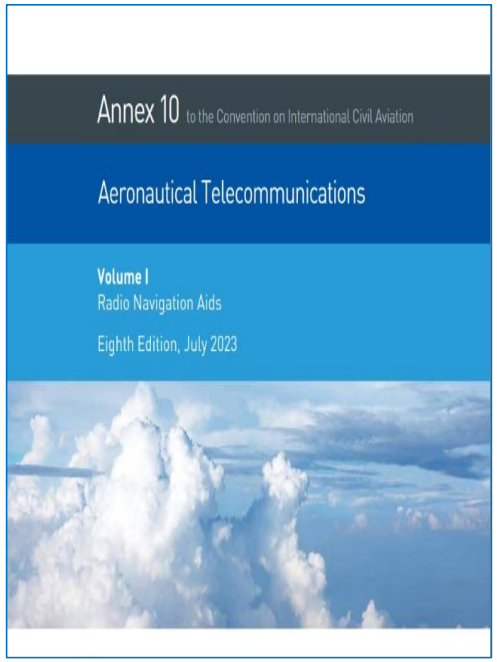
Global Developments related to GNSS RFI

ICAO SAM Radio Navigation Workshop
2-4 September 2026

Muna Alnadaf

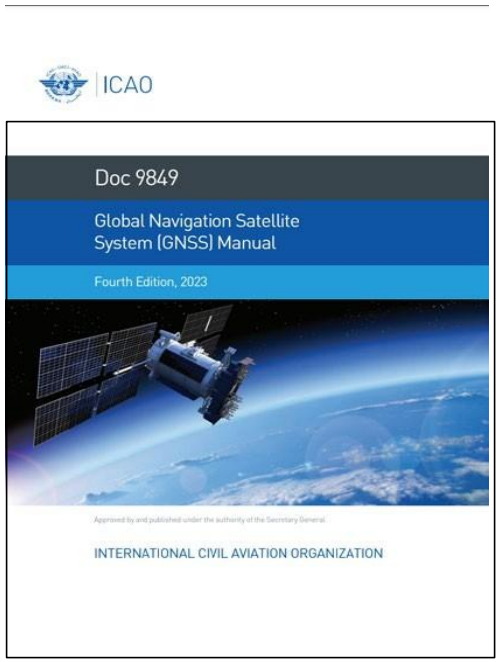
Technical Officer CNS / ICAO HQ
Secretary of the Navigation Systems Panel

Relevant ICAO Provisions



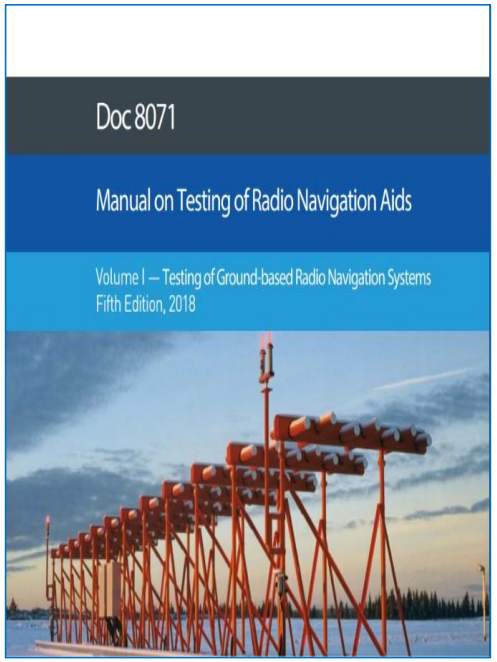
Annex 10, Volume I

Aeronautical Telecommunications:
Radio Navigation Aids



ICAO Doc 9849

Global Navigation Satellite
System (GNSS) Manual



ICAO Doc 8071, Vol I

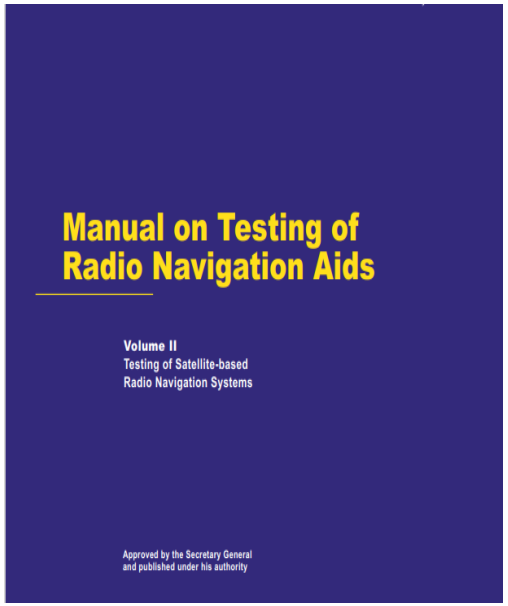
Testing of Ground-based
Radio Navigation Systems

Additional ICAO Provisions

1

ICAO Doc 8071, Vol II

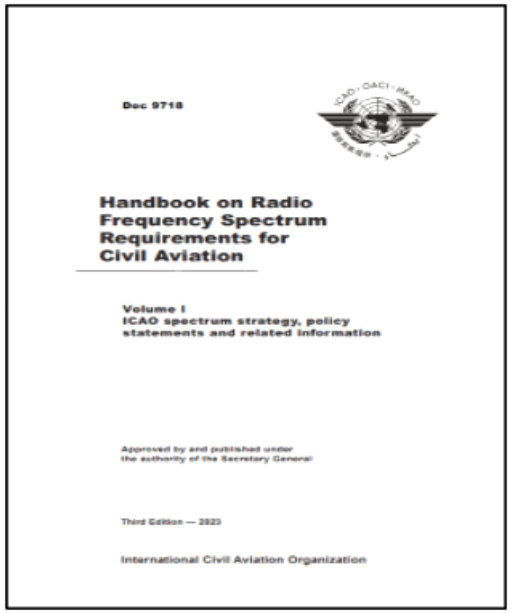
Manual on Testing of Satellite-based Radio Navigation Systems



2

ICAO Doc 9718

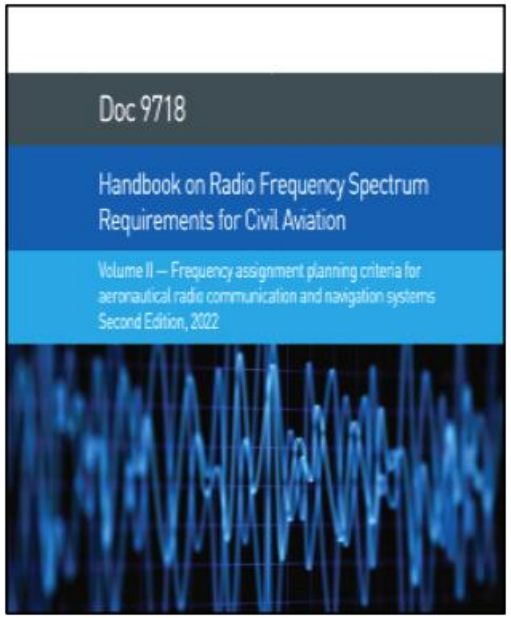
Handbook on Radio Frequency Spectrum Requirements for Civil Aviation



