International Civil Aviation Organization

**WORKING PAPER**

AN-Conf/14-WP/196
31/7/24
**(Information Paper)**
**English only**

# FOURTEENTH AIR NAVIGATION CONFERENCE

**Montréal, Canada, 26 August to 6 September 2024**

**Agenda Item 2: Timely and safe use of new technologies**
**2.2: Addressing safety risks related to evolving aviation technologies**

## A LOW COST SATELLITE CONSTELLATION FOR GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)-INDEPENDENT SAFETY-CRITICAL SURVEILLANCE APPLICATIONS IN LOW EARTH ORBIT(LEO)

(Presented by France and the European Space Agency (ESA))


**EXECUTIVE SUMMARY**

In the current aviation landscape, safety-critical surveillance services heavily rely on Global Navigation Satellite Systems (GNSS). However, these systems are susceptible to signal interference, spoofing, and failures, posing significant operational risks. This working paper introduces an innovative Nano Satellite constellation designed to provide a global GNSS-independent, resilient safety-critical surveillance service in Low Earth Orbit (LEO).

**Action:** The Conference is invited to:

a) note the development and potential benefits of the GNSS-independent surveillance service;
b) consider the integration of such systems to enhance global aviation safety and resilience; and
c) support further research and collaboration on GNSS-independent technologies.


## 1. INTRODUCTION

1.1 The aircraft transponder sends frequent and automatic broadcast transmissions such as Mode S or automatic dependent surveillance–broadcast (ADS-B) of an aircraft identification, position and velocity (in case of ADS-B), altitude, and other information to any receiver (airborne or ground) within range of the broadcasted information. Aircraft global navigation satellite system (GNSS) receivers use the signals provided by the GNSS, and transmitted at least once per second, to calculate their range from each satellite in view, and then to calculate three-dimensional position and time.

1.2 Under legacy usage, the ADS-B data is broadcasted in an unencrypted structured format allowing the ground-based air traffic management (ATM) systems, of the Air Navigation Services Providers (ANSPs), to provide air traffic services (ATS) by supporting the surveillance function which is required by air traffic control (ATC) to deliver safe separation between aircraft.

1.3 In the aviation sector, continuous and reliable surveillance is essential for safety-critical operations. Dependence on GNSS for these services introduces vulnerabilities that could compromise safety. This paper presents a Nano Satellite constellation offering an independent and resilient solution for global surveillance in LEO.

1.4 GNSS is critical for existing space-based navigation and surveillance systems but faces risks such as interference, spoofing, and jamming. The proposed satellite constellation leverages advances in miniaturized satellite technology, robust high accuracy, on board timing systems and inter-satellite communication to provide an alternative, ensuring uninterrupted surveillance capabilities. This gives multiple layers of independence from any third-party system whose disruption would affect traditional satellite-based surveillance/positioning systems.

1.5 Ground based multilateration techniques are currently used (WAM-MLAT system) to locate the aircraft where a high number of Mode-S/ADS-B receivers are positioned in the field of view of the aircraft giving a reliable technology baseline for the safety critical elements of the GNSS independent system.

## 2. **DISCUSSION**

### 2.1 System Design and Architecture

2.1.1 *Satellite Configuration*: The constellation consists of a network of Nanosats strategically placed in Low Earth Orbit (LEO). Each satellite is equipped with state-of-the-art RF sensors, to ensure accurate data collection and robust operational capabilities in diverse environmental conditions. The constellation is designed to achieve the availability standards required by European Organisation for the Safety of Air Navigation (EUROCONTROL) Specification for ATM Surveillance System Performance (ESASSP) and EUROCAE ED-142, by balancing a highly reliable satellite design with a constellation level redundancy approach.

2.1.2 *Low Latency*: The satellites use advanced inter-satellite communication links (ISLs) to maintain a cohesive network, which enables near-real-time data sharing and redundancy.

2.1.3 *GNSS Independence*: Orbit determination and time synchronization (ODTS) signals sent from the constellation are received on the ODTS ground stations use sophisticated algorithms, to determine the position of, and track, aircraft even in GNSS-denied environments.

