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Agenda Item 24: Aviation Safety and Air Navigation Priority Initiatives

REAL-TIME MONITORING AND ANALYSIS OF GNSS INTERFERENCE TO ENHANCE AVIATION SAFETY

(Presented by China)

EXECUTIVE SUMMARY

The Global Navigation Satellite System (GNSS) provides a flexible and accurate positioning architecture for modern aviation, enabling precise air navigation, real-time tracking, and enhanced situation awareness to support safe and efficient operations.

With the increasing reliance on GNSS signals by global aviation, there are at the same time growing concerns about GNSS radio frequency interference, particularly, the safety risks posed by jamming and spoofing. In addition to the current and developing mitigation measures for GNSS interference, the implementation of a real-time GNSS monitoring and analysis system provides additional benefits. Such system would significantly enhance situational awareness while effectively contributing to aviation safety assurance and optimization of operational efficiency

Action: The Assembly is invited to:

- note the information contained in this paper;
- recognise the benefits of the development of real-time GNSS monitoring and analysis systems; and
- invite States to share experience and challenges in the detection and monitoring of GNSS Interference

<i>Strategic Objectives:</i>	This working paper relates to <i>Every Flight is Safe and Secure</i> .
<i>Financial implications:</i>	The activities referred to in this paper are expected to be undertaken with the resources available in the 2026-2028 Regular Budget and/or from extra-budgetary contributions as guided by the ICAO Business Plan 2026-2028.
<i>References:</i>	Annex 10 — <i>Aeronautical Telecommunications</i> , Volume I - <i>Radio Navigation Aids</i> Doc 9849, <i>Global Navigation Satellite System (GNSS) Manual</i>

¹ English and Chinese versions provided by China.

1. INTRODUCTION

1.1 The Global Navigation Satellite System (GNSS) has evolved into a robust and highly versatile positioning architecture, providing flexibility and accuracy for aviation navigation.

1.2 For air navigation, several systems rely on GNSS for navigation and landing, such as Aircraft Based Augmentation System (ABAS), Ground Based Augmentation System (GBAS) and Space Based Augmentation System (SBAS). Furthermore, area navigation (RNAV) and required navigation performance (RNP) utilize GNSS to improve routing efficiency. For surveillance, automatic dependent surveillance–broadcast (ADS-B) relies on GNSS to enable real-time tracking of aircraft position. Together, these systems play an important role in ensuring safe and efficient air navigation.

1.3 For flight operations, several onboard systems, such as the Terrain Awareness and Warning System (TAWS) and the Enhanced Ground Proximity Warning System (EGPWS), depend on valid GNSS positioning data. If GNSS signals are compromised or inaccurate, this can lead to false warnings/alerts in the cockpit, or on the contrary, inability to generate real alerts due to inaccurate aircraft position, thereby potentially jeopardizing flight safety.

1.4 Over the years, as the reliance on GNSS in air navigation increases, the availability and integrity of GNSS signals have become key contributors to enhancing aviation safety and efficiency.

2. CURRENT AND DEVELOPING MITIGATION MEASURES FOR GNSS RADIO FREQUENCY INTERFERENCE

2.1 The current situation regarding GNSS radio frequency interference, especially under the rising trend in jamming and spoofing events, has become an international concern over aviation safety. Spoofing poses a particularly significant risk, as it can lead to confusion to pilots and air traffic controllers by the incorrect positioning data, jeopardizing flight safety and operational efficiency. Mitigation measures are being developed to ensure the safety of air navigation.

2.2 Existing mitigation measures

2.2.1 Maintaining robust navigation capabilities includes provision of conventional ground navigational aids, such as very high frequency omni-directional radio range/distance measuring equipment (VOR/DME) and instrument landing system (ILS), which provide alternative sources of navigational guidance when the GNSS signals are lost in an aircraft.

2.2.2 At the flight planning stage, NOTAMs are the primary means of disseminating information concerning any known or suspected GNSS interference. Any real-time GNSS interference encountered during flight is promptly reported to ensure immediate operational awareness for other users in the airspace regarding such safety-critical information.

2.2.3 Collaborating among stakeholders, including aviation authorities, air navigation service providers, airlines, avionics manufacturers, etc., in sharing ongoing strategies for managing GNSS interference is necessary to maintain navigation integrity and safety in the current operational environment.

2.3 Long-term mitigation measures

2.3.1 Enhancing the performance and reliability of GNSS through the use of dual-frequency/multi-constellation (DFMC) and multi-frequency multi-constellation (MFMC) receivers is in progress. Concurrently, the establishment and continuous refinement of Minimum Operational Performance Standards (MOPS) for GNSS ensure that these receivers meet stringent performance, interoperability and safety requirements for effectiveness in aviation operations.