3

ICAO Doc 9718 Vol II

Frequency Assignment Criteria for Aeronautical Radio Communication & Navigation systems

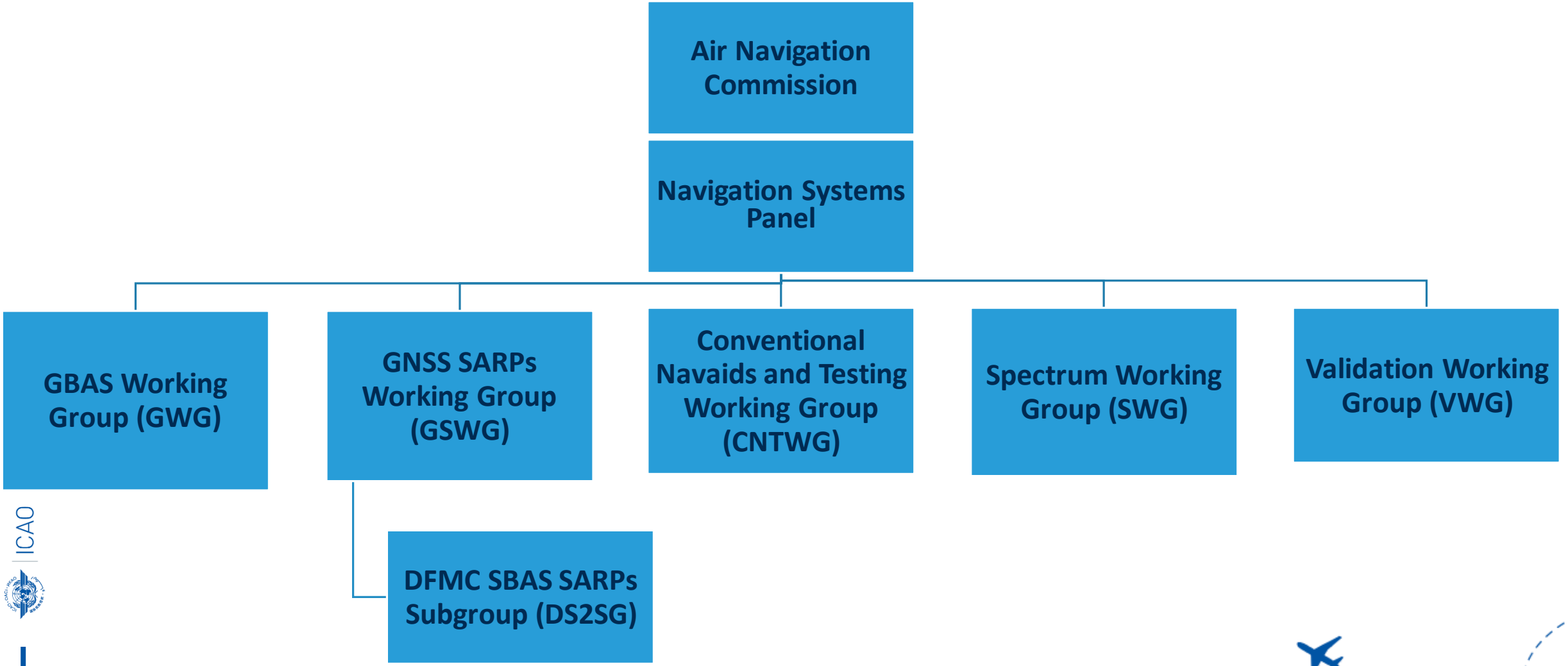


ICAO Navigation Systems Panel (NSP)

- Was established in 2003
- Composed of 30 members from States and organizations.
- NSP members & advisors are experts involved in design, development, planning, implementation and operation of aeronautical navigation systems

- To develop, as required, SARPs and guidance material pertaining Radio navigation. It should also Monitor the development and implementation of aeronautical navigation systems and facilities in order to facilitate worldwide coordination of implementation.

