



International Civil Aviation Organization

Twenty Third Meeting on the improvement of Air Traffic Services over the South Atlantic (SAT/23) [Durban, South Africa, 4-8 June 2018]

## Agenda Item 2: Improvement of the CNS systems in the SAT Region (ADS-B)

### Overview of emerging Satellite-based Surveillance capability for Global ATM

*Presented by Aieron*

#### SUMMARY

This working paper presents an ANS system overview and timelines for new/emerging satellite-based global surveillance capabilities to be deployed end-2018. Starting in 1992 with the 29th Assembly endorsement to the ICAO work program under the Future Air Navigation System (FANS) concept and continuing today with the Global Air Navigation Plan (GANP), ICAO has actively promoted States to work closely with the satellite-based industry to take advantage of available global satellite technologies for safe & efficient ATM.

While the Communications and Navigational operational capabilities for global ATM via satellite have been achieved over the last 2 decades, the successful launch of a next-generation LEO satellite system for ATS Surveillance services will mark a major milestone in aviation history to complete a truly satellite-based CNS system for global Air Traffic Management.

This paper also summarizes and highlights the application of and safety & operational benefits to the SAT region, with a view to seeking feedback and support from the SAT group.

Action by the SAT/23 is in paragraph 11.1

#### References:

- Doc 9750 Ed.5 Global Air Navigation Plan
- Doc 9689 Manual on Airspace Planning Methodology for the Determination of Separation Minima
- ICAO SASP/2 Meeting Report
- ASBU B0-FRTO Improved Operations through Enhanced Enroute Trajectories
- ASBU B0-ASUR - Initial Capability for Ground Surveillance
- GANP Ed.5 Appendix 5 – Technology Roadmap

## 1. Introduction, History

1.1 ICAO defines the primary objective of Air Traffic Control (ATC) to provide a safety of life service for the purpose of:

a) preventing collisions:

- 1) between aircraft, and
- 2) on the maneuvering area between aircraft and obstructions; and

b) expediting and maintaining an orderly flow of air traffic.

1.2 ATC is thus dependent entirely on Surveillance in the provision of safety-of-life services for which controllers are in turn, solely reliant on the accuracy, integrity, continuity and availability of aircraft tracking data. Surveillance systems serve as your “eyes in the sky” that provides the ‘who’, ‘where’ and ‘when’ of each active aircraft on the ground or airborne. Surveillance data has and continues to rely on tracking. In other words, a system directly connected to an ATS system rather than a communications relay. A data relay with a direct feed off the transponder from aircraft sensors directly into an ATS unit.

1.3 A new constellation of satellites equipped with ADS-B receive/transmit payload via space signal will become operational, end 2018. This satellite-based functionality will provide global surveillance in areas outside terrestrial surveillance coverage to complete global satellite-based ATM services for surveillance in addition to the existing NAV & COM capabilities.

## 2. The Maturity Process Evolution of satellite-based CNS

2.1 The maturity process for Surveillance on a global baseline can be seen to have evolved as such:

**1983:** The ICAO Council established the Special Committee on Future Air Navigation Systems (FANS) to develop recommendations for the future development of air navigation for civil aviation over a period of the order of twenty-five years.

**1991:** 10th Air Navigation Conference endorsed the FANS concept. The 2<sup>nd</sup> FANS Committee was established to monitor and coordinate transition planning for the future air navigation system that would be satellite based in order to overcome terrestrial limitations

**1992:** First developed as global coordinated plan for satellite-based CNS/ATM Systems.

**1992:** the 29th ICAO Assembly endorsed the ICAO work program to work closely with the satellite-based industry under the Future Air Navigation System (FANS) concept to take advantage of available technologies of GNSS for satellite Navigation and Satellite Voice and Data for Communications to effectively enhance procedural environment for reduced separation for the safe passage of aircraft.

**1996:** The ICAO Council determined that CNS/ATM systems had sufficiently matured and a more concrete plan was needed which would include spearheading global developments and possible technical solutions, while focusing on regional implementation

**1998:** The Global Plan for CNS/ATM systems released

**2003:** The 11th ICAO Air Navigation Conference recognized ADS-B as the Surveillance technology of the future.

**2004:** The 35<sup>th</sup> ICAO Assembly (A35-15) introduced the Global ATM Operational Concept to guide planning & implementation of CNS/ATM systems.