2.1.4 *WAM/MLAT Algorithm Integration*: Advanced algorithms are embedded within the ground system architecture to process and analyze data for precise location tracking, anomaly/false detection, and predictive analytics. These algorithms utilize machine learning techniques to continuously improve the accuracy and reliability of the surveillance data.

2.1.5 *Cybersecurity*: Spire prioritizes the security of our information systems and the data required to operate our services. We are dedicated to maintaining cybersecurity standards and are committed to continuously improving our security posture. Our adherence to internationally recognized standards of cybersecurity reflects our comprehensive approach to information security management, ensuring that we implement sufficient controls and best practices to protect against evolving cyber threats. By fostering a culture of security awareness and vigilance, we aim to safeguard our operations, customers, and stakeholders from potential risks.

### 2.2 Operational Benefits

2.2.1 *Safety and Efficiency Enhancements*: The proposed constellation significantly enhances the safety and efficiency of critical applications in air traffic management and surveillance. It can ensure continuous certified surveillance in cases of GNSS outages, radar outages or unavailability of other surveillance services, or act as primary surveillance system, all of which are crucial for air traffic management (ATM).

2.2.2 *GNSS-Independent Operations*: By providing an independent surveillance capability, the system mitigates risks associated with GNSS signal loss, jamming, or spoofing. This redundancy ensures uninterrupted service, maintaining the integrity and reliability of Safety-of-Life operations.

2.2.3 *Resilience Against Cyber Threats*: The constellation's decentralized architecture and robust encryption protocols enhance cybersecurity, making it resilient against potential cyber-attacks. This is particularly important for maintaining the integrity of critical surveillance data and ensuring the safety of ATM and separation services.

2.3 Implementation and Scalability

2.3.1 *Deployment Strategy*: The modular design of the constellation allows for phased deployment, minimizing initial investment while enabling incremental capacity expansion. This strategy ensures that initial operational capabilities can be achieved quickly, with subsequent enhancements added as needed.

2.3.2 *Scalability and Flexibility*: The system is designed to be highly scalable, allowing for easy addition of new satellites and capabilities in response to growing demand or emerging threats. This flexibility ensures that the constellation can evolve with technological advancements and changing operational requirements.

2.3.3 *Implementation Challenges*: Key challenges include Meeting the low latency requirements for ATC surveillance, ensuring compliance with the high availability needs, RF performance in regions of high aircraft density, ensuring interoperability with existing ATM systems, obtaining regulatory approvals, and managing the spectrum allocation for satellite communications. Addressing these challenges will require close collaboration with international regulatory bodies and continuous engagement with stakeholders.

2.3.4 *Migration Strategies*: Transitioning to this new system involves developing migration strategies that ensure seamless integration with current infrastructure. This includes comprehensive testing and validation phases, training for operational personnel, and establishing contingency plans to manage potential disruptions during the transition period.

2.4 Potential Future Developments

2.4.1 *Technological Innovations*: Future enhancements could include integration with emerging technologies such as quantum communication for ultra-secure data transmission, artificial intelligence for advanced predictive analytics and optimization, and higher-resolution sensors for improved data accuracy.

2.4.2 *Expanded Applications*: the constellation could support key applications in the area of disaster response (e.g. ATS portability), and environmental monitoring, but beyond ATM, other applications (e.g. SAR and GADSS), could take advantage of the service. These applications could benefit from the same robust and resilient surveillance capabilities, further extending the system's value.

2.4.3 *International Collaboration*: Ongoing international collaboration will be crucial for the successful deployment and operation of the constellation. Partnerships with global stakeholders, including other space-faring nations, international regulatory bodies, and industry leaders, will drive the adoption and integration of this innovative technology.

## 3. CONCLUSION

3.1 The Nano Satellite constellation represents a disruptive advancement in safety-critical air traffic surveillance, providing a GNSS-independent solution that enhances the resilience, accuracy, scope and reliability of global surveillance services.

3.2 The Conference is invited to:

a) note the information provided in this paper;

b) consider the integration of GNSS-independent surveillance systems to enhance aviation safety; and

c) encourage further research and international collaboration on the development and implementation of resilient surveillance technologies.

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