Navigation Systems Panel Structure



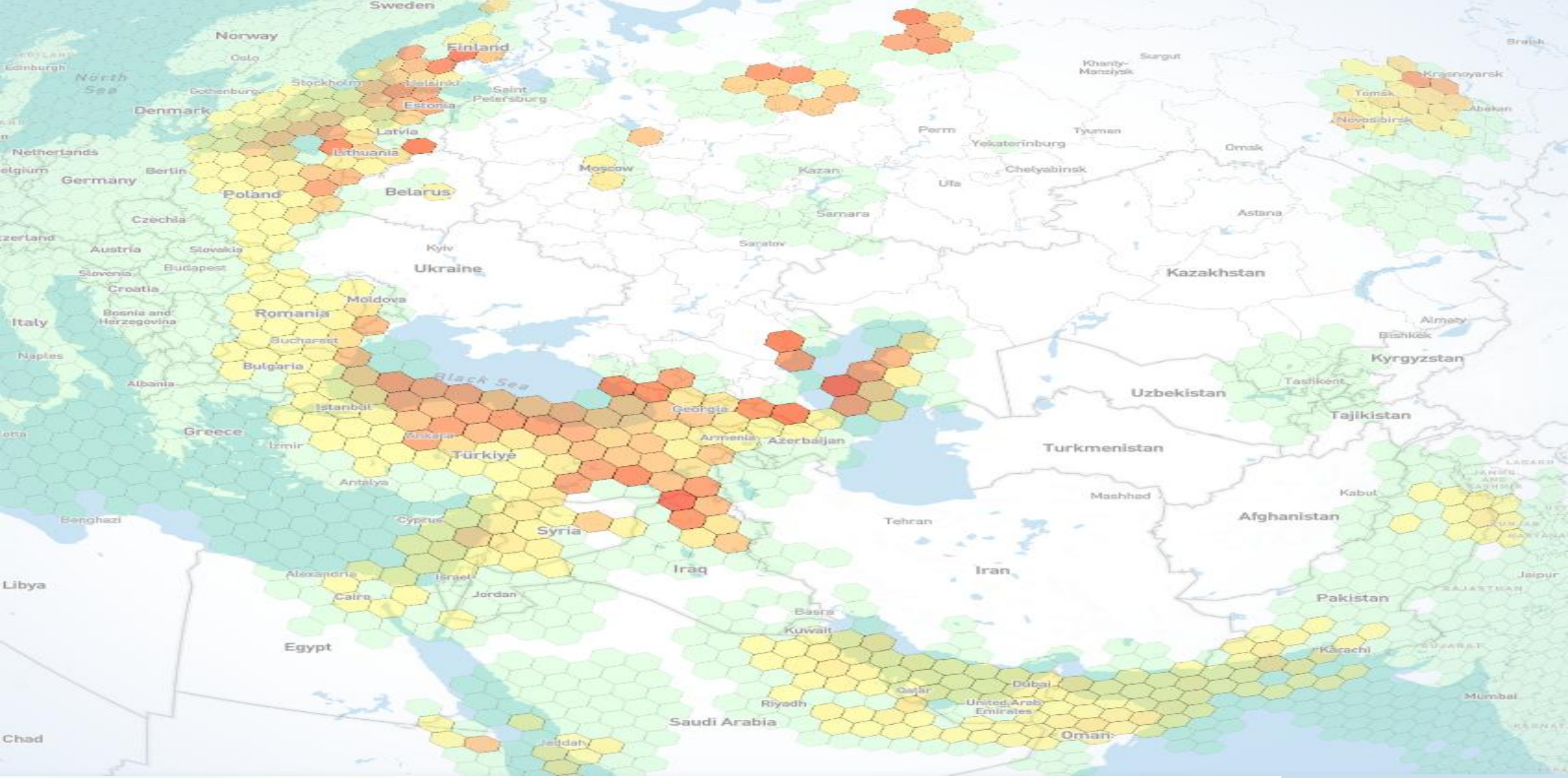
ICAO

GNSS Vulnerability

GNSS signals are susceptible to interference, both intentional and unintentional, which can compromise system reliability and accuracy

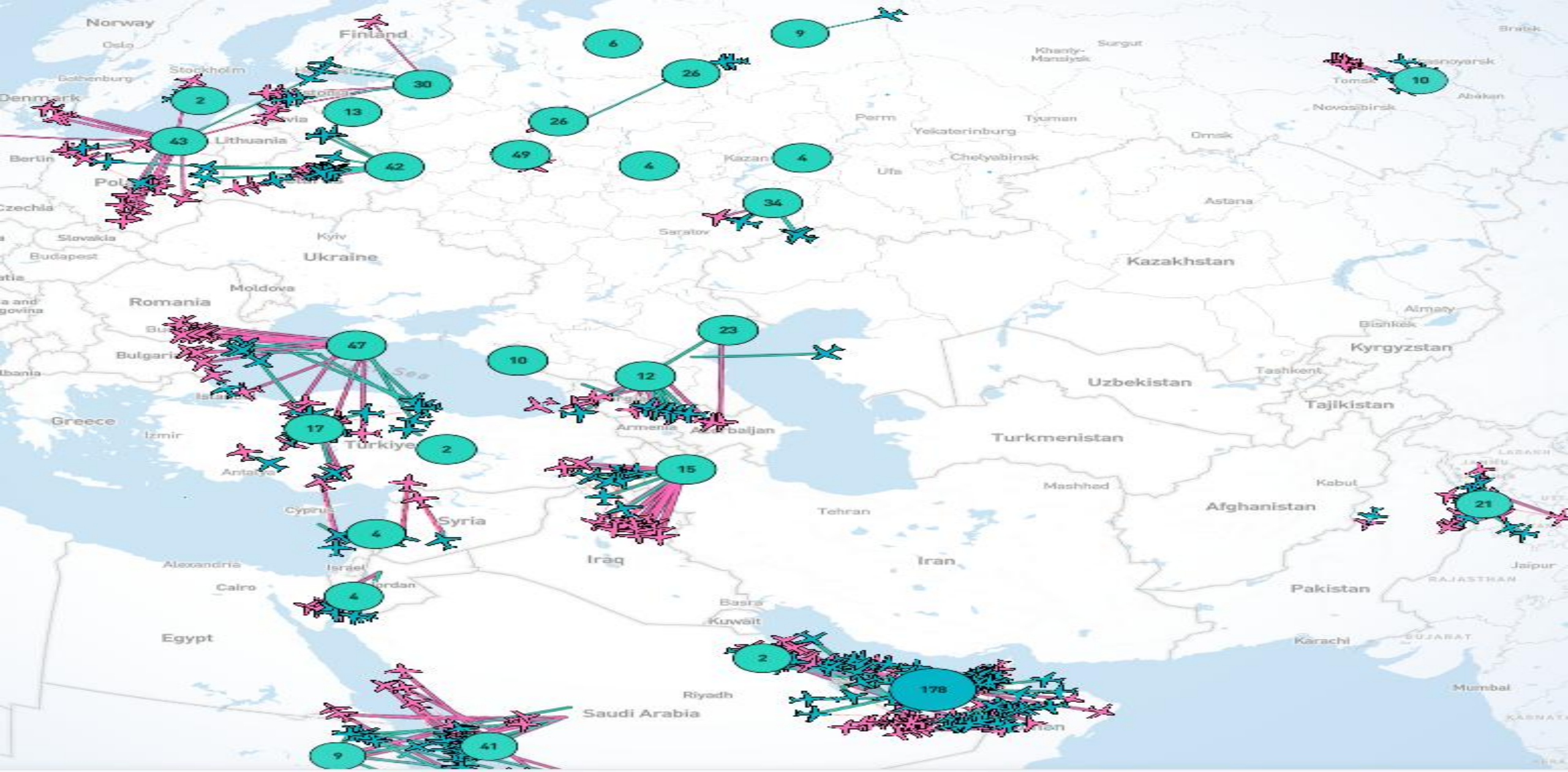
Jamming is an iintentional Radio frequency interference that prevents GNSS receiver from locking onto satellite signals, effectively rendering the GNSS system unusable or degraded for users in the jammed area. UNTERM - jamming

Spoofing is the broadcast of GNSS-like signals that cause avionics to calculate erroneous positions and provide false guidance. This sophisticated form of interference can be particularly dangerous as it may go undetected by the receiver. UNTERM - spoofing



