GNSS INTERFERENCE IN CIVIL AVIATION

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SUMMARY

Summary and proposed actions

The GNSS interference threat is active and evolving. It is a worldwide problem addressed at both industry and State level, and it was a main agenda item of the 42nd ICAO Assembly, with actions assigned to the relevant expert panels. The evolution of regulations, standards and recommended practices has already begun, to address short-term challenges and develop long-term solutions.

ACTION PROPOSED TO THE MEETING

1. Note the evolution of GNSS interference and its reported operational effects.
2. Support the implementation of Recommendation 2.2/2 of the 14th Air Navigation Conference.
3. Endorse the actions arising from the 42nd Assembly on resilience and operational continuity.
4. Promote the protection of aeronautical spectrum within the preparatory framework for WRC-27.

STRUCTURE

Contents of the presentation

01	**Background**	ITU definitions, harmful interference, jamming and spoofing, types of RFI and signal vulnerability
02	**Observed problem**	Evolution near conflict zones, reported events, flight deck effects and possible effects (EASA SIB)
03	**ICAO position**	Recommendation 2.2/2 of the 14th Air Navigation Conference and outcomes of the 42nd Assembly
04	**ITU framework**	Radio Regulations and WRC, interference reported to RNSS, key provisions and Resolution 676 (WRC-23)
05	**Mitigation**	Joint action plan, duty to report, operational awareness, RON and MON networks, resilient navigation and standardization
06	**Conclusions**	State of the threat, regulatory evolution and ongoing work of the Navigation Systems Panel

ITU definition of interference

> *"The effect of unwanted energy due to one or a combination of emissions, radiations or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation or loss of information which could be extracted in the absence of such unwanted energy."*

ITU Radio Regulations, Vol. 1, Art. 1, Sec. VII

Intentional interference

Generally understood as interference whose purpose is to disrupt reception of the signal. Most effects of interferers on air navigation services are collateral and may stem from conflict zones, sensitive areas or personal privacy devices.

The ITU classifies interference as permissible, accepted or harmful. Source: ICAO NSP/5 IP/26, Montreal, 6-15 November 2018.

Harmful interference: jamming and spoofing

> Harmful interference: “interference which endangers the functioning of a radionavigation service or of other safety services, or seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with the Radio Regulations.”

The two main proposed types of harmful interference threat are jamming and spoofing.

JAMMING

Emissions that do not mimic GNSS signals but interfere with the receiver's ability to acquire and track those signals.

- Obvious effect: loss or degradation of service
- A single emitter can affect a wide area
- Includes low-power personal privacy devices (PPD)

SPOOFING

Emissions of GNSS-like signals that may be acquired and tracked alongside, or instead of, the intended signals.

- Produces an apparently valid but erroneous navigation solution
- May induce incorrect position, velocity or time
- Its effects may appear after leaving the affected area

Types of interference affecting aviation services

The classification of the source determines the applicable mitigation strategy.

UNINTENTIONAL

- Equipment failures, e.g. a faulty filter emitting harmonics
- Non-compliant installations, such as poorly installed GNSS re-radiators
- Spurious emissions and radio operating errors
- Ionospheric and scintillation effects, with similar symptoms

INTENTIONAL

- Targeted at aviation or with collateral effect on it
- Military or State-authorized activities
- Personal privacy devices (PPD)
- Interference intended to disrupt or falsify GNSS reception

The vulnerability of the constellations and the difficulty of eliminating certain RFI sources call for a combination of outreach, law enforcement against unauthorized emitters, and coordination of interference-generating tests.

Why the GNSS signal is vulnerable

The GNSS signal power received at the surface is below thermal noise. A nearby low-power emitter can raise the noise density enough to prevent receiver lock over wide areas, making spectrum protection a central issue for WRC-27.

L1	**1,575.42 MHz**	GPS L1 C/A and L1C, Galileo E1. Primary civil aviation band and the most exposed to low-cost emitters.
L5 / E5a	**1,176.45 MHz**	Second protected civil frequency (ARNS). Basis for dual-frequency, multi-constellation operations.
L2	**1,227.60 MHz**	Not protected for ARNS; its use in civil aviation is limited by spectrum considerations.

Note. The vulnerability is intrinsic to the link budget and cannot be eliminated; it is managed through spectrum protection, receiver robustness and the availability of alternative PNT sources.

