

CANSO ACADEMY:



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GNSS INTERFERENCE: INTENTIONAL GNSS JAMMING AND SPOOFING

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MODERATOR



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Operations Programme Manager

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AGENDA

- Overview
- Operational Impacts and Mitigations
- ICAO ANC/14 Conclusions
- Tools
- Summary
- Q&A



CONTEXT OF GNSS VULNERABILITIES



- GNSS satellite signals are vulnerable to interference because of their extremely low power
- Interference can be unintentional and naturally-occurring, such as atmospheric scintillation and solar effects — or deliberate, such as jamming or spoofing
- GNSS is incorporated into a large number of modern aircraft systems, e.g., the FMS, Hybrid IRS, the aircraft clock, GPWS, Weather Radar, CPDLC, ADS-B, ADS-C, numerous others, as well as ATM ground systems

— thus, severe and cascading impacts from a spoofed GNSS signal

• Real-world incidents that result in disruption to GNSS have been rapidly rising



INTENTIONAL GNSS INTERFERENCE



• **Spoofing** involves broadcasting counterfeit satellite signals to deceive GNSS receivers, causing them to compute incorrect position, navigation, and timing (PNT) data.

Spoofing events are not automatically detected by the current avionics systems and no specific alert is provided to the flight crew

With few exceptions, GPS Spoofing is conducted by state actors as a result of regional conflict

• **Jamming** is an intentional radio frequency interference (RFI) with GNSS signals that prevents receivers from locking onto satellites signals and has the main effect of rendering the GNSS system ineffective or degraded for users in the jammed area

Jamming effects are generally detected by avionic systems and often alerts are provided to the flight crew

Primary jamming sources include Personal Privacy Devices (PPD), Military RFI, TV Broadcast Station malfunction

GNSS INTERFERENCE IS A GLOBAL PROBLEM

Level of GPS interference Low 0-2% Medium 2-10% High > 10%

CONFLICT ZONES AND SENSITIVE AREAS CANSO

- Southern and eastern Mediterranean area, and the Middle East: Nicosia LCCC, Beirut OLBB, Damascus OSTT, Tel-Aviv LLLL, Amman OJAC, north-eastern part LLLL, Amman OJAC, north-eastern part of Cairo HECC, eastern part of Athinai LGGG - Baghdad ORBB, Kuwait OKAC, Bahrain OBBB, north-western part of Tehran OIIX - Northern part of Tripoli HLLL
- **Black Sea area:** Istanbul LTBB, Ankara LTAA, Eastern part of Bucuresti LRBB, Sofia LBSR, Tbilisi UGGG, Yerevan UDDD, Baku UBBA
- Eastern Europe area: Bratislava LZBB, Budapest LHCC, Chisinau LUUU
- Baltic Sea area: Helsinki EFIN, Tallin EETT, Riga EVRR, Vilnius EYVL, eastern part of Warszawa EPWW
- Arctic area: Northern part of Helsinki EFIN, northern part of Polaris ENOR





Severe impacts to civil aviation from GNSS spoofing beginning Sep 2023

- by January 2024 ~ 300 flights/day
- by August 2024 ~ 1500 flights/day
- between 15 Jul 15 Aug, 2024, 41,000 flights.



*Data source: ZHAW/SkAI Data Services, using the OpenSky Network, from OPSGROUP GNSS Spoofing Final Report.



FIRs most affected by in-sector spoofing—15 Jul – 15 Aug 2024

The actual number for some sectors is likely a lot higher

- Nicosia FIR (5,655 flights)
- Tel Aviv FIR (3,228 flights)
- Cairo FIR (2,375 flights)
- Ankara FIR (1,195 flights)
- Samara FIR (1,186 flights)
- Moscow FIR (988 flights)
- Lahore FIR (492 flights)
- Minsk FIR (372 flights)
- Beirut FIR (371 flights)
- Delhi FIR (316 flights)
- Sofia FIR (235 flights)
- Bucharest FIR (231 flights)



SAMPLING OF REGULATORY AND INDUSTRY GUIDANCE CANSO

State regulations

- Eu REG.2020/469 amending 2017/373 (from 27 January 2022)

Safety and technical information bulletins

- IATA: 30 March 2023
- EASA: 2022-02R3, 05 July 2024
- FAA: SAFO 24002, 25 Jan 2024
- SINGAPORE: 2022-01 R3, 11 Jan 2024

Papers/Reports

- IATA: Global Navigation Satellite System GNSS-Radio Frequency Interference Safety Risk Assessment, 4 Sep 2024.

https://www.iata.org/contentassets/c8e90fe690ce4047a8edfa97f4824890/iata_safety_risk_assessment _gnss_interference.pdf