**2006:** The Global Plan for Air Navigation Systems was developed

**2007:** ICAO formally acknowledged that ‘radar-like’ systems had been developed and the 15th Edition of the Procedures for Air Navigation Services - Air Traffic Management (PANS- ATM; ICAO Doc 4444) incorporated updated references to “ATS surveillance” rather than “radar”.

**2012:** A revised Global Plan was presented during the 12<sup>th</sup> AN Conference.

The ASBU methodology introduced- a programmatic-system approach for implementation

Endorsement for the realization of the “One Sky” concept- a guide to States to address the challenge of the integration, interoperability and harmonization of the systems

12th ICAO Conference adopted two recommendations

Recommendation 1/9 requested ICAO to:

- Support the inclusion in the Global Air Navigation Plan, development and adoption of space-based automatic dependent surveillance - broadcast surveillance as a surveillance enabler;
  - Develop Standards and Recommended Practices and guidance material to support space-based automatic dependent surveillance - broadcast as appropriate; and
  - Facilitate needed interactions among stakeholders, if necessary, to support this technology
- Block 0 module ASUR is included in Priority & Minimum Path strategy. It recognizes the lower costs of dependent surveillance infrastructure in comparison to conventional radars, supports business decisions to expand radar-equivalent service volumes and the use of ‘radar-like’ separation procedures into remote or non-radar areas. Additionally, the non-mechanical nature of the ADS-B ground infrastructure allows it to be sited in locations that are difficult for radar installations”.

## 3. ICAO Global Surveillance Planning Methodology and recognition for ADS-B

3.1 Given the doubling of air traffic growth rates every 15 years since the 1970s, ICAO has alerted 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*”. ADS-B was seen as the opportunity in bridging surveillance gaps and its role in supporting future trajectory-based air traffic management operating concepts.

3.2 ICAO has established clear guidelines through triennial global Assemblies and the resultant Global Air Navigational Plan to recognize ADS-B technology as the Surveillance technology of the future. Moreover, the International Air Transport Association (IATA) and other airline trade associations have taken a definitive position as outlined below:

- There is no airline requirement for using Primary Surveillance Radar (PSR) technology, should transponder aircraft equipage be sufficient to ensure relevant separations
- Multilateration is a superior replacement for Secondary Surveillance Radar (SSR) in terminal airspace
- SSR Mode S is preferred over SSR Mode A/C3 where radar must be installed or replaced
- Support for the implementation of Advanced Dependent Surveillance-Broadcast (ADS-B) OUT based on Mode S Extended Squitter (1090ES) data-link to supplement and eventually replace radar
- The single choice for ADS-B installations in non-radar airspace and where traffic could benefit from ATC surveillance.

3.3 ICAO has also noted that the full potential of ADS-B has yet to be fully realized and must be leveraged further as a means of cooperation between States as key towards improving flight efficiency and enhancing safety involving the use of automatic dependent surveillance — broadcast technology.

3.4 The GANP Roadmap 5<sup>1</sup> states that fused ground systems baselined on cooperative surveillance will provide the sophistication for separation, surface operations and safety net functions. It denotes year 2023 for when Space-based ADS-B will be fully available. It further states “*The twin demands of increased traffic levels and reduced separation will require an improved form of ADS-B* “

3.5 All four Performance Improvement Areas (PIA) that carry direct interest to States & ANSPs in relation to the Space-based ADS-B are:

- a. Airport operations;
- b. Globally-interoperable systems and data;
- c. Optimum capacity and flexible flights; and
- d. Efficient flight paths.

3.6 ADS-B as an enabler, especially in its satellite-based delivery format has been recognized extensively in all sections of the ICAO GANP- i.e. the Policy Principles, Performance Improvement Areas, ASBUs and Technology Roadmap. Additional uses have also been identified for Remotely Piloted Aircraft (RPA) Integration in Traffic, Full 4D Trajectory-based Operations (TBO) etc.