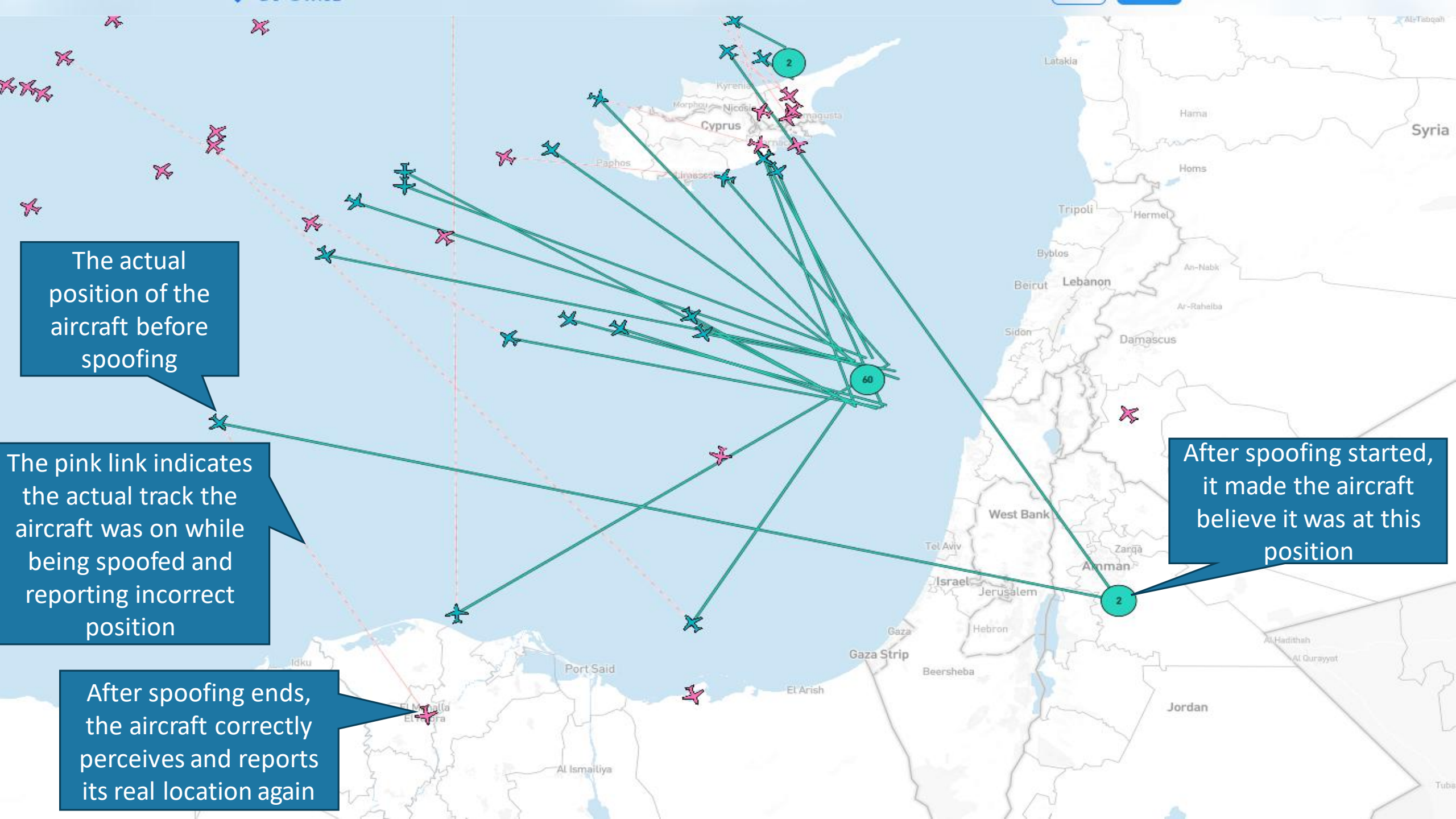
Jamming Map

GPSWISE



Spoofing Map

GPSWISE


The actual position of the aircraft before spoofing
The pink link indicates the actual track the aircraft was on while being spoofed and reporting incorrect position
After spoofing ends, the aircraft correctly perceives and reports its real location again
After spoofing started, it made the aircraft believe it was at this position
Cyprus
Syria
Lebanon
Israel
West Bank
Gaza Strip
Jordan
Latakia
Hama
Homs
Tripoli
Hermel
Byblos
Beirut
Sidon
Damascus
Tel Aviv
Jerusalem
Amman
Zarqa
Hebron
Gaza
Beersheba
Port Said
El Arish
Al Ismailiya
Paphos
Nicosia
Limassol
Larnaca
Kyrenia
2
60
2

Online GNSS Jamming & Spoofing Monitoring Tools

- GPSJAM: GPSJAM GPS/GNSS Interference Map
- Live GPS Spoofing and Jamming Tracker Map: Real-time GPS Spoofing & Jamming Detection | GPSwise
- Flightradar24 GPS jamming map: GPS jamming & interference map | Flightradar24

ICAO 42nd Assembly Resolution

Complete

APPENDIX C

Ensuring the resilience of ICAO CNS/ATM systems and services

the CNS/ATM systems are evolving and so are the associated CNS threats and vulnerabilities;

the occurrences of interferences against satellite-based CNS systems and global navigation satellite
n particular, have significantly increased;

CNS resiliency to interference needs to be addressed at a global level with a holistic approach, ensu
nd coordinated evolution between the infrastructure architecture, improved technological capabilities, c
erational procedures, radio regulatory authorities and civil-military coordination;

ing that resiliency to interference needs to be improved by maximizing the integration of all suitable
ure, space infrastructure and airborne components in a complementary and cooperative manner, to be as
le to cases of satellite-based service disruption or environments where false or deceptive signals are pre

ing that both the aircraft on-board and ground infrastructure complementing the satellite-based CNS s
adapted to include, where appropriate, interference detection, mitigation and reporting functions to supp
of operationally encountered performance anomalies;

that, combined with the use of the appropriate legal framework, such capabilities and measures will allow
uthorities to act upon harmful interferences caused by the illegal operation of transmitters and av
on and the use of such illegal transmitters and the misuse of test and maintenance equipment;

that, with appropriate coordination and application of best practices, military and State authorities can c
ated testing and other interventions using radio equipment as necessary and without causing an undue
iation;

that civil-military coordination should facilitate the sharing of relevant information with airspace users, es
g in the vicinity of a conflict zone; and

dging that loss of crew's situational awareness from malicious origin is classified as a cybersecurity thr
tolerated in civil aviation; and that intentionally sending misleading signals to replace the accurate sig
erious threat to flight safety than the loss of this signal.

mbly:

Encourages States to transition towards optimized, secure CNS systems based on complementary inte
and independent aircraft capabilities, satellite- and ground-based infrastructure which maximize resilier
s to any type of interference;

Encourages standardization bodies and industry to develop appropriate interference detection, mitigati
capabilities for the aircraft on-board, satellite- and ground-based CNS system components, in order to
S resiliency, continuity of operations and prevent any cascading effects from the use of compromised p
time data;

Encourages States to ensure that sufficient terrestrial CNS capabilities remain available to ensu
s and complement aircraft-level integration of position, velocity and time with independent surv
n;

Invites ICAO to develop high-level principles on how to integrate CNS ground, space and on-board s
bilities to obtain more resilient positioning and timing services;

Resolution A42-8, Appendix C

(Updated Resolution A41-8)

ICAO Policy on GNSS Resilience

- Included operative clause on NAV RON *"…. . Encourages States to ensure that*
- ~~*sufficient*~~ ***resilient*** *terrestrial CNS capabilities remain available …."*

- Encouraged standardization bodies and industry to collaborate with ICAO in advancing PNT solutions that align with ICAO initiatives; (*New Operative clause)*

