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Agenda Item 31: Aviation Safety and Air Navigation Standardization

IMPROVING COMMUNICATION NAVIGATION AND SURVEILLANCE (CNS) RESILIENCE THROUGH GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) INTERFERENCE MITIGATION

(Presented by Czechia on behalf of the European Union and its Member States[1],
the other Member States of the European Civil Aviation Conference[2], the
Member States of the African Civil Aviation Commission[3], and
EUROCONTROL)

EXECUTIVE SUMMARY

The global navigation satellite system (commonly referred to as GNSS) is a key technology to provide communications, navigation, surveillance (CNS) and air traffic management (ATM) services worldwide. GNSS is essential for the implementation of Performance Based Navigation (PBN) and Automatic Dependent Surveillance-Broadcast (ADS-B) which are bringing substantial safety, capacity and environmental benefits to ATM. It is also used in safety-related systems and provides the time reference to synchronise systems (e.g. communication networks) and operations in ATM. However, GNSS is vulnerable to radio frequency interference (RFI) such as jamming, and cyber-attacks (e.g. spoofing). Therefore, it is essential to mitigate GNSS vulnerabilities adequately.

The ICAO 40th Assembly agreed in 2019 on actions to strengthen CNS system resilience and mitigation against GNSS RFI. However, we continue to witness a growing number of reported occurrences of GNSS RFI in various areas of the world. Therefore, it is paramount to implement measures to improve GNSS resilience in the short term (e.g. improved civil-military coordination, avoiding the proliferation of illegal jamming devices) and long term (e.g. improved integration of CNS airborne, ground and satellite-based complementary positioning sources). These measures should enable to preserve benefits from PBN and ADS-B even in GNSS-compromised environments.

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1 Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden

2 Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Georgia, Iceland, Republic of Moldova, Monaco, Montenegro, North Macedonia, Norway, San Marino, Serbia, Switzerland, Türkiye, Ukraine and the United Kingdom

3 Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cabo Verde, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia and Zimbabwe.

Action: The Assembly is invited to adopt the Resolution proposed in the Appendix to this working paper (note that the proposed Resolution includes Recommendations from the 40th Assembly on this topic).	
Strategic Objectives:	This working paper relates to the Safety, Air Navigation Capacity and Efficiency, and Security and Facilitation Strategic Objectives.
Financial implications:	The activities referred to in this working paper will continue subject to the resources available in the 2023-2025 Regular Programme Budget and/or from extra-budgetary contributions.
References:	A40-WP/82, *Interference-resilient satellite-based CNS systems* Doc 10007, *Twelfth Air Navigation Conference. Montreal, 19-30 November 20212. Report* Resolution A32-19, *Charter on the Rights and Obligations of States Relating to GNSS Services* Resolution A32-20, *Development and elaboration of an appropriate long-term legal framework to govern the implementation of GNSS* Resolution Resolution A35-15, Consolidated statement of continuing ICAO policies and practices related to a global air traffic management (ATM) system and communications, navigation and surveillance/air traffic management (CNS/ATM) systems A37-11, *Performance-based navigation global goals* A40-28, Appendix F, Consolidated statement of continuing ICAO policies in the legal field State letter AN 7/5-20/89

1. AN INCREASING DEPENDENCE ON GNSS

1.1 Global Navigation Satellite System (GNSS) includes constellations of satellites providing signals from space that transmit positioning and timing data to GNSS receivers, including those on board aircraft. These receivers determine accurate aircraft position. Satellite navigation and GNSS benefit aviation by enabling the design of new procedures that allow aircraft to fly more direct routes with reduced spacing, minimising fuel consumption, noise, and carbon emissions.

