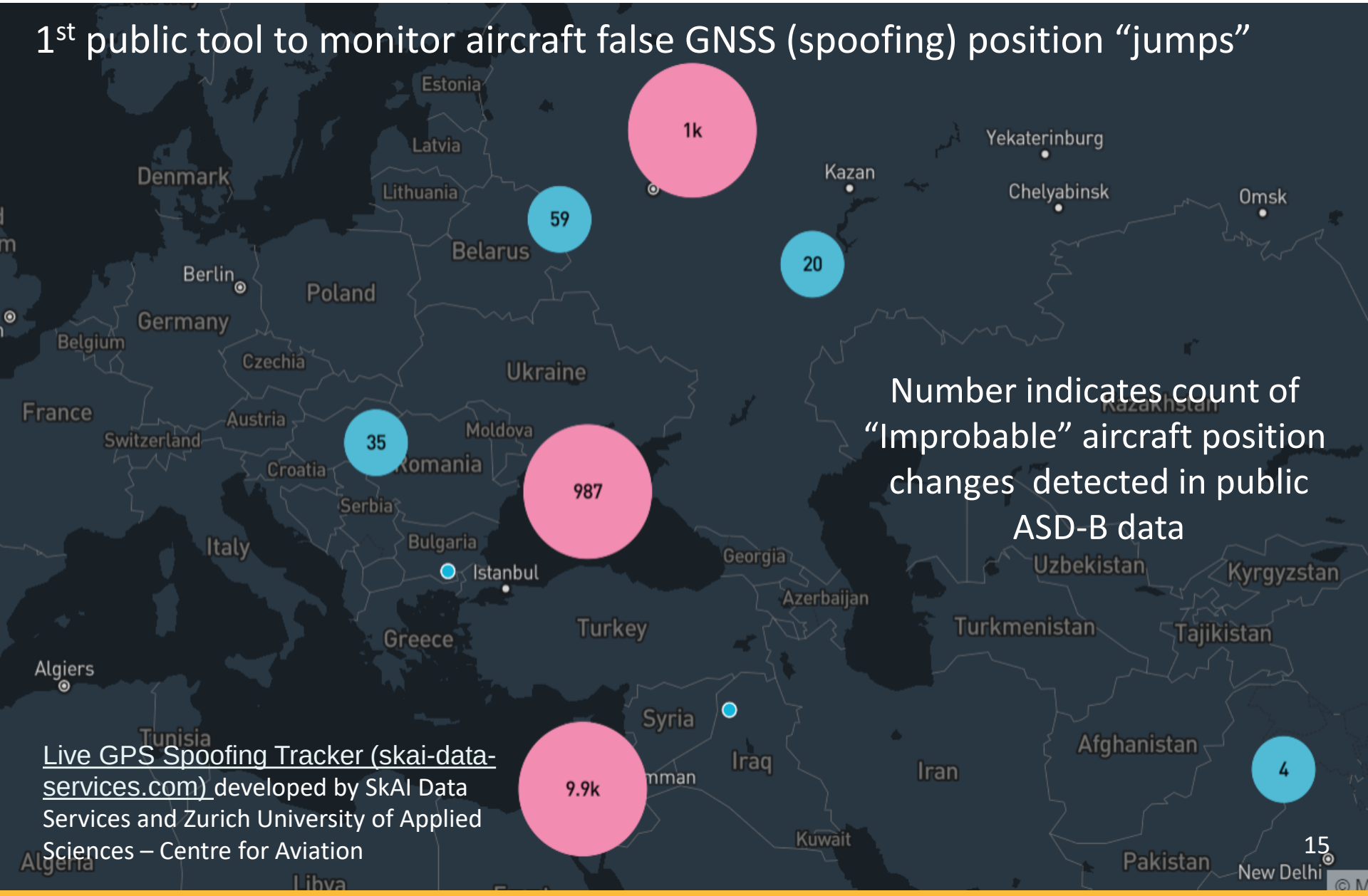
Spoofing and jamming



Live GPS Spoofing Tracker

2nd week of April 2024

1st public tool to monitor aircraft false GNSS (spoofing) position “jumps”



Number indicates count of “Improbable” aircraft position changes detected in public ASD-B data

Live GPS Spoofing Tracker (skai-data-services.com) developed by SkAI Data Services and Zurich University of Applied Sciences – Centre for Aviation

Eurocontrol Summary to ICAO Forum

- Multi-DME Navigation can make a significant contribution for resilient navigation--Not same as DME/DME (single pair) broadly known today
  - INS and DME can, and should, support ADS-B
  - DME is not the solution for all environments or all aircraft
  - Needs harmonized “integration upgrades” with FMS, DFMC GNSS and INS
  - “DME Forever” will not work for spectrum reasons, need evolution path
- Avionics integration needs to become more resilient & take better advantage of available complementary sensors to reduce CNS interdependencies
  - Need to overcome “magic is in the box” mentality
  - Similar efforts required at CNS ground system level
  - Need improved cooperation and common performance language
- ANSP need to improve service provision for GNSS contingency

ICAO 41st Assembly Resolution Fall 2022
(AR41-8C excerpts)

Ensuring resilience of ICAO CNS/ATM systems and services

Resiliency to interference needs to be improved by maximizing integration of all suitable ground infrastructure, space infrastructure and airborne components in a complementary and cooperative manner to be as robust as possible to cases of satellite-based service disruptions or environments where false or deceptive signals are present

Recognizing both aircraft on-board & ground infrastructure . . . need to be adapted to include . . . interference detection, mitigation and reporting

Acknowledging loss of crew's situational awareness from malicious origin is classified as a cyber-security threat & cannot be tolerated in civil aviation

