



ICAO

*International Civil Aviation Organization***Twenty Sixth Meeting of the Communications/
Navigation and Surveillance Sub-group (CNS SG/26) of
APANPIRG**

Video Tele-Conference, 5 – 9 September 2022

Agenda Item 7: Surveillance

- 7.1 Review Report of Sixth Meeting of the Surveillance Implementation Coordination Group (SURICG/7), including:
- Report of the Fifth Meeting of Mode S Downlinked Aircraft Parameters Working Group (Mode S DAPs WG/5);
 - Report of the Second Meeting of the Surveillance Study Group (SURSG/2).

**OUTCOMES OF THE SEVENTH MEETING OF THE SURVEILLANCE
IMPLEMENTATION COORDINATION GROUP (SURICG/7)**

(Presented by Secretariat)

SUMMARY

This paper presents the outcomes of the Seventh Meeting of the Surveillance Implementation Coordination Group (SURICG/7) for review and action.

1. INTRODUCTION

1.1 The Seventh Meeting of the Surveillance Implementation Coordination Group (SURICG/7) was held from 24 to 27 May 2022 via video teleconference. The meeting was attended by 117 participants from 21 States/Administrations, 4 International Organizations and 2 service providers from industry (IATA, ICCAIA, IFATCA, RTCA, CDATC and PCCW Global). The SURICG/7 meeting considered 12 working papers, 17 information papers and 1 presentation and endorsed three (3) Draft Conclusions for consideration and endorsement in CNS SG/26, and adopted one (1) Decision. The meeting report, working papers, information papers and other resources can be accessed at <https://www.icao.int/APAC/Meetings/Pages/2022-SURICG-7.aspx>.

1.2 SURICG/7 reviewed the report of the Fifth Meeting of Mode S Downlinked Aircraft Parameters Working Group (DAPs WG/5) which was held from 23 to 25 March 2022 via video Tele-conference. DAPS WG/5, together with the APAC Regional Workshop on Mode S Implementation held on 22 March 2022 before the meeting, was attended by 114 participants from 18 States/Administration and 2 International Organizations. The DAPs WG/5 meeting report, working papers, information papers, and other resources can be accessed at <https://www.icao.int/APAC/Meetings/Pages/2022-Mode-S-DAPs-WG5.aspx>.

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1.3 SURICG/7 also reviewed the report of the Second Meeting of the Surveillance Study Group (SURSG/2) which was held from 15 to 17 March 2022 held via video tele-conference. The meeting was attended by 97 participants from 16 States/Administration, 2 International Organizations and 1 industry partner. The SURSG/2 meeting report, working papers, information papers, and other resources can be accessed at <https://www.icao.int/APAC/Meetings/Pages/2022-SURSG2.aspx>.

1.4 This paper summarized relevant information and updates from the meeting.

2. DISCUSSION

2.1. The summary of discussion in the meeting is given in following paragraphs.

Outcome of Relevant Meetings on Surveillance (WP/02)

2.2. The meeting reviewed relevant information and updates on Surveillance and related matters arising from SURICG/6, CNS SG/25 and APANPIRG/32.

2.3. The meeting noted the discussion during CNS SG/25 on points of contact for CNS for timely, effective, and efficient response from States/Administration, which was important in addressing CNS-related operational deficiencies notified to the Regional Office. The meeting supported the suggestion from the ICAO Secretariat on the need for DAPs WG to set up the list of Points of Contact for Mode S matters, such as the Mode S Interrogator Identifier (II)/ Surveillance Identifier (SI) code coordination.

2.4. The SURICG Co-Chair suggested that States to present surveillance related implementation matter in SURICG or its contributory bodies meetings first before considering to present in higher level meetings such as CNS SG / APANPIRG.

Review Report of Mode S DAPs WG/5 (WP/03)*APAC Regional Workshop on Mode S Implementation*

2.5. The Workshop organized in conjunction with the Mode S DAPs WG/5 was moderated by Mr Ho Wee Sin, Co-Chair of Mode S DAPs WG, and presented by Mr Chen Yang (Isaac), an experienced radar engineer who was recommended by the Air Traffic Management Bureau (ATMB) of Civil Aviation Administration of China (CAAC). Mr Robert Witzen supported the presentation. The Workshop discussed various topics under Mode S operations and know-how of flight inspection to a Mode S Radar, and the introduction of APAC's proposed modifications to Appendices H and J of Doc 9924 to facilitate the implementation of Mode S.

Update on Interregional IC Coordination

2.6. The latest updates about the procedures on Interrogator Codes (IC) interregional coordination were discussed at a virtual meeting organized for technical officer CNS, ANB, and all ICAO Regional Officers CNS on 20 January 2022 to review and understand procedures established for SSR IC code assignment and Inter-regional coordination mechanism. This 20 January 2022 meeting reviewed the relevant documents for SSR IC code assignment and inter-regional coordination mechanism including excerpts from Annex 10 Volume 4 and Doc. 9924; an example of coordination conducted by APAC Region; a presentation on the coordination using SSR Module of the Frequency Finder tool and its future improvements; and a secretariat paper on International and inter-regional coordination of Mode S II and SI codes, and the outcome of this discussion was summarized into a draft procedure.

Guidance Material for Assignment of Interrogator Codes (IC) for MLAT and ADS-B

2.7. During Mode S DAPs WG/2, it was discussed whether interrogators that come with ADS-B need to be assigned with a distinct IC. Current practices suggested that II=0 can be used. However, the existing provisions in ICAO documents are not clear to the reader and can be confusing. The Surveillance Panel Aeronautical Surveillance Working Group is working on revising the text in the SARPS and guidance material. The paper provided the updates on the proposed amendments to Annex 10 Vol IV and ICAO Doc 9924 Appendix M which have been endorsed by the Technical Sub-group in Feb 2022. It will be further discussed at the Aeronautical Surveillance Working Group in Apr 2022 and subsequent meetings before its formal adoption.

Reservation of IC Codes for Research and Military

2.8. The feasibility for the APAC Region to adopt the practice of reserving II code 14 for testing, research, and development of Mode S Radar and II 15 for military deployable and shipborne radar was discussed, and the practices in Europe and Australia were referenced in the meeting. An initial study was conducted on current situation in APAC and showed that not all current Mode S radars that are on II 14 and II 15 can be re-allocated to other codes in the II range 1-13 to ensure code uniqueness. Considering States are modernising with Mode S radars, APAC is in the direction of migrating from II to SI code to create capacity for more Mode S radars. An Action Item was recorded to decide when a significant number of radars migrated from II to Surveillance Identifier (SI) codes with ICAO APAC Office to make a conscious effort to avoid allocating II 14 and 15 (and the matching SI codes) to new radars unless due to capacity issue.

Options for Vacating the SSR Mode S II Codes 14 and 15 in the APAC Region

2.9. This paper provided the detailed analysis conducted by ICAO Mr Robert Witzen on the feasibility to replace the existing II codes 14 and 15 with the other codes within the range 1 to 13 using SSR II code module in Frequency Finder tool. Outcome of the study showed that it was not possible to replace all the existing II code 15 in the APAC Region, and in geographical area around Japan and Malaysia, the option of using alternative II codes is very limited and the alternative codes may be needed for additional Mode S II code assignment. For II Code 14 there were three (out of 15) current assignments to II code 14 that have no alternative II codes that are fully compatible with the planning criteria for SSR Mode S II codes. States were invited to provide necessary radar information to ICAO APAC Regional Office for II/SI code coordination.

Update on Mode S IC Code Module in Frequency Finder

2.10. The latest enhancements and functionalities brought to the SSR module of the Frequency Finder tool to assist ICAO Regional Offices and States to manage and coordinate SSR Mode S II/SI codes were presented. With the need for APAC Region to introduce SI code was identified, relevant change proposals to DOC 9924 are being reviewed in Surveillance Panel and these changes will be reflected in the Mode S IC Code Module to assess the compatibility of both Mode S II and SI Codes. The updated Frequency Finder tool is being tested by ICAO Head Quarters and APAC Regional Office and will be released in 2022. A demo was presented by Mr Robert Witzen in the meeting to show the interface and functions for updated Mode S IC Code Module. The meeting was invited to make extensive usage of the updated module, and provide feedback such as usage, suggestions, bugs and recommendations on the updated Frequency Finder tool.

An Abnormal Problem of CPR Decoding caused by the Incorrect Air-ground State of an Aircraft in China

2.11. China introduced an abnormal Compact Position Reporting (CPR) decoding problem caused by the airborne aircraft transmitting the Surface Position state, and proposed the corresponding solution. A case of ADS-B target position jumped was analysed by decoding the DF17 message

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received, and concluded the source of error was due to an airborne aircraft mistakenly transmitted a Surface Position state message by comparing different fields in various messages. Optimizing methods including initialisation state CPR check and change local-decode method, with the logic of CPR message processing, were introduced in depth.

Mode S Interrogator Codes Allocation and Conflict Analyses

2.12. China shared the information about their Mode S II codes allocation principles and the related conflicts with neighbouring countries. There are 140 SSRs in service in China, with 78 of them are Mode S radars and allocated II codes between 1-13. II code 14 and 15 are reserved for test and military respectively. Without the usage of SI codes, II codes are a shortage in the eastern coastal areas in China. Therefore, interrogation strategies of all-call lockout override protocol, roll-call non-lockout, or intermittent lockout commands have been set to radars with overlapping coverage. To solve the II codes shortage issues effectively, China centralised allocation of II codes, analysed conflict of code allocation inside China and with neighbouring countries. China recommended the release of II 14 for civilian radars and reserve II code 15 for both testing and military purposes. China actively supports ICAO APAC as the centre for the distribution and coordination of II codes in the APAC region. China will also further confirm the issue of II code conflicts with neighbouring countries and apply to ICAO APAC for coordination.

Progress on the Trials of Mode S Surveillance Co-ordination Network in China

2.13. China informed DAPs WG/5 about the implementation background and progress of the trials on Surveillance Co-ordination Network (SCN) of the Mode S secondary radar in China. Based on results, China plans to formulate guidelines to regulate the SCN structure, operation mode, and corresponding interface. The trial of SCN implemented surveillance co-ordination functions (SCF) such as target information sharing, track fusion, and smoothing among multiple radars, thereby improving the quality of target detection in a specific area. The implementation of SCN could solve the problem of insufficient II code; alleviate 1090MHz spectrum occupancy; and overcome defects by a single radar source. The Mode S SCN trials in China are carried out in three stages which are expected to complete by end of 2022.

Upper Air Wind Speed Estimation based on Mode S SSR DAPs

2.14. China introduced the research for upper air wind speed estimation based on Mode S SSR DAPs and discussed the issue of airborne magnetic deviation from DAPs. Wind speed estimation includes completed part of aircraft observed wind speed estimation and its verification; and the regional wind speed estimation is in progress and further results verification required. The paper explained the estimation progress and the data used in detail. Observing the data of aircrafts on the runway, certain error was observed for magnetic deviation. The paper introduced how they worked around with the issue in their estimation.

Suggestions of Performance Parameters and Benchmarking of Radar System for APAC Region

2.15. China presented a brief overview of the radar performance parameters included in the Guidance Material on Surveillance Technology Comparison (GMST) and Doc 8071 Vol 3, and proposed some suggestions for the related study of the radar performance parameters study group. General surveillance system performance parameters, issues to be considered and recommended performance parameters are summarized. The paper recommended to study the radar performance parameters based on the GMST and Doc 8071 Vol3, and develop corresponding standard software for the test and analysis of the above parameters according to the research results. China was suggested to consider taking lead in the ad-hoc group for responding in a WP in SURICG/7. While EUROCONTROL Specification for ATM Surveillance System Performance (Volume 1) Edition 1.1 issued in September 2015 was suggested for additional reference, some commented that this document could be too complex to refer

to and it lacked the necessary measurement on performance.

SI Operation Plan at Incheon Airport

2.16. ROK reported their 15-day trial of using SI code in Incheon Airport, and their future plan to adapt Mode S SI operation at the Incheon airport to expand Mode S IC availability. The paper reported that the target detection performance of SI code was same with II code, and provided update information about the SI operation at Incheon airport, including a summary of SI operation test results from DAPS WG/4 IP/07. The paper suggested that SI flag must not be used to decide the capability of SI/II at transponders. The radar issues lock-out command to SI capable transponder leaving non-SI capable transponder to reply to all-calls. Incheon airport is planning to install a third PSR/MSSR by 2023, which will use SI code as all II code already allocated in Republic of Korea. Considering a reduced number and types of aircraft being flown during the pandemic, ROK agreed for a more thorough test could better warrant the performance of SI operations.

A GPS Interference Identification Method based on ADS-B Data

2.17. China introduced a GPS interference source identification and screening method in civil aviation operations. Using the changes of aircraft ADS-B report data, combined with the change rule of historical data when GPS was interfered and the principle of satellite navigation signal, this paper presented the construction of an index of GPS interference, which can check and locate interference area and time sensitively. By providing two examples of GPS signal interference and illustrating the change pattern in ADS-B data, it was shown that when NIC index changes due to GPS interference, ground speed and position information would also change. If only NIC changed but other indicators do not, GPS interference did not occur in most cases. Such analysis of GPS signal could be applicable to other States as the method introduced analyses ADS-B report data.

An Evaluation Example of a Non-Cooperative Method for DAPS Data Recognition

2.18. Japan introduced an evaluation result of a non-cooperative DAPs data recognition and determination method, which may enable DAPs data interception and avoid BDS swap phenomenon. As reported in previous DAPs WG meetings, a candidate solution was proposed in SURICG/6 via IP/19 by China, and ENRI evaluated the basic mechanism of the method using measurement data from our experimental SSR. The BDS code in a reply is estimated by examining agreement with the standardized message format. Some values, such as the Mach number, must be within the physical boundaries. It is noted that the original method including identification of BDS 50 and 60 by comparing with ADS-B was not conducted in the evaluation. Further improvements such as adding a new physical boundary were made in our evaluation. An experimental Mode S SSR was set up in the ENRI campus in Tokyo. BDS was estimated by using only the reply data, and the estimated result was compared with the correct BDS known from the interrogation data. Good performance of high success (estimated BDS agreed with the transmitted BDS) on BDS 20, 40, 50 and 60, showing the potential of the proposed method. Future evaluation includes other BDS such as 10, 17, 30 and performance improvement. The meeting identified that this evaluation exercise from one State independently verified the study and model done by other States, which was an example of a great collaboration.

Management of 1030/1090MHz Utilization

2.19. The utilization of the 1030/1090 MHz frequencies has greatly increased in certain areas of the world. If no action is taken, the situation will reach an unacceptable level that will result in harmful corruption or loss of information to the aeronautical surveillance and collision avoidance systems, resulting in an increase in the probability of mid-air collisions, disruption to Air Traffic Services, and a reduction in airspace efficiency. It must be ensured that the spectrum capacity is being utilized in the most efficient way to preserve the performance of current systems and to consider future applications that require an increase in capacity. The Surveillance Panel therefore established the Surveillance

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Spectrum Focus Team (SSFT) in September 2019 to look into the overall issue of 1030/1090 MHz utilization, including the impact of evolving systems that will potentially share the 1030/1090 MHz link contributing to the spectrum load. It also covers examining techniques and capabilities that could be considered to reduce 1030/1090 MHz congestion. The SSFT will develop specific solutions, which can be transferred into Proposals for Amendment for Annex 10 Volume IV or change proposals for ICAO Manuals. A list of identified issues related to 1030/1090 MHz spectrum load and possible mitigations is provided in Annex A to the paper. Information on affected ICAO documents and specific aspects like regulations and already available standards were also provided. All material is considered as a basis to formulate appropriate text for ICAO SARPs and guidance material.

Roadmap on Mode S Implementation for APAC Region

2.20. The ICAO Secretariat summarised the history of the Roadmap on Mode S implementation for APAC Region and proposed the future work on it for information and attention by the meeting. Being one of the key deliverables since established, this Working Group has continued its effort and the Roadmap was adopted as Conclusion **APANPIRG/32/10 (CNS SG/25/09) - The APAC Regional Roadmap for Mode S Implementation**. The adopted Roadmap was circulated through State Letter with ref: T 8/5.11-AP200/21 (CNS), Subject: Mode S Implementation in APAC Region, dated 22 December 2021. The meeting was informed that the Roadmap is a regional planning reference to provide certainty to stakeholders in the near term, while as a living document which is subject to change with the revision of APAC Surveillance Strategy and the new relevant outcome from Assembly 41st Session.