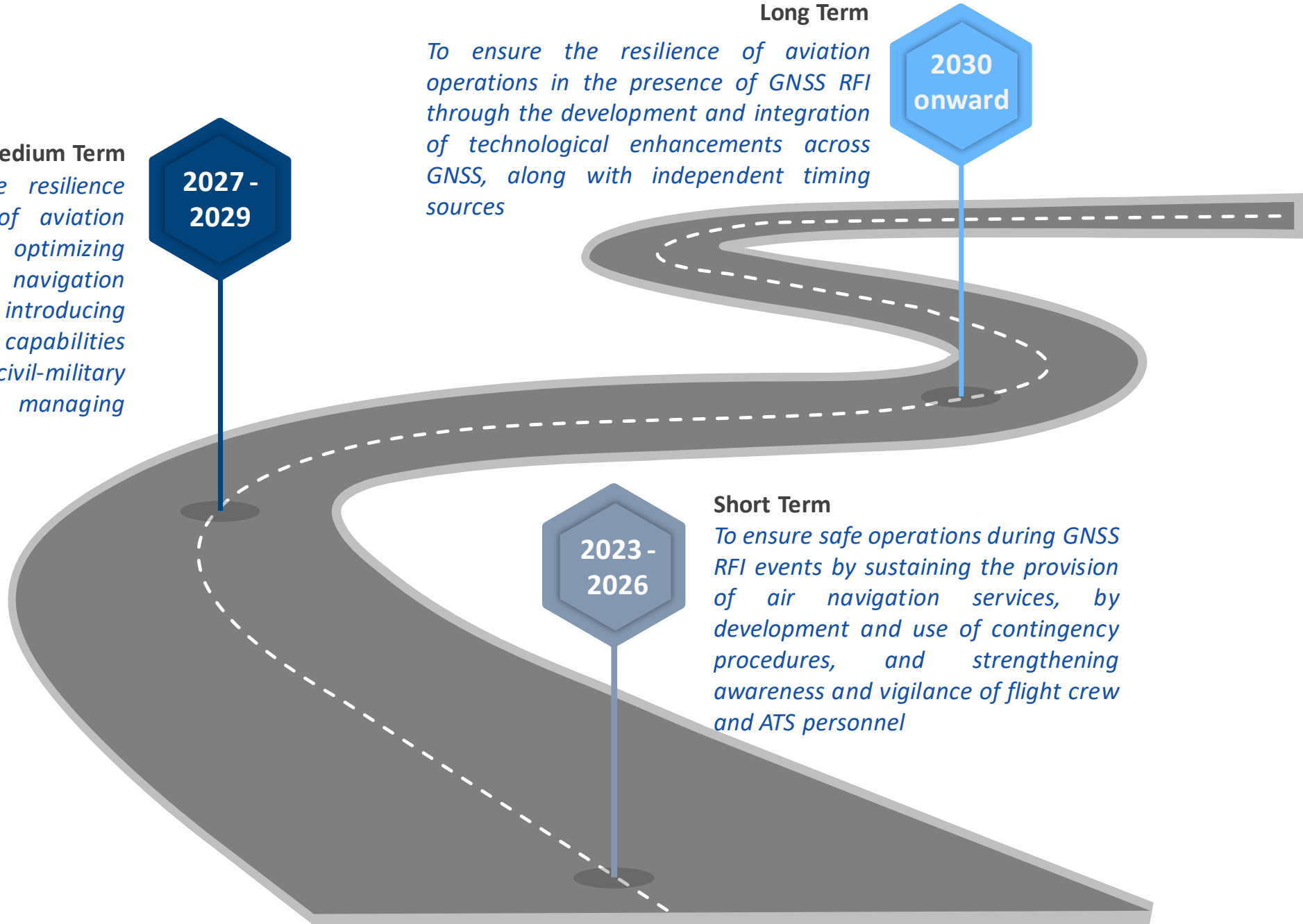
- Updated the operative clause on the requirement for protection from harmful interference "**.** *Urges States to apply necessary measures to avoid the commercialization/ proliferation**, purchase, possession**, and the use of illegal transmitters such as jammers ….:*

- Need for resilient systems and services "… *invites ICAO to establish a comprehensive review framework to enhance the CNS/ATM resilience;*

ICAO GNSS RFI Roadmap

ICAO GNSS RFI Roadmap

ICAO GNSS RFI Roadmap



Long Term

To ensure the resilience of aviation operations in the presence of GNSS RFI through the development and integration of technological enhancements across GNSS, along with independent timing sources

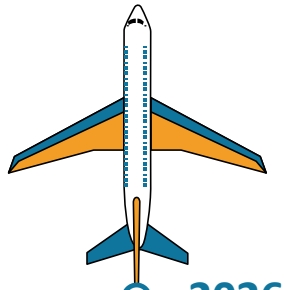
Medium Term

To enhance the resilience and efficiency of aviation operations by optimizing ground radio navigation infrastructure, introducing RFI detection capabilities and improving civil-military coordination in managing GNSS RFI

Short Term

To ensure safe operations during GNSS RFI events by sustaining the provision of air navigation services, by development and use of contingency procedures, and strengthening awareness and vigilance of flight crew and ATS personnel

Short-Term



2026

iPack for the Mitigation of GNSS RFI

To support States in managing GNSS RFI incidents and to ensure the continuous provision of safe and efficient ANS

2026

Online Reporting of GNSS RFI to ITU

Enhance international coordination (between States, ICAO and ITU) for resolution or escalation

2025

GNSS RFI-related NOTAM Codes & Text

Harmonized text and codes to enhance situational awareness and support more efficient NOTAM filtering by operators

2025

Inter-agency UN Collaboration

A joint ICAO-ITU-IMO declaration called upon States to protect GNSS from harmful interference

2023 - 2026

ICAO Workshops & Publications

Conducted regional Workshops and Symposia, & disseminated info on the evolution of RFI (emerging threats, mitigation measures, existing gaps, lessons learned and best practices)

ICAO Outreach

Complete

Plan for 2026

- ICAO SAM Radio Navigation Workshop

2-4 September 2026

- ICAO MID PBN/GNSS Workshop

28-30 September 2026

- Air Navigation World – CNSS 2026

12-15 October 2026

- ICAO EUR/MID Radio Navigation Symposium (6-8 Feb 2024, Antalya, Türkiye)
- ICAO/ACAO Radio Navigation Workshop (24-26 Feb 2025, Rabat, Morocco)
- ICAO APAC Radio Navigation Symposium (7-9 April 2025, New Delhi, India)
- ICAO NACC Radio Navigation Workshop (2-4 September 2025, Mexico City, Mexico)

Global event on GNSS resilience is planned in 2027

ICAO Outreach

Complete

Tel.: +1 514-315-1872 30 April 2024

Ref.: E 3/5-24/54

Subject: Aviation safety concerns regarding interference to the Global Navigation Satellite System (GNSS)