3.7 In summary, the CNS lifecycle in an ANSP environment typically ranges between 15-20 years. It will remain a conscious choice for each ANSP and State to decide on how it intends to manage a long-term efficient and cost-effective technological surveillance strategy. It will need to consider strategic CNS planning in context of its commitments at Global (ICAO Assembly & Divisional Conferences) and Regional & sub-regional planning & implementation programs. It will need to consult with its customers including the Aircraft operator community to align with their policy pronouncements. The adoption of the ASBU planning framework is a catalyst in this process, with a clear recognition for SB ADS-B.

#### 4. Implementation Planning

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<sup>1</sup> ICAO GANP Doc. 9750 ed.5 pp.108

4.1 As of date, 55 of a total of 75 satellites have been successfully launched. The full constellation will be deployed and become fully operational Q3- 2018.

4.2 With respect to implementation in anticipation of operational deployment, end 2018, the Civil Air Navigation Services Organization – CANSO published “[ANSP Guidelines for Implementing ATS Surveillance Services Using Space-Based ADS-B](#)” in 2016. These guidelines were developed through a multi-stakeholder Surveillance Task Force of its Operations Standing Committee (OSC). While recognizing the past benefits gained from deployment of ground-based surveillance systems, the rationale for these additional guidelines was to complete a ubiquitous global ATS Surveillance coverage in CANSO’s goal of achieving global ATM. It states “Space-based reception of ADS-B signals (space-based ADS-B) will use existing technologies (satellites, ADS-B transponders and ADS-B receivers) to leverage current capabilities and knowledge to provide global coverage”.

4.3 In supporting with complementary guidance to the ICAO GANP, IATA issued the “[User Requirements for Air Traffic Services- URATS](#)” as guidance to ANSPs and Airlines in determining requirements/capabilities for air navigation services. It recognizes the potential of encompassing the globe with global surveillance and states “*ADS-B is the next generation surveillance technology capable of replacing radar. Space-based ADS-B is a technology where ADS-B receivers are placed on satellites. If the satellites provide global coverage, then ADS-B surveillance can be provided globally.*”

## 5. Safety Certification

5.1 Safety is an evolving activity that is becoming a key component of the Space based ADS-B deployment. Aireon has robust SMS monitoring and assessment processes to verify suitability, adequacy and effectiveness of the end-to-end system in order to continuously improve the safety management process throughout the life cycle of the constellation and data system.

5.2 Aireon has established a unique relationship with EASA that will also benefit States & ANSPs in approval processes and system safety cases. Aireon is working with EASA for certification approval as an ATM/ANS Surveillance Service Provider Organization. The certification aspects cover the airborne 1090ES signal as it leaves the airplane and audited against current European & US MASPS (DO-260, 260A, 260B / ED-109, ED-109A, DO-178C / ED-12C). Another layer of certification covers the data as it moves in space from the hosted payload, satellite crosslinks and hosted payload operations center on the ground to finally reach the ANSP service delivery point. Aireon is currently supporting EASA with conducting a series of audits to validate safety assurance. Included are:

- Software assurance, system verification and Management Processes - Complete
- Operations readiness Q2 2018
- Provisional Certification Q3 2018

Aireon is preparing Assurance documents to be ready Q3-2018 covering Declaration of Verification and Suitability of use.

## 6. Deploying Space Based ADS-B – via ICAO Standards

6.1 In order to maximize value for their Space-based surveillance investments, ANSP users of SB ADS-B have developed a ‘two-pronged’ approach for regulatory approvals and implementation:

- a. Add Space based ADS-B to the existing certification (or exemption) for ground based ADS-B for its use as ATS Surveillance in terrestrial COM areas
- b. Implement 15/15 separation in the Remote-Oceanic airspace where VHF is not available.

