International Civil Aviation Organization

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Agenda Item 7: Aeronautical Surveillance

ADS-B Implementation: Avionics Standards and Airworthiness Approval Requirements

(Presented by the International Air Transport Association)

Summary

APIRG Decision 16/27 establishes an AFI Aeronautical Surveillance Implementation Task Force (AS/I/TF) tasked with developing a consistent Surveillance Implementation Plan for the Region including implementation target dates, taking into account availability of SARPs and readiness of airspace users and air navigation service providers for a coordinated implementation of service as required.

The AFI AS/I Task Force is expected to complete its work in coordination with APIRG ATS/AIS/SAR and CNS Sub-groups.

This working paper reviews issues related to airspace users' readiness in respect of ADS-B Avionics Standards and Airworthiness Approval Requirements, for consideration by APIRG ATS/AIS/SAR and CNS Sub-groups when addressing their tasks relating to the development of an AFI Surveillance Implementation Plan.

Particular attention is drawn to the various factors that need to be considered from an airlines' perspective in terms of current flight capabilities, and to the need to plan for an all-encompassing and global airborne solution that complements the service offered from the ground-up.

References:

- APIRG/16 Report.
- AFI AS/I/TF/1 Report

1. INTRODUCTION

1.1. The CNS Sub-group participates in the development of an AFI Aeronautical Surveillance Plan in coordination with the ATS/AIS/SAR Sub-group. It particularly analyzes and reviews the CNS aspects of the report of the AFI Aeronautical Surveillance Implementation Task Force.

1.2. The ATS/AIS/SAR Sub-group identifies the ATS requirements for Aeronautical Surveillance (Radar, ADS, Voice, etc.) in accordance with AFI/7 Recommendation 11/1.

1.3. This working paper reviews issues related to airspace users' readiness in respect of ADS-B ADS-B Avionics Standards and Airworthiness Approval Requirements, for consideration by APIRG ATS/AIS/SAR and CNS Sub-groups when addressing their tasks relating to the development of an AFI Surveillance Implementation Plan.

1.4. It refers to DO-242 MASPS *(Minimum Aviation System Performance Standards)* and DO-260 MOPS *(Minimum Operational Performance Standards)*, which form the baseline for the vast majority of current ADS-B implementations. They served as the specification to which the avionics could be designed and built. There are strong relationships in these specifications to ICAO Annex 10 and Mode S transponder MOPS and Technical Standard Orders (TSOs).

2. DISCUSSION

THE CURRENT ADS-B AVIONICS

The Transponder

2.1. The Mode S Extended Squitter Transponder is essentially the core of the ADS-B System. It combines the functions of assembling the message elements, formatting them and transmitting (or squitting) them via the Radio-Frequency interface to the antennas. More importantly, it acts as a data concentrator for all the required input sources, such as the GPS, the Air Data Computer etc. It must be emphasized that the MOPS are written primarily around the functions of the Mode S Transponder, rather than the entire ADS-B Airborne System. There undoubtedly are constraints placed on the reliability of the position source. There are also bounds placed on the accumulated values of airborne latencies. However these and several other parameters that satisfy the ADS-B 'out' application requirements are beyond the scope or control of the MOPS.

2.2. Detailed specifications for the operation of the transponder and the aircraft position source do not take into account the other aircraft avionics systems that have loosely combined to form part of today's airborne ADS-B transmitter. In the majority of cases where aircraft are fitted with Flight Management Systems (FMS), the position source does not currently feed the transponder directly. It comes instead as an input to the FMS, which in turn connects to the transponder via a data bus. Today's airborne ADS-B System is comprised of multiple avionics "boxes" that are loosely assembled in a federated architecture. Each box has its own TSO, but no single TSO completely covers today's ADS-B airborne system specification.

The FMS

2.3. The FMS is a data concentrator for a number of avionics sub-systems. The air data system and a variety of navigation sensors, form the primary inputs directly to the FMS. The FMS is designed and functions to create a composite navigation solution for the aircraft and flight crew. It is however not designed to pass on all this information on to an external and extended process such as ADS-B. As an example, the FMS receives the GPS position with the associated accuracy and integrity parameters. The position is further checked in a hierarchical manner and corrected by means of autonomous Aircraft-based augmentation algorithms. The extension of such information from the FMS to other external applications outside the current architecture is however restricted to position information only. The complete ADS-B data-set being essentially an add-on requirement to an already existing set of aircraft avionics therefore cannot be expected to deliver without redefining pre-existing avionics installations. For the same reasons, the total airborne latency values available to the FMS cannot contribute to the value of the ADS-B data-set.