. . . and that intentionally sending misleading signals to replace the accurate signal is a far more serious threat to flight safety than loss of GNSS signal

ICAO Headquarters Recommendations (Slide 1 of 5)

All Stakeholders Be aware of potential safety & capacity impacts of GNSS interference, jamming, and spoofing

Civil Aviation Authorities (CAAs) Ensure Air Navigation Service Providers (ANSPs) deploy & maintain adequate Distance Measuring Equipment (DME) Infrastructure & DME Performance Based Navigation procedures

CAAs Enable aircraft operators use of Multi DME & Multi-DME/Inertial Reference System (IRS) complementary solutions

- To maintain PBN operations during GNSS local or regional events

CAAs Ensure ANSPs implement & maintain Minimum Operational Networks (MON), or greater, of Navigation Aids & Radar infrastructures

- Including VHF Omni-directional Range (VOR)
- Instrument Landing System (ILS) Cat I/II/III &
- DME

. . . to ensure resilience for navigation when core constellations or their augmentations are unusable

ICAO Headquarters Recommendations (Slide 2 of 5)

ANSPs Develop GNSS RFI event contingency procedures (Tech & Ops) to minimize any Ops impacts & ensure continuous safe air traffic Operations

- Note: Contingency procedures may require provision of reliable surveillance coverage resilient to GNSS interference

ANSPs Implement/maintain GNSS independent time source(s) for CNS/ATM infrastructure

CAAs/ANSPs Facilitate or deploy real-time monitoring & detection for GNSS RFI situational awareness -- recognizing aircraft operator responsible to determine ability to navigate

ANSPs Issue timely GNSS RFI Notice to Airmen (NOTAMs) in coordination with neighboring regions on sharing Navigation infrastructures when GNSS RFI might result in air traffic diversions

ICAO Headquarters Recommendations (Slide 3 of 5)

CAAs/ANSPs Improve civil-military coordination in GNSS testing & conflict zone risks to ensure uninterrupted & reliable use for diverse applications

National Military Authorities Coordinate GNSS RFI with National Spectrum Regulators, CAAs and ANSPs (to extent possible)

- To enable mitigation of any safety impacts to civil aviation

CAAs Foster RFI collaboration with National Spectrum Regulators

National Spectrum Regulators Locate and determine GNSS RFI source & attempt to resolve (as appropriate)

- May require coordination with authorities at national/regional levels

National Spectrum Regulators Report frequent, unresolved GNSS RFI to ITU Radiocommunication Bureau, describing impacts experienced or as reported by registered aircraft

ICAO Headquarters Recommendations (Slide 4 of 5)

Aircraft Operators Develop crew GNSS RFI procedures to notify ATC

Aircraft Operators Notify aircraft & avionic manufacturers (OEMs) & acft's State of design CAA by safety channels when encountering safety effects

Aircraft Operators Develop procedures & training based upon information from aircraft & avionics OEM and aircraft's State of design CAA

Aircraft Operators Place add'l emphasis on flight crews closely monitoring aircraft equipment performance for any discrepancies/ anomalies

- Promptly inform ATC of any apparent GNSS degradation and be prepared to operate without GNSS navigation systems

Original Equipment Manufacturers (OEMs) Improve equipment (capabilities) & provide add'l aircraft equipment guidance/information on GNSS RFI effects & mitigations (incl. interference, jamming & spoofing)

ICAO Headquarters Recommendations (Slide 5 of 5)

OEMs Ensure aircraft equipment quickly recovers and resumes GNSS navigation once no longer impacted by GNSS RFI event(s)

ICAO Navigation Systems Panel (NSP) Develop recommendations on sharing information on GNSS RFI (NOTAM or other measures)

All stakeholders Collaborate on simple & automated GNSS RFI reporting

All stakeholders Continue to evolve solutions and leverage ICAO NSP as common focal point

ICAO Continue raising awareness and supporting States, as required

New Threats Dictate new Strategies for Operational and Technical Mitigations

Questions

Contact Info:
Christina Clausnitzer
Christina.Clausnitzer@faa.gov
+1.303.342.1965

and
Ken Alexander
Ken.Alexander@faa.gov
+1.202.236.9794

BACKUPS

2014 FAA Guidance for Industry to address GNSS Misleading Position and Navigation Threats

- May 2014, FAA modified AC 20-138D *Airworthiness Approval of Positioning and Navigation Systems* and avionics standards to enable spoofing mitigations
  - Prescriptive Guidance mitigates spoofing as well as re-radiators

2014 FAA Aviation Circular (AC20-138D) as well as GPS, GBAS, & SBAS FAA Technical Order Standards and RTCA/EUROCAE MOPS state:

- *Improperly used or installed GNSS re-radiators can present misleading information to GNSS equipment*
- *Equipment manufacturers should consider measures to mitigate against use of erroneous data for GNSS position and navigation*
- *Possible measures to consider include implementing or enabling cross-checks of GNSS sensor data against independent position sources and/or use of other detection monitors using GNSS signal metrics or data*

EASA actions in response GNSS RFI

- → EASA SIB 2022-02R2 on Global Navigation Satellite System Outage and Alterations Leading to Navigation / Surveillance Degradation
- → 'Over-reliance on satellite navigation' is a safety issue (SI-0034) under assessment (CAT CAG) => completion by 2024 with proposed mitigations
- → CARI (CAW) for TCH & OEM to evaluate effects of GNSS jamming or spoofing on CS25/CS29 products at system and aircraft level
- → EASA/IATA Workshop on PNT Resilience hosted at EASA premises on 25 January 2024