- OPSGROUP: GPS Spoofing; Final Report of the GPS Spoofing Workgroup, 6 Sep 2024.
 <u>GPS-WG-FinalReport_v2.4 (ops.group)</u>
- Workshops
 - IATA-EASA Position, Navigation, Timing Workshop, Jan 2024
- ICAO
 - ICAO Doc 9849, GNSS Manual, Chapter 5
 - Annex 10, Vol I, Radio Navigation Aids
 - Air Navigation Conference 14 Conclusions



PRESENTER



Ruby Sayyed

Global Head of Air Traffic Management

IATA

Airline Perspective – GNSS RFI

Ruby Sayyed



GPS loss events evolution

GPS Loss events - FDX program





Mitigations

- Risk assessment
- Simulator training sessions
- Aircrew awareness / notifications / briefings
- Regular engagements with
 the manufacturers



Global Navigation Satellite System GNSS-Radio Frequency Interference

Safety Risk Assessment

Version 4 September 2024



1 Global Navigation Satallite System GNSS-Radio Proquency Interference

Version 4 September 2024



Mitigations

- Recovery / in-flight procedures
- Crew reports



Global Navigation Satellite System GNSS-Radio Frequency Interference

Safety Risk Assessment

Version 4 September 2024



1 Global Navigation Satalito System GNSS-Radio Proquency Interference

Version 4 September 2024



Actions External to Airlines





Safety Issue Updated: 9/2/2024 3:10:46	Hub Search Key Risk Areas Operational Regions	A-Z Share an	Issue 🔊
> Reset All Filters	Safety Issue Source: 🔲 IATA 🔅 External Source 💭 Safety Risk Assessment 2 S	afety Issues(s) avail	able to read
GNSS Q Ø	Issue 01/07/2024	Guidance Materials	Last Updated
Filter by Key Risk Areas	GNSS - Radio Frequency Interference		
Select all	Spoofing or jamming of GNSS signals impacting aircraft systems that are reliant upon this input, resulting in misleading or the unavailability of navigation and/or surveillance information. Leading to controlled flight into terrain or mid-air collision.		
CFIT	SkAI - GPS Spoofing and Jamming Tracker Map	ବ	01/07/2024
SYS	SIRM blog - GNSS Interference, insights from operators	Ø	14/05/2024
	FAA - Safety Alert for Operators / Global Navigation Satellite System (GNSS) Disruptions	Q	05/02/2024
	EUROCONTROL - GNSS Threat Assessment Tool	Q	25/01/2024
	EASA - SIB - Global Navigation Satellite System Outage and Alterations Leading to Navigation / Surveillance Degradation	Q	06/11/2023
Filter by Operational Areas	AIRBUS GNSS Interference	Ø	18/10/2023
To select more press Ctrl + Op. Areas	AIRBUS GNSS loss and interference In service Information	Ø	18/10/2023
Select all	IATA Safety Risk Assessment	0	18/10/2023
	IFALPA - GNSS Interference at MMMX (Mexico City)	®	16/06/2023
- Flight operations	EASA Safety Information Bulletin	@	17/02/2023



Thank you!





PRESENTER



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Senior Systems Engineer: Surveillance and Display Systems, Air Traffic & Navigation Services, ATNS

Co-chair CANSO CNS WG



OPERATIONAL IMPACTS & MITIGATIONS

ATM Perspective

AVIATION ECOSYSTEM AND GNSS USAGE CANSO

 ATM/CNS is a complex system of Navigation Satellite systems Communications Satellite • GNSS systems are frequently used as a GNSS source of precision timing information within communication Voice and radar systems and Data are also used for Position automatic dependent surveillance (ADS) services. Airport Voice Airline Data Satellite Flow Mgr. Comms. ANSP Radar 20000 000 Internet 0000000 000 00000 Surveillance Airband Comms

AVIONICS IMPACTS



- Inability to use GPS/GNSS or hybrid GPS/GNSS inertial systems for navigation
- Loss of area navigation (RNAV) capability, to include required navigation performance (RNP)
- Unreliable triggering of Terrain Avoidance and Warning systems (TAWS)
- Inaccurate aircraft position on navigation display (e.g. moving map and electronic flight bag);
- Unanticipated effects to use of conventional navigation aids (e.g. inability to autotune);
- Unanticipated position-dependent flight management system effects (e.g. insufficient fuel indication)

ATM OPERATIONAL IMPACTS FROM GNSS INTERFERENCE



ATM Technical Impacts

- Failure or degradation of ATM infrastructure and its associated systems reliant on GPS/GNSS
- Time shift affecting ground-based systems using GNSS as reference for timing only
- Abnormal differences between Ground speed and True airspeed
- Loss of or erroneous ADS-B message outputs
- Data link (CPDLC or ADS-C) message corruption or errors

Result in...