Planning Criteria for II/SI Code Assignment

2.21. The ICAO Secretariat presented the planning criteria for the coordination and planning of SSR Mode S II/SI codes, which was in line with the modifications to the Aeronautical Surveillance Manual (Doc. 9924) which was coordinated by the APAC Team and approved by the Technical Sub Group of the Surveillance Panel (SP/TSG). The paper introduced an initial Mode S II/SI code assignment planning based on the need to accommodate transponders, and the consideration of II/SI Code assignment planning criteria under different combinations of these criteria, which are further summarized in the table for ease of reference for the planning of Mode S II/SI code by States. The meeting thanked Mr Robert Witzen for his dedicated effort in summarising all the necessary requirements for consideration by States into this concise and precise paper.

Updates to the Mode S DAPs Implementation and Operations Guidance Document

2.22. China proposed the revised draft of Edition 4.0 of the Mode S DAPs Implementation and Operations Guidance Document, developed based on the adopted edition 3.0. The revised draft supplemented the guidance material of ADS-B DAPs, including:

- Introduce ADS-B DAPs and their benefits
- Describe ADS-B DAPs data and the differences between Mode S SSR DAPs and ADS-B DAPs
- Supplement the mandate of implementing ADS-B DAPs, and the Mode S extended squitter transponder capability to broadcast ADS-B DAPs
- Add a new section to describe ADS-B DAPs broadcast by Mode S extended squitter
- Insert the application of ADS-B DAPs in the ATM automation system
- Give one example of ADS-B DAPs application

2.23. Other amendments included the revision of the description of the use of Mode S DAPs data for the weather forecast, the addition of a new appendix about guidance on measurement of 1030/1090 MHz usage. Upon review and discussion, SURICG/7 endorsed the updates to the IGD as in the following Draft Conclusion for further consideration CNS SG/26:

Draft Conclusion SURICG/7/1 (DAPs WG/5/1): Mode S DAPs IGD 4.0	
What: The Mode S DAPs Implementation and Operation Guidance Document Edition 4.0 provided in Appendix A to this Paper be adopted	Expected impact: ☐ Political / Global ☐ Inter-regional ☐ Economic ☐ Environmental ☒ Ops/Technical
Why: The revised draft includes ADS-B DAPs and adds guidance on the measurement of 1030/1090 MHz usage.	Follow-up: ☒ Required from States
When: 19-Aug-22	Status: Draft to be adopted by Subgroup
Who: ☒ Sub groups ☐ APAC States ☐ ICAO APAC RO ☐ ICAO HQ ☐ Other: -	

Review of Terms of Reference

2.24. SURICG/7 reviewed and deliberated the proposal from DAPs Working Group to rename the Group and update its Terms of Reference (ToR) to better reflect the current work scope that covers not only DAPs but also Mode S radars. After deliberation, SURICG/7 considered it appropriate to rename the Group as “Mode S and DAPs Working Group”, and the relevant contents of the ToR were updated accordingly, provided in **Appendix B to this paper**, and endorsed in the following Decision:

Decision SURICG/7/2 (DAPs WG/5/2): Revised ToR of the Mode S and DAPs Working Group	
That, the Revised Terms of Reference of the Mode S and DAPs Working Group provided in Appendix B to the Report be adopted.	Expected impact: ☐ Political /Global ☐ Inter-regional ☐ Economic ☐ Environmental ☒ Ops/Technical
Why: SURICG/6 suggested that DAPs Working Group be renamed, and its Terms of Reference be amended to better reflect the current work scope that covers not only DAPs but also Mode S radars.	Follow-up: ☐ Required from States
When: 19-May-22	Status: Adopted by SURICG
Who: ☐ Sub groups ☐ APAC States ☐ ICAO APAC RO ☐ ICAO HQ ☐ APANPIRG ☐ Other: -	

Clarification of II/SI Code Allocation in Doc 9924 Appendices H and J (IP/03)

2.25. China, Singapore and the ICAO Secretariat shared the current proposals for amending the Aeronautical Surveillance Manual (Doc. 9924) Appendix H and J. Amendments in Appendix H will clarify the steps that can be taken to secure a safe introduction of Mode S II/SI capable interrogators and transponders with the focus on an environment where both Mode S II only and Mode S II/SI capable systems are being introduced. Amendments in Appendix J will update the Mode S II code assignment planning with Mode S SI code and provide for compatibility with Mode S interrogators and transponders that are not Mode S SI capable. Enhancement of the material would help States and regions migrate from II to SI under a mixed environment. They are proposed to clarify and elaborate the acquisition and detection of Mode S II-only (non-SI capable) transponders by Mode S II/SI capable

interrogators as well as the acquisition and detection of Mode S II/SI capable transponders by Mode S II-only interrogators as currently described in paragraphs 1.2.5 – 1.2.11 of Appendix H to the Aeronautical Surveillance Manual (Doc. 9924); and introduce the planning criteria in Appendix J for co-existence of II and SI codes under the environment where there are non-SI capable transponders still in operations. Following the discussion at the Aeronautical Surveillance Working Group in Apr 2022, EUROCONTROL proposed improvements to the document. The meeting reviewed the latest proposal provided in Annex A of the paper. The proposed text was still being worked out, and SP Chair commented that the enhancement work could be completed by SP/5 in fall 2023.

Review Report of the Second Meeting of the Surveillance Study Group (SURSG/2) (WP/04)

Surveillance Study Group: Progress Report, Recommendations in Study Report on surveillance sharing, and moving forward

2.26. SURSG/2 provided a progress summary of SURSG tasks since SURSG/1, lists out major recommendations in the Study Report and proposed way forwards for the recommendations for members' discussion and decisions. The list of tasks, volunteer task leads, and members along with latest status, was provided by Table 1 "Progress of SURSG Tasks in Feasibility Study Stage" in the paper. The Study Report on Surveillance Sharing was prepared following the framework set out in the task list, which the report was provided in Appendix A to the paper. A list of the high-level recommendations extracted from the Study Report is provided in Table 1 "High-level Recommendations from Study Report" in the paper. SURSG/2 reviewed and deliberated the recommendations and moving forward proposals provided in the Table. The details of revised high-level recommendation and moving forward agreed by SURSG/2 was given in the paper.

2.27. SURSG/2 deliberated the necessity for establishment of the Surveillance Sharing in SWIM Trial Implementation Group (S3TIG) to oversee such a trial proposed by the recommendation. China, Hong Kong China, IATA, Singapore, and Thailand seconded the proposal, with PCCWG also indicated its interest in participating in the trial. SURSG/2 agreed for PCCWG to participate in the trial and accepted that the recommendations agreed upon would be tabled for SWIM TF/6 and SURICG/7 endorsement. Draft ToR of S3TIG was prepared in mid-April 2022 offline and it was agreed that the draft ToR would be revised based on comments from the SURSG/2 delegates and it would be presented to SURICG/7 for endorsement along with the proposal to endorse formation of S3TIG. SWIM TF/6 was invited to review the ToR and support the establishment of S3TIG as an ad-hoc group, and participate in S3TIG. As per SURSG ToR, outcome of its meetings shall be reported to and sought endorsement from the SURICG, the proposal for establishment of S3TIG shall be further discussed in SURICG/7. SWIM TF/6 supported the need for establishment of S3TIG.

2.28. SURICG/7 discussed the proposal for establishment of S3TIG. The meeting noted that the S3TIG proposal was raised in SURSG/2 meeting and ToR was drafted offline in April 2022 so that the group can start working as soon as possible. Therefore, it would be more effective to form S3TIG as an ad-hoc group within SURSG in lieu of a contributory body under SURSG. As S3TIG members include the members from SWIM TF, it would not be an issue even not getting consensus for adding SWIM TF in reporting channel of S3TIG in SWIM TF/6.

2.29. The meeting considered there is no need for endorsement of a separate ToR of S3TIG in SURICG, as S3TIG will be working as an ad-hoc group within the ToR of SURSG. The meeting suggested to add ATFM SG into Liaison bodies in S3TIG and requested to add drafting and proposing surveillance data exchange model in the task list of S3TIG ad-hoc group. In addition, in SURICG/7, enquiries were raised on the difference between the adopted values of service level of shared data for Tiers 1 and 2 in the SURSG outcome and those specified in the AIGD. The Study group adopted the specifications from the AIGD v13.0, therefore, the abovementioned specification should be discussed and further reviewed. The meeting agreed to further discuss this matter.

Surveillance Data Sharing Proof of Concept

2.30. The paper introduced the Surveillance Data Sharing Proof of Concept (POC) conducted by HKCAD, PCCWG and Frequentis ComSoft. PCCWG shared the outcomes of a POC conducted on 4 March 2022, which was the collaboration of HKCAD, PCCWG and partner Frequentis ComSoft to demonstrate sharing ADS-B data in a simulated SWIM over CRV environment and the benefits of a Surveillance Central Data Processor (SCDP). The POC focused on ADS-B Asterix CAT21 ver2.1 data sharing and AMQP 1.0 was used for EMS-to-EMS communication and introduced 3 different scenarios. PCCWG further shared and compared the three scenarios in detail in the paper, including Scenario 1- Direct surveillance data sharing through SWIM registry Publish and Subscribe mechanism, Scenario 2 - Surveillance data sharing through SCDP, and Scenario 3 - Tailor-made services by SCDP. Furthermore, PCCWG summarized the benefits of SCDP with SWIM over CRV in the POC demonstration. The benefits include (i) eliminating potential bottlenecks of the data contributor and consequently the efforts of trouble shooting; (ii) promoting the service of the data contributor in the centralized Service Registry listing; (iii) enabling Data Consumer without SWIM capability to contribute and receive surveillance data; (iv) minimizing the dilemma and concerns of commitment of a data contributor; (v) offering tailor-made services to interested parties; and (vi) expediting the surveillance data sharing enablement by Tailor-made services. PCCWG prepared a video to introduce the POC exercise which was presented in SURICG/7.

Implementation of FF-ICE Interoperability using GUF1 in SWIM

2.31. ROK presented its efforts to Implement FF-ICE Interoperability using Globally Unique Flight Identifier (GUF1) in SWIM Environment. ROK has been researching to find a way to improve the usage of surveillance data in SWIM by introducing the GUF1 to the surveillance data which enables intuitive and unambiguous association surveillance data with FPL without inconsistency and redundancy. Since 2016, for ROK SWIM R&D, KAC developed mediation services and information services related on FPL and Surveillance Messaging/Web Services. By introduction of GUF1 to the surveillance data, it not only solved mismatch problems on co-relation between FPL and surveillance data by Call sign, DoF, departure/arrival aerodrome, but also made the co-relation become simple and reliable. Additionally, ROK shared the detailed method of introducing the GUF1 in the surveillance information domain.

ATS Surveillance and Direct Controller and Pilot Communication VHF Coverage Charts for APAC Region (WP/05)

2.32. The work and progress of updating the coverage charts of ATS Surveillance and Direct Controller and Pilot Communication (DCPC) for APAC Region were discussed and expected to be incorporated in the next update of the APAC Seamless ANS Plan. The ICAO APAC Regional Office has issued the State Letter AP027/22 (CNS) in February 2022 for States/Administrations to respond to the survey. As of mid-May 2022, ICAO APAC Regional Office received replies from 13 States/Administrations to the survey. With the great assistance by Thailand/AEROTHAI, data received were being validated for correctness and the work was in progress. Coverage charts on DCPC and surveillance will be produced and expected to discuss in CNS SG/26 meeting in August 2022, and subsequently, be included in the next update of the APAC Seamless ANS Plan. SURICG/7 noted that the work is essential for the APAC Region to produce the overall pictures of ATS surveillance and DCPC VHF coverage, especially in the areas and regions identified in the APAC Seamless ANS Plan, to identify any gaps in coverage thus formulating improvement plans in reducing such gaps, and States which have not yet responded to the survey were invited to contribute by replying the State Letter.

Review of Regional Requirements for Surveillance in APAC e-ANP and Seamless ANS Plan (WP/06)

2.33. The ICAO Secretariat reviewed and consolidated the Regional surveillance requirements specified in the APAC Regional e-ANP and the Seamless ANS Plan (Version 3.0, November 2019).

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The paper introduced the nature of all three volumes in APAC Regional e-ANP, listed out the surveillance-related content in e-ANP, and provided updates on the current status of e-ANP. States are encouraged to review TABLE CNS II-APAC-3 SURVEILLANCE in the Specific Regional Requirements in e-ANP Volume II, and provide update to ICAO APAC Regional Office as necessary through the PfA Process mentioned in the paper. The meeting noted the Surveillance-related components in the Asia/Pacific Seamless ANS Plan version 3.0, which would be reviewed in the Second Half of 2022.

1090MHz Occupancy Monitoring (WP/07)

2.34. Singapore and ICCAIA discussed in this paper on the need to measure 1090MHz channel occupancy at flight levels as well as at ground level, and proposed some congestion mitigations. Congestion in the 1090MHz band could be driven by various factors and initiated by different sources e.g. non-legal interferences, and it also depends on the numbers of interrogators and their interrogation rates and power, numbers of aircraft, site monitors, ground vehicles and other transmitters. The impact of high channel occupancy is collision and consequential corruption of messages, which can result in reduced detection probability for both ground systems as well as ACAS, ADS-B IN and Space-based ADS-B. The paper suggested that congestion seen by receivers depends on “coverage volume”, as the proper operation of the aviation system overall requires both terrestrial and airborne receivers to operate correctly. Various methodologies to avoid/reduce channel congestion at 1090Mhz were discussed and provided in the paper. States were encouraged to 1090 MHz channel occupancy monitoring at operating Flight levels and at ground level, and to always seek to minimise 1090MHz channel occupancy commensurate with their operational needs and environment. The meeting agreed to extract suitable contents from the paper into the AIGD for providing guidance materials for 1090Mz congestion measurement and mitigating measures.

The Sharing of the Software Resource for Benchmarking Radars (WP/09)

2.35. To address the need to access the radar performance among APAC ANSPs for the maintenance and the evaluation purpose, this paper proposed that each member states share the relevant radar analysis software for the radar benchmark. ROK introduced their radar analysis software “Astecat” developed by Incheon International Airport as one of the cost-free software tools for benchmarking radar performance that is openly shared for APAC States to use with no warranty and minimum maintenance support. The paper introduced the details of benchmarking of their surveillance systems, and their use of software in evaluating SI operation tests in Incheon International Airport. ROK was invited to provide their point of contact to ICAO on sharing their software.

Inconsistent ICAO Aircraft Address and Target Identification between Surveillance Data and Flight Plan (WP/10)

2.36. SURICG/7 noted of the update on the observed discrepancies and contributing factors of ICAO Aircraft Address and Target Identification between surveillance data and flight plans for some aircraft flying within the Hong Kong Flight Information Region (HKFIR). Despite Conclusion CNS SG/25/13 (SURICG/6/7) endorsed to urge States/Administrations to proactively follow up with air operators to address discrepancies, the problems still persist and improvement in the overall situation has not been seen. Detailed analysis of the causal factors contributing to “Aircraft Address” (AD) / “Target Identification” (ID) discrepancies were provided in the paper and discussed in the meeting. The paper further discussed the remedial and preventive measures taken by Hong Kong China to mitigate the impact on operation caused by the recurring discrepancies. IATA appreciated the effort by Hong Kong China and agreed to continue their effort to communicate with airlines for any ANSPs that encounter such discrepancies by copying to IATA when following up with airline operators. The meeting further suggested three action items: (i) Hong Kong China to consider submitting a Working Paper to RASG-APAC to facilitate discussion of the issue with the aviation flight safety community; (ii) A workshop to be organized with Hong Kong China, IATA and ICAO to educate stakeholders and the aviation community, as well as the exploration of follow-up procedure with proper points of contact;

and (iii) Hong Kong China to redress this paper into a guidance document and ICAO to issue State Letter to communicate with the APAC Region.