The Navigation Position Source

2.4. GPS is the only acceptable position source for ADS-B. Most current aircraft are capable of using a number of navigation sources; GPS, IRS, DME-DME, VOR, NDB, etc, however GPS is the only navigation source that provides position, accuracy and integrity. These parameters are derived from the Latitude and Longitude: HFOM and HPL: Horizontal Protection Limit and Horizontal Figure of Merit respectively. The altitude component is the Barometric Altitude, and derived from the same source as utilized for Mode C.

2.5. Due to satellite geometry, there can be brief periods when HPL is unavailable. Whether the ADS-B target is coasted by the tracker, as in a radar environment, or the ADS-B surveillance service is suspended for a period of time, the Safety Analysis will ultimately determine the optimum means of dealing with the outage. It is important to note, that this is an availability issue, and therefore (can and) must be mitigated on the ground, in the air or a combination of both. It is not a safety issue.

Mode 3/A Code (SSR Code)

2.6. Many States still depend on legacy systems which require the Mode 3/A code for Flight Plan correlation. Added to this, is an Air Traffic Control (ATC) cultural mindset that is difficult to change. The controller assigns the SSR code to the aircraft and in this way ensures that the flight plan and target correlation are under their control. This is a completely different methodology to the Mode S environment, where correlation is enabled by the ICAO 24 Bit address and the Flight identification (Flight ID). Both Mode S and ADS-B messages have 24 bits of parity and error correction, the 24 Bit address is linked to one particular aircraft, and the Flight ID is set by the flight crew, as per the filed flight plan. This provides a far higher level of confidence in the target and flight plan correlation, but it is different in the sense, that with MODE S and ADS-B, these parameters are sent by the aircraft, and not assigned by an individual controller. Europe has a Mode S mandate, and therefore ATC are more used to the newer technology, and the transition to ADS-B, thus simplified.

2.7. The Mode 3/A code is available in the aircraft, and provided to the transponder, but the ADS-B message set had to be modified at a later date to include it.

Generic Emergency Code- Special Position Indicator (SPI)

2.8. In an SSR environment, there are three distinct Emergency codes: 7500/7600/7700. These codes are selected by the Flight Crew, sent as part of the radar reply, and appropriate action taken by Air Traffic Control (ATC). When the Flight Crew sets one of the three 7000 codes, the ADS-B ground system only sees a single emergency indicator. Air Traffic Control has to then institute procedures to determine which of the emergencies is in effect. Procedures have been developed by the implementing States to deal with this situation, but it still remains as an issue which is not present in an SSR environment.

2.9. SPI works the same way in both SSR and ADS-B environments, and therefore requires no mitigation. When an Air Traffic Controller issues the “Squawk Ident “command, the results will be identical.

TSO C129 GPS Receiver as Primary Navigation Source

2.10. It is assumed that a direct GPS signal will be the only useable position source for ADS-B. The vast majority of the current fleet is equipped with TSO C129 GPS receivers. It would be unrealistic to publish any ADS-B specification today, completely discarding the reliability and availability of the GPS signal via this source. Requiring an SBAS receiver due to its higher availability as a GPS position source, immediately eliminates the entire worlds’ airline fleet.

2.11. As a surveillance tool, ADS-B has proven to easily equal or surpasses the performance of SSR. A TSO 129 receiver is fully capable of supporting the ADS-B ‘out’ application. Every State (or

Air Navigation Service Provider), that has analyzed the performance of the application concluded that the demonstrated availability, accuracy and integrity are sufficient for the intended application.

2.12. ADS-B 'out' implementations technology has opened the door to a wide variety of applications other than 'radar-like' surveillance. ADS-B IN, CDTI, ASAS based on ADS-B rather than TCAS, ground surveillance applications and many others.

2.13. The basic TSO C129 receiver that pre-existed ADS-B 'out' services is evolving to include Fault Detection and Exclusion (FDE) and Selective Availability (SA) Aware, further improving integrity, accuracy and availability. But is it capable of supporting these emerging technologies?