Action required: a) disseminate guidance material; and b) implement recommendations, as applicable

Sir/Madam,

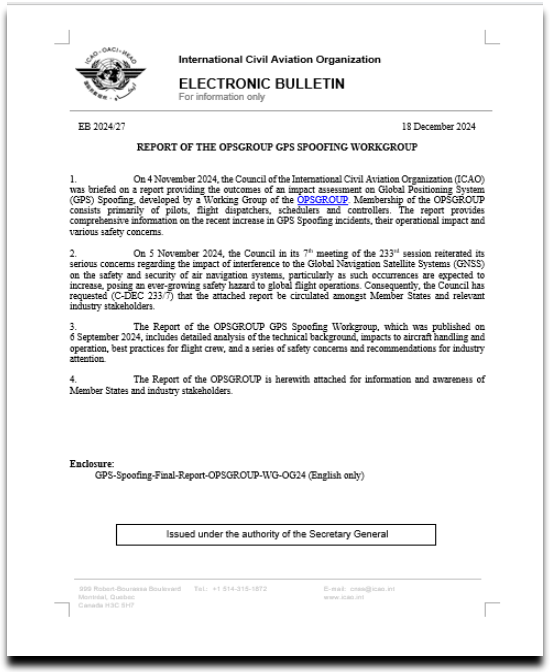
1. I have the honour to bring to your attention the concerning escalation of jamming spoofing activities targeting the global navigation satellite system (GNSS), which have been increasin observed recently in various regions globally. GNSS, as one of the main enablers for performance-ba navigation (PBN), provides navigation guidance for all phases of flight, from enroute through to precis approach. By providing accurate position and timing information, GNSS enables several systems critica the safety of flight.

2. Since 2003, the International Civil Aviation Organization (ICAO) has been activ developing recommendations and guidance concerning GNSS Radio Frequency Interference (RFI). I pertinent to recall ICAO Assembly Resolution A41-8, Appendix C: *Ensuring the resilience of IC CNS/ATM systems*, which serves as the latest ICAO policy on GNSS resilience.

3. To bring attention to the critical issue of GNSS interference, and to foster discussions on management of GNSS vulnerabilities and potential mitigation measures against GNSS RFI, ICAO recer convened the ICAO EUR/MID Radion Navigation Symposium from 6 to 8 February 2024 Antalya, Turkey. One important outcome of this symposium is the attached list of recommendati regarding Stakeholders' continued efforts towards ensuring safe, reliable, and resilient air navigation.

4. I would like to take this opportunity to refer to recent safety-related publications by European Union Aviation Safety Agency (EASA), Safety Information Bulletin No. 2022-02R2 and

ICAO SL on the recommendations from ICAO EUR/MID Radio NAV Symposium, Antalya, 2024



International Civil Aviation Organization

ELECTRONIC BULLETIN

For information only

EB 2024/27 18 December 2024

REPORT OF THE OPSGROUP GPS SPOOFING WORKGROUP

1. On 4 November 2024, the Council of the International Civil Aviation Organization (ICAO) was briefed on a report providing the outcomes of an impact assessment on Global Positioning System (GPS) Spoofing, developed by a Working Group of the OPSGROUP. Membership of the OPSGROUP consists primarily of pilots, flight dispatchers, schedulers and controllers. The report provides comprehensive information on the recent increase in GPS Spoofing incidents, their operational impact and various safety concerns.

2. On 5 November 2024, the Council in its 7th meeting of the 233rd session reiterated its serious concerns regarding the impact of interference to the Global Navigation Satellite Systems (GNSS) on the safety and security of air navigation systems, particularly as such occurrences are expected to increase, posing an ever-growing safety hazard to global flight operations. Consequently, the Council has requested (C-DEC 233/7) that the attached report be circulated amongst Member States and relevant industry stakeholders.

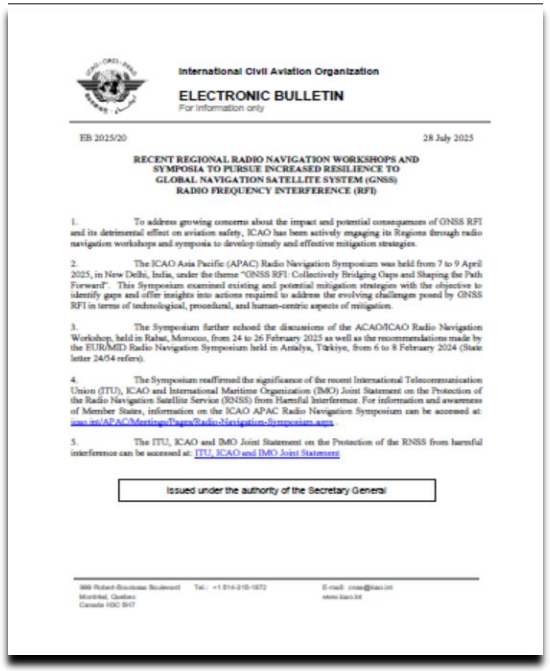
3. The Report of the OPSGROUP GPS Spoofing Workgroup, which was published on 6 September 2024, includes detailed analysis of the technical background, impacts to aircraft handling and operation, best practices for flight crew, and a series of safety concerns and recommendations for industry attention.

4. The Report of the OPSGROUP is herewith attached for information and awareness of Member States and industry stakeholders.

Enclosure:
GPS-Spoofing-Final-Report-OPSGROUP-WG-OG24 (English only)

Issued under the authority of the Secretary General

Dissemination of OPSGroup Report, December 2024



International Civil Aviation Organization

ELECTRONIC BULLETIN

For information only

EB 2025/20 28 July 2025

RECENT REGIONAL RADIO NAVIGATION WORKSHOPS AND SYMPOSIA TO PURSUE INCREASED RESILIENCE TO GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) RADIO FREQUENCY INTERFERENCE (RFI)

1. To address growing concerns about the impact and potential consequences of GNSS RFI and its detrimental effect on aviation safety, ICAO has been actively engaging its Regions through radio navigation workshops and symposia to develop timely and effective mitigation strategies.

2. The ICAO Asia Pacific (APAC) Radio Navigation Symposium was held from 7 to 9 April 2025, in New Delhi, India, under the theme "GNSS RFI: Collectively Bridging Gaps and Shaping the Path Forward". This Symposium examined existing and potential mitigation strategies with the objective to identify gaps and offer insights into actions required to address the evolving challenges posed by GNSS RFI in terms of technological, procedural, and human-centric aspects of mitigation.