Suggestions of Performance Parameters of Radar System and Relevant Test Methods for APAC Region (WP/12)

2.37. China presented a minimal set of performance parameters that can effectively evaluate radar systems as the follow-up on ACTION ITEM 6-4 of SURICG/6 that an ad-hoc group was formed to study performance specifications and benchmarking of radar for APAC Region. China updated the minimal set of performance parameters from last paper WP10 in DAPs WG/5 with the continued research on these documents, and provided the updated two minimal sets of radar performance parameters before and after updates with relevant test methods in the paper. Parameters to consider including Probability of Detection (PD), Valid Mode A/C Detection Rate, False Target Rate, Accuracy, Processing Delay, and PSR/SSR Combination Rate were discussed in detail with specific test methods given in the Appendix of the paper. Considering it an interesting paper that could benefit the Region, and China's courtesy to share their research work documents with SURICG, the meeting agreed to include these useful information in this paper into a guidance document for the Region. The ad-hoc group established for ACTION ITEM 6-4 could carry on the discussion on generating the proposed guidance document.

ADS-B Equipage and Quality Performance in the U.S. (IP/05)

2.38. FAA provided a summary of observed NIC/NACp performance compared to the requirements of the USA ADS-B mandate, as well as ADS-B equipage trends in the USA. It was informed that during the two-year reporting period ending 9 April 2022, the NIC and NACp results are relatively consistent with NIC <7 ranges between 0.0438% and 0.2398%, and NACp <8 ranges between 0.0050% to 0.0188% in each of 2-month monitoring periods. FAA informed that NIC ≥7 and NACp ≥8 are ranges which the ADS-B position qualities meet the requirements for ATC use to support 3nm or closer separation minima. The paper demonstrated how the performance benchmarking from airlines fleet were performed. FAA added that FAA's ADS-B Performance Monitor (APM) has capabilities for tracking ADS-B equipage trends, including ADS-B versions and the link type of aircraft (1090ES, UAT or DUAL). The meeting discussed the figures presented in the paper, the way to improve ADS-B coverage for low levels and gap area with complementary technologies such as WAM and radars with ADS-B, the challenges on the use of UAT with DME using same frequency, as well as the concerns on using Dual-Out ADS-B data broadcasting on both 1090 and 978MHz/UAT. The paper further provided the FAA ADS-B coverage map at FL350, which extends somewhat beyond the airspace of U.S. ADS-B mandate. FAA clarified that the figures presented in this paper were from the monitoring of mandate data in all airspace.

Recent ADS-B Avionics Issues Observed in the United States (IP/07)

2.39. FAA described two recent ADS-B avionics issues observed in the USA with DO-260B/ED-102A systems, namely Embraer 17x track jumping and Honeywell Primus II RCZ. FAA informed that it monitors all ADS-B Version 2 information received in all airspace covered by FAA-contracted ADS-B ground stations via a tool called the ADS-B Performance Monitor (APM). FAA described the issue of early 2018 related to ADS-B "track" jumping by an Embraer 175 regional jet equipped with Honeywell Version 2 transponders and similar issue in October 2016 with a SkyWest E175. Details of issues and actions taken by FAA were provided in the paper. FAA mentioned the latest revision of the SB and SIL for Honeywell issue was referenced in the Safety Airworthiness Information Bulletin (SAIB) AIR-21-15 R1 issued by the FAA on 16 September 2021. The SAIB will bring further awareness to the problem, its impacts, and inform the aviation community of the resolutions available to ensure aircraft compliance when operating in ADS-B required airspace. In addition, FAA Flight Standards personnel have begun a campaign to reach out to aircraft owners, operators, and certificate holders that operate this equipment to inform them of the Service Bulletin available to correct the issue.

Performance-Based Operations Aviation Rulemaking Committee (PARC) Action Team (AT) Exemption 12555 Report (IP/08)

2.40. FAA presented the report by the Performance-based Operations Aviation Rulemaking Committee (PARC) to the FAA that contained an assessment of how well operators (exemption holders) will be able to achieve planned position source upgrades prior to the expiration of Exemption No. 12555 by December 31, 2024. The meeting was informed that the Exemption was published in 2015 to permit exempted operators to continue using Global Positioning System (GPS) position sources that may not always meet the integrity and accuracy requirements of FAA and one of the conditions of the Exemptions was that each operator must create, maintain, and update a GPS position source equipage plan for aircraft equipped for ADS-B Out. It was explained that the report included assessments to different factors related to the exemption and certain recommendations made by the Action Team, which have been submitted to FAA for their review and evaluation. In response to a recommendation by PARC Action Team, FAA published a Notice in the Federal Register, available at <https://www.federalregister.gov/d/2022-09936>, which announces revisions to the FAA's policy on performance requirements for aircraft with ADS-B Out equipment using the Selective Availability (SA)-Aware GPS receivers in ADS-B rule airspace. The FAA no longer expects operators of aircraft with this equipment to perform a preflight availability prediction before operating in ADS-B rule airspace, with details of requirements and applicability of this policy given in the paper.

Study on Application Optimization and Improvement of ADS-B technology for CAAC Air Traffic Control (IP/11)

2.41. China introduced the outcomes of the ADS-B application study carried out by ATMB CAAC between 2020 and 2021, which stemmed from issues that affected the quality of ATC surveillance for the National ADS-B Project. This study was dedicated to standardising the construction and operation of ADS-B ground equipment in China, making them in better accordance with the needs of ADS-B operation in China. The study identified issues in three aspects, including data outputting of ground stations, data pre-processing of the data centres, and application of ATM automation systems, with details of the issues and corresponding solutions given in the paper. With the adjustment contents including the data output rules of ADS-B ground stations, the enhanced pre-processing of abnormal ADS-B data by the data processing centres, and upgraded fusion algorithm and couple functions by ATM automation systems, the experimental results showed that the study conclusions are reasonable, the issues could be well resolved by those adjustments and the fusion performance of ADS-B and radar data improved.

An Anomaly of Mode A/C only Transponder Reply to Mode S Interrogation (IP/12)

2.42. China introduced a case where an aircraft equipped with the Mode A/C only transponder generated false targets in response to Mode S radar interrogation in January 2022, and explained how they analysed the causation of the phenomenon in combination with the relevant ICAO Annex 10 specifications, and provides some suggestions for Mode S radar manufacturers and aircraft maintenance engineers. The paper described the symptom observed with the detailed procedure of analysis. The paper recommended that radar manufacturers to measure the pulse amplitude of P6 or choose other phase inversion implementation methods before leaving the factory, and the aircraft maintenance personnel regularly test the Mode A/C-only transponder to ensure the effectiveness of the 3.1.1.7.4 SUPPRESSION function in "ICAO Annex 10 Volume IV". Australia shared that they have also experienced a similar issue in 2015 and by increasing the tolerance of pulse width from the radar, thus reducing the instances of false targets.

ADS-B IN Retrofit Spacing (AIRS) Evaluation Project (IP/06)

2.43. United States presented the updates to the ADS-B In Retrofit Spacing (AIRS) evaluation project after the introduction in SURICG/6 IP/08, a large-scale operational evaluation of two ADS-B In applications since September 2017, namely Cockpit Display of Traffic Information (CDTI)-Assisted

Visual Separation (CAVS) and Interval Management (IM). It was informed that the project aimed to promote early adoption of ADS-B In applications and benefits data will be gathered for one year after operation commenced. Details of equipage and trials were explained. It was added that FAA and AAL are also planning to conduct an operational trial using CAVS avionics functionality in ceiling and visibility conditions that would not currently qualify for “pilot-applied visual separation” in the USA, which is referred as “CDTI-Assisted Separation” (CAS). These operational trial are tentatively expected to commence in Fall 2022 for equipped AAL A321 aircraft and data will be gathered for one year after operations commence as well. FAA commented that some time taken on building up and certifying necessary equipment, the installation on airplane started only in January 2020 before the pandemic.

Update on Air Traffic Control Surveillance Activities in Australia (IP/09)

2.44. Australia presented updates on their ATC surveillance activities. Nine new radars with both Primary and Mode S Secondary capabilities will be in operation by 2025 and surveillance data will be shared with Airservices Australia for civil use with a plan to migrate data transport from dedicated serial lines to an IP based network over the next 1 to 2 years. Additionally, WAM systems, which are expected to end their operational life by 2025/6, are not planned for replacement and more reliance will be placed on ADS-B, with parallel runway operation in Sydney under review that might place less reliance on WAM in Sydney. For A-SMGCS, Sydney is in the process of upgrading the ground display system where A-SMGCS is integrated into the tower automation system and over 50 ADS-B installations will be replaced over the next 3 years. Australia informed about a trial ground surface movement situational awareness system and a work on low-cost ADS-B avionics for VFR and added that future joint Civilian/Military Australia wide ATM system will provide a “Multi Sensor” surveillance tracking function. Australia is in the implementation phase of an Integrated Drone Surveillance System (IDSS) Trial, aiming to demonstrate existing market capability in drone detection and surveillance along with associated data management, tracking and display and control systems.

Update on Surveillance Activities in New Zealand (IP/10)

2.45. New Zealand presented an overview of their current and planned surveillance activities. New Zealand’s current surveillance structure is based on MSSRs, PSRs, Multilateration and ADS-B. With current MSSRs/PSRs at the end of operational life and new MSSR/PSR procurement is in progress, ADS-B, the prime surveillance system, provides countrywide coverage of controlled airspace and a significant amount of uncontrolled airspace. From Dec 31 2022, ADS-B will be mandated for use within all controlled airspace in NZCC FIR. Regulatory requirements state that ADS-B is to be backed up by a non-GNSS contingency surveillance system to cover the main trunk Jet routes. If a GNSS failure the contingency system cannot rely on GNSS for continued operation. WAM at Queenstown used for approach and en-route surveillance and MLAT at Auckland for surface movement will reach their operational life around 2024/25 and programmed for replacement, and airports other than Auckland have been using ADS-B only for enhanced situation awareness of surface movement since 2018. All data from surveillance systems migrated to IP-based network over the last few years. Since the Covid Pandemic no further work was done on trial drone surveillance system. UAS Traffic Management (UTM) system “Airshare” was in operational use since 2014, and New Zealand will continue to follow the use of low-cost ADS-B avionics such as electronic conspicuity (EC) devices. The paper also shared the other surveillance-associated projects, such as their new Air Traffic Management system “SkyX” which will be operational in Q1 2023, and a joint project between Australia and New Zealand for the introduction of a Satellite-based augmentation system called the Southern Positioning Augmentation Network (SouthPAN) to improve GNSS accuracy to be less than a metre, and down to 10 centimetres, with some initial services expected in late 2022.

The Update Activity of ATC Surveillance in China (IP/13)

2.46. China introduced their current status of civil ATC surveillance system business and the latest development, including the large number of radars which more than half are Mode S radars, the extensive use of SMRs, MLAT and ADS-B ground stations, with local, regional and national data

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processing centres as their hierarchal processing infrastructure. Initial operation of ADS-B based ATC operation implementation commenced since October 2019 into two phases with details provided in the paper. Besides wide deployment of Mode S Radars and ADS-B, CAAC actively carries out research on Mode S DAPs application, including BDS SWAP Recognition, DAPs based Upper Air Wind Speed Estimation, DAPs application in Safety Net of ATMAS and DAPs Extraction Strategy Research, and the development of Mode S DAPs IGD. It has launched surveys on II conflict and II/SI mix operation capabilities for the APAC Region, launched Mode S Clustering trials to evaluate its feasibility in China, and further promote Surveillance Coordination Network (SCN) trials in three stages. For A-SMGCS, 24 airports in China have installed A-SMGCS with Level-II function, and CAAC issued “The Suggestions on Promoting Deployment and Application of A-SMGCS” which suggested all airports install Stop Bars for their importance and effectiveness, and new/reconstructed/expanded large busy multi-runway airports to equip taxiing guidance and runway status lights as Level IV requirements. The first Level IV A-SMGCS has been put into operation in Beijing Daxing Airport. The paper also presented the Development Plan for CNS approved by CAAC in 2021. Upon enquiry, China expressed that they are increasing the use of Beidou in addition to conventional GNSS means.

Introduction to the Test of the WAM Technology in the Final Approach Monitoring (IP/14)

2.47. China introduced the construction of WAM system for testing the final approach monitoring at Chengdu Shuangliu airport, and evaluated the position accuracy of the WAM data from 2020 to 2021. The system directly uses the MODE S downlink response triggered by the Mode S interrogator and the 1090 ES downlink broadcast to perform the positioning solution. The WAM test system deploys 5 receiving stations (RXU) around the runways’ extension lines, use 9 receiving stations (RXU) of the airport MLAT as its supplement. The position accuracies of WAM and ADS-B are about 6-7 meters and about 20 meters respectively. WAM has high accuracy in detecting aircraft position, and could provide controllers with more accurate situation prediction, and WAM stations could be placed with good visibility on both sides of the runway extension line. The shielding and radio interference of buildings near the proposed site should be fully analysed to avoid the influence of signal reception caused by environmental factors. The selection of WAM sites is flexible and has low requirements for the electromagnetic environment, but it is necessary to consider the balance of the layout of each site in the system network. The site selection and construction need to comprehensively consider factors such as GDOP, operation and maintenance costs, and implementation difficulty.

Exploration and Practice of Electronic Handover in Complex Transfer Environment between Adjacent ATC units (IP/15)

2.48. Further to the verification and practical application of the industry standard "Civil Aviation Air Traffic Control Automation System - Part 3: Flight data exchange" (MH/T 4029.3) screen handover in SURICG/4, this paper introduced the experimental operation of electronic handover in complex transfer environment between adjacent ATC units, gives and analyses the test verification results, puts forward the follow-up measures and plans. As in preliminary work, the design of the technical solution was discussed in IP15 of APA TF/7 “Application of electronic handover technology between high level and low-level sectors”. The coordination message is extended based on the open structure and extensible characteristics of MH/T 4029.3, to facilitate the rapid feedback of control intention. Safety evaluation was conducted in December 2021 in handling handover failure caused by link delay, timeout by manual operation delay, and unreasonable parameter settings. Details of experimental operation scenarios, messages and procedures, transmission link of Category C handover and Statistics of handover flight data, the test verification results, and problems observed and solution measures were discussed in the paper. Optimization of the automatic sending of Category C messages and the controller operational process in HMI of the automation system to further improve the efficiency of Category C handover in adjacent control areas.

Surface Security Enhancement Application Based on Voice and Photoelectric Intelligent Assistant (IP/16)

2.49. This paper described the exploration and application of various new technologies that China put forward the application of panoramic photoelectric video and two-way recognition technology of tower control voice, to realize the application of airport scene intelligent security enhancement. CAAC has built the intelligent surface security assistant system, which is independently operated at Shanghai Hongqiao Airport to serve basic functions including the monitoring of surface operation information, the consistency of voice information between the controller and the crew, and combining the Electronic Flight Strip information to judge the conflicted relationship between the scene and the intention, and provision of real-time warnings of aircraft crossing runway-holding position or road-holding position, readback error, and allowed round taxi type error, as well as post-event analysis and review. The paper introduced in depth components of key technology implemented. The system is added to the traditional control and command operation system based on A-SMGCS and the tower Electronic Flight Strip, which provides auxiliary surface operation monitoring supplements and alarm function enhancement applications to improve the alarming accuracy in specific runway intrusion scenarios. The Tower ATM Automation System (Integrated Tower) will be promoted and applied in the new towers in the future to provide differentiated, efficient, and integrated interface display information for various control work positions to support the airport tower control operation.

Evaluation of Space Based ADS-B (IP/17)

2.50. This paper describes how low-cost evaluation of Space based ADS-B at customer premises was supported. ICCAIA mentioned that the space-based ADS-B provider, Aireon, has developed the capability to demonstrate and test the integration of Space based ADS-B into customer ATC automation systems. This system has been used in a number of States to allow ANSP staff to evaluate and become familiar with Space based ADS-B and its capabilities, as well as to allow specialists to convince and demonstrate the benefits. To support ANSP decision making, the provider can provide a space based ADS-B service at a very low cost, for typically a 3 months as evaluation period, using a VPN circuit over the internet as service with certain limitations presented in the paper. Evaluation of output from the trial system can be used to assess coverage and update interval, conduct initial integration to ATC automation test systems and allow ANSPs to better assess the benefits. The paper also shared the experience and the way forward to arrange such evaluation.