CURRENT AIRLINE FLEET STATUS

2.14. Enhancing TCAS capability and the European Mode S mandate were the two driving factors behind air carrier Mode S equipage. Extended Squitter (as per ICAO Annex 10) was being included by the avionics manufacturers and GPS had become the standard for navigation. All these factors combined resulted in a fleet of over 10,000 air transport aircraft squitting DO-260 based ADS-B messages. There were no State implementations, except the various test scenarios, and more importantly, there were no existing aircraft certification frameworks.

2.15. Compounding this situation, were the various technical papers being written and distributed, proposing ADS-B as a replacement technology for outdated and expensive SSR surveillance. There was also a moderate level of customer demand for surveillance in non-radar areas, and a desire from the airlines to achieve some benefit from the avionics which they had already paid for.

EVOLUTION OF THE AVIONICS

2.16. It is evident from the foregoing that the current level of avionics will have to evolve considerably in order to meet the new requirements. Great care must be exercised before committing to changes.

The Airborne Avionics System

2.17. One of the major criticisms of the current ADS-B regulatory documents is their failure to capture and address the complete airborne application and airworthiness system. As explained previously, it is very difficult to implement new capabilities within the framework of including pre-existing avionics. For example: How could DO-260 mandate a specific latency limit for an FMS *(Flight Management System)*, which is already certified and installed on the aircraft? This would result in an unacceptable situation where a TSO issued to one piece of equipment (transponder), negated a TSO already assigned to a different piece of equipment (FMS).

2.18. RTCA addressed this issue with the publication of DO 302r1 STP MOPS (Surveillance Transmit Processing). This document attempts to define the performance of the airborne system, in such a way as to stipulate the necessary performance required of each component. The FMS would be responsible to assign integrity and accuracy parameters to its output, regardless of which input source was selected. Although currently under revision, this is a very important document, and should be considered for all future implementations. One also must realize that it will be years before we actually have equipment built to this standard.

The GPS Position Source

2.19. One of the most significant developments in aviation is the acceptance of GNSS for navigation as a safety service in all flight phases. It was a logical progression to ADS-B for surveillance, and ground based navaids will continue to be replaced by GPS. RNP, RNAV, ADS-B, FANS are all dependent on GNSS. RNP/RNAV is possible with a good infrastructure of ground based navaids, but they do not exist everywhere, and they are costly to install and maintain. GNSS provides integrity and accuracy, whereas ground based navaids do not. Consider a situation where the safety constraints required from GPS were to be placed on the traditional navaids infrastructure, and it will be immediately evident how far we have progressed. Space-based augmentation (SBAS) of the re-broadcasted signal by way of geo-stationary satellites was a logical extension of GNSS. The US WAAS *(Wide Area Augmentation System)* program was late being delivered costed over $3 billion and not without its share of problems. But it is available now. Additional GNSS constellations and (as yet non-operational) SBAS systems elsewhere e.g. EGNOS *(European geostationary navigation overlay service),* MSAS *(Multifunctional transport satellite (MTSAT) Satellite-based Augmentation System)*, GAGAN *(GPS and Geostationary Earth Orbit Augmented Navigation)* etc. will continue to add to this functionality.

SBAS (WAAS) GPS Receivers on Commercial Aircraft

2.20. The inclusion of SBAS receivers into the ADS-B 'out' equation comes with its own complexities. As mentioned in earlier sections, this receiver is designed specifically for the SBAS service.

2.21. From an equipage perspective, no airline today is equipped for the SBAS application. For an airline today to equip for an SBAS receiver is just not justified in order to benefit from ADS-B applications when the existing radar network already provides for the very same functionality. The cost business case for retrofit just does not hold. In terms of forward-fits, both Airbus and Boeing will only provision for a given airline requirement. This is currently non-existent.

2.22. The proposed upgrade path from traditional C129 receivers to SBAS receivers is predicated on a software filter that serves to eliminate the signal to noise ratio from the squitted ADS-B output, better than currently done on the C129 receiver. It must be mentioned here that the recommendations to replace airline GNSS receivers (C129) with SBAS (145/146) receivers only serves to improve the 'readability' of the ADS-B report and with a lower latency. SBAS as a service must not be considered in this context; it is the GNSS receiver replacement in question.

2.23. The manner in which these mandates are being put forth and their value in supporting a required level of ADS-B service must be carefully thought out in context of the requirements.

