Agenda Item 4: **Assessment of operational requirements to determine the implementation of improvements in communications, navigation and surveillance (CNS) capabilities for operations in route and terminal area**

SPACE-BASED ADS-B SYSTEM IMPLEMENTATION UPDATE

(Presented by Aireon)

SUMMARY

This paper provides the Meeting with an update and actions relating to the deployment of Space based ATS Surveillance via satellite. It highlights ICAO's leadership role in promoting Safety & Efficiency among States and to work closely with industry to take advantage of available global satellite technologies for safe & efficient ATM. It records the advancements on surveillance via satellite over the last 2 decades and looks ahead at the successful launch of a next-generation low-earth orbital satellite system for ATS Surveillance services that will mark a major milestone in aviation history to complete a truly satellite-based surveillance system for global Air Traffic Management. Finally, the paper summarizes the safety & operational benefits that this breakthrough in global surveillance brings. A cost-effective capability that enables many developing States to leapfrog legacy Surveillance and Search & Rescue capabilities and offering an Alternative Surveillance capability aligned with the basic building blocks (BBB) framework and to help ensure that 'no State is left behind'.

Strategic Objectives:	• Safety • Air Navigation Capacity and Efficiency
References:	• Global Air Navigation Plan • PANS ATM Doc. 4444

1. Introduction – An ICAO perspective on surveillance

1.1 ICAO forecasts traffic growth to double every 15 years, a trend witnessed since the 1970s. The Global Air Navigation Plan warns that *"unmanaged air traffic growth can also lead to increased safety risks in those circumstances when it outpaces the regulatory and infrastructure developments needed to support it"*. Equally, and under the guiding principles of ATS Safety Management, ICAO suggests in equal part that *"States shall ensure that the level of air traffic services (ATS) and communications, navigation and surveillance, as well as the ATS procedures applicable to the airspace or aerodrome concerned, are appropriate and adequate for maintaining an acceptable level of safety in the provision of ATS"*.

1.2 Further, better surveillance and communications performance means lower separation minima that would allow States and ANSPs to accommodate more traffic in a safe and organized manner.

1.3 ICAO PANS-ATM Doc.4444 defines an Air traffic management system as one *"that provides ATM through the collaborative integration of humans, information, technology, facilities and* *services, supported by air and ground- and/or* ***space-based*** *communications, navigation and surveillance. An Air Traffic Control service in turn, is provided directly by means of a ground-based ATS Surveillance system installed at an Air Traffic Facility".* The Air Traffic structure and services at TMA-Macaé were implemented mainly to support the air operations of interest of the oil activity, which is characterized by the flow of helicopters between the mainland and the oil platforms or vessels anchored in that Basin, in the ocean area, for the transportation of persons and cargo.

1.4 Minimum Operational Performance System (MOPS) requirements of an end-to-end ATS system to support safe ATS separations are covered under EUROCAE ED-129B. ICAO PANS ATM Doc.4444 deems such a system as *"has been demonstrated, by comparative assessment or other methodology, to have a level of safety and performance equal to or better than monopulse SSR".* The key performance characteristics of this segment are denoted by:

a. Position Latency of 4 seconds ≤ 2.0s (99th percentile);
b. Position Update Interval rate of ≥ 96% for an Update Interval of 8 seconds (for low density en-route airspace); and
c. Service Volume Availability of ≥ 0.999.

1.5 Starting at a conceptual level at the 11th ICAO Air Navigation Conference in 2003, with the primary objective of recognizing ADS-B and cooperative surveillance capability of the future, ADS-B has matured significantly in the years since. Various sections of the GANP recognize its capabilities as a key enabler that provides Alternative Surveillance to conventional Radar and primarily for 3 key reasons:

a. the lower costs of dependent surveillance infrastructure in comparison to conventional radars support business decisions to expand radar-equivalent service volumes;
b. the use of radar-like separation procedures into remote or non-radar areas. It enables a "significant increase in traffic density compared to procedural minima"; and
c. overcome ground-siting location constraints and to eventually transition to a space-based enabled alternative.