ICAO Surveillance Panel Activities (IP/02)

2.51. Chair of the ICAO Surveillance Panel updated SURICG/7 about the information and discussions from the Fourth Meeting of the Surveillance Panel (SP/4) held on 28 March – 8 April 2022, and the current plans for SP/5. The two working groups of SP, i.e. the Fifteenth Meeting of Aeronautical Surveillance Working Group (SP-ASWG/15) and the Thirteenth Meeting of Airborne Surveillance Working Group (SP-AIRBWG/13), were held as breakout sessions during the SP/4 period.

2.52. SP/4 considered and agreed to recommend that the Air Navigation Commission consider a Proposal for Amendment (PfA) to Annex 10 Volume III - Communication Systems. This proposal will increase the 24-bit aircraft address allocation of all States that currently are allocated 1024 addresses to 2048 addresses. SP/4 also considered a proposal for amendment to Annex 10, Volume IV —Surveillance and Collision Avoidance Systems. The proposal updates technical provisions related to Secondary surveillance radar (SSR) Mode S transponder and 1090 MHz extended squitter (Initial Proposal 1), airborne collision avoidance systems (ACAS) III (Initial Proposal 2), and airborne surveillance applications (Initial Proposal 3), with details of these Proposals given in the paper with consequential amendments to other Annexes and Docs introduced. SP/4 considered and agreed to recommend that Doc 9924, the Aeronautical Surveillance Manual be amended to make changes proposed by the SP-ASWG. SP/4 considered and agreed to recommend a change to the Panel's Terms of Reference (ToR), and reviewed and propose revisions to the Job Cards assigned by the Air Navigation Commission to the Panel. Current plans are that SP/5 will consider the significant PfA to

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Annex 10, Volume IV to align SARPs with the latest EUROCAE/RTCA avionics standards. Additionally, it is expected that consequential changes to Doc 9871 will accompany the SARPs changes to be considered at SP/5. Consequential changes to other ICAO documents under the purview of the SP, such as Doc 9924 and Doc 9863, may either be presented for consideration at SP/5, or will be prepared for SP/6. SP/5 was scheduled to be held in September 2023.

RTCA Status (SP/01)

2.53. RTCA introduced their operations as an independent standards development organization which supports ICAO, coordinates with EUROCAE and supports certain organisations including FAA. Their non-profit nature supports various domains across the aviation industry. The presentation explained the background and objectives of SC-186 WG-4 with a summary of their activities of this group. Future meeting topics to work on, including human-in-the-loop study results, recommended updates to IM Sample Algorithm, overview of FAA Tech Center capabilities, update on SESAR activities, tactical uses of IM in en-route and terminal environments and ADS-B In benefits updates and were provided in the presentation. In addition, outcomes to date were identified, including increased industry awareness of CAS operations and opportunity to provide input on operational concepts, increased awareness of FAA activities in support of operational trials and CAS and IM deployment, identified and mitigated challenges with using CAVS application + supplemental requirements for all CAS operations, ongoing FAA/industry discussion on how FIM MOPS, requirements support IM operations, and increased awareness of how ADS-B In applications will be integrated with TBO. The ICAO Secretariat appreciated the effort from RTCA, and the coordination by SP Chair.

Review APAC Regional Surveillance Strategy (WP/08)

2.54. The Surveillance Strategy for the APAC Region is expected to be regularly reviewed to cope with the prevailing circumstances and developments, and under this agenda, the ICAO Secretariat presented the last version of Surveillance Strategy for the APAC Region adopted in 2019 to the meeting for review and actions. The meeting reviewed the comments/views received for revising the Surveillance Strategy, discussed the amendment proposals, and formulated the revised Strategy provided in **Appendix C to this paper** as following Draft Conclusion for consideration by CNS SG/26:

Draft Conclusion SURICG/7/3 - Revised Surveillance Strategy for the APAC Region	
What: That, the Revised Surveillance Strategy for the APAC Region provided in Appendix C to this paper be adopted.	Expected impact: ☐ Political / Global ☒ Inter-regional ☒ Economic ☐ Environmental ☒ Ops/Technical
Why: To reflect the outcome of the latest development in surveillance technology.	Follow-up: ☒ Required from States
When: 23-Nov-22	Status: Draft to be adopted by PIRG
Who: ☒ Sub groups ☒ APAC States ☒ ICAO APAC RO ☐ ICAO HQ ☒ Other: SURICG	

Positive Effect of CPR Reasonableness Test on ADS-B Security (WP/11)

2.55. Japan presented the reasonableness test for Compact Position Reporting (CPR) decoding is useful for improving ADS-B security via numerical simulation, and reducing false information that is intentionally transmitted. ADS-B being a dependent surveillance and also an open system without encryption and authentication, there is a possibility of false position information caused by avionics and security issues. In Mode S DAPs WG/5, China presented in IP/06 the technique called reasonableness test for CPR Decoding, which was originally written in RTCA-DO260B. This technique addressed a

false position caused by an airborne aircraft transmitting a surface position format. The reasonableness test is a technique to verify the decoded position. The basic mechanism was introduced in the paper. ENRI conducted a numerical simulation with the procedure, parameters and results provided in the paper. Based on the result, this paper also proposes to add a suggestion to ADS-B Implementation and Operation Guidance Document (AIGD).

Revision of Updates to AIGD

2.56. In addition to WP/11 by Japan, Hong Kong China led the discussion and incorporation of materials to update AIGD during the meeting with the methodologies to measure 1090MHz congestions and mitigating measures raised in WP07 by Singapore and ICCAIA. The meeting agreed to formulate the following Draft Conclusion for consideration by CNS SG/26 meeting.

Draft Conclusion SURICG/7/4 - Revised ADS-B Implementation and Operations Guidance Document (AIGD)			
What: That, the revised ADS-B Implementation and Operations Guidance Document (AIGD) provided in Appendix D to this Paper , which consolidated all change proposals during SURICG/7, be adopted as Version 15.0.		Expected impact: ☐ Political / Global ☐ Inter-regional ☐ Economic ☐ Environmental ☒ Ops/Technical	
Why:	Updates from SURICG/7	Follow-up:	☐ Required from States
When:	19-Aug-22	Status:	Draft to be adopted by Subgroup
Who:	☒ Subgroup ☐ APAC States ☒ ICAO APAC RO ☐ ICAO HQ ☒ Other: SURICG		

2.57. Hong Kong China clarified the reasons for the difference between the adopted values of service level of shared data for Tiers 1 and 2 in the SURSG outcome and those specified in the AIGD, and suggested a need to align the SURSG outcome as described in **Table 1 – High-Level Recommendations from Study Report** with the definitions of Appendix 6 of AIGD. After deliberation, Hong Kong China will take up an action to discuss with the Chair of SURSG to align the SURSG outcome with AIGD thus ensuring no misunderstanding and the specified performance requirements are suitable for the targeted services.

2.58. In response to the abovementioned action item, the Study Report was updated to align with the definitions of Appendix 6 of AIGD. The updated report was shared on 15 June 2022 via email with the focal point of voluntary Administrations/Organizations of SURSG and members who shared comments on Tier 1 and 2 values in SURICG/7. In response, Vietnam shared the concurrence with study report and no feedbacks from other States/members were received. Therefore, the study report is updated after incorporating all the comments of SURICG/7. The revised study report is provided in **Appendix E to this paper** with updates marked in track change.

Amendment 91 to Annex 10 Volume IV - Introduction of ACAS Xa/Xo (IP/04)

2.59. The ICAO Secretariat presented the main points of State Letter Ref.: AN 7/66.2.2-22/27 Subject: Adoption of Amendment 91 to Annex 10, Volume IV was circulated to States on 29 March 2022 and the action required by the letter was to notify any disapproval before 18 July 2022; notify any differences and compliance before 3 October 2022; and consider the use of the Electronic Filing of Differences (EFOD) System for notification of differences and compliance regarding the Adoption of Amendment 91 to Annex 10, Volume IV, regarding the introduction of ACAS Xa/Xo, for review and action if necessary. The State Letter was provided in Appendix A to the paper, and the meeting was reminded to take note on the guidance on the determination and reporting of differences given in the Note on the Notification of Differences in the Attachment D of the State Letter. Information on

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implementation and available guidance material, as well as an impact assessment relevant to this adoption of an Annex amendment, are presented in the letter's Attachments E and F respectively, and the AMENDMENT 91 text is at the end of the State Letter package. As raised in 2.1.2 of the impact assessment on page 17 of the State Letter, the cost impact for States will be minimal as this simply gives an additional option to implement ACAS II. However, States that will accept ACAS Xa/Xo-compliant equipment in their airspace and that run an ACAS monitoring program need to update their message interpretation software.

3. ACTION BY THE MEETING**3.1 The meeting is invited to:**

- a) note the information contained in this paper;
- b) adopt the Draft Conclusion defined in **Section 2.23**;
- c) note the Decision defined in **Section 2.24**;
- d) adopt the Draft Conclusion defined in **Section 2.54**;
- e) adopt the Draft Conclusion defined in **Section 2.56**; and
- f) discuss any relevant matter as appropriate



**INTERNATIONAL CIVIL AVIATION ORGANIZATION
ASIA AND PACIFIC OFFICE**

**MODE S DOWNLINK AIRCRAFT PARAMETERS IMPLEMENTATION
AND OPERATIONS GUIDANCE DOCUMENT**

Edition 4.0 - August 2022

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PREFACE

This publication is one of the deliverables of the Mode S DAPs WG according to the Terms of Reference (TOR). It aims at providing guidance materials to States and airspace users on the use of Mode S DAPs in the Asia and Pacific Regions from both operational and technical perspectives. A working team was established to develop the contents, and China has volunteered to take lead on coordinating and consolidating inputs from members of the working team.

During Mode S DAPs WG/1 held in March 2018, the meeting considered that further development work is required before the initial draft (Edition 0.1) proposed by China and Hong Kong China becomes ready for approval. Then the working team began to develop the contents of the guidance document, China organized two internal conferences and ICAO APAC office organized a web conference for reviewing the contents. Based on numerous rounds of review and comments with joint efforts from the working team, China has revised the draft into five previous versions. Finally, Edition 1.0 was submitted for endorsement after Mode S DAPs WG/2, and published in the CNS SG/23. China revised the document and circulated it to the members of the Working Group for comments. Then Edition 2.0 was released in 2020, during CNS SG/24. The latest version (Edition 3.0) was adopted by CNS SG/25 in 2021. This version includes information related to ADS-B DAPs, and the revised draft is prepared and proposed to be endorsed by Mode S DAPs WG/5.

The support from ICAO APAC Office and contributions from the following volunteer State/Administration and industry partner in preparing the guidance material is acknowledged and highly appreciated:

- Air Traffic Management Bureau of CAAC, China
- The Second Research Institute of CAAC, China
- Hong Kong Civil Aviation Department, China
- Civil Aviation Authority of Singapore
- Japan Civil Aviation Bureau
- Electronic Navigation Research Institute, Japan
- Airways, New Zealand
- Airservices, Australia

*Mode S Downlink Aircraft Parameters
Implementation and Operations Guidance Document*

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1. INTRODUCTION

1.1 Purpose

This Mode S Downlink Aircraft Parameters Implementation and Operations Guidance Document (DAPs IGD) provides guidance for the planning, implementation and operational application of Mode S DAPs technology in the Asia and Pacific Regions.

The procedures and requirements for Mode S DAPs operations are detailed in the relevant States' AIP. This IGD is intended to provide key information on Mode S DAPs performance, integration, principles, procedures and collaboration mechanisms.

The content is based upon the work to date of the Mode S DAPs Working Group and various ANC Panels for the operational use of Mode S DAPs.

1.2 Background

1.2.1 Mode S and DAPs

Mode S (Select) is an extension of conventional SSR which permits selective addressing of individual aircraft equipped with Mode S transponders. Additional data known as Downlink Aircraft Parameters (DAPs) may also be extracted from the aircraft, including aircraft identification which should correspond to the ACID entered in the flight plan.

Mode S operates on the same radio frequencies (1030 and 1090 MHz) as conventional SSR systems, allowing for interrogation of Mode A/C only transponders and Mode S transponders.

Each Mode S equipped aircraft is assigned a unique ICAO 24-bit aircraft address. Using the selective interrogation capability of the Mode S SSR, Mode S Sensors are able to first acquire and then selectively interrogate a specific aircraft via its unique ICAO 24-bit aircraft address. This significantly improves the radar's detection and tracking performance, and therefore improving the ability of ATC to monitor and control the aircraft, as well as the others around it.

The innovation of Mode S resides in the use of selective addressing of aircraft which offers technical advantages over conventional SSR, such as reducing "fruit" and "garbling", providing higher integrity radar tracks.

Mode S technology has the following characteristics:

- a) selective interrogation,
- b) individual aircraft address and
- c) datalink capability.

The Mode S application includes Mode S radar system, datalink Systems, MLAT Systems, etc.

Various avionics systems onboard an aircraft receive data from sensors to provide the DAPs output. The data mainly comes from several sets of sensors, such as air data sensors (including pitot probe, static port, temperature sensor, and angle of attack sensor), inertial sensors (including position gyroscopes, rate gyroscopes and accelerometers) and magnetic sensor(s). Part of the parameters produced by other

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avionics systems (such as MCP/FCU, FMS, TCAS, etc.) are also defined as downlink aircraft parameters. These parameters are then sent to the transponder through standard data buses, and stored inside the relevant transponder's 256 different 56-bit wide Binary Data Store. Ground-based surveillance systems (such as MSSR or MLAT) can downlink the desired parameters using specific Mode S protocols.

For detailed information about DAPs data source, please refer to Appendix 3.

Mode S DAPs is an application of the Mode S Datalink System. The downlink standard length transaction interface shall deliver DAPs to the transponder which then makes data available to the ground surveillance systems. Each DAP shall be packed and then transmitted by the downlink SLM, ground-initiated and broadcast protocols.

There are 255 Comm-B registers within the Mode S transponder, some of them are assigned for Mode S SSR DAPs and some are assigned for ADS-B DAPs. The Mode S transponder transmits extended squitter to support the ADS-B message transmitted on 1090 MHz which is called ADS-B DAPs. And the SSR DAPs can be extracted using either the ground-initiated Comm-B (GICB) protocol, or using MSP downlink channel 3 via the data flash application.

There are four 1090 MHz Extended Squitter ADS-B MOPS versions with the latest, Version 3 published in December 2020. With each new version, some messages have different formats and contain additional or eliminated message subfields ~~in different versions, as the version 3 was published in December, 2020,~~ As version 3 is so new there are few if any avionics which meet the standards, therefore the related information of ADS-B DAPs in this document is based on the version 2 and earlier versions.

1.2.2 Benefit of Mode S and Use of DAPs

The Mode S application reduces the weakness of Mode A/C, because of the selective interrogation reducing synchronous garble and asynchronous interference. The parity check technique improves the reliability and integrity of surveillance data. The availability of almost 17 million unique aircraft addresses, in conjunction with the automatic reporting of flight identity, alleviates Mode 3/A code shortages and enables unambiguous aircraft identification, if the correct aircraft address and/or Aircraft Identification are entered in both the flight plan and aircraft systems. The datalink technique assists the acquisition of downlink aircraft parameters, and the additional track label information improves the air situational awareness. The controller and pilot are presented with improved situation awareness, which reduces the R/T workload.

Another benefit is to maximize SSR Mode 3/A code savings. By introducing the Mode S Conspicuity Code, all aircraft identified by Mode S via DAPs (ACID) can use the same SSR Mode 3/A code. During the 6th meeting of ATM SG, the following Conclusion is adopted:

Conclusion ATM/SG/6-3: Proposed Air Navigation Plan Volume II Amendment

'A1000' was reserved for the Mode S Conspicuity Code for the ICAO APAC region.

The ADS-B DAPs also provide benefits such as economical, enhanced safety and efficiency. The position report in ADS-B message is transmitted with an indication of the integrity associated with the data. And the ADS-B ground station is simpler than the stations of primary radar, secondary radar and multilateration, and acquisition and installation costs are significantly lower. Since ADS-B messages are broadcast, it supports both ground-based and airborne surveillance applications.