6.2 **Scenario 1** COM availability- VHF co-located

For ANSPs that are already using Radar and/or ADS-B within their current surveillance ground systems, the addition of SB ADS-B is deemed as being analogous to adding an additional ADS-B source from a new

‘manufacturer’ of ADS-B receivers. As can be expected, some additional work will be required to ensure that the ANSP ground system and Aireon’s system agree on data quality, interfaces and displays. Integrating the SB ADS-B system can be fast tracked for regulatory approvals once the EASA ANSP certification is published. Aireon using globally recognized technical performance metrics would provide ANSPs with guarantees that the comparability requirement achieved as a supplier of SB ADS-B data signals meets the key minimum success criteria under ICAO, EUROCAE ED-129B and Eurocontrol specifications

With the introduction of SB ADS-B as an additional data source, it is expected that a short period of operational observation would be required in order to establish parity of the ground-based and space-based data quality. Through the various ongoing technical and safety management activities, each ANSP will assemble evidence to demonstrate to its Regulator that Space-Based ADS-B conforms to the technical standards for a ground based ADS-B surveillance system. We note here that the original specification EUROCAE ED-129 as it applied to a ground station has been augmented to EUROCAE ED-129B to envelop the entire ANSP ground system. ICAO PANS ATM carries the published minima ranging from 5nm enroute, down to 3nm and 2.5nm in the Terminal area. ANSPs continue to work with State regulators to support mandates to upgrade all aircraft operating in certain parts of their airspace with ADS-B equipment

### 6.3 Scenario 2: Surveillance services where VHF is not available

Based on direction and guidance from the ANC, the SASP/2 has recently concluded its work on the Collision Risk Model and the development of Advanced-Surveillance Enhanced Procedural Separation (ASEPS). The SASP/2 has also developed draft Manual “*Guidelines for the Implementation of Separation Minima Using ATS Surveillance Systems where Very High Frequency (VHF) Communications are not available*”. The standards (where VHF is not available) will now go through the ICAO Air Navigation Commission and State Letter consultations for final promulgation in November 2010.

## 7. Benefit Statement

8.1 Safety is our primary objective. The Safety benefits are undeniable and will enable the SAT region to reduce and sustain current airspace risk for its entire area of operations within the target level of safety (TLS). The ability to track all 1090Mhz equipped ADS-B aircraft (including equipped helicopter, bizav & itinerant traffic) provides surveillance tracking capability as also to monitor route and level adherence.

8.2 Primary Improved Safety benefits accruing to “safety net” features such as elements of:

- RAM- Route Adherence Monitoring (RAM)
- ARCW11: ADS Route conformance warning
- CLAM- Cleared Level Adherence Monitoring (CLAM)
- STCA- Short term Conflict Alerts (STCA)
- Safety “buffer” zone beyond airspace boundary provides early identification of coordination errors.
- Improve on pre-emptive benefits by design to avoid Coordination Time errors,
- Awareness (including ‘missing’ flight plans) to detect aircraft ‘not expected’ on
  - boundary point
  - on expected route
  - at expected Time
  - expected Flight Level.

8.3 Benefits are complementary to the requirements defined under Annex 19- State Safety Program & State Safety Oversight.

8.4 Turning to Large Height Deviations, unknown traffic in the South Atlantic and lack of coordination of traffic between ACCs has been identified as two of the major causes of LHD occurrences in the SAT area. It

will be recalled that SAT/22 had been advised about an analysis conducted by NavCanada, regarding the estimated impact of Space-based ADS-B surveillance on Vertical Collision Risk in the ICAO NAT region and how through the use of the system, it was estimated that collision risks could be improve by as much as 77%.

Recognizing that the SAT Group is an informal body constituted essentially of industry partners, Aireon continues to offer its assistance to the SAT group in conducting a similar analysis for the SAT by means of a study and operational trial on the use of Space-based ADS-B data and how it could tangibly improve upon the reduction of lateral and LHD risks. The CARSAMMA had reported 49 LHD occurrences (2015) and Conclusion SAT19/02 notes concern in reducing numbers of LHD reports being received by SATMA.

8.5 Automatic Conformance Monitoring within current ATM systems offers route conformance and cleared level monitoring alert mechanisms based on the Space ADS-B data feed in the SAT. The automation could be configured in ATM systems to automatically alert and log every lateral deviation to enable playback of the event and investigation. It would be clear from the playback what actually took place, the magnitude of the lateral deviation, if the pilot changed altitude in accordance with the contingency procedures etc. This could relieve controllers of having to report such events. The provision of space-based ADS-B data, albeit under an operational trial could be a 'goldmine' for the analytical community because it would enable estimating the actual risk in the airspace, monitor the use of SLOP etc. ATS ground systems can also prioritize and enable immediate recognition by the controller of the lateral and vertical deviations so that the controller has the capability to respond within a reduced time span (45 seconds).