1.2 At the 40th Assembly, multiple papers highlighted the need to improve the resilience of communications, navigation, and surveillance (CNS) systems, including GNSS. The Assembly agreed with proposals reinforcing CNS resilience to radio frequency interference (RFI) by working to i) prevent the use of illegal interfering devices, ii) increase collaboration with radio regulatory and enforcement authorities, iii) reinforce civil-military coordination to address interference risks associated with GNSS testing and conflict zones, iv) retain essential conventional navigation infrastructure for contingency support in case of GNSS outages, and developing mitigation techniques for loss of services. The importance of the actions was reiterated by ICAO State letter AN 7/5-20/89.

1.3 ICAO encouraged Member States to implement existing provisions to reduce and mitigate GNSS RFI occurrences. However, due to increasing GNSS RFI, there is a need to further improve CNS resilience and mitigate the impact on performance-based navigation (PBN), automatic dependent surveillance — broadcast (ADS-B), and other uses of GNSS position and time.

1.4 Progress in implementing PBN and ADS-B leads to an increasingly complex dependence on GNSS for both navigation and surveillance. Europe and many other regions of the world are moving towards a PBN-based navigation environment while reducing procedures based on conventional navigation aids. Similarly, the use of ADS-B and its integration in the wider surveillance chain is advancing, enabling the realisation of associated advanced air traffic control (ATC) capabilities. Furthermore, many surveillance and trajectory management applications are now designed to use GNSS timing to synchronise the associated air and ground systems.

1.5 While many air transport aircraft can maintain position and time information in the case of GNSS RFI, by using alternate navigation systems, other airspace users rely more heavily on GNSS. In some airspaces where PBN has been implemented, reversion to conventional procedures is no longer possible, meaning that an alternate contingency infrastructure needs to be provided (minimum operational network, (MON)). Since ADS-B position and velocity information is derived from GNSS, any degradation or outage of GNSS also affects ADS-B performance. Therefore, CNS infrastructure must ensure that navigation and surveillance MON's support contingency operations in case of GNSS outage.

1.6 Inertial navigation system (INS) and terrestrial navigation systems such as distance measuring equipment (DME), currently do not support all PBN applications and are not used for ADS-B. The related position uncertainty computed by some flight management systems may not be suitable for supporting a particular PBN operation or ADS-B service level. Consequently, it is difficult to assess the impact of GNSS RFI on each aircraft's ability to continue its own navigation based on equipage information contained in the flight plan. This increases air traffic control workload and generates uncertainties in ATC sector capacity planning.

1.7 GNSS-derived position, velocity or time (PVT) information is also used in several other aircraft applications, e.g. data link and satellite communication services. This makes it difficult for pilots to understand the impact of GNSS RFI on all affected aircraft systems and increases pilot workload when experiencing RFI. For this reason, many aircraft manufacturers have published guidance to aircraft operators, describing both the impact of GNSS RFI on avionics and how to deal with it. This requires further training for the crew to properly manage such situations.

1.8 A recent analysis[4] conducted by EUROCONTROL concludes that 38 per cent of traffic in the European network passes through regions subject to extensive and regular GNSS RFI. This traffic is exposed to reduced safety margins for long periods of time, making the handling of other system faults more difficult.

1.9 While most of the observed GNSS RFI has led to outages of associated navigation and surveillance capabilities, pilots have also reported several types of anomalies. These anomalies include map shifts, incorrect indications of ground speed, unusual behaviour of aircraft clocks, and in a few rare cases, false ground proximity warnings. These issues may be attributed to the increasing level of aircraft equipment integration and aircraft manufacturers are taking steps to address them. However, it must be considered that some of these anomalies could be caused by intentionally false or deceptive signals (spoofing). Indeed, it has become easier to generate such signals since it no longer requires military-grade capabilities. Current indicators of navigation integrity have been developed as a safety metric only, and do not specifically take into account spoofing.

[4] https://www.eurocontrol.int/event/eurocontrol-stakeholder-forum-gnss

1.10 Much of the GNSS RFI is geographically linked to conflict zones, and drone defence. Aircraft will continue to be exposed to such RFI, even if efforts are maximised by ICAO and the International Telecommunication Union (ITU) to encourage States to limit harmful RFI to the greatest extent possible. However, even when far away from conflict zones, RFI events can occur at any moment and affect significant volumes of airspace[5]. RFI sources may also include the use of counter-UAS (nnmanned aircraft systems) systems by authorized State security actors – either in a planned or tactical deployment.