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1.3 Arrangement of DAPs IGD

The Mode S DAPs Implementation and Operations Guidance Document consists of the following parts:

Section 1	Introduction
Section 2	Acronym Lists
Section 3	Reference Documents
Section 4	Description of Mode S DAPs Data
Section 5	Implementation Principles and Phase
Section 6	System Integrity and Monitoring
Section 7	Regulations and Procedures
Section 8	Training and Competence
Section 9	Specific Examples on Mode S DAPs Applications

1.4 Document History and Management

The framework of this document was introduced in the first Working Group Meeting of Mode S Downlink Aircraft Parameters in March 2018. The Meeting agreed to further develop based on the proposed framework to a complete document for approval as a regional guidance document. A working team, consisting of volunteers from China, Hong Kong-China, Japan, Malaysia, Singapore, Thailand and New Zealand was established by the Meeting to contribute to the content of the document. In July 2018, the completed draft of this document was ready for circulation among States for review and comment.

The aim of this document to supplement SARPs, PANS and relevant provisions contained in ICAO documentation, and it will be regularly updated to reflect evolving provisions.

1.5 Copies

Paper copies of this DAPs IGD are not distributed. Controlled and endorsed copies can be found at the following website: <http://www.icao.int/APAC/Pages/edocs.aspx> and may be freely downloaded from the website, or by emailing APANPIRG through the ICAO Asia and Pacific Regional Office who will send a copy by return email.

1.6 Changes to DAPs IGD

Whenever a user identifies a need for a change to this document, a Request for Change (RFC) Form (see Section 1.8 below) should be completed and submitted to the ICAO Asia and Pacific Regional Office. The Regional Office will collate RFCs for consideration by the Surveillance Implementation Coordination Group.

When an amendment has been adopted by the meeting of the Surveillance Implementation Coordination Group, then a new version of the DAPs IGD will be prepared, with the changes marked by an “|” in the margin, and an endnote indicating the relevant RFC, so a reader can see the origin of the change. If the change is in a table cell, the outside edges of the table will be highlighted, e.g.:

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Final approval for publication of an amendment to the DAPs IGD will be the responsibility of APANPIRG.

1.7 Editing Conventions

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1.8 DAPs IGD Request for Change Form

RFC Nr:	
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Please use this form when requesting a change to any part of this DAPs IGD. This form may be photocopied as required, emailed, faxed or e-mailed to ICAO Asia and Pacific Regional Office +66 (2) 537-8199 or APAC@icao.int

1. SUBJECT:			
2. REASON FOR CHANGE:			
3. DESCRIPTION OF PROPOSAL: [expand / attach additional pages if necessary]			
4. REFERENCE(S):			
5. PERSON INITIATING:		DATE:	
ORGANISATION:			
TEL/FAX/E-MAIL:			
6. CONSULTATION RESPONSE DUE BY DATE:			
	Organization	Name	Agree/Disagree
			Date
7. ACTION REQUIRED :			
8. DAPs IGD EDITOR		DATE REC'D :	
9. FEEDBACK PASSED		DATE :	

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1.9 Amendment Record

Amendment Number	Date	Amended by	Comments
0.1	20 March 2018	China Hong Kong, China	Initial draft for consideration by Mode S DAPs WG/1
0.2	1 August 2018	China Hong Kong, China Japan Singapore Malaysia	First completed draft based on the agreed document framework in Mode S DAPs WG/1 for review and comment by States
0.3	23 August 2018	China	Based on Version 0.2 draft, China hold a meeting to discuss problems respecting the first completed draft. This is a revised document according to content of this meeting.
0.3.1	26 September 2018	China Hong Kong, China Singapore New Zealand	Based on Version 0.3 draft, States make a full comment on the content of IGD. This is a revised document according to those comments.
0.3.2	6 November 2018	China New Zealand Hong Kong, China Singapore Malaysia	Based on Version 0.3.1 draft, States discussed all comments of IGD in the Mode S DAPs WG 1st Web Conference. This is revised by the meeting decisions.
0.4	27 December 2018	China New Zealand Singapore Australia	Based on Version 0.3.2, States review and comment on the IGD. This is a revised document according to those comments.
1.0	14 March 2019	China Japan Singapore Malaysia	Consideration by Mode S DAPs WG/2
1.1	17 February 2020	China New Zealand Singapore	Modify based on Version 1.0, States review and comment on the IGD.
2.0	13 May 2020	China	Consideration by Mode S DAPs WG/3
3.0	March 2021	China	Consideration by Mode S DAPs WG/4
4.0	March 2022	China	Add information related to ADS-B DAPs and guidance on measurement of 1030/1090 MHz usage

2. ACRONYMS LIST

AA	Aircraft Address
AAD	Assigned Altitude Deviation
AC	Altitude Code
ACAS	Airborne Collision Avoidance System
ACID	Aircraft Identification
ADS-B	Automatic Dependent Surveillance-Broadcast
AICB	Air-Initiated Comm-B
AIGD	ADS-B Implementation and Operations Guidance Document
AIP	Aeronautical Information Publication
AMC	Acceptable Means of Compliance
ANC	Air Navigation Conference
ANSP	Air Navigation Service Provider
APAC	Asia Pacific
ASE	Altimetry System Error
ASTERIX	All Purpose Structured EUROCONTROL Surveillance Information Exchange
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Service
ATSEP	Air Traffic Safety Electronic Personnel
BDS	Comm-B Data Selector
CA	Capability
CDTI	Cockpit Display Traffic Information
CFL	Cleared Flight Level
CLAM	Cleared Level Adherence Monitoring
CNS	Communications, Navigation and Surveillance
DAPs	Downlink Aircraft Parameters
DF	Downlink Format
EASA	European Aviation Safety Agency
EHS	Mode S Enhanced Surveillance
ELM	Extended Length Message
ELS	Mode S Elementary Surveillance
ES	Extended Squitter
EUROCAE	European Organization for Civil Aviation Equipment
EUROCONTORL	European Organization for the Safety of Air Navigation
FCU	Flight Control Unit
FIR	Flight Information Region
FLTID	Flight Identification (transmitted by aircraft)
FMS	Flight Management System
FRUIT	False Relies Unsynchronized In Time
FS	Flight Status
FTE	Flight Technical Error
HDG	Heading
HRD	Horizontal Reference Direction
GICB	Ground-Initiated Comm-B
GNSS	Global Navigation Satellite System
GVA	Geometric Vertical Accuracy
HMI	Human Machine Interface

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IC	Interrogator Code
ICAO	International Civil Aviation Organization
ID	Identity
IFR	Instrument Flight Rules
II	Interrogator Identifier
IRF	Interrogation Repetition Frequency
MCP	Mode Control Panel
MET	Meteorological
MHz	Megahertz
MIP	Mode Interlace Patterns
MIT	Massachusetts Institute of Technology
MLAT	Multilateration
MOPS	Minimum Operational Performance Standard
MSAW	Minimum Safe Altitude Warning
MSP	Mode S Specific Protocol
MTCD	Medium Term Conflict Detection
NAC	Navigation Accuracy Category
NIC	Navigation Integrity Category
NUC	Navigation Uncertainty Category
RA	Resolution Advisory
RVSM	Reduced Vertical Separation Minimum
SARPs	(ICAO) Standards and Recommended Practices
SFL	Selected Flight Level
SI	Surveillance Identifier
SIL	Surveillance Integrity Level
SSR	Secondary Surveillance Radar
STCA	Short-Term Conflict Alert
TCAS	Traffic Alert and Collision Avoidance System
TRK	Track Angle
TVE	Total Vertical Error
UTC	Universal Time Coordinated
WAM	Wide Area Multilateration
WG	Working Group

3. REFERENCE DOCUMENTS

Id	Name of the document	Edition	Date	Origin	Domain
1	Aeronautical Telecommunications, Annex 10 - Vol. III - Communication Systems	Edition 2	2007	ICAO	
2	Aeronautical Telecommunications, Annex 10 - Vol. IV - Surveillance Radar and Collision Avoidance Systems	Edition 5	2014	ICAO	
3	Doc 9871, Technical Provisions for Mode S Services and Extended Squitter.	Edition 2	2012	ICAO	
4	Doc 9688 Manual on Mode S specific service.	Edition 2	2004	ICAO	
5	ED-73E, Minimum Operational Performance Standards for Secondary Surveillance Radar Mode S Transponders.	Edition 1	May 2011	EUROCAE	
6	ADS-B Implementation and Operations Guidance Document (AIGD)	Edition 13	April 2021	ICAO APAC	
7	Concept of Operations Mode S in Europe (Mode S CONOPS)	Edition 2	November 2013	Eurocontrol	
8	Mode S Elementary Surveillance (ELS) Operations Manual	Edition 1	January 2011	Eurocontrol	
9	Asia/Pacific Seamless ATM Plan		May 2015	ICAO APAC	
10	Doc 9924 Aeronautical Surveillance Manual	Third Edition	2020	ICAO	
11	Preliminary System Safety Analysis for the Mode S Elementary Surveillance	Edition 1.8	April 2004	Eurocontrol	EATMP
12	Elementary Surveillance (ELS) and Enhanced Surveillance (EHS) validation via Mode S Secondary Radar		April 2008	MIT Lincoln Laboratory	ATC Project
13	Aircraft Derived Data Validation Algorithms		August 2012	MIT Lincoln Laboratory	ATC Project
14	Doc.4444 Procedures For Air Navigation Services Air Traffic Management	Sixteenth Edition	November 2016	ICAO	

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15	Clarification Mode S Transponder in an Airport/A-SMGCS Environment	Edition 1.1	3 May 2005	Eurocontrol	
16	Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System /Mode Select (ATCRBS / Mode S) Airborne Equipment	Edition E	17 March 2011	RTCA	
17	MARK 4 AIR TRAFFIC CONTROL TRANSPONDER (ATCRBS/MODE S)	Edition 4	15 November 2011	ARINC	
18	DO-260 Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B)		13 September 2000	RTCA	
19	DO-260A Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)		2003	RTCA	
20	DO-260B Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)		2 December 2009	RTCA	
21	Doc9574 Manual on a 300 m(1 000 ft) Vertical Separation Minimum Between FL 290 and FL410 Inclusive	Edition 3	2012	ICAO	

4. DESCRIPTION OF MODE S DAPs DATA

Inside the aircraft transponder, DAPs are stored in different BDS Registers for responding to interrogation requests by a Mode S ground system. Aircraft parameters are periodically delivered from aircraft sensors, flight management system, etc., to these registers via the downlink standard length transaction interface. BDS Registers, which have not been updated within the specified maximum update interval, are cleared or indicated as invalid and such aircraft parameters would be unavailable for ground interrogations. When a Mode S SSR sends an interrogation requesting the downlink of registers, Mode S SSR DAPs are packed into Comm-B format (known as “MB” field) and are extracted using either the GICB protocol or Mode S specific protocols (MSPs) channel 3. Mode S transponder transmit extended squitter to broadcast ADS-B DAPs.

BDS Registers are identified by a two-digit hex number. For example, BDS Register for selected vertical intention, which is identified by hex number 40₁₆, is commonly written as BDS code 4, 0 in publications. Depending on the stage of Mode S implementation, i.e., Mode S ELS and Mode S EHS, the scope of Mode S SSR DAPs data involved would be different as illustrated in the following subsections. These subsections also describe ADS-B DAPs data and the differences between Mode S SSR DAPs and ADS-B DAPs.

Detailed data format and maximum update interval of each BDS register are given in “ICAO Doc 9871 - Technical Provisions for Mode S Services and Extended Squitter”.

4.1 Mode S ELS

In Mode S ELS implementation, aircraft and ground Mode S system should be compliant with providing the following functionalities over conventional Mode A/C systems:

- a) Selective interrogation.
- b) Use of ICAO Aircraft Address.
- c) Automatic reporting of ACID.
- d) Report of transponder capability;.
- e) Altitude reporting with a resolution of 25ft (subject to aircraft capability).
- f) Provision of flight status to indicate airborne or on-the-ground (subject to aircraft capability).
- g) Report of SI Code capability; and
- h) ACAS active resolution advisory report (when equipped with TCAS).

DAPs associated with Mode S ELS are stored in BDS code 1,0, BDS code 1,7, BDS code 2,0 and BDS code 3,0 registers of the aircraft’s transponder.

Table 4-1 DAPs in Mode S ELS

Register	Name	Usage
BDS code 1,0	Datalink Capability Report	To report the data link capability of the Mode S transponder/data link installation.
BDS code 1,7	Common Usage GICB	To indicate common usage GICB services currently

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	Capability Report	supported.
BDS code 2,0	Aircraft Identification	To report aircraft identification to the ground.
BDS code 3,0	ACAS Resolution Advisory Report	To report ACAS active resolution advisory

With the above functionalities properly configured, Mode S ELS could bring the following benefits to ATC operations:

- a) Provide unambiguous aircraft identification using the unique aircraft address and aircraft identification.
- b) Help to solve Mode 3/A code shortage in congested airspace, using the Mode S conspicuity code (A1000) instead of discrete Mode 3/A codes.
- c) Improve surveillance data integrity by;
 - 1) reducing synchronous garble*,
 - 2) lessening over-interrogations, and
 - 3) simplifying aircraft identification in case of false targets.
- d) Improve the accuracy of multi-surveillance tracking and safety nets with more accurate target detection from Mode S radars and high resolution in altitude reporting; and
- e) Able to process more aircraft tracks than conventional Mode A/C radars; and
- f) Able to provide ACAS active resolution advisory from suitably equipped aircraft.

*Note, while Mode S will help to reduce data garble it will not resolve the issue. Issues around multi-path and different transponder types in close proximity (e.g., Mode A/C near a Mode S transponder) can mean that the return received by the radar may not be correct. In the case of a Mode A/C transponder close to a Mode S transponder, instances have been recorded where the Mode S address has been transposed into the reply from the Mode A transponder.

4.2 Mode S EHS

Mode S EHS implementation includes all the features of Mode S ELS with the addition of DAPs stored in BDS code 4,0, BDS code 5,0 and BDS code 6,0 registers of the aircraft's transponder. The following table summarizes the details of DAPs of these three registers:

Table 4-2 DAPs in Mode S EHS

Register	Name/Downlink Aircraft Parameters		Usage
BDS code 4,0	Selected Vertical Intention	MCP/FCU Selected Altitude	To provide information about the aircraft's current vertical intentions
		FMS Selected Altitude	
		Barometric Pressure Setting	
		MCP/FCU Mode	
		Target Altitude Source	
BDS code 5,0	Track and Turn Report	Roll Angle	To provide track and turn data to the ground systems.
		True Track Angle	
		Ground Speed	
		Track Angle Rate	
		True Air Speed	
BDS code 6,0	Heading	Magnetic Heading	To provide heading and speed data to

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	and Speed Report	Indicated Air Speed	ground systems.
		Mach Number	
		Barometric Altitude Rate	
		Inertial Vertical Velocity	

In addition to those improvements contributed by Mode S ELS in Section 4.1, Mode S EHS implementation provides the following benefits to ATC operation:

- a) Further improve multi-surveillance tracking accuracy and performance through the use of DAPs on track, turn, speed and heading of the aircraft in the track calculation.
- b) Further improve the accuracy of safety nets, e.g., Short-Term Conflict Alert (STCA), through the provision of more accurate aircraft tracks, and Medium-Term Conflict Detection (MTCD), Minimum Safe Altitude Warning (MSAW), through the provision of the earlier judgment of vertical movement.
- c) Allow the implementation of new safety nets in ATM automation system for cross-checking selected aircraft vertical intention (i.e., Selected Altitude) with ATC controllers' instruction as well as verifying the barometric pressure setting applied in the aircraft with QNH setting in ATM automation system; and
- d) Improve situational awareness of ATC controllers by enabling the direct access of aircraft parameters in ATM automation system, e.g., Indicated Air Speed, Mach speed, Selected Altitude, Barometric Pressure Setting, etc.
- e) Progressive reduction of R/T workload per aircraft.

4.3 ADS-B DAPs

According to the current situation and operation requirements of airborne ADS-B transponder, only the aircraft downlink parameters corresponding to ADS-B 1090ES Version 2 are considered. DAPs associated with ADS-B are stored in BDS Code 0,5, BDS Code 0,6, BDS Code 0,8, BDS Code 0,9, BDS Code 6,1, BDS Code 6,2 and BDS Code 6,5.