Evolution of interference near conflict zones

Geographic concentration

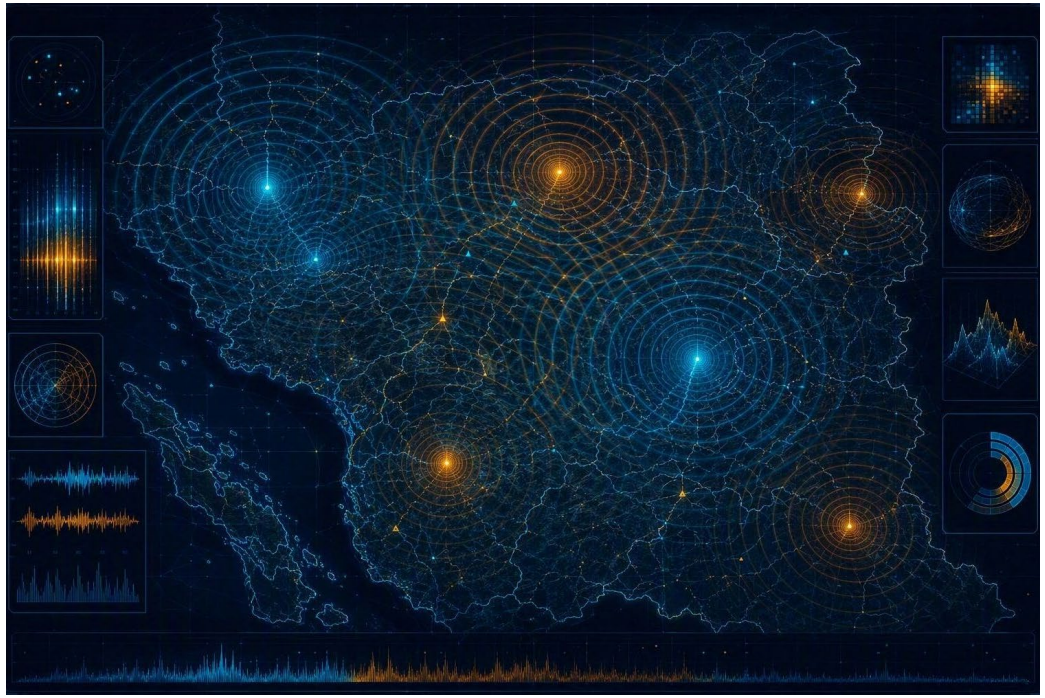
Events are concentrated near conflict zones and sensitive areas, with a steadily expanding reach.

Wide-area effect

A single emitter can simultaneously affect numerous aircraft en route and on approach, beyond the border of the emitting State.