1.6 ICAO has recognized the capabilities of ADS-B through multiple layers of its provisions, embedded within the Executive Summary of the GANP, the ASBU Block Modules and the Technology Roadmap with the following objectives:

i Executive Summary: That Alternative Surveillance (B0-ASUR) "*may eventually become the subject of ICAO Standards with mandated implementation dates*" and along the concept of "*minimum path to global interoperability and safety*" is introduced.

ii ASBU Block 0 (implementable 2018) Alternative Surveillance – ASUR. Clear benefits in Capacity, Efficiency, Safety and Cost (Appendix 2)

iii Technology Roadmap 5: highlighted based on the following extracts

- *Functionality will migrate from the ground to the air … Downlinked aircraft parameters bring advantages*
- *B0- There will be significant deployment of cooperative surveillance systems: ADS-B (ground- and space-based)*
- *B1- Deployment of Coop. Systems will expand. Additional Safety Net Functions based on aircraft data. Enhanced Surface Operations*
- *B2- Primary surveillance radar will be used less and less as it is replaced by cooperative surveillance techniques*
- *B3- Cooperative surveillance techniques will be dominant as primary surveillance radar (PSR) use will be limited*

1.7 12th ICAO Conference adopted three recommendations. Recommendation 1/9 requested ICAO to:

i **Support** the inclusion in the Global Air Navigation Plan, development and adoption of space-based automatic dependent surveillance - broadcast surveillance as a surveillance enabler;

ii **Develop** Standards and Recommended Practices and guidance material to support space-based automatic dependent surveillance - broadcast as appropriate; and

iii **Facilitate** needed interactions among stakeholders, if necessary, to support this technology

1.8 The 13th ICAO Air Navigation Conference held in October 2018 considered WP/176 presented by CANSO that provided an update on global ATS surveillance technology. *"The Committee recognized the significant potential safety and operational benefits of introducing ATS surveillance services into areas where they have not previously been available. It was recalled by the Committee that various ATS surveillance technologies were key enablers of the Global Air Navigation Plan (GANP, Doc 9750) and were being progressed by the appropriate ICAO technical expert groups"*.

2. Equipage

2.1 The ADS-B service is characterized by being dependent/cooperative. The overall performance of ADS-B is affected by avionics performance and compliant equipage rate. ANSP ADS-B Out mandates enable the surveillance capability for space-based ADS-B. The ADS-B position, velocity and identification data is transmitted from the aircraft on the 1090 MHz Extended Squitter (1090-ES) link and received by Aireon's ADS-B receiver payloads. The ADS-B payload decodes the ADS-B messages it receives and (using the Iridium space and ground network) sends the content of the message to the Aireon ground segment for processing and distribution. The data is then routed to ANSP customer automation platforms for use in surveillance applications.

2.2 At the Twenty-first Workshop / Meeting of the SAM Implementation Group (SAM / IG / 21), the International Air Transport Association (IATA) presented a working paper that points to a percentage higher than 90% (in some cases it reaches 99%) of aircraft, operated by the airlines, equipped with transponder with ADS-B Out capability.

2.3 Although IATA´s survey only includes information from IATA member airlines and does not include information from General, Executive and Military aviation, in a country, the information is important because it can mark the strategy of the CAA and ANSP in the SAM Region.

3. Space-based ADS-B system implementation update

3.1 Aireon has completed its seventh successful satellite launch, with 55 satellites in orbit. It's estimating its eighth and final launch by December 2018, bringing the space-based ADS-B constellation and system into operations.

3.2 EASA certification is expected for March 2019 and Nav Canada, its first user, will start operations February 2019.

3.3 Testing update 1 – Independent validation of aircraft position via Space-based ADS-B.

3.3.1 A risk that needs to be overcome by States and ANSPs in any ADS-B system used for separation services is the ability to verify the quality of the data being delivered. Incorrect or misleading surveillance information provides hazardous and misleading information to air traffic controllers. In the case of terrestrial systems, validation can be done through comparison to radar, WAM, or other surveillance sources. In the oceanic case however, this is not possible. In April of 2018 Aireon began receiving Precision Timing and Position (PTP) messages for both timing and satellite position to perform the Time Difference of Arrival (TDOA) calculations. Aireon has incorporated TDOA into a position validation algorithm allowing for verification of an aircraft's reported position independent of GNSS. This independent validation algorithm augments Aireon's surveillance system to be resistant to spoofers (devices that are intentionally transmitting incorrect positions), faulty avionics, and GNSS outages. The nature of the satellite polar orbits and the size of the payload's footprints usually allows for coverage overlap between adjacent payloads. This overlap allows for two or more measurements to perform Time Difference of Arrival (TDOA) calculations.

3.3.2 Aireon's validation algorithm utilizes two primary techniques:

i using two or more satellites to perform TDOA calculations and verify the aircraft reported position is within a configurable distance from truth. Above 43° and below -43° latitude all aircraft are always covered by at least two satellites; and

ii use of the aircraft's kinematics to persist and verify their validation state in regions where there is no satellite overlap. Single satellite coverage only exists near the equator. But even at the equator where coverage overlap is reduced, an aircraft still has an 80% chance of being covered by more than one satellite.