The following table summarizes the details of these parameters:

Table 4-3 ADS-B DAPs

Register	Name/Downlink Aircraft Parameters		Usage
BDS code 0,5	Airborne Position	Airborne Position	To provide accurate airborne position information
		NIC Supplement-B	
		Pressure Altitude	
		GNSS Height	
		Surveillance Status	
BDS code 0,6	Surface Position	Surface Position	To provide accurate surface position information.
		Ground Speed Vector	
BDS code 0,8	Aircraft Identification and Category	Aircraft Identification	To provide aircraft identification and category
		Emitter Category	
BDS code 0,9 Subtype 1/2	Velocity Over Ground	Ground Speed Vector	To provide additional state information for both normal and supersonic flight
		NACv	
		Vertical Rate	

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		Intent Change Flag	
		Difference from Baro Altitude	
BDS code 0,9 Subtype 3/4	Airspeed and Heading	Air Speed	To provide additional state information for both normal and supersonic flight based on airspeed and heading
		Heading	
		NACv	
		Vertical Rate	
		Intent Change Flag	
		Difference from Baro Altitude	
BDS code 6,1 Subtype 1	Emergency/Priority Status	Emergency/Priority Status	To provide additional information on aircraft status
		Mode A Code	
BDS code 6,1 Subtype 2	ACAS RA Broadcast	ACAS RA Report	To report RAs generated by TCAS/ACAS equipment.
BDS code 6,2 Subtype 1	Target State and Status Message	Selected Altitude	To provide aircraft state and status information
		Barometric Pressure Setting	
		Selected Heading	
		NAC _P , SIL, NIC _{BARO} ,	
		SIL Supplement	
		MCP/FCU Mode	
		TCAS/ACAS Operational	
BDS code 6,5 Subtype 0	Aircraft Operational Status-While Airborne	Airborne Capability Class	To provide the capability class and current operational mode of ATC-related applications and other operational information.
		Airborne Operational Mode	
		MOPS Version	
		NIC Supplement-A	
		NAC _P , GVA, SIL, NIC _{BARO}	
		HRD	
		SIL Supplement	
BDS code 6,5 Subtype 1	Aircraft Operational Status-On the Surface	Surface Capability Class	
		Length/Width	
		Surface Operational Mode	
		MOPS Version	
		NIC Supplement-A	
		NAC _P , SIL	
		TRK/HDG	
		HRD	
		SIL Supplement	

4.4 The Data Item in SSR DAPs and ADS-B DAPs

The airborne Mode S transponder may transmit the same data item to radar and ADS-B via different routes. The following table summarizes some of the parameters in use.

Table 4-4 The Data Item in SSR DAPs and ADS-B DAPs

Data Items	SSR DAPs		ADS-B DAPs	
	BDS/DF	ASTERIX	BDS/DF	ASTERIX
Aircraft Address	DF4/5/20/21 AP DF11 AA	I048/220	DF17 AA	I021/080
Mode A Code	DF5/21 ID	I048/070	BDS Code 6,1	I021/070
Pressure Altitude	DF4/20 AC	I048/090	BDS Code 0,5	I021/145
Airborne/On-the-ground	DF4/5/20/21 FS	I048/230	Determine by position	I021/040

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			message type (BDS Code 0,5 or 0,6)	
Aircraft Identification	BDS Code 2,0	I048/240	BDS Code 0,8	I021/170
Aircraft Emitter Category	-	-	BDS Code 0,8	I021/020
Special Position Indication/SPI	DF4/5/20/21_FS	I048/020 I048/230	BDS Code 0,5	I021/200
Emergency Status	DF5/21_ID	I048/230 I048/070	BDS Code 6,1	I021/200
ACAS RA Report	BDS Code 3,0	I048/260	BDS Code 6,1	I021/260
MCP/FCU Selected Altitude	BDS Code 4,0	I048/250	BDS Code 6,2	I021/146 I021/148
FMS Selected Altitude	BDS Code 4,0		BDS Code 6,2	I021/146
Barometric Pressure Setting	BDS Code 4,0		BDS Code 6,2	I021/REF
MCP/FCU Mode	BDS Code 4,0		BDS Code 6,2	I021/148 I021/REF
Roll Angle	BDS Code 5,0		-	I021/230
True Track Angle	BDS Code 5,0		BDS Code 0,9+6,5 BDS Code 0,6+6,5	I021/160
Ground Speed	BDS Code 5,0		BDS Code 0,9 BDS Code 0,6	I021/160
Track Angle Rate	BDS Code 5,0		-	I021/165
True Air Speed	BDS Code 6,0		BDS Code 0,9	I021/151
Magnetic Heading	BDS Code 6,0		BDS Code 0,9+6,5 BDS Code 0,6+6,5	I021/152
Indicated Air Speed	BDS Code 6,0		BDS Code 0,9	I021/150
Mach Number	BDS Code 6,0		-	-
Barometric Altitude Rate	BDS Code 6,0		BDS Code 0,9	I021/155
Inertial Vertical Velocity	BDS Code 6,0			-
Position in WGS-84 Co-ordinates	-	-	BDS Code 0,5 BDS Code 0,6	I021/130 I021/131
GNSS Height	-	-	BDS Code 0,5 + 0,9 BDS Code 0,5	I021/140
Geometric Vertical Rate	-	-	BDS Code 0,9	I021/157
Quality Indicator	-	-	BDS Code 0,5 BDS Code 0,9 BDS Code 6,2 BDS Code 6,5	I021/090
Aircraft Length and Width	-	-	BDS Code 6,5	I021/271
GNSS Antenna Offset	-	-	BDS Code 6,5	I021/REF

Note: The airspeed and magnetic heading values are only available from airborne participants that are not providing information about their velocities over the ground in ADS-B DAPs.

4.5 DAPs Data Exchange Protocol Between Surveillance and ATM Automation System

The decoding of DAPs data from downlink messages is handled by ground surveillance equipment such as radars, ADS-B, MLAT and WAM ground stations. The Surveillance Data Processor (SDP) within the ATM automation system can combine multiple downlink messages into a single target report for display to controllers. All Purpose Structured EUROCONTROL Surveillance Information Exchange (ASTERIX)

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formats are commonly used as the protocol for target report transmission from surveillance systems to the ATM automation system.

For detailed information about ASTERIX formats please refer to the following link of EUROCONTROL web site:

<https://www.eurocontrol.int/asterix>

ASTERIX formats are categorized based on the types of surveillance data involved. ASTERIX Category 20, ASTERIX Category 21 and ASTERIX Category 48 are responsible for the DAPs data transmission from MLAT systems, ADS-B systems and radars respectively. For each ASTERIX category, the protocol format is further divided into different editions with variations on the supported DAPs data. ANSP's should carry out appropriate studies on the available protocol editions during the design stage to ensure the chosen format can cater to the scope of DAPs proposed to be implemented and that the Surveillance and ATM automation systems can correctly process the protocol selected.

For details, previous and current versions of ASTERIX Category 20, Category 21 and Category 48 specification documents can be downloaded from the following link of EUROCONTROL web sites:

<https://www.eurocontrol.int/publication/cat020-eurocontrol-specification-surveillance-data-exchange-asterix-part-14-category-20>

<https://www.eurocontrol.int/publication/cat021-eurocontrol-specification-surveillance-data-exchange-asterix-part-12-category-21>

<https://www.eurocontrol.int/publication/cat021-eurocontrol-specification-surveillance-data-exchange-asterix-part-12-category-0>

<https://www.eurocontrol.int/publication/cat048-eurocontrol-specification-surveillance-data-exchange-asterix-part4>

5. IMPLEMENTATION PRINCIPLES AND PHASES

Implementation guidance is developed to progress the DAPs implementation from concept to operational use in the ICAO APAC region. In this chapter, section one addresses the implementation principles, which describes the issues of international coordination, system compatibility, data integrity and system integration, while section two addresses the implementation phase, to assist States with the management of DAPs implementation activities.

5.1 Implementation Principles

5.1.1 Stakeholders Coordination

DAPs provide useful information from aircraft which can benefit ANSP and airspace users. Improvements in efficiency and safety can be achieved, however the resultant changes in operational procedures to provide the improvements, will affect ANSPs, Regulators, Airlines, and other related airspace users. Before implementation by any State, a coordination team should be formed to study, coordinate, support and consult the implementation plans and related activities. The coordination team should include field experts on avionics, data link, surveillance infrastructures and end users.

Changes in the ATM operational procedures as the result of the use of DAPs require coordination among ATS providers, Regulators, Airlines, and where applicable, coordination among neighboring States to maximize the benefits. All States are encouraged to share their operational experiences, and to report anomalies through Mode S DAPs WG and the Surveillance Implementation Coordination Group.

Not all Surveillance and ATM automation systems are capable of processing and using DAPs, therefore investment in all related fields needs to be considered by all States. The coordination team should be consulted for future investment plans and related activities considering the technical and operational aspects. Consideration needs to be given to achieve a balance between investment and benefits.

5.1.2 System Compatibility

a) Technical:

DAPs can be obtained by different surveillance technologies such as Mode S Radar, ADS-B, MLAT and WAM, however not all the transponders can support DAPs. Different surveillance technologies in the ICAO APAC States mean that system compatibility should be considered.

Potential interference between different surveillance technologies should be fully considered before implementation, otherwise the efficiency and safety of the system cannot be ensured. Harmonization between different technologies should be considered and optimized to reduce the RF congestion on 1030MHz and 1090MHz.

Since not all aircraft are equipped with Mode S transponders, and not all the Mode S transponders have the ability to support DAPs, compatibility and efficiency should always be considered before implementation.

When DAPs are implemented, the data rate will increase compared to the conventional radar data, and the related BDS information extraction strategies should be considered. To reduce the load on the 1090MHz spectrum, only those registers intended for operational use should be interrogated/extracted.

b) Operational:

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Different processing systems can support DAPs in different levels, hence the quality and information of the target may be different after the processed DAPs have been added. For example, some radar tracking algorithms will consider DAPs as an input to the tracking, so the quality and information of the target will be a little bit different, therefore there should be compatibility considerations between different systems before use of the target data.

There are different air traffic management and operation strategies used by neighboring States. So, the operational procedures should always consider the operational compatibilities. For example, Mode A/C transponders and Mode S transponders may be working in the same area.

5.1.3 DAPs Data Integrity

DAPs data integrity should always be the first consideration when putting DAPs data into use. Since the data integrity from the source is not delivered by any related BDS register now, States are encouraged to find a reliable methodology to ensure the data integrity before the use of the data. Additionally, ongoing means of determining data integrity should be implemented, along with an ability to exclude invalid DAPs data from ATM automation systems.

States which already have experience on data integrity are encouraged to share this information with other States. The coordination team could support and harmonize this activity, and provide a standard method to evaluate the data integrity, and share the method with all the States.

5.1.4 System Integration

By introducing DAPs, the target characteristic from the source to the end user may be different compared to pre-DAPs implementation. In different phases of the processing flow of target data, DAPs can be used by different systems to improve tracking performance. Some key points in the data flow are as follows:

a) Airborne Avionics Systems

As DAPs data comes from different kinds of sensors and avionics systems on the aircraft, the reliability of the data should be ensured before the data is used operationally. Research has shown that some BDS data is missing or not updated correctly. The reasons for this need to be established, as it can mean that the use of some DAPs data is not suitable for implementation. Examples of issues include:

- 1) Older Flight Management Systems which do not provide all the DAPs data, and
- 2) Incorrect installation (e.g., onboard equipment wired to wrong registers)

b) Ground Sensor Systems

Ground sensors may use the DAPs to improve their target tracking performance, having an impact on the tracking function; the target data produced by this kind of sensors will show different characteristics to the pre-DAPs implemented tracking function, such as the turning rate, the kinematic movement and so on. Data users need to be aware of this performance improvement.

c) Ground Automation Systems

Ground automation systems can use DAPs information for a wide variety of uses, such as for tracking, safety net processing, situational awareness, en-route meteorological information sharing and so on. Ensuring DAPs information is processed and used in an appropriate way should be considered during implementation.

d) Other Surveillance Systems

Any DAPs data should be capable of being integrated with other surveillance systems data, and any potential difference and impact should be considered before use. Some of the information can be cross checked by different surveillance technologies.

e) Other Related Systems

5.2 Implementation CHECKLIST

The purpose of this implementation checklist is to document the range of activities that need to be considered to bring a DAPs application from an initial concept to operational use. Some activities of this checklist may be specific to individual stakeholders.

5.2.1 Activity Sequence

The activities are listed in approximate sequential order. However, each activity does not have to be completed prior to starting the next activity. In many cases, a parallel and iterative process should be used to feed data and experience from one activity to another. It should be noted that not all activities will be required for all applications.

5.2.2 Concept Phase

- a) Construct operational concept:
 - 1) Purpose.
 - 2) Operational environment.
 - 3) ATM functions; and
 - 4) Infrastructure.
- b) Identify benefits:
 - 1) Safety enhancements.
 - 2) Efficiency.
 - 3) Capacity.
 - 4) Environmental.
 - 5) Cost reductions.
 - 6) Accessibility; and
 - 7) Other metrics (e.g., predictability, flexibility, usefulness);
- c) Identify constraints:
 - 1) Air-Ground interoperability.
 - 2) Compatibility with non-equipped aircraft.
 - 3) Need for exclusive airspace.
 - 4) Required ground infrastructure.
 - 5) RF spectrum.
 - 6) Integration with existing technology.
 - 7) Technology availability; and

- 8) Actuality of existing infrastructure.
- d) Prepare business case:
 - 1) Cost benefit analysis; and
 - 2) Demand and justification.

5.2.3 Design Phase

- a) Identify operational requirements:
 - 1) Security; and
 - 2) Systems interoperability.
- b) Identify human factors issues:
 - 1) Human-machine interfaces.
 - 2) Training development and validation.
 - 3) Workload demands.
 - 4) Role of automation vs. role of human.
 - 5) Crew coordination/pilot decision-making interactions; and
 - 6) ATM collaborative decision-making.
- c) Identify technical requirements:
 - 1) Standards development.
 - 2) Prevailing avionics standards.
 - 3) Data required.
 - 4) Functional processing.
 - 5) Functional performance.
 - 6) Required certification levels; and
 - 7) Identify the infrastructure that needs upgrade.
- d) Equipment development, test, and evaluation:
 - 1) Prototype systems built to existing or draft standards/specifications.
 - 2) Upgrade and test scheme for the existing infrastructure.
 - 3) Developmental bench and flight tests.
 - 4) Acceptance test parameters: Acceptance test should be performed to ensure all the key indicators are met; and
 - 5) Select and procure technology.
- e) Develop procedures:
 - 1) Pilot and controller actions and responsibilities.
 - 2) Standardize the interaction and phraseologies.
 - 3) Controller's responsibility to maintain a monitoring function, if appropriate.
 - 4) System certification procedure should be made.

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- 5) Standard Operating Procedure should be made if the human machine interface of the system is changed.
 - 6) Contingency procedures: For example, duplicate Mode S address is detected.
 - 7) Emergency procedures, for example ACAS message is received.
 - 8) General procedures for unforeseen issues should be made; and
 - 9) Develop AIP and Information documentation.
- f) Prepare design phase safety case:
- 1) Safety rationale.
 - 2) Safety budget and allocation; and
 - 3) Functional hazard assessment.

5.2.4 Implementation Phase

- a) Prepare implementation phase safety case.
- b) Conduct operational test and evaluation:
 - 1) Flight deck and ATC validation simulations; and
 - 2) Flight tests and operational trials.
- c) Obtain systems certification:
 - 1) Aircraft equipment; and
 - 2) Ground systems.
- d) Obtain regulatory approvals:
 - 1) Air traffic certification of use.
- e) Impact Assessment

An impact assessment should be conducted to gauge the effect in terms of security, efficiency, operating regulations, human factors, infrastructure, environment, and so on.
- f) Implementation transition:
 - 1) Promulgate procedures.

The regulatory authority shall promulgate general regulations to the participants. Each participant shall formulate corresponding detailed regulations.
 - 2) Deliver training.