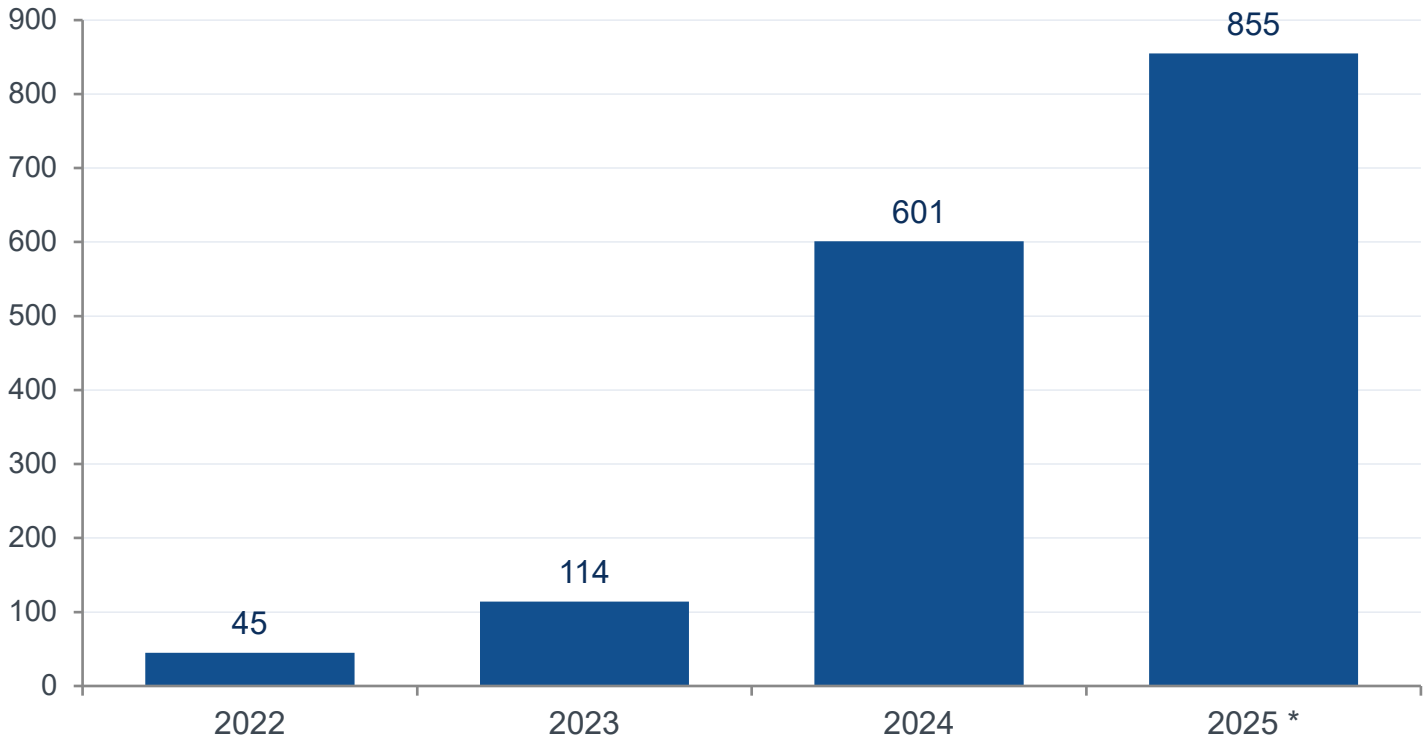
Tracking with operational data

Jamming and spoofing areas can be identified and tracked through fleet operational data dashboards.



> Emissions affecting aviation are largely collateral: their origin is not necessarily aeronautical, but their effects certainly are.

Interference events reported to the manufacturer



Source: GNSS RFI event data reported to the manufacturer [identify manufacturer / database], complemented with IATA FDX data. 2025 figure: projection.

Exposure to GNSS interference is not decreasing

Projection based on IATA Flight Data eXchange (FDX) data:
2024: 56 flights affected per 1,000
2025: 59 flights affected per 1,000

** 2025 figure is a projection.*

The sustained growth of reported events between 2022 and 2025 confirms a persistent and expanding threat, not a temporary phenomenon tied to a single scenario.

Effects observed on the flight deck

Most frequent effect categories in events reported by flight crews:

Alignment

Problems aligning the inertial reference systems.

GPS lock

Inability of the GPS receiver to lock on.

Temporary GPS loss

Transient interruption of the position solution.

Guidance / map shift

Inconsistent guidance and shift of the displayed position.

TAWS

Terrain awareness warning system alerts.

Time jump

Discontinuity in the time reference of onboard systems.

Main risk: that the crew treats valid flight deck alerts as spurious, and therefore fails to apply emergency procedures in the event of a genuine alert.

Possible effects of GNSS interference

Surveillance	Loss or misleading information in surveillance functions: corrupted ADS-B, TAWS, TCAS and ACAS.
Display systems	Loss or misleading information in synthetic vision systems (SVS), weather datalink, predictive windshear and other surface functions.
Flight guidance	Inconsistent guidance with possible route divergence, uncommanded turns and deviations from ATC clearances or instructions, with risk of airspace penetration, loss of separation or insufficient terrain clearance.
Position and velocity	Inconsistent or misleading position, GNSS altitude and ground or wind speed on the navigation display or the EFB.
Delayed effects	Inconsistent or misleading GNSS position or altitude later in the flight, after leaving the affected area, for example during approach.
Time systems	Loss or misleading information in time- or date-dependent systems: clock, fuel computation, FMS and rejection of CPDLC messages.

Source: EASA Safety Information Bulletin SIB 2022-02R3, 5 July 2024.