2. IMPROVING THE FUTURE INTEGRATION OF COMPLEMENTARY POSITIONING CAPABILITIES

2.1 ICAO, its Member States and industry are developing next-generation GNSS capabilities through dual-frequency, multi-constellation (DFMC) GNSS, which, along with advanced security features, will significantly mitigate non-RFI-related vulnerabilities and protect GNSS against single-frequency RFI.

2.2 Following recommendations 6/8 e) and f) from the Twelfth Air Navigation Conference on the value of inertial navigation systems (INS) and distance measurement equipment (DME), these systems should be further developed to become complementary to DFMC GNSS, such that operations can continue seamlessly. While suitably equipped avionics already switch to these sources of position in case of GNSS outage, any associated service degradation should be minimised. Such improved integration will provide highly robust aircraft PVT data, meeting both aircraft and ATC needs safely and securely.

2.3 To that end, Member States, ICAO and industry should support the work undertaken by standardisation bodies and further develop methods to associate PVT data with better quality indicators, preventing PVT use when compromised. This should eliminate cascading effects on other systems, and allow for the continuous provision of all en-route and terminal PBN and ADS-B services even in GNSS-compromised environments. Complementary planning activities should ensure consistent implementation, building on all available and suitable space, aircraft and ground infrastructure components, taking into account evolving security threats and the integration of future CNS technology evolutions.

2.4 The high-level performance goal is to obtain more robust position and timing data to serve all possible applications, based on information from all available CNS ground, space and on-board systems. These systems can efficiently complement each other, either by improving service continuity through backup capabilities or by enhancing service integrity through independent position cross-checking (including between independent surveillance systems), thus improving the safety and security of those operations. High-level principles should be coordinated through ICAO while industry standardisation bodies should develop the associated detailed technical specifications.

3. IMMEDIATE SHORT-TERM ACTIONS

3.1 Until the achievement of such an improved level of integration, current aircraft will continue to experience GNSS RFI and its operational consequences. Therefore, it is essential to protect GNSS services to the maximum extent possible by developing methods to monitor ADS-B position reporting, enabling air navigation services providers (ANSPs) to determine which aircraft are subject to

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[5] As experienced in a recent example involving a yacht equipped with a powerful anti-paparazzi drone jammer (turned on accidentally).

GNSS outages and thereby ensure that operations can continue safely. This can provide for the location of the RFI source to be estimated, and may lead to its elimination through radio regulatory enforcement.

3.2 Aircraft manufacturers should continue to assess the cascading effects of GNSS RFI on their systems, consider the on-board detection of interference and reporting through automated data collection systems, publish suitable guidance to manage any operational issues and recommend suitable training for pilots. Pilots should continue to report GNSS performance issues and associated cockpit effects.

3.3 ANSPs should carefully analyse the impact of GNSS RFI on their CNS facilities and ensure that any system degradations can be recognised and dealt with. Suitable backup capabilities for CNS systems should be available, including backups for systems and applications requiring time synchronisation. Furthermore, infrastructure and operational procedures should be available to support contingency operations for aircraft operators not equipped with multi-sensors capabilities.

3.4 While it is recognised that national security needs sometimes require exercises and testing that generate GNSS RFI, any such activity needs to be supported by enhanced civil-military coordination and collaborative decision making. Such coordination should minimise the impact of GNSS RFI on civil aviation to the greatest extent possible. This coordination should include cross-border collaboration between States when required.

3.5 The efforts to reduce RFI should not be limited to aviation as GNSS services are essential to many user communities and other critical infrastructure sectors. Aviation authorities are encouraged to reach out to the appropriate government actors to ensure that the proliferation of GNSS RFI is limited to the maximum extent possible. This should include the reinforcement of both preventive (regulation, market intervention) and reactive (ability to detect, locate and stop RFI sources) capabilities as appropriate.