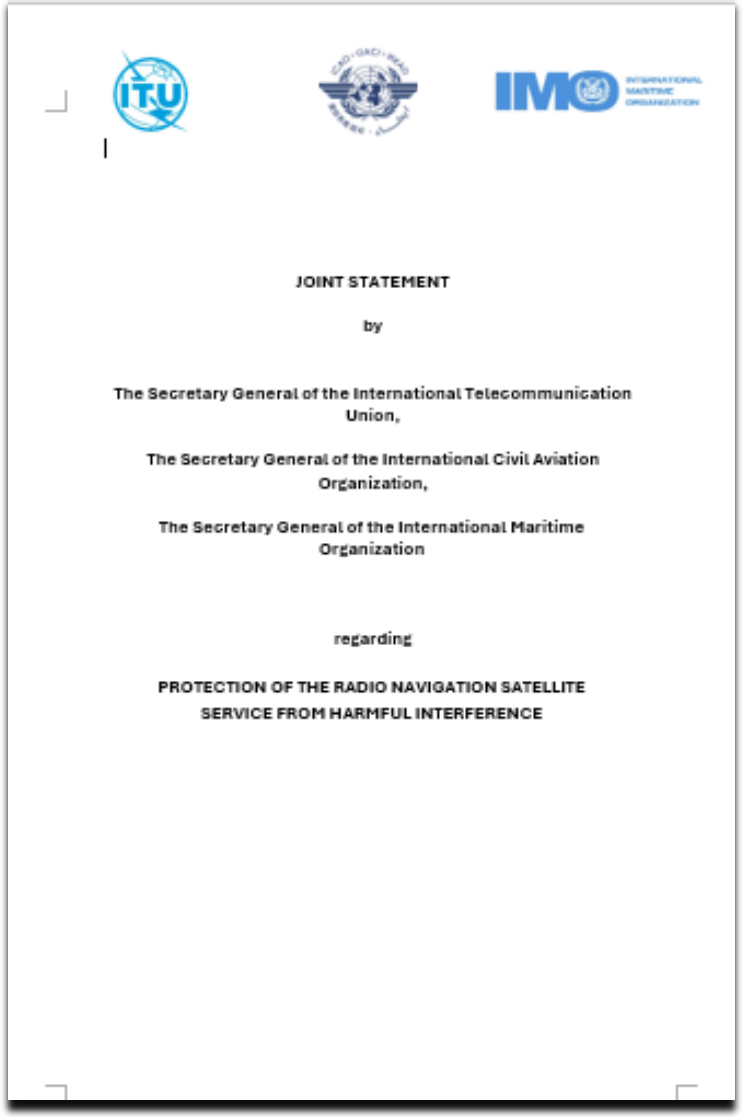
3. The Symposium further echoed the discussions of the ACAO/ICAO Radio Navigation Workshop, held in Rabat, Morocco, from 24 to 26 February 2025 as well as the recommendations made by the EUR/MID Radio Navigation Symposium held in Antalya, Türkiye, from 6 to 8 February 2024 (State letter 24/54 refers).

4. The Symposium reaffirmed the significance of the recent International Telecommunication Union (ITU), ICAO and International Maritime Organization (IMO) Joint Statement on the Protection of the Radio Navigation Satellite Service (RNSS) from Harmful Interference. For information and awareness of Member States, information on the ICAO APAC Radio Navigation Symposium can be accessed at: icao.int/APAC/Meetings/Pages/Radio-Navigation-Symposium.aspx .

5. The ITU, ICAO and IMO Joint Statement on the Protection of the RNSS from harmful interference can be accessed at: ITU, ICAO and IMO Joint Statement

Issued under the authority of the Secretary General

ICAO Electronic Bulletin on recommended actions from ICAO APAC Radio NAV Symposium, New Delhi, July 2025



JOINT STATEMENT

by

The Secretary General of the International Telecommunication Union,

The Secretary General of the International Civil Aviation Organization,

The Secretary General of the International Maritime Organization

regarding

PROTECTION OF THE RADIO NAVIGATION SATELLITE SERVICE FROM HARMFUL INTERFERENCE

Joint Statement by ITU, ICAO, & IMO regarding the protection of Radio Navigation Satellite System (RNSS) from harmful interference

Joint Statement by ITU, ICAO, and IMO

a **Protect RNSS**

protect the RNSS from transmissions that can adversely cause harmful interference degrading, interrupting or misleading signals used for civilian and humanitarian purposes;

b **Reinforce Resilience**

reinforce resilience of the systems which rely on RNSS for navigation, positioning and timing in relation to this type of interference;

c **Retain Infrastructure**

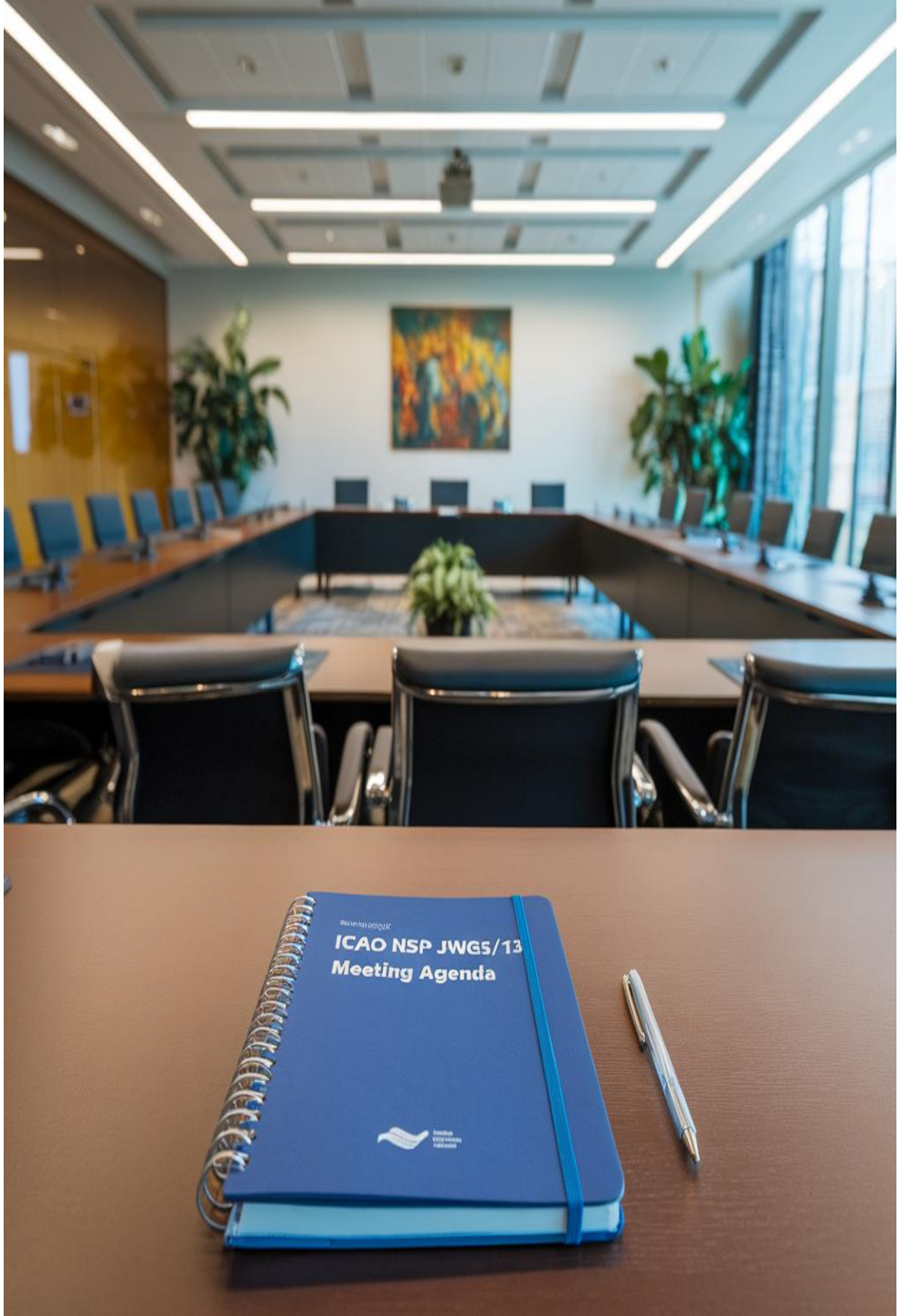
retain sufficient conventional navigation infrastructure for contingency support in case of RNSS outages and misleading signals, and develop mitigation techniques for loss of services;