3.3.3 Aireon has thus developed a comprehensive method of position validation that will be used to authenticate the state vector integrity of ADS-B data delivered to any consumer. This fully independent validation layer alleviates concerns about using ADS-B as a single source of surveillance and increases the ability to use 'version zero'. Aireon is the only surveillance provider positioned to perform this type of validation via Space-Based ADS-B and will be delivering this new feature to customers by the first quarter of 2020.

3.4 Testing update 2 – Using Space-based observations in identifying ACAS advisories and aircraft avionics anomalies

3.4.1 Non-compliant aircraft are commonly observed in the global ADS-B data set. Examples of non-compliant aircraft include aircraft transponders that do not adhere to the Minimum Operational Performance Standards (MOPS) and the rules outlined in ICAO Annex 10. Position outliers duplicate 24-bit addresses, and invalid aircraft identification data are examples of such observations. The transponder issues are probably not intentional and aircraft operators, Air Navigation Service Providers (ANSPs), Civil Aviation Authorities (CAAs), and ICAO may be unaware of many of the non-compliant transponders due to a lack of data and coverage and reliance on radar. The presence of duplicate 24-bit addresses is a safety concern that can lead to dropped tracks in surveillance systems and missed alerts in TCAS.

3.4.2 In addition to non-compliant aircraft, Aireon has had the opportunity to analyse Traffic Collision Avoidance System (ACAS) Resolution Advisories (RAs) on a global scale using the RA broadcast message included in version two of the 1090 Extended Squitter ADS-B MOPS. This data can be used to better describe collision risk scenarios and identify areas with frequent RA activity. Some States independently monitor ACAS via Mode S, but Aireon can monitor ACAS data received via ADS-B messages, including oceanic regions outside of radar coverage. EUROCONTROL's December 2017 ACAS Guide states that there is no European-wide data on the frequency of RA occurrence. The data collected from Aireon may be the first global look at RA occurrences.

3.4.3 ICAO document 9863 notes that monitoring via controller reports where typically mandated by a State, pilot reporting can be used, and data from surveillance is voluntary. A 2009 report concludes that only 48% of climb/descend RAs and 20% of other RAs are reported by pilots. A global monitoring system could assist in filling in the gaps and correlating preventative and corrective TCAS RA events.

3.4.4 With the unique capability of a global dataset of ADS-B data that can be used to help ICAO, ANSPs, airlines, avionics manufacturers, and regulatory bodies actively support alignment to standards and regulations, Aireon is an active part of the aviation community and plans to offer additional services and applications in support of achieving higher levels of global interoperability.

3.5 On-orbit tests and characterizations to validate technical performance metrics

3.5.1 In just a few short years, space-based ADS-B has already transformed the roadmap for aircraft surveillance within the Air Traffic Management (ATM) industry. ADS-B (Automatic Dependent Surveillance – Broadcast) avionics is rapidly becoming mandatory aircraft equipage for many airspaces. ADS-B is ushering in a new era of flight tracking, surveillance, improved safety, and increased efficiency. Operational acceptance by Air Navigation Service Providers (ANSPs) of new technologies such as space-based ADS-B will depend in part on the outcomes of rigorous testing. Aireon conducted a series of on-orbit tests and characterizations to verify and validate key requirements and expectations of the system.

3.5.2 The key surveillance TPMs of Availability, Latency, and Update Interval were evaluated from on-orbit satellite data, working with about 10 billion ADS-B position messages that are currently received per month. In each case, significant margin was found in the measurements relative to the internal and external requirements. These results were achieved even with a partial constellation and other temporary constraints. En-route areas, terminal, airport, and helicopter operations were included. Clearly the potential of this system has only begun to be explored, giving rise to new metrics and applications in the ADS-B frontier. The group of requirements with the highest priority for validation are known as the Technical Performance Metrics (TPMs) and provided the following outcomes:

- i Availability: The overall risk was contained, such that a service volume availability of ≥ 0.9999 is achievable even for areas near the equator;
- ii Latency: Using 4 SDPs deployed at ANSP locations and 2 local (within the APD control station) results, measured from the payload receiver to different end point locations, show an impressive 1655 ms of margin relative to the 2.0s requirement. Latency characteristics of 345 ms (99%) are clearly well within the same domain as terrestrial surveillance systems and in some cases faster;
- iii Update Interval: In one study (of several) using a coverage plot at Keflavik (KEF) airport in Iceland over a 24-hour period, the combined UI performance was observed to provide a seamless continuity of service from en-route (8s) to terminal/approach (5s) to surface (although surface would require a UI of 1s).

4. Recommended actions

4.1 The meeting is invited to:

a) Note the information contained in this information paper; and

b) discuss any relevant matters as appropriate.