Recommendation 2.2/2 — actions for States

14th Air Navigation Conference — Addressing GNSS interference and contingency planning. That States:

Effective mitigation	Ensure implementation of effective GNSS RFI mitigation measures, based on those developed by ICAO and industry, including the need to maintain a sufficient network of conventional navigation aids to ensure safety and sufficient airspace capacity during interference periods.
Regional reporting	Develop, through the regional planning and implementation groups, regional reporting mechanisms that raise operational awareness of the affected geographic areas, to the extent possible, in line with the GNSS Manual (Doc 9849).
Resilience of onboard systems	Work with industry to identify means of making aircraft systems more resilient to RFI events and to provide guidance on detecting jamming or spoofing and maintaining safe, efficient operations in the presence of GNSS anomalies.
Minimum equipment lists	Review aircraft minimum equipment lists to ensure compatibility with the minimum operational networks implemented by States.

Recommendation 2.2/2 — actions for ICAO

14th Air Navigation Conference — Addressing GNSS interference and contingency planning. That ICAO:

Continuous assessment	Continue assessing the impact of GNSS interference on the safety and continuity of civil aviation operations, and define appropriate mitigation measures, reminding States of their obligations.
Standardized implementation package	Develop a standardized implementation package to assist and guide States in applying effective RFI mitigation measures, including optimization and rationalization of conventional navigation aids according to local conditions, to ensure continuity of air navigation services.
Information sharing and civil-military coordination	Develop guidance on sharing information on GNSS interference and on civil-military coordination regarding harmful interference originated or detected by military authorities.
Harmonized minimum equipment	Develop recommendations for globally harmonized aircraft minimum equipment lists, so that available navigation infrastructure can be used by airspace users in line with the air traffic services available.

42nd Assembly — WP/108: resilience and operational continuity

"Mitigating GNSS vulnerabilities in aviation: strengthening resilience and operational continuity" — presented by ICCAIA, CANSO, IFALPA and IBAC. The paper examines current GNSS vulnerabilities, their implications, possible mitigations and a set of recommendations.

THE ASSEMBLY IS INVITED TO:

a	Urge Member States to develop interference detection systems and supporting means that provide operators with timely, operationally relevant information.
b	Task ICAO to work with States and industry to develop standards and guidance material delivering that information to operators.
c	Task ICAO to accelerate work to define and standardize complementary PNT (C-PNT) systems going beyond the capabilities of current conventional navigation aids.
d	Task ICAO to accelerate development of signal authentication standards for GNSS core constellations and their augmentations.
e	Task ICAO to develop, with States, standards bodies (RTCA, EUROCAE, IEEE and others) and industry, performance requirements and standards for time synchronization across all flight domains, with guidance on the required levels of accuracy, integrity and continuity.
f	Urge States to support industry in developing and deploying technologies making GNSS receivers and aircraft more resilient to jamming and spoofing.

Outcomes of the 42nd Assembly

ASSEMBLY CONCLUSIONS

- The Assembly expressed broad support for this subject.
- It recognized that GNSS interference and unresolved radio spectrum issues, such as potential interference with radio altimeters, significantly impact aviation safety, security and efficiency.
- It reiterated the vital and growing importance of radio spectrum and called for active State participation to ensure resilient CNS capabilities remain available.
- The Technical Commission recognized the urgency of the subject and agreed to bring the content of A42-WP/329 and A42-WP/348 to the attention of the relevant expert panels.

MAIN ACTIONS AND OUTCOMES OF THE 42nd ASSEMBLY

- Request the Council to periodically assess the evolution of RFI on aeronautical safety systems.
- Strengthen support for ICAO spectrum policy by amending Resolution A41-7.
- Reiterate the responsibility of States to keep safety as the highest priority and to ensure interference-free operation of aeronautical safety systems.
- Recommend to the expert panels strategies enabling faster, safer innovation, certification and deployment of avionics systems.
- Request ICAO to continue organizing interactive workshops with particular focus on protecting aeronautical safety services.

Overall industry approach to GNSS interference

Detection and reporting	Interference detection systems and regional reporting mechanisms providing operators with timely, operationally relevant information on affected areas.
User segment resilience	More robust receivers and aircraft: controlled reception pattern antennas (CRPA), adaptive processing, dual frequency and multi-constellation, and consistency checks against spoofing.
Signal authentication	Authentication standards for core constellations and their augmentations, enabling the receiver to distinguish legitimate from spoofed signals.
Complementary PNT and minimum network	Complementary PNT (C-PNT) systems beyond conventional aids, together with a minimum operational network of ground aids ensuring service continuity.

The approach combines State action on spectrum with industry development of more resilient onboard systems. Neither path alone is sufficient.