8.6 Aircraft handling at FIR cross-over points can benefit from the ability to "look" 50NM beyond each ANSPs boundary. The space-based data feed can also be used for tactical control. Aireon provides all ANSPs with a standard data buffer of 50nm beyond the FIR. The situational awareness benefits for ATC must also be emphasized here. Additional benefits to ATCOs accrue from increased ATC Capacity by rearranging the sector configuration and reduced ATCO workload by cross-border data flows

8.7 Compliance with ICAO Normal Tracking (NATI) and Global Aeronautical Distress and Safety System (GADSS). The ICAO Normal Tracking Standards and Recommended Practices (SARPs) represents a 1st mandate - that airlines be able to track their airplanes within 15 minute intervals in areas where ATC does receive such position reports. Effective 20 March 2016 and with an Applicability date of 8 November 2018, this ICAO mandate takes effect.

8.8 On 2 March 2016, the ICAO Council adopted a 2nd Mandate for distress tracking. These SARPs relating to the location of an aeroplane in distress and aiding rescue mandates multiple requirement for an aeroplane to autonomously transmit information from which a position can be determined at least once every minute when in a distress condition. The SARPs will be applicable on 1 January 2021. Based on a scrutiny of the requirements of both mandates and the functional capabilities of the Aireon - Global Beacon / FlightAware joint offering, the mandate requirements and associated timelines for compliance will be met.

#### 8.9 Search & Rescue

With respect to supporting Search & Rescue efforts, such feeds could also be considered useful to support the work of Rescue Coordination Centers (RCC) together with the Aireon ALERT service, a free service that will provide the last position of an aircraft in an emergency situation. Registration is planned to start in Q3 - 2018

#### 8.7 Summary of Efficiency Benefits

- Improved efficiency for your customers/operators- i.e. UPRs, DCTs, wx avoidance
- Reduced & more flexible separation standards- i.e. supports PBN with reduced minima
- More clearances to requested route/level, less metering
- Reduced stepped climb/descent
- Increased flexibility in poor weather
- Less delay
- Lower pilot & ATC workload
- Reduced fuel burn & operating time
- Less transactional work for ATC/Pilots

- Potential to have a common hosted ATFM for the entire SAT region
- Data sharing benefits among neighboring FIRs
- CIV-MIL collaboration includes flexible airspace use benefits
- Enable early implementation of key ASBU elements for ATFM, CDM, SWIM etc.

## 8.8 Technical Benefits

- “Surveillance as a service” – “plug and play” ASTERIX 21 data
- Ground infrastructure limited to a connection (service Delivery Point (SDP) set-up.
- Reliance on data feed, no further infrastructural capital outlays or yearly Operations & Maintenance costs incurred by SAT ANSP States
- Reduced reliance on AIDC and automation to look beyond each oceanic boundary

## 8. Studies on Improving Cost Effectiveness & Flight Efficiency

9.1 RTCA: Based on research under the auspices of the RTCA performed in July 2016 by the Enhanced Surveillance Task Group (ESTG) which was tasked to help the FAA in introducing better surveillance methods for U.S. controlled oceanic airspace, the study revealed annual benefits of up to \$440.5 million in fuel burn and reductions of more than 1.2 million metric tons of carbon dioxide. This was done under a Task Force including mainly North American airlines and which was submitted to the FAA.

9.2 Purdue University, USA Study: In December 2016, the School of Aeronautics and Astronautics, Purdue University, USA carried out an academic study focused on the Environmental Benefits of Space-based ADS-B. The report analyzes the potential impact of Space-based ADS-B technology on global aviation carbon emissions in remote and oceanic airspace. Authored by Dr. Karen Marais, the report titled [Environmental Benefits of Space-based ADS-B](#) indicates that the implementation of this technology can offer benefits preventing approximately 14.3 million metric tons of carbon dioxide (CO<sub>2</sub>) from being released into the atmosphere between 2020 and 2030. This is equivalent to removing more than 300,000 cars from U.S. roads each of those years, while making no changes to aircraft design or fuel.