Training should be conducted to ensure the personnel is familiar with the standard, regulation, and technology of the Mode S DAPs implementation and operation. Licensing process could be executed if needed.
 - 3) Continue data collection and analysis.
 - 4) Resolve any unforeseen issues; and
 - 5) Continue feedback into standards development processes.
- g) Performance monitoring to ensure that the agreed performance is maintained.

6. SYSTEM INTEGRITY AND MONITORING

6.1 Introduction

CNS and ATM environment is an integrated system including physical systems (hardware, software, and communication networks), human elements (pilots, controllers, and engineers), and the operational procedures for its applications. The integration of Mode S DAPs with other surveillance technologies enables more information from an aircraft to be used to provide a safer service.

Because of the integrated nature of such system and the degree of interaction among its components, comprehensive system monitoring is recommended. The procedures described in this section aim to ensure system integrity by validation, identification, reporting and tracking of possible problems revealed during system monitoring with appropriate follow-up actions.

6.2 Personnel Licensing and Training

Prior to operating any element of the Mode S DAPs system, operational and technical personnel shall undertake appropriate training as determined by the ANSP or State Regulatory Authority, including compliance with the Convention on International Civil Aviation where applicable. Such training will ensure that personnel are familiar with the regulation, standards and requirements of the Mode S DAPs implementation and operation.

6.3 ATS System Validation

6.3.1 Safety Assessment Guidelines

To meet system integrity requirements, ANSPs or States should conduct a validation process that confirms the integrity of their equipment and procedures. Such processes shall include:

- a) A system safety assessment for new implementations is the basis for definitions of system performance requirements. Where existing systems are being modified to utilize additional services, the assessment demonstrates that the ATS Provider's system will meet safety objectives.
- b) Integration test results confirming interoperability for operational use of airborne and ground systems; and
- c) Confirmation that the ATS operation procedure is compatible with those of adjacent providers where the system is used across a common boundary.

6.3.2 System Safety Assessment

The objective of the system safety assessment is to ensure that the implementation and operation of Mode S DAPs are safe. The safety assessment should be conducted for implementation as well as any future enhancements and should include:

- a) Identifying failure or error conditions.
- b) Assigning levels of criticality.
- c) Determining risks/probabilities for occurrence.

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- d) Identifying mitigating measures.
- e) Categorizing the degree of acceptability of risks; and
- f) Operational hazard ID process.

Following the safety assessment, States should institute measures to offset any identified failure or error conditions that are not already categorized as acceptable. This should be done to reduce the probability of their occurrence to an acceptable level. This could be accomplished through the automation of procedures.

6.3.3 Integration Test

States should conduct trials with suitably equipped aircraft to ensure the DAPs data meets the operational and technical requirements to provide ATS. The introduction of the Mode S DAPs will give more information about the aircraft, and should not affect the performance of the existing system. States should be satisfied by test results and analysis carried out by the ANSP.

6.3.4 ATS Operation Manuals

States may coordinate with adjacent States to confirm that their ATS operation manuals contain standard operating procedures to ensure harmonization of procedures that impact across common boundaries.

6.4 System Monitoring

During the implementation and operation of the Mode S DAPs technology, routine collection of data is necessary to ensure that the system continues to meet or exceed its performance, safety and interoperability requirements, and that operational service delivery and procedures are working as intended.

6.4.1 Consideration for System Monitoring

Mode S transponders may have been installed a long time ago to support mandatory ACAS functionality. The Mode A/C function has been permanently used by ATC, but the Mode S functions may not have been used. Any failure impacting Mode A/C would have been detected by ATC during normal operation and corrective action would have been undertaken. Before implementing Mode S for surveillance, system checks are usually made to ensure the correct operation of the Mode S transponders (e.g., continue to correctly process Mode A/C and Mode S replies), but possibly no system checks were made to ensure that the DAPs data was correct, so several undetected failures may have existed over the years of operation.

A number of Mode S transponder from different OEMs have been observed to be non-compliant with Annex 10 Volume IV requirements (e.g., no SI code capability, no reply to aircraft register extraction, incorrectly configured aircraft address, incorrect content of BDS registers), even though the transponder is certified to level 2. Although actions have been taken in some areas (mainly where Mode S has been implemented) to address these problems, some aircraft with Mode S which are not working correctly still operate (mostly in areas where Mode S has not yet been implemented).

During the initial deployment of European Mode S, it was discovered that avionics upgrade performed on some aircraft had resulted in erroneous transponder operations so that, in some cases, the aircraft could not even be detected by the ground radar. It is therefore recommended that before commencing Mode S surveillance operations in a given airspace, system monitoring be put in place for timely

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detection and rectification of hidden transponder problems. This will enable the ANSP and aircraft operators to remedy identified issues prior to using Mode S operationally.

The communication lines for transferring surveillance information in a Mode S radar require much higher data throughput as there is more information per aircraft. For example, compared to a Mode A/C radar, Mode S DAPs require up to three times more data throughput.

Mode S DAPs bring safety benefits even when only a portion of the traffic is properly equipped. Some aircraft can be configured to provide additional data items, but their use should be considered with caution since some airborne installations may not have been certified, hence data may be erroneous. System monitoring to validate the transmitted information is considered desirable for DAPs operation.

6.4.2 Mode S DAPs Problem Reports

During the application of the Mode S DAPs, some problems may be found during the observation of one or more specific events. Faulty Mode S DAPs data should be recorded and analyzed. Problems may be found during the routine analysis of application data. Any problem should be documented and reported to the DAPs WG.

After a problem has been found, the finder can attempt to resolve it with the appropriate party and report the solution to the DAPs WG. The problem and solution will be distributed to the DAPs WG members. If the problem has not been resolved, the problem should be reported to the DAPs WG, and members will be encouraged to resolve the problem. In many cases, a Mode S DAPs problem will be systematic across a particular aircraft or avionics configuration. Engagement with, and correction by the manufacturer may be required.

The mode S DAPs problem should be reported with the form as shown in Table 6-1.

Table 6-1 Mode S DAPs Problem Report Form

PRS#			
Start Time/Date UTC		End Time/Date UTC	
Registration		Aircraft ID	
Flight ID		ICAO Aircraft Address	
Aircraft Type			
Flight Sector/ Location			
ATS Unit			
Description / additional information			
Originator		Originator Reference number	
Organization			

PRS#: A unique identification number assigned by the PRS Administrator to this problem report. Organizations writing problem reports are encouraged to maintain their internal list of these problems for tracking purposes. Once the problems have been reported to the PRS and incorporated in the database, a number will be assigned by the PRS and used for tracking by the SURICG.

Start Time/Date UTC: UTC time/date when the event started.

End Time/Date UTC: UTC time/date when the event ended.

Registration: Registration number (tail number) of the aircraft involved.

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Aircraft ID:	Coded equivalent of call sign as entered in FPL Item 7.
Flight ID:	The Flight ID/Flight Number downlinked from the aircraft.
ICAO Aircraft Address:	Unique aircraft address expressed in Hexadecimal form.
Aircraft Type:	The aircraft model involved. For the aircraft type designators please refer to ICAO Doc 8643.
Flight Sector/Location:	The departure airport and destination airport for the sector being flown by the aircraft involved in the event. For the airport indicators please refer to ICAO Doc 7910 or related AIP. Or if more descriptive, give the location of the aircraft during the event.
ATS Unit:	ICAO identifier of the ATC center or tower controlling the aircraft at the time of the event.
Originator:	Point of contact at the originating organization for this report (usually the author).
Organization:	The name of the organization (airline, ATS provider or communications service provider) that created the report.
Description:	This should provide as complete a description of the situation leading up to the problem as is possible. Where the organization reporting the problem is not able to provide all the information (e.g., the controller may not know everything that happens on the aircraft), it would be helpful if they would coordinate with the other parties to obtain the necessary information. The description should include: a) A complete description of the problem that is being reported b) The route contained in the FMS and flight plan c) Any flight deck indications d) Any indications provided to the controller when the problem occurred e) Any additional information that the originator of the problem report considers might be helpful but is not included on the list above If necessary, to contain all the information, additional pages may be added. If the originator considers it might be helpful, diagrams and other additional information (such as printouts of message logs) may be appended to the report.

6.4.3 Example of Mode S DAPs Problem

Through monitoring, it has been reported that erroneous DAPs data have been observed due to failure or improper setting/installation of Mode S equipment. A Working Paper of the ICAO Surveillance Panel Working Group (WP ASP12-20) has indicated that a lot of incorrect, outdated and even erroneous data and parameters are present for DAPs data. The errors and/or miss-matches can be frequent, including:

- a) The ACID is not always correct (erroneous)
- b) The Selected Altitude is not correct or is not updated (For example Selected Altitude data should be provided by the MCP/FCU instead of the FMS as the FMS data is usually incorrect).
- c) Mode S DAPs data does not correspond to the content of the requested register (BDS swap).

6.5 Application Analysis

During the Operation of Mode S DAPs application, the analysis is necessary to ensure that the system continues to meet or exceed its performance, safety, and interoperability requirements. To analyze the Mode S DAPs applications, routine data should be recorded.

6.5.1 Data Recording

It is recommended that ATS providers and communication service providers retain the records defined below for at least 30 days to allow for accident/incident investigation processes. These records should be made available on request to the relevant State safety authority. Where data is sought from an adjacent State, the usual State to State channels should be used.

Where possible these recordings shall be in a form that permits a replay of the situation and identification of the messages that were received by the ATS system. Data exchange across borders may not be possible due to different Radar or ATM message formats or to State regulatory issues.

Not only the data from ground equipment, but also the data from aircraft equipment should be recorded. By analyzing the recorded data, the exact reason for the failures can be found.

6.5.2 Local Data Collection

ATS providers and communication service providers should identify and record Mode S DAPs system component failures that have the potential to negatively impact the safety of controlled flights or compromise service continuity.

6.5.3 Avionics Problem Identification and Correction

ATS providers should develop systems or procedures to:

- a) detect Mode S DAPs avionics anomalies and faults
- b) advise the regulators and where appropriate the aircraft operators on the detected Mode S DAPs avionics anomalies and faults
- c) devise mechanisms and procedures to address identified faults

Regulators should ensure that appropriate corrective actions are taken to address identified faults.

An example of Mode S DAPs analysis is taken in Appendix 1.

6.6 Identified Issues

Several identified issues had already been recognized during the implementation of the Mode S DAPs data application in the ATM automation system. Some of them even disrupted the operation of ATC services. Thus, it is necessary to ensure the reliability of DAPs for utilization for ATC operation. This section will present some issues for helping to figure them out.

Based on the experience gained from States, the common Mode S SSR DAPs problems are summarized under different categories in Appendix 2, and ADS-B DAPs problems can refer to the Appendix2 of AIGD. It is noted that many cases of the wrong DAPs found in Mode S implementation were because of the aircraft avionics capability. Some issues resulted from human factors. Experiences showed that it was important to keep close coordination with airlines to promote the DAPs application. Airlines should be informed of the issues in time and to check their aircraft Mode S transponders promptly. At the same time, airlines need to improve their working procedures including ensuring they file flight plans correctly.

7. REGULATIONS AND PROCEDURES

Mode S DAPs involve the transmission of specific data from aircraft. These data messages can be interrogated by the ground equipment (Mode S interrogator) or broadcast by the Mode S extend squitter. ATM uses the data to show the more precise and integrated situation of the surveilled aircraft. The following procedures relate to the use of Mode S DAPs data in ATS ground surveillance applications.

The implementation of the Mode S DAPs system will support the provision of high-performance surveillance, enhancing flight safety, improving the controller efficiency, and reducing the workload of both the controller and pilot.

7.1 Mandating Mode S DAPs

- a) Depending on the type of operations that States are going to conduct, States will have to consider whether there is a need to publish mandates. Some operations will require all aircraft within airspace to be suitably equipped while others can still work well on a ‘best equipped best served’ basis.
- b) Use of Multilateration on airport surface is an example of an operation where it is recommended for all aircraft to be equipped with Mode S transponders. Another example is the conspicuity code environment, where Flight Identification may be used as the prime means to couple/correlate flight plans, allowing ANSPs to overcome the shortage of Mode A codes. Equipage mandates would be necessary for such operations.
- c) States intending to implement ADS-B based surveillance services may designate portions of airspace within their area of responsibility by:
 - i. *mandating the carriage and use of ADS-B equipment; or*
 - ii. *providing priority for access to such airspace for aircraft with operative ADS-B equipment over those aircraft not operating ADS-B equipment.*
- d) With appropriate software, ATM automation systems can use Mode S DAPs to provide additional information to controllers, enabling a reduction in controller workload and the enhancement of Safety Net systems. Equipage mandates are not necessary, but consideration of the nature of the services required and/or a cost-benefit study, may warrant such mandates.
- e) As of May 2018, examples of States which use Mode S SSR DAPs without publishing mandates are Australia¹, New Zealand and Singapore. Examples of States with published mandates for Mode S SSR DAPs are France, Germany and the United Kingdom.
- f) In publishing mandate/regulations, States should:
 - 1) Define the standards applicable to the State.
 - i. E.g., *Joint Aviation Authorities (JAA) Temporary Guidance Leaflets (TGL) 13 Revision 1* for Elementary Surveillance in version 0 and version 1 transponders; or
 - ii. E.g., *European Aviation Safety Agency (EASA) Acceptable Means of Compliance (AMC) 20-13* for Enhanced Surveillance in version 0 and version 1 transponders; or

¹ Australia has a mandate for Mode S transponders at selected airports utilizing Multilateration for surface surveillance, but no widespread mandates for airborne DAPs usage

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- iii. E.g., *Elementary Surveillance (ELS) requirements stated in European Aviation Safety Agency (EASA) CS-ACNS-Subpart D, Section 2 (i.e., CS ACNS.D.ELS) for Elementary Surveillance in version 2 transponder; or*
 - iv. E.g., *Enhanced Surveillance (EHS) requirements stated in European Aviation Safety Agency (EASA) CS-ACNS-Subpart D, Section 3 (i.e., CS ACNS.D.EHS) for Enhanced Surveillance in Version 2 transponder*
 - v. E.g., *Mode S level 2 if the requirement is simply for Airport Surface Multilateration.*
 - vi. *, ADS-B avionics compliant to Version 2 ES (equivalent to RTCA DO-260B) or later version 2.*
 - vii. E.g., *European Aviation Safety Agency - Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHZ Extended Squitter (AMC 20-24);or*
 - viii. E.g., *European Aviation Safety Agency - Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance Subpart D — Surveillance (SUR) (CS-ACNS.D.ADS-B);or*
 - ix. E.g., *Federal Aviation Administration – Advisory Circular No: 20-165A (or later versions) Airworthiness Approval of Automatic Dependent Surveillance – Broadcast (ADS-B) Out Systems; or*
 - x. E.g., *the equipment configuration standards in Appendix XI of Civil Aviation Order 20.18 of the Civil Aviation Safety Authority of Australia.*
- 2) Define the airspace affected by the regulations
 - i. E.g., *Within the [FIR Authority] Flight Information Region above Flight Level XXX*
 - 3) Define the category of aircraft that the regulation applies to
 - i. E.g., *Aircraft with a maximum certified take-off mass exceeding 5,700 kg or having a maximum cruising true airspeed capability greater than 250 kt; or*
 - ii. E.g., *All IFR aircraft*
 - 4) Define the timing of the regulations allowing sufficient time for operators to equip.
 - i. E.g., *With effect from 1 Jan 2020.*

Note: More information of mandate for 1090 MHz ADS-B can refer to section 9.2 of AIGD.

7.2 Avionics

7.2.1 Mode S Transponder Capabilities

- a) The various levels of capabilities for Mode S Transponders are described in subsequent paragraphs. The state should select the capability as required by its operations.
- b) According to ICAO Annex 10, Vol. 4, Mode S transponders shall conform to one of five levels of capability as follows:
 - 1) Level 1 is the basic transponder. Level 1 permits surveillance based on Mode A/C as well as on Mode S. With a Mode S aircraft address, it comprises the minimum features for compatible operation with Mode S interrogators. It has no datalink capability and will not be used by international air traffic.