The Radio Regulations and the World Radiocommunication Conferences

The ITU is the United Nations specialized agency responsible for standardizing and regulating international radiocommunications. Its Radio Regulations (RR) are an international treaty binding on its 194 Member States.

Purpose of the treaty	Facilitate equitable access to and rational use of the spectrum and the geostationary orbit; ensure the availability of and protection from harmful interference for distress and safety frequencies; and assist in preventing and resolving interference cases.
Spectrum management	The highest level of spectrum management rests with the World Radiocommunication Conferences (WRC), held every four years, which maintain the Table of Frequency Allocations.
Consequence for aviation	Aeronautical frequency managers must build and defend an aviation position: since 1906 the WRCs have accommodated all wireless technologies and aviation is only one of many spectrum users.

WRC decisions relevant to aviation: 1947, VHF/UHF allocations to ARNS and AM(R)S; 1963, first allocations to satellite services; 2023, allocations for satellite VHF and broadband HF; 2027, maintaining interference-free operation of radio altimeters.

Harmful interference to RNSS reported to the ITU

Protected radionavigation-satellite service (RNSS) bands: 1 164 – 1 215 MHz and 1 559 – 1 610 MHz (RR Article 15)

1) UNAUTHORIZED EMITTERS

- Use of transmitting devices (jammers) without authorization.
- The risk to the safety and regularity of flights is spread worldwide.
- It is not limited to areas near armed conflicts.

2) MILITARY ACTIVITY

- Military exercises or operations near conflict zones.
- Affects the safety and regularity of flights, maritime activity and the time synchronization of telecommunication networks.
- The effects extend beyond the conflict zone.

127,610

flights affected worldwide detected via ADS-B between 17.10.2022 and 19.06.2023

5.25 ×

increase in reports received by the ITU in 2024 compared with the same period in 2023

22 / 4

affected administrations and satellite systems involved: GPS, Galileo, GLONASS and BeiDou

Main regions reported to the ITU: Middle East, north-eastern Europe (Baltic Sea), Black Sea region, Korean Peninsula and central Africa. Sources: ITU Member States, UN WFP, EUROCONTROL, IATA, ICAO and gpsjam.org.

Key regulatory provisions

Constitution, Art. 45	All stations, whatever their purpose, must be established and operated so as not to cause harmful interference to the radiocommunication services or communications of other Member States or of recognized or duly authorized operating agencies.
Constitution, Art. 47	Member States undertake to take the necessary steps to prevent the transmission or circulation of false or deceptive distress, urgency, safety or identification signals, and to collaborate in locating and identifying stations under their jurisdiction transmitting them.
RR No. 15.1	All stations are forbidden to carry out unnecessary transmissions, to transmit superfluous, false or deceptive signals, or to transmit signals without identification.
RR No. 15.28	Recognizing that transmissions on distress and safety frequencies and on those used for the safety and regularity of flights require absolute international protection, and that the elimination of harmful interference to such transmissions is imperative, administrations undertake to act immediately when any such interference is brought to their attention.

These provisions legally underpin RNSS protection: the obligation is one of result for the State authorizing the emission, and of immediate action for the State receiving the report.

Resolution 676 (WRC-23) and reporting through SIRRS

MAIN CALLS OF THE RESOLUTION

- Apply the measures needed to prevent the proliferation, circulation and operation of unauthorized emitters causing or likely to cause harmful interference to RNSS systems.
- Take action to prevent and mitigate harmful interference to RNSS, without prejudice to administrations' right to deny RNSS access on security or defence grounds.
- Foster cooperation among aeronautical, maritime and security authorities as well as spectrum regulators, to address interference risks arising from those authorities' activities (§ 2.2).
- Report cases of harmful interference to RNSS to the Radiocommunication Bureau, in accordance with Article 15.

HOW AND WHERE TO REPORT

- SIRRS online application of the ITU Radiocommunication Bureau (satellite interference reporting and resolution).
- RR No. 15.41: communication for information purposes.
- RR Nos. 13.2 and 15.42: request for assistance from the Bureau.
- Escalation to the Radio Regulations Board and, ultimately, to the WRC.
- Dispute settlement: Art. 56 of the Constitution, diplomatic channels, bilateral agreements or arbitration.

Resolution 676 (WRC-23) was developed by aviation experts with the support of ICAO expert panels and refers expressly to Assembly Resolution A41-8.