4. CONCLUSION

4.1 The central role of GNSS in CNS/ATM, as outlined in this working paper, makes it imperative that GNSS RFI is mitigated, and that CNS system resilience is strengthened, in particular through improved integration of complementary positioning capabilities. To this end, the Assembly Resolution proposed in the Appendix has been developed to guide and support effective action by States, ICAO and industry.

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APPENDIX

PROPOSED ASSEMBLY RESOLUTION

A35-15: Consolidated statement of continuing ICAO policies and practices related to a global ATM system and CNS/ATM systems

APPENDIX A

General Policy

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APPENDIX B

Harmonization of the implementation of the ICAO CNS/ATM systems

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APPENDIX C

Ensuring the resilience of ICAO CNS/ATM systems and services

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

Whereas the occurrences of interferences against satellite-based CNS systems and GNSS, in particular, have significantly increased;

Whereas CNS resiliency to interference needs to be addressed at a global level with a holistic approach, ensuring an efficient and coordinated evolution between the infrastructure architecture, improved technological capabilities, civil and military operational procedures, radio regulatory authorities and civil-military coordination;

Recognising that resiliency to interference needs to be improved by maximising the 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 disruption or environments where false or deceptive signals are present;

Recognising that both the aircraft onboard and ground infrastructure complementing the satellite-based CNS systems need to be adapted to include, where appropriate, interference detection, mitigation and reporting functions to support the resolution of operationally encountered performance anomalies;

Believing that, combined with the use of the appropriate legal framework, such capabilities and measures will allow for the relevant authorities to act upon harmful interferences caused by the illegal operation of transmitters and avoid the proliferation and the use of such illegal transmitters and the misuse of test and maintenance equipment;
Believing that, with appropriate coordination and application of best practices, military and State authorities can conduct GNSS-related testing and other interventions using radio equipment as necessary and without causing an undue impact on civil aviation;

Believing that civil-military coordination should facilitate the sharing of relevant information with airspace users, especially when flying in the vicinity of a conflict zone; and

Acknowledging that loss of crew's situational awareness from malicious origin is classified as a cyber-security threat and 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 the loss of this signal.

The Assembly:

1. *Encourages* States to transition towards optimised, secure CNS systems based on complementary integration of suitable and independent aircraft capabilities, satellite- and ground-based infrastructure which maximise resiliency and robustness to any type of interference;

2. *Encourages* standardisation bodies and industry to develop appropriate interference detection, mitigation and reporting capabilities for the aircraft on-board, satellite- and ground-based CNS system components, in order to ensure higher CNS resiliency, continuity of operations and prevent any cascading effects from the use of compromised position, velocity or time data;

3. *Encourages* States to ensure that sufficient terrestrial CNS capabilities remain available to ensure safe operations and complement aircraft-level integration of position, velocity and time with independent surveillance information;

4. *Invites* ICAO to develop high-level principles on how to integrate CNS ground, space and on-board systems and capabilities to obtain more resilient positioning and timing services;

5. *Urges* States to apply necessary measures to avoid the commercialisation/proliferation and the use of illegal transmitters such as jammers and the misuse of test and maintenance equipment which may impact CNS systems;

6. *Urges* States to ensure close collaboration between aviation authorities, military authorities, service providers, radio regulatory and spectrum enforcement authorities to put in place any special measures required to ensure that spectrum used by all CNS systems, and GNSS in particular, is free from harmful interference;

7. *Urges* States to refrain from any form of jamming, or spoofing affecting civil aviation;

8. *Urges* States to coordinate and notify to the maximum extent possible in advance with the ANSP responsible for the affected airspace in case of military or other State-authorised security or defence-related operations or training, potentially causing any form of jamming, or spoofing affecting civil aviation; and

9. *Urges* States and operators when assessing the interference risks associated with conflict zones to consider that the use of satellite-based CNS systems can potentially be impacted beyond those zones

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