2.3.2 Implementing cryptographic authentication protocols, such as navigation message authentication (NMA), ensures that receivers can verify the legitimacy of the received signals.

2.4 Challenges in GNSS radio frequency interference detection and monitoring

2.4.1 While the long-term mitigation measures are being developed, maintaining situational awareness for both pilots and air traffic controllers as soon as a GNSS radio frequency interference event occurs is of paramount importance as the primary mitigation strategy. However, obtaining information from such an event and subsequent dissemination in an efficient manner poses significant challenges, making it difficult to timely assess and effectively address potential issues.

2.4.2 *Limitations of conventional ground radio monitoring stations*

2.4.2.1 Ground-based stations and airborne stations operate in very different environments. Ground-based stations often face challenges in understanding the situations at high altitudes, making it difficult to accurately assess GNSS interference affecting airborne operations. Besides, terrains and the limited density of ground-based monitoring stations might create blind spots, reducing overall detection capability and hindering the effective monitoring of dynamic airborne conditions.

2.4.3 *Limitations of manual reporting GNSS interference*

2.4.4 Reliance on manual reports might lead to delay in information dissemination. During a GNSS interference event, pilots may be occupied to ensure flight safety is not affected, which could create a time gap between the occurrence of interference and its communication to relevant stakeholders.

2.4.5 Currently, airborne systems are not designed to provide information on GNSS interference. Even if such information is available, challenges in communication and coordination can hinder effective sharing. Similarly, existing air traffic control procedures also need to be enhanced to provide systematic guidance for controllers on reporting and responding to interference events.

3. ENHANCEMENT OF GNSS RADIO FREQUENCY INTERFERENCE DETECTION AND MONITORING

3.1 Challenges in GNSS interference detection stem from delay and limited information of the reports, highlighting the need for automated systems and technologies capable of real-time monitoring and detection of GNSS interference. Implementation of a real-time GNSS monitoring and analysis system is beneficial in reducing reliance on manual reporting, providing pilots and air traffic controllers with timely and safety-critical information to enhance the overall safety and efficiency in aviation operations.

3.2 ADS-B is a surveillance technology that relies on GNSS signals and onboard avionics to determine an aircraft position. It broadcasts the aircraft position, along with GNSS signal integrity information derived from onboard avionics, for surveillance of the aircraft through ADS-B ground receivers. Therefore, leveraging ADS-B technology, a real-time GNSS monitoring and analysis system could continuously monitor GNSS signal integrity without relying on manual reporting.

3.3 Additionally, integrating ADS-B and radar data enables real-time monitoring of aircraft movements, allowing for the rapid identification of unusual patterns or abnormal aircraft movements, as well as the detection of discrepancies that may indicate potential spoofing.

3.4 The real-time GNSS monitoring and analysis system should be capable of generating and displaying an interference heatmap, providing a visual representation of affected areas. This real-time monitoring enables timely alerts and notifications to concerned airspace users, facilitating proactive measures to mitigate interference issues. Additionally, the system could assist in the identification of possible areas in which the interference sources might locate, supporting effective strategies to locate and eliminate the interference sources and enhance overall airspace safety and reliability.

3.5 In 2024, a real-time GNSS monitoring and analysis system, leveraging ADS-B technology, has been developed and put into trial use in China (see Figure 1 below). Its performance is promising compared to conventional ground-based radio monitoring stations. The system can autonomously monitor and detect potential GNSS radio frequency interference in real time, providing timely and meaningful information to radio authorities for locating and eliminating the source of interference.

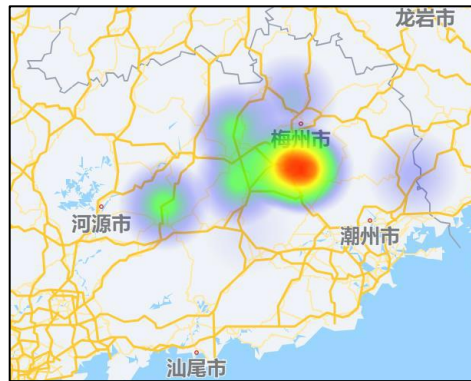


Figure 1. GNSS radio frequency interference schematic heatmap

4. CONCLUSION

4.1 The implementation of a real-time GNSS monitoring and analysis system, based on ADS-B technology, safeguards aviation safety while boosting operational efficiency, particularly as long-term solutions for GNSS radio frequency interference and avionics systems continue to evolve and develop. Continuous and real-time monitoring ensures rapid detection of anomalies, supporting prompt decision-making and corrective actions to mitigate the interference, thereby contributing to a secure and reliable aviation electromagnetic environment.