Joint action plan on GNSS RFI and mitigation layers

FOUR WORKSTREAMS

- Human factor: controllers, pilots and phraseology.
- Procedures: contingency and interference monitoring.
- Aircraft capabilities.
- Navigation infrastructure.
- Short-, medium- and long-term actions, aligned with the ICAO implementation package (iPack).

Short term

Operational measures to keep airspace safe and open.

Radio regulation

Preventive and reactive action before spectrum bodies.

Short-term avionics and ATM

Voluntary improvements based on existing standards and product updates.

Long-term avionics and ATM

New, more robust standards: complementary PNT (C-PNT).

The classification of the RFI source determines the applicable strategy: sources that are hard to eliminate force us to live with the interference through procedures and onboard capabilities.

The “duty to report” and technical evidence

Paper WP/63 of the 14th Air Navigation Conference refers to Article 15 of the Radio Regulations and to the use of the formal reporting procedure.

What is seen on the ground is not what is seen in the air	Propagation at altitude differs from that observed at the surface: the absence of effects on the ground does not rule out significant degradation en route or on approach.
ADS-B is not a radio measurement	ADS-B makes the impact on the aircraft visible but is not a measurement of the interfering signal. Spectrum measurements are required, ideally with geolocation of the source.
Develop airborne measurement capability	Flight inspection, other aerial work or unmanned aircraft, especially against persistent sources operating continuously.
Indisputable and impartial evidence	Formal reporting requires solid technical evidence. If the neighbouring State does not answer the bilateral letter, the case is escalated to the ITU Radiocommunication Bureau.
Coordination among cooperating States	Develop procedures for counter-drone systems (C-UAS), military exercises and interference-generating tests.

Coordinating RFI tests, protecting the spectrum and enforcing the law against unauthorized jammers are preventive measures that precede any formal report.

Operational awareness: EFB and RFI downlink

"GPS WEATHER" ON THE EFB

- Already implemented by some operators in commercial electronic charting products.
- The crew can deselect GPS before entering a degraded GNSS environment and reactivate it upon leaving the known RFI area.
- Ongoing debate: inhibiting the EGPWS function only in the case of spoofing.

RFI STATUS DOWNLINK

- The ADS-B PIC and other data detect RFI and report it to the ground.
- Ground stations process the PICs and integrate the RFI status over a given area.
- The ATSEP or supervisor coordinates with operations and determines the applicable mitigation measures.

Concept of operations use cases (agreed ICAO NSP work item): jamming awareness · spoofing awareness · persistent lock awareness · maintaining the RNP approach · RFI event coordination

Estimate of aircraft that may require ATC vectoring assistance

- If the aircraft has DME/DME (flight plan) and DME coverage is good: acceptable.
- If it has an inertial system and drift time is short: acceptable.
- If it is "GPS only" for PBN: not acceptable. If the number of unacceptable aircraft exceeds a threshold, reducing sector capacity should be considered.

Short-term measures: resilient network (RON) and minimum network (MON)

Monitoring and reporting	Resilient operational network (RON)	Minimum operational network (MON)
• Move towards real-time monitoring of GNSS RFI. • Improve reporting and operational procedures, in particular those for terrain proximity. • Safety collaboration between service providers and operators (ANConf/14 WP/61).	• DME/DME-based SIDs, STARs and en-route wherever possible. • Ensure ILS availability and that it can be intercepted without GPS, with waypoints for the IAF and the missed approach point. • Ensure the operator knows the contingency services and that the aircraft is equipped to use them.	• VOR/DME for users not equipped with DME/DME, allowing a safe landing. • Ensure CNS/ATM infrastructure is robust against a compromised GNSS time reference.

The aim of these measures is to keep airspace safe and open: preserving operational capacity during RFI events rather than merely restricting traffic.

Complementary resilient navigation (Resolution A42-8, Appendix C)

An interoperable “all-sensor” integrity is required: beyond multi-sensor, cross-checking between sensors for anomaly detection, robust propagation of position and time to all systems including ADS-B, and resilient time synchronization.

DFMC GNSS	Dual frequency and multi-constellation, with SBAS augmentation and advanced ARAIM.
Inertial systems	Inertial navigation integrated with GNSS, with standardization work already under way.
Multi-DME navigation	Evolution from DME/DME to multi-DME, as an effort complementary to DFMC.
VOR/DME backup	Backup functions for less capable aircraft, with an evolution path still to be defined.
Flight management system	Integrated position and time management function: figure of merit, protection level and radio health status, with data from other sensors (speed, heading, altitude, motion models).