9.3 NavCanada: Airlines too are excited about the potential for space-based ADS-B [NAV CANADA, 2016 ]:

- One large US carrier estimates that better routing, access to higher altitudes as fuel is burned, and variable airspeed can result in annual savings of \$18.25 M, or \$475 per flight.
- Another large US carrier estimates that reduced oceanic separation through access to better altitudes and more efficient trajectories can save 2-4% fuel on average per flight.
- Another carrier estimates that access to higher altitudes and variable airspeeds can save 4.8% fuel per flight on their 777 fleet.
- A carrier operating in the Caribbean estimates that they can save \$5M per year by reducing oceanic delays.

9.4 Flight Safety Foundation: A benefit analysis of Space-based ADS-B was conducted by the [Flight Safety Foundation in 2016](#). The study was conducted in the context of the safety challenges of managing predicted air traffic growth in commercial Air transport over the next 20 years. Numerous potential benefits, mainly related to safety were identified and grouped into the Immediate, Mid-Term and Long-term phases of the Space-based ADS-B program roll-out. Benefits ranged from access to tactical ATC tools and improved safety nets through to strategic ATM enhancements and global harmonization opportunities. FSF felt that the introduction of space-based ADS-B is likely to challenge risk levels in oceanic and remote continental regions that are currently deemed ‘acceptable’ by the industry. Experts interviewed in this report believe that a ‘step-change’ in improved levels of safety was now possible in applying the ‘as low as reasonably practicable’ ALARP principle.

9.6 NAT EFG: In the North Atlantic alone, NavCanada estimates that the 1st phase introduction of space-based ADS-B will deliver a total net present value for SB ADS-B in the NAT Region of USD \$168 Million, which represents a positive business case over its 15 year lifecycle (2019-2033). The total present value of benefits, including fuel and time savings, amount to just over USD \$1 Billion for the 15 year lifecycle. Detailed benefits were qualified as follows:

“The estimated total fuel savings for SB ADS-B per flight in the NAT Region averages 210 kilograms (kg). Of this total, tactical climbs and reduced separation account for 147 kg of fuel savings and 0.2 minutes of time savings, while variable Mach adds 22 kg of fuel savings and 0.1 minutes of time savings per flight. The benefit associated with predictability saves operators 41 kg of fuel per flight “.

9.7 Airlines- JetBlue: Airlines understand the importance of equipping their aircraft with ADS-B transponders. An example is JetBlue, a major low-cost US based carrier with nearly 200 aircraft that has announced plans to equip all its aircraft with Space-based capability for ADS-B. This will allow seamless flight across its entire network and allow its flights to receive FAA Surveillance services outside terrestrial coverage areas. It will also permit JetBlue to rationalize its avionics investment strategy and maximize the value for its investments in meeting the 2020 FAA Mandate for ADS-B and a business case whereby “the dollar will follow benefit”.

## 9. Considerations for SAT Trial

10.1 Aireon is currently collaborating with DECEA and ASECNA to provide surveillance data for a common defined area in the SAT as well as pockets of off-shore activities to benchmark against multiple metrics. Given a large and rich global data set to track end-to-end flight profiles, there are numerous opportunities that could be leveraged and in accordance with the SAT operational needs:

- Plan vs Flow comparisons for
  - Routes, Altitudes, Speeds, Oceanic Separations
- Filed and Flown Routes and Altitudes
- Tactical Conflict Resolutions
- Closest Point of Approach (CPA) set to ANSP separation parameters

## 10. ACTION BY THE MEETING

10.1 The meeting is invited to:

- a) note the information contained in this paper;
- b) support the safety benefits offered by space-based ADS-B and alignment to the work of the SAT CMA in reducing risk in the EUR-SAM Corridor and trials thereof
- c) test and validate any improvements to the EUR SAM Corridor Airspace concept that Space based Surveillance brings (surveillance instead of procedural) and trials thereof
- d) note the revised ICAO Standards PfA released under SASP/2 report for Doc.4444 – Separation Minima using ATS Surveillance systems where VHF voice communications are not available