d **Increase Collaboration**

increase collaboration between radio regulatory, civil aviation, maritime, defense and enforcement authorities; and

e **Report Interference**

report cases of harmful interference affecting RNSS to the appropriate telecommunication, aeronautical and maritime authorities, and to the ITU Radiocommunications Bureau, to enable the monitoring of the situation.



GNSS RFI-related NOTAMs

1) NOTAM QCodes:

- New NOTAM Code for Spoofing (LO) –PANS ABC need to be updated (2029)
- Associate jamming code (LF) with GNSS

2) Recommended Item E Text for Jamming:
GNSS MAY BE UNRELIABLE WITHIN …

3) Recommended item E text for GNSS Spoofing:
GNSS MAY BE MISLEADING WITHIN …

Update of relevant ICAO provisions is currently in progress

Reporting GNSS RFI to ITU

Complete

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Space Services Department

YOU ARE HERE ITU > HOME > ITU-R > SPACE SERVICES > SIRRS

SHARE

SIRRS

Satellite Interference Reporting and Resolution System

- As per Resolutin 55 (Rev. WRC-23) Reports of Harmful Interference affecting Space Services are to be submitted by SIRRS -

This online application has been developed by the Radiocommunication Bureau in response to Resolution 186 of ITU Plenipotentiary Conference 2014 with the aim to facilitate Administrations and space stakeholders to report a case of harmful interference affecting space services, to request assistance from the BR, to be informed in case a radio station under your jurisdiction is causing harmful interference to space services of other Administrations, and to exchange all necessary information among the concened parties involved in the case.

In order to be able to use the system, a user account must be open as indicated below:

Reporting

(ITU Registered Users)

LOGIN I forgot my password...

References:

Short Video to Use SIRRS

In-Progress

Implementation Package (iPack) for GNSS RFI Mitigation

Raise Awareness

Educate stakeholders on effects of GNSS RFI on CNS/ATM systems, aviation operations, and GNSS-based services through comprehensive training materials and workshops

Risk Mitigation Framework

Provide methodologies for threat monitoring, risk assessment, and implementation of mitigation measures tailored to specific operational environments

Expert Support

Deliver hands-on guidance to develop essential policies, procedures, and training requirements for managing GNSS RFI events

Infrastructure Assessment

Assist States in assessing conventional navigation infrastructure for a rationalized approach to maintaining necessary backup capabilities

Short-Term

GNSS Manual Update (Doc 9849)

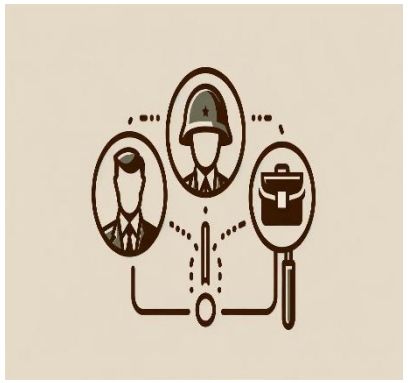
The forthcoming update to the GNSS Manual will include the following enhancements:

- guidance on monitoring and mitigation techniques
- effects of spoofing on navigation and timing capabilities
- possible effects of GNSS RFI on other aircraft capabilities
- alternative and complimentary conventional navigation capabilities
- Revising terminology and reorganizing content to better address current, global impacts and a wider audience of stakeholders affected by GNSS RFI
- Updating and correcting content to reflect the current threat environment

- Manual updates are expected to be completed by November 2026.

In-Progress

Resilient Navigation Operational Network (NAV RON)



New Guidance for Civil-Military coordination

Update PBN Manual to support PBN operations in case of GNSS RFI

Onboard RFI detection capability

Medium-Term

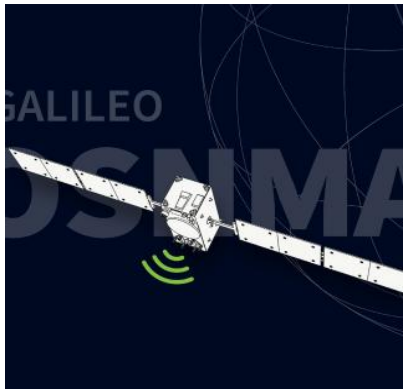
2027-2029

Objective

To enhance the resilience and efficiency of aviation operations by optimizing ground radio navigation infrastructure, introducing RFI detection capabilities and improving civil-military coordination in managing GNSS RFI

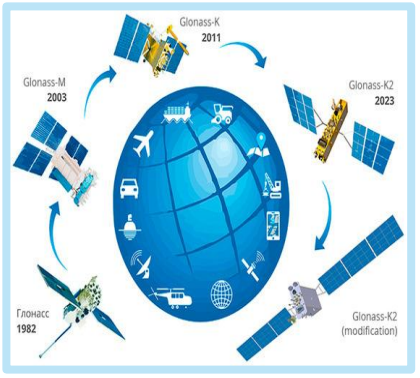
In-Progress

Complementary Positioning, Navigation and Timing (C-PNT)



GNSS Signals Authentication for Core Constellations (Galileo OSNMA)

GNSS Signals Authentication for augmentation systems (SBAS Authentication)



Dual Frequency Multiple Constellation (DFMC GNSS)

Long-Term

2030 onward

Objective

To ensure the resilience of air navigation in the presence of GNSS RFI through the development and integration of technological enhancements across GNSS, along with independent timing sources.

Nos vemos pronto en Kotor!