2.24. In the final analysis, we are left with 3 possible choices

1. Stay with the current GNSS receivers (C129) and the level of service provided by SSR radars

2. Software upgrades to the current GNSS receivers for SA Aware- thus increasing position availability and latency

3. A next generation of GNSS receivers that will accommodate GPS, Galileo, Compass, GLONASS etc.

2.25. For these reasons, IATA'position is one to stand firmly against any moves to create a requirement for SBAS (145/146) receivers and eventually mandate them as the FAA ADS-B out NPRM[1] would suggest.

[1] *NPRM - Notice for Proposed Rule Making - Summary of Requirements:*

1. *The Ground System will be completed by 2013, in all areas currently served by surveillance*
2. *Airspace user's must be equipped by Jan 1, 2020*
3. *Ruling covers Class A, B, C airspace, and Class E above 10,000 Ft.*
4. *Above FL 240, aircraft must use the 1090 Mhz link*
5. *UAT link aircraft are confined to FL 240 and below.*

- The manufacturers must design and manufacture the receivers, and obtain certification. This exercise is well underway, with many products already available.
- The manufacturers have to meet the demand, and be capable of supplying units in the required quantity to meet airspace mandates.
- Airbus and Boeing have not indicated support for SBAS. The manufacturer must go through a design analysis program for each aircraft type.
- STCs must be developed in order to modify existing aircraft not under manufacturer's control.
- SBAS receivers may impact other airborne systems, and a plug-in replacement for C129 units may not be possible in every case. SBAS receivers typically supply a separate Time Mark, and have higher update rates than a C129 receiver. (0.2 Sec vs. 1.0 Sec)
- The airlines would only be able to upgrade during maintenance cycles, followed by testing, crew training, documentation upgrades (Aircraft Flight Manual/Pilot Operating Handbooks).
- The certification burden is imposed on the airline, as it has been for Acceptable Means of Compliance (AMC) 20-24. This adds to an already substantial implementation cost.

THE WAY FORWARD.

2.26. There are many issues which need to be considered, and they all must be viewed with three critical items in mind:

2.27. The first is always safety, and the second must be flight efficiency. The third is airspace utilization and efficiency. The airlines continue to languish in one of the worst economic downturns- ever in the history of the air transportation industry. They however remain supportive of new and emerging technologies. But each new technology must be dictated by user requirements and not vice-versa, as is the case today.

2.28. ADS-B can improve safety, increase effective airport, terminal and enroute capacity. It can provide for cost-effective alternatives to ground installations such as SSR radar. It can migrate the aviation paradigm from a ground-based one to a globally resilient space-based system. In areas where ADS-B as a 'radar-like' service replaces procedural separation, it increases effective capacity by a factor of 12. It can provide more efficiency, optimality across FIRs, which in turn saves time and fuel with the resulting CO_2 avoidance. This is reflected in lower operating costs, which offsets the avionics and certification expenditures. States must seize all opportunities to complement existing avionics with complementary ground solutions, such as ADS-NRA (non-radar airspace) where a clear business case exists. It is equally vital that States actually begin to provide these services once the installations are completed.

COSTS

2.29. Beyond the basic need for collaboration, IATA further emphasizes a major role for incentive schemes where new technologies increasingly place the onus of costs on the cockpits. The avionics costs are variously estimated at USD$40 billion on a global basis. Airlines cannot be expected to shoulder the entire burden of State programs as they migrate the investments from the ground into the cockpit.

2.30. Ways, often driven by innovative business models must be found to offset and correct the imbalance in the avionics costs. A further balance needs to be struck between costs and performance. A sound business case should clearly demonstrate the tangible benefits that moving away from the current SSR will bring in flight efficiencies, capacity and infrastructural costs.

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6. *Avionics must comply with DO-260A CH2, TSO C166a*
7. *UAT avionics must comply with DO-282A, TSO-C154b*
8. *Minimum Position Source parameters are:* $NAC_P = 9$, *NIC = 7, SIL = 2, Latency* ≤ 1.0 *Sec.*

CONCLUSION

The Airline Perspective

2.31. The central issue for the airlines must be a sound business case. Every upgrade to the airborne systems must be shown to generate a return on investment. A considerable amount of money has been invested to meet current airspace requirements: the MODE S mandate in Europe, the ADS-B initiatives, TCAS, RNP/RNAV etc. The current ADS-B 'out' programs have been quite successful, because they have been structured around the existing avionics. The existing airborne ADS-B avionics were paid for long before any airspace benefits were available. As the standards evolve, and the airspace is restructured around ADS-B for surveillance; there must be a single question at the top of the list:

"What are the maximum benefits we can derive from the currently approved avionics?"