The same principles can be applied to position integration in surveillance, comparing ADS-B with secondary radar and multilateration positions.

Aviation standardization roadmap and DME evolution

DFMC SBAS AIRBORNE EQUIPMENT · ED-259B / DO-401A

- Enhanced robustness against jamming and spoofing, including recovery capability.
- RFI indicator in the L1/E1 and L5/E5a bands.
- Spoofing indicator, still under development.
- Clock function supporting time synchronization for authentication services.
- Galileo Open Service Navigation Message Authentication (OSNMA).
- Greater navigation capability: DFMC with SBAS and advanced RAIM; work started on controlled reception pattern antennas (CRPA) and on integrating DFMC GNSS with inertial systems.

DME NAVIGATION

- Available on more than 90% of commercial flights; supports RNAV 1 and possibly RNP 1.
- Current transponders exceed the specification and typically achieve an integrity of 1×10^{-7}/h.
- Evolution towards multi-DME, with better accuracy and integrity; RNP 0.3 feasible, possibly with inertial integration.
- Enhanced DME (eDME) in demonstration; LDACS-NAV and Mode N less mature.

Schedule: ED-57A published in August 2026; new editions of DO-189/ED-54 and of the MASPS and MOPS expected in the fourth quarter of 2027. Updating the standards is necessary to exploit the real performance of DME.

Conclusions

- The GNSS interference threat is active and evolving.
- It is a worldwide problem, addressed at both industry and State level.
- It was a main agenda item of the 42nd ICAO Assembly, with actions assigned to the relevant expert panels.
- The evolution of regulations, standards and recommended practices has begun, to address short-term challenges and develop long-term solutions:
  - The SARPs for Galileo Open Service NMA have been validated by ICAO NSP/8.
  - Two new NSP work items have been approved to develop standards and recommendations on assured time synchronization, resilient operational network and DME-based PBN.
- RFI persists in areas with no evident link to any conflict; experience shows that States act once they suffer the events, and today no one can claim they were not warned.
- Even occasional events carry a significant cost: prevention is better. Improvements, even simple ones, take time to deploy, so service providers must be prepared for a dynamically evolving situation.

Sources: ITU Radio Regulations; ICAO NSP/5 IP/26 (2018); GNSS Manual (Doc 9849); Recommendation 2.2/2 of the 14th Air Navigation Conference; A42-WP/108, A42-WP/329 and A42-WP/348; EASA SIB 2022-02R3 (5 July 2024); manufacturer-reported event data and IATA Flight Data eXchange (FDX); ITU Constitution and Radio Regulations (CS Art. 45 and 47; RR 15.1, 15.28, 13.2, 15.41 and 15.42); Resolution 676 (WRC-23) and the Bureau's SIRRS application; Assembly Resolution 42-8C; ANConf/14 WP/61 and WP/63; ED-259B/DO-401A and ED-57A (EUROCAE WG-62 / RTCA SC-159); presentations to the ICAO Radio Navigation Workshop, Lima, 2-4 September 2026.

Recommendations for the NAM/CAR Region

1. Regional reporting mechanism	A common regional mechanism for reporting GNSS RFI events in line with Doc 9849, with harmonized format, thresholds and deadlines and periodic consolidation of the information.
2. Formal reporting to the ITU	An aeronautical spectrum focal point in each State, systematic recording in SIRRS under Article 15 and Resolution 676 (WRC-23), and capability to measure and geolocate the source.
3. Resilient network and minimum network	Define the RON and MON before rationalizing navigation aids: DME/DME on SIDs, STARs and en-route; ILS interceptable without GPS; VOR/DME for less equipped users; infrastructure robust against a compromised time reference.
4. Civil-military coordination and enforcement	Procedures agreed with military and security authorities for exercises, tests and counter-drone systems, and regulator action against unauthorized jammers and personal privacy devices.
5. Contingency, training and equipment	Update contingency procedures and ATC phraseology, train controllers and flight crews on jamming and spoofing, and review minimum equipment lists.

Proposal to NACC/WG/11: adopt these five lines as a regional work plan, with a focal point per State and a progress report at the next meeting.