- Potential airspace infringements and/or route deviations
- Reduced Airspace Capacity
- Unable to provide oceanic clearances or certain altitudes to affected aircraft

STRATEGIC MITIGATIONS

States

Both



- Report to ICAO cases of harmful interference to global navigation satellite system that may have an impact on international civil aviation operations;
- **Develop and enforce a strong regulatory framework** governing the use of global navigation satellite system repeaters, pseudolites, spoofers and jammers;
- Allow for realization of the full advantages of on-board mitigation techniques, particularly inertial navigation systems.
- Ensure surveillance coverage is resilient to GNSS interference.
- Ensure contingency plans include procedures in case of large-scale GNSS jamming and/or spoofing events.
- Include GNSS jamming or spoofing in ATCO training.
- Assess the likelihood and effects of global navigation satellite system vulnerabilities in their airspace and apply, as necessary, recognized and available mitigation methods.
- Provide effective spectrum management and protection of GNSS frequencies to reduce the likelihood of unintentional interference or performance degradation;
- Retain specific ground-based navigation aids as part of a Minimum Operational Network. Where terrestrial aids are needed as part of a mitigation strategy, give priority to retention of distance measuring equipment (DME) in support of inertial navigation system (INS)/DME or DME/DME area navigation, and of instrument landing system at selected runways.

TACTICAL MITIGATIONS



- Provide relevant and timely information to airspace users as appropriate, e.g., through ATIS, NOTAMs, AIP, etc.
- In areas affected by GNSS jamming and/or spoofing promote the use of conventional navigation flight procedures
- Be prepared to provide navigation assistance to aircraft (using radar vectoring) as long as needed
- Monitor traffic closely to prevent any deviation from ATC clearances (e.g., navigation track and altitude)



RISK MITIGATION THRU SPECTRUM MANAGEMENT

Spectrum Allocations to Aeronautical Services Utilized by Civil Aviation



AVIATION SPECTRUM CHALLENGES



 Congestion imposes the need for efficient frequency spectrum management

Spectrum management:

- Combination of administrative and technical procedures
- Necessary to ensure interference free and efficient operation of radio services (e.g., Air/Ground Communications and Radionavigation)
- Aviation frequency managers need to develop, and lobby for an aviation position on frequency spectrum use



ANSO

Nonindustrial nations have more complications with GNSS signal reception due to:

- Lack of State spectrum management
- GNSS interference incidents do not receive sufficient publicity.



ICAO AIR NAVIGATION CONFERENCE/14

Recommendations Addressing GNSS Interference and Contingency Planning

RECOMMENDATIONS FOR STATES



• Ensure that effective GNSS RFI mitigation measures are implemented based on measures developed by ICAO and industry, including the need to maintain:

o a sufficient network of conventional navigation aids to ensure operational safety

o sufficient airspace capacity during times of GNSS interference

• Through the planning and implementation regional groups (PIRGs):

 develop regional or global navigation satellite system reporting mechanisms, as described in the Global Navigation Satellite System (GNSS) Manual (Doc 9849)

 Work with industry to provide guidance on detecting GNSS jamming or spoofing and maintaining safe and efficient aircraft operation in case of global navigation satellite system anomalies

RECOMMENDATIONS FOR ICAO



- Develop a standardized implementation package to assist and guide States in implementing effective GNSS RFI mitigation measures, including:
 - o ptimization and rationalization of conventional navigation aids, commensurate with their local conditions, to ensure continuity in the provision of air navigation services
- Develop guidance on civil-military coordination in relation to harmful interference to global navigation satellite system(s) originated or detected by military authorities
- Review aircraft minimum equipage lists to ensure compatibility with States' implemented minimum operational networks.



PRESENTER



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AIREON GNSS INTERFERENCE MONITORING TOOLS

WHAT KIND OF ANOMALIES CAN BE DETECTED?





Unintentional

- GNSS/GPS Interference (terrain, multipath, space weather, L-Band noise)
- Malfunctioning avionics • or aircraft GNSS receiver
- Malfunctioning GNSS constellation or payload

Intentional

•

- GNSS/GPS Interference -Jamming (Ground-based, Air-based)
- **GNSS/GPS** Interference with a stronger GNSS/GPS signal (signal spoofing)
- Malfunctioning avionics (cyber event)
- ADS-B message spoofing • (non-aircraft transmissions)



Satellites



Unintentional Interference

Unintentional

Interference



ADS-B Position + PIC





GNSS Jammer



WHAT KIND OF ANOMALIES CAN BE DETECTED?



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ISSUE #2: In case of such GNSS interferences, can we calculate the 'Real Track' of the aircraft?