- ANSPs have valid reasons to adopt ADS-B. It is much less costly than radar, and requires far less maintenance. If the use of ADS-B in terminal areas requires substantial upgrades to the avionics, then the airlines are inclined to tell the ANSPs to keep their terminal radars. The States who have Mode S airspace, and do not require the transmission of the Mode 3/A code, are best able to utilize the current DO-260 avionics.

- Exactly the same argument applies to the use of ADS-B for Surface applications. There are other technologies available (MLAT), which will perform the same function without upgrades to the avionics. Airports still have a large population of aircraft with Mode A/C transponders rather than Mode S; and MLAT will capture those aircraft, whereas ADS-B will not.

- The vast majority of airliners are currently equipped with C129a GPS receivers, and the operators want the best return on their investment.

- There is no question that an SBAS receiver would provides a stronger noise-free signal, but one of the most important aspects of DO-229 (WAAS MOPS), is that it is fully configured for SA AWARE and FDE. These two characteristics are the major contributors to increased performance and not the issue of whether in a WAAS coverage area or not.

SA Aware and FDE Capabilities

2.32. This point cannot be overemphasized, as in many (if not all) cases. SA AWARE and FDE can be added to existing C129a receivers, via software upgrades. Rockwell Collins is advertising this capability on its corporate website, for the GLU-920 MMR *(Multi-Mode Receiver)*. Maximizing the performance of the installed C129a GPS receiver therefore must remain the priority until a future DO260X standard is developed. An interim software upgrade based on consultations and agreements with users may however be considered if it can be demonstrated that it does indeed provide the most cost efficient upgrade for the airlines.

THE IATA SOLUTION

2.33. IATA, as a single focal point, representing over 230 airlines globally, proposes the following approach:

- Phase One. Maximize the benefits of Acceptable Means of Compliance (AMC) 20-24 in the ADS-B 'out' operating environment. The non-radar (NRA) environment is where ADS-B 'out' in its current state can be leveraged most effectively. Capacity and fuel efficiencies can be improved by a factor of 12 or more. The number of aircraft currently, or about to be approved, is a powerful argument.

- Phase Two. Maximize the performance capabilities of the C129a receivers. An upgrade to include SA Aware and FDE might be considered a practical option for forward-fits. This upgrade should not require re-certification, and may be sufficient for the majority of implementations. Retrofits must however be evaluated on a case-by-case basis based on a sound Safety assessment by each State and as a last recourse, on the understanding that the signal availability issues cannot be mitigated on the ground.
- Phase Three. Drive the final evolution of ADS-B avionics to meet the end-state global requirements of Trajectory-Based Operations (TBO). Develop globally acceptable Standards and Requirements for Origin Equipment Manufacturers (OEMs), ANSPs and Airlines. Define globally acceptable Airworthiness and Certification Standards for States, OEMs to build to and certify. Adopt the final DO-260 (X) transponders and complementary GPS receiver upgrades (if required). Devise a final standard that safely and efficiently integrates all cockpit based applications with the end-state Trajectory-Based Operations requirements.

2.34. The meeting may wish to acknowledge the importance of:

- Implementing enroute services that deliver for current solutions using current avionics that deliver immediate ADS-B ‘out’ services in the non-radar environment. Implementations in Canada and Australia have demonstrated that it is possible to do so and in a safe manner. State certification and Airworthiness requirements have also demonstrated that such an implementation is possible in a harmonious manner.
- Using the “lessons learned” experience, to also plan for a robust and harmonious architecture for future ADS-B applications in ATM. This common and all-encompassing system definition should meet the more demanding and full suite of ADS-B applications in all phases of flight.

3. CONCLUSION

3.1. When reviewing and analyzing the Report of the AFI Aeronautical Surveillance Implementation Task Force, the meeting is invited to:

a) Agree that:

1. Any ADS-B short-term technology solutions must recognize current airplane capabilities and investments;
2. Any ADS-B future technology definitions must be based on a sound case for efficiency, capacity and globally accepted air carrier-driven solutions; and

b) Accordingly ensure that this approach is reflected in the AFI Surveillance Strategy.

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