HOW AIREON IS MONITORING GNSS INTERFERENCES CANSO

- Global persistent coverage
- Normalized Data that is processed by a system that is certified to standards
- Low latency "real time alerting"
- Multiple payload detection of events
- Timedifference-ofarrival (TDOA) geolocations
- Independent positioning Identification and reference track



Aireon's Space-based technology is advantageous for GNSS Interference detection

/ideo

Real-time

situational

Performance

within Airspace

geographic GPS

Integration with Safety Dashboard

Development of

Real-time Alerting

Development of

Reference Track

Independent

Position Validation

performance,

awareness of GPS

Historical analysis of events and



REAL TIME MONITORING AND EVENT ALERTS





POST- EVENT ANALYSIS

Singapore, Feb 2024

CANSO

Multiple Aircraft reported GPS navigation issues



Video

Bahrain, Nov 2023







INDEPENDENT POSITION IDENTIFICATION AND REFERENCE TRACK

MULTILATERATION AND REFERENCE TRACK

- CANSO
- Leveraging the precision and timing of the Iridium constellation, Aireon can detect the location of a transmitting aircraft even when the position reports are no longer valid
- Allows for the tracking of ADS-B equipped aircraft during periods of faulty avionics or when there may be environmental interference
- Provides resilient source for GPS Integrity issues





AIREON INDEPENDENT POSITION AND REFERENCE CANSO TRACK





GNSS INTERFERENCE AND SPOOFING: 25 DECEMBER 2023 (CHH764)



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GNSS INTERFERENCE: FINLAND 26 APRIL 2024





4601F4 Ref. Track





GNSS Interference

WOULD YOU LIKE TO LEARN MORE?

WHITE PAPER

CANSO

WHITE PAPER

MAY 2024 Dr. Michael Garcia Chief Innovation Scientist

Aireon.

Dr. Michael Garcia Chief Innovation Scientist John Dolan Director, Modeling & Analysis/Data Science Dr. Giuseppe Sirigu Principal Data Scientist

GPS interference and spoofing in the Baltics

Air Navigation Service Providers (ANSP) and aircraft operators rely on the integrity of the GPS signal to navigate the aircraft to its destination. Increasingly, however, the integrity of the GPS signal has become a target for interference — via nefarious actions like spoofing or jamming, or non-intentional actions like malfunctioning avionics. This trend has prompted many in the aviation industry to seek creative, technological redundancies to the GPS signal to ensure the aircraft is able to continue operating safely in the event of an interference.

Using its one-of-kind, space-based automatic surveillance broadcast (ADS-B) data, Arieon has developed a proof-of-concept multilateration solution that allows for independent position determination of ASS-B-aquipped aircraft. This autoin on will allow Airon to continue tracking aircraft even when they are unable to broadcast their GPS position using only their transmitted 24-bit aircraft address and the time of reception at the Aircen Notest Physicals onboard the Holms atellities.

This is done through a Satellite Wide Area Multilateration (SWAM) application that uses Time Difference of Arrival (TDDA) measurements from simultaneous detection of ADS-B transmissions on multiple payloads.

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EXARCONSISTENT OF A SUBJECT OF

Aircraft operators, Air Navigation Service Providers (ANSP), air traffic control organizations, and others rely heavily on data and associated systems to safely and efficiently operate and navigate aircraft throughout the airspace. From takeoff to touchdown and beyond, positional data is critical. But what happens when the systems fail? What if the GPS data is somehow compromised?

Aireon has developed a proof-of-concept multilateration solution that allows for independent position determination of ADS-8-equipped aircraft. This solution will allow Aireon to continue tracking aircraft even when they are unable to broadcast their GPS position using only their transmitted 24-bit aircraft address and the time of reception at the Aircen tested Payloads onboard the indium satellites.

This is done through a Satelite Wide Area Multilateration (SWAM) application that uses Time Difference of when ((TDOA) measurements from simulaneous detection of ADE-It transmissions on multiple payloads. This solution leverages traditional multilateration techniques used by terrestrial systems but applied via stellate. This is possible due to both the follow montestation, with its significant overlapping satellite coverage, and indiant's ability to accurately track the position and timing of each satellite (on the order of hundrest of managescond), which is alread with the position and timing of each satellite (on the order of hundrest of managescond), which is alread with Areas.

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Available at <u>www.Aireon.com</u> Contact: <u>diego.albert@aireon.com</u>





SUMMARY

- Overview of GNSS interference and the rapid increase in incidents of intentional interference
- Airline and ANSP perspectives on impacts and mitigations
- ICAO ANC/14 recommendations related to GNSS interference
- Aireon GNSS interference monitoring tools



MODERATOR



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THANK YOU



SHAPING OUR FUTURE SKIES