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- 2) Level 2 has the same capabilities as Level 1 and permits standard length datalink communication from ground to air and air to ground. It includes automatic aircraft identification reporting. This is the minimum level permitted for international flights. Data parity with overlay control (ICAO Annex 10, Vol. 4, 3.1.2.6.11.2.5) for equipment certified on or after 1 January 2020.
 - 3) Level 3 has the capabilities as level 2 and also those prescribed for ground-to-air ELM communications.
 - 4) Level 4 has the capabilities as level 3 and also those prescribed for air-to-ground ELM communications.
 - 5) Level 5 has the capabilities as level 4 and also those prescribed for enhanced Comm-B and ELM communications.
- c) Other than the various levels, transponders also can have the following features:
- 1) Extended squitter - transponders that shall have the capabilities of level 2, 3, 4, or 5 and those prescribed for extended squitter operation.
 - 2) SI Capability - Transponders with the ability to process SI codes shall have the capabilities of level 2, 3, 4, or 5 and those prescribed for SI code operation.
 - 3) Data flash Application – transponders that implement the data flash mode.
 - 4) Hijack Mode Capability – transponders that support the Hijack Mode and have the capabilities of level 2, 3, 4, or 5.
 - 5) ACAS Compatibility –transponders compatible with ACAS.
 - 6) Antenna Diversity – in aircraft with transponder using two antennas, receivers and transmitting channels.
 - 7) According to ED-73E, Elementary Surveillance – elementary surveillance transponders will require at least a level 2 transponder and have the following capabilities:
 - i. Flight status reporting
 - ii. Barometric pressure altitude reporting
 - iii. Transponder capability (CA)
 - iv. II and SI code capable
 - v. Declaration of capability (BDS code 1,0)
 - vi. Common usage GICB capability report (BDS code 1,7)
 - vii. Mode S specific services capability (BDS code 1,8 to BDS code 1,C)
 - viii. Flight identification (BDS code 2,0)
 - ix. ACAS Active Resolution Advisory (BDS code 3,0) if equipped with ACAS II
 - x. Aircraft register (BDS code 2,1) – optional
 - 8) According to ED-73E, Enhanced Surveillance – enhanced surveillance transponders have the capabilities of elementary surveillance transponders, plus the capability to provide the following DAPs:
 - i. Magnetic Heading (BDS code 6,0)
 - ii. Indicated Airspeed and/or Mach No. (BDS code 6,0)
 - iii. Vertical Rate (climb/descend) (BDS code 6,0)
 - iv. True Airspeed (provided if Track Angle Rate is not available) (BDS code 6,0)
 - v. MCP/FCU Selected Altitude (BDS code 4,0)
 - vi. Ground Speed (BDS code 5,0)
-

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- vii. Roll Angle (BDS code 5,0)
- viii. Track Angle Rate (if available) (BDS code 5,0)
- ix. True Track Angle (BDS code 5,0)
- x. Barometric Pressure Setting (BDS code 4,0)

Note: For more information of transponder capabilities for 1090 MHz ADS-B refer to section 9.2 and appendix 3 of the AIGD.

7.2.2 Mode S Transponder Mandate

During the 31st APANPIRG meeting, the following Conclusion regarding the fitment of Mode S equipage was adopted, States/Administrations may consider the following conclusion when considering the publishing of Mode S transponder mandate.

Conclusion APANPIRG/31/14 (CNS SG/24/13 (SURICG/5/3(DAPS WG3/1))) - Mode S Forward Fit Equipage in APAC Region		
What:	Regarding fitment of Mode S equipage, That, States/Administrations in APAC Region be strongly encouraged to mandate that registered aircraft with a maximum certified take-off mass exceeding 5 700 kg or having a maximum cruising true airspeed capability greater than 250 knots, with a date of manufacture on or after 1 January 2022 be equipped with Mode S avionics compliant with Enhanced Surveillance (EHS).	Expected impact: ☐ Political / Global ☐ Inter-regional ☒ Economic ☐ Environmental ☒ Ops/Technical
Why:	Considering that a number of DAPs applications will require EHS and that it's easy for new aircraft to be equipped with EHS. Retrofitting existing airframes with EHS will need further deliberation under the challenging pandemic situation.	Follow-up: ☒ Required from States
When:	16-Dec-20	Status: Adopted by PIRG
Who:	☒ Sub groups ☒ APAC States ☒ ICAO APAC RO ☒ APANPIRG ☐ ICAO HQ ☒ Other: SURICG	

7.2.3 Transition Guidelines

- a) Equipage of aircraft will be achieved over a period of time. Not all aircraft will be equipped with the necessary capability. A transition plan is required to accommodate varying degrees of aircraft equipment compliance.
- b) As part of the formulation for a transition plan, States should assess the impact of having aircraft that are not suitably equipped within the affected airspace, to enable the implementation of suitable mitigating measures. States should also collect statistics on the readiness of the aircraft within the affected airspace.
- c) For different operations, the mitigation measures in the transition plan could be different. For example, if the operation is just to use the Mode S DAPs to provide useful information to the controllers, the impact of having unequipped aircraft is minor. Mitigating measures could be as simple as making the controllers aware that not all aircraft are able to provide the information. On the other hand, where mode S is mandated for airport surface Multilateration, mitigating

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measures for having unequipped aircraft may include having special procedures for non-equipped aircraft or the deployment of a surface movement radar.

7.2.4 Mode S Transponder Working on the Ground

Table 7-1 summarizes the requirements to inhibit or not inhibit replies from aircraft on the ground.

Table 7-1 The Requirements of Transponders on Ground

Type of interrogations	Transponder reply
Mode A/C	Should be inhibited
Mode A/C/S All Call	Shall always be inhibited
Mode S only All Call (UF =11)	Shall always be inhibited
Mode S (Roll call UF=0,4,5,16,20,21,24)	Shall not be inhibited
Acquisition Squitter (Short Squitter)	Shall be inhibited if surface type of extended squitter is transmitted
Extended Squitter (Long Squitter)	Shall not be inhibited

[Information obtained from Eurocontrol's Clarification Mode S Transponder in an Airport/A-SMGCS Environment Ed 1.1 dated 3 May 2005]

- Replies to Mode A/C/S all call and Mode S only all call interrogations shall always be inhibited when the aircraft declares the on the ground state. It shall not be possible to inhibit replies to discretely addressed Mode S interrogations regardless of whether the aircraft is airborne or on the ground.
- Mode A/C replies should be inhibited (i.e., Mode A/C transponder set to standby) when the aircraft is on the ground to prevent interference when in close proximity to an interrogator or other aircraft. Mode S discretely addressed interrogations do not give rise to such interference. An exception on the recommendation to inhibit Mode A/C replies will be at airports having Multilateration systems working with Mode A/C.
- Mode S transponders shall be set to the correct mode according to its flight status (i.e., airborne mode when it's in the air and ground mode when on the ground). When an aircraft is in ground mode, replies to all call are inhibited. It is recommended that aircraft provide means to determine the on-the-ground state automatically and provide that information to the transponder.

7.2.5 1090MHz Extended Squitter Transponder capability

- According to the ICAO 1090MH ADS-B Minimum Operational Performance Standard (MOPS), in a Mode S Transponder-Based Subsystem, the ADS-B Message generation function and the modulator and 1090 MHz transmitter are present in the Mode S transponder itself. The transmit antenna subfunction consists of the Mode S antenna(s) connected to that transponder.
- According to ICAO Annex 10, Volume 4. Extended squitter ADS-B transmission requirements. Mode S extended squitter transmitting equipment shall be classified according to the unit's range capability and the set of parameters that it is capable of transmitting consistent with the following definition of general equipment classes:
 - Class A extended squitter airborne systems support an interactive capability incorporating both an extended squitter transmission capability (i.e., ADS-B OUT) with a complementary extended squitter reception capability (i.e., ADS-B IN) in support of onboard ADS-B

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applications.

- 2) Class B extended squitter systems provide a transmission only (i.e., ADS-B OUT without an extended squitter reception capability) for use on aircraft, surface vehicles, or fixed obstructions; and
 - 3) Class C extended squitter systems have only a reception capability and thus have no transmission requirements.
- c) According to the ICAO 1090Mhz ADS-B Minimum Operational Performance Standards (MOPS), the 1090ES ADS-B transponder has 4 versions, which included:
- 1) RTCA DO-260/EUROCAE ED-102 (Version 0)

The International Civil Aviation Organization issued the 1090ES ADS-B initial standard "Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B)" (DO-260/ED-102) in September 2000, and was known as ADS-B version 0. This version defines the 1090 MHz ADS-B Transmitting Subsystem takes position, velocity, status, and intent inputs from other systems onboard the aircraft and transmits this information on the 1090 MHz frequency as Mode S Extended Squitter messages.

According to DO-260/ED-102, the 1090ES transponder should send State Vector (SV), Mode Status (MS) Reports, and support the following DAPs capabilities:

- i. airborne position (BDS 0,5).
- ii. surface position (BDS 0,6).
- iii. identification and type (BDS 0,8).
- iv. airborne velocity (BDS 0,9).
- v. emergency/priority status (BDS 6,1).
- vi. Current/Next Trajectory Change Point (TCP) (BDS 6,2).
- vii. Current/Next Trajectory Change Point (TCP+1) (BDS 6,3).
- viii. Aircraft Operational Coordination Message (BDS6,4).
- ix. Aircraft operational status (BDS 6,5).

2) RTCA DO-260A (Version 1)

The International Civil Aviation Organization issued "Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance–Broadcast (ADS-B) and Traffic Information Services–Broadcast (TIS-B)" (RTCA DO-260A) in April 2003, and was known as ADS-B version 1. The formats and protocols for 1090 ES were revised in part to overcome the limitation of the reporting of surveillance quality using only navigation uncertainty category (NUC). In the revised formats and protocols, surveillance accuracy and integrity are reported separately as:

- i. navigation accuracy category (NAC),
- ii. navigation integrity category (NIC), and
- iii. surveillance integrity level (SIL).

Other features added in Version 1 messages include the reporting of additional status parameters and formats for traffic information service — broadcast and ADS-B rebroadcast (ADS-R). Version 1 formats are fully compatible with those of Version 0, in that a receiver of either version can correctly receive and process messages of either version.

According to D0-260A, the 1090ES ADS-B transponder should send State Vector (SV), Mode Status (MS), Target state (TS), Air Reference Velocity (ARV) Reports, and support the following DAPs capabilities:

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- i. airborne position (BDS 0,5).
- ii. Surface Position (BDS 0,6).
- iii. Aircraft Identification and Category (BDS 0,8).
- iv. Airborne Velocity (BDS 0,9).
- v. Aircraft Status (BDS 6,1).
- vi. Target State and Status (BDS 6,2).
- vii. Aircraft Operational Status (BDS 6,3).

3) RTCA DO-260B/EUROCAE ED-102A (Version 2)

The International Civil Aviation Organization issued "Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance–Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)" (DO-260B/ED-102) in December 2009, and was known as ADS-B version 2. The formats and protocols for 1 090 ES Version 2 were revised based on experience gained from operational usage with ADS-B that revealed a number of needed improvements, which included:

- i. separated reporting of source and system integrity.
- ii. additional levels of NIC to better support airborne and surface applications.
- iii. incorporation of the broadcast of the Mode A code into the emergency/priority message, increased transmission rates after a Mode A code change, and the broadcast of the Mode A code on the surface.
- iv. revision to the target state and status message to include additional parameters.
- v. eliminated the vertical component of NIC and NAC.
- vi. T = 0 position extrapolation accuracy changed from within 200 ms of the time of transmission to within 100 ms; and
- vii. capabilities were added to support airport surface applications.

According to D0-260B/ED-102A, the 1090ES ADS-B transponder should send State Vector (SV), Mode Status (MS), Target State (TS) and Air Reference Velocity (ARV) Reports, and support the following DAPs capabilities:

- i. Airborne Position (BDS 0,5).
- ii. Surface Position (BDS 0,6).
- iii. Aircraft Identification and Category (BDS 0,8).
- iv. Airborne Velocity (BDS 0,9).
- v. Aircraft Status (BDS 6,1).
- vi. Target State and Status (BDS 6,2).
- vii. Aircraft Operational Status (BDS 6,5).

7.3 Extract Mode S SSR DAPs using a MODE S Interrogator

7.3.1 Working Principles

The Mode S interrogator transmits interrogation to elicit replies for detection of Mode S transponders and more information from the aircraft. The use of a unique ICAO 24-bit aircraft address and provision of all the required aircraft data in one reply will reduce interrogation rates.

Each aircraft can be interrogated selectively, needing only one or two ‘hits’ per aircraft per scan and minimizing interference problems associated with SSR Mode A/C.

The operation of a Mode S interrogator will not interfere with the SSR performance of any aircraft equipped with a Mode A/C transponder.

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A Mode S interrogator is capable of performing the conventional surveillance function with Mode A/C transponders.

7.3.2 Interrogator Codes

The Mode S system requires each interrogator to have an IC, which can be carried within the uplink and downlink transmissions. The 4-bit IC uplink field in UF11 shall contain either 4-bit II code or the lower 4 bits of the 6-bit SI codes. It is recommended that whenever possible an interrogator should operate using a single interrogator code.

The II codes shall be assigned to interrogators in the range from 0 to 15. The II code value of 0 shall only be used for supplementary acquisition. The SI codes shall be assigned to interrogators in the range from 1 to 63. The SI code value of 0 shall not be used.

The assignment of interrogator II or SI codes, where necessary in areas of overlapping coverage, across international boundaries of flight information regions, shall be the subject of regional air navigation agreements. The ICAO Asia Pacific Regional Office maintains a register of II codes used – where States have provided this information to the office. States are encouraged to provide this information to the Regional Office and update it when changes are made.

7.3.3 Mode Interlace Pattern

The particular air traffic and environment of each interrogator will influence the selection of suitable interrogation periods, interrogation repeat frequency, MIP and Probability of Reply.

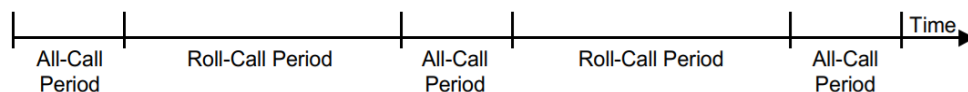


Figure.7-1 The Typical MIP

The repetition frequency and duration of the All-Call period is a local implementation issue (the stated ICAO maximum is 250Hz). The exact duration of either period will depend on the characteristics of the system such as the antenna revolution rate, the beam-width and the maximum range. There will normally be several all-call periods (and hence roll-call periods as one will always follow the other) available to interrogate all targets in range during one revolution.

There is a careful balance between the reliable acquisition of all targets and the potential of flooding the RF environment with unwanted replies to acquisition interrogations. It is necessary to choose an appropriate Mode Interlace Pattern to manage the acquisition activities to ensure minimal interference. The default objective is to define a MIP which effectively detects and performs surveillance on classical SSR Mode A/C aircraft using Mode A/C interrogations which also detects and acquires Mode S aircraft using Mode S interrogations. The MIP is constructed in order to separate Mode A/C and Mode S all-calls from Mode S selective (roll-call) activity. MIP defines the sequences of all-call interrogation types that might be made during cycles of all-call periods. Every interrogator is likely to have different needs and hence different ways of operating.

China presented an IP about the Mode S Parameter Set during the 3rd meeting of DAPs WG. For detailed information please refer to Appendix 4.

7.3.4 Mode S SSR DAPs Extraction using GICB Protocol

The GICB procedure is initiated by a Mode S interrogator for eliciting the Mode S DAPs containing aircraft derived data from a Mode S aircraft installation.

The GICB protocol allows for the immediate transfer of data required by the ground and the extraction of information stored in the Mode S transponder. This information (if available) is contained in the reply to an interrogation specifying the address (BDS code) of the storage location containing that information.

The interrogation with specific BDS can elicit the corresponding Comm-B data where contained in Mode S transponder's registers. The Mode S DAPs can be implemented in two stages: ELS and EHS.

The first processing step for any Mode S data link application is to obtain the transponder CA value from the aircraft. The 3-bit CA field is found in the "Mode S All-Call Reply" (DF=11) and the "Extended Squitter" (DF=17) downlinks. If CA=0, then this transponder is surveillance-only and supports no data link functions at all. If $CA \geq 4$ indicates that the Mode S transponder is fully capable of at least 56-bit short uplink and downlink message transfer. These Mode S transponders may support the ELS, EHS requirements. The values of CA= 1, 2, 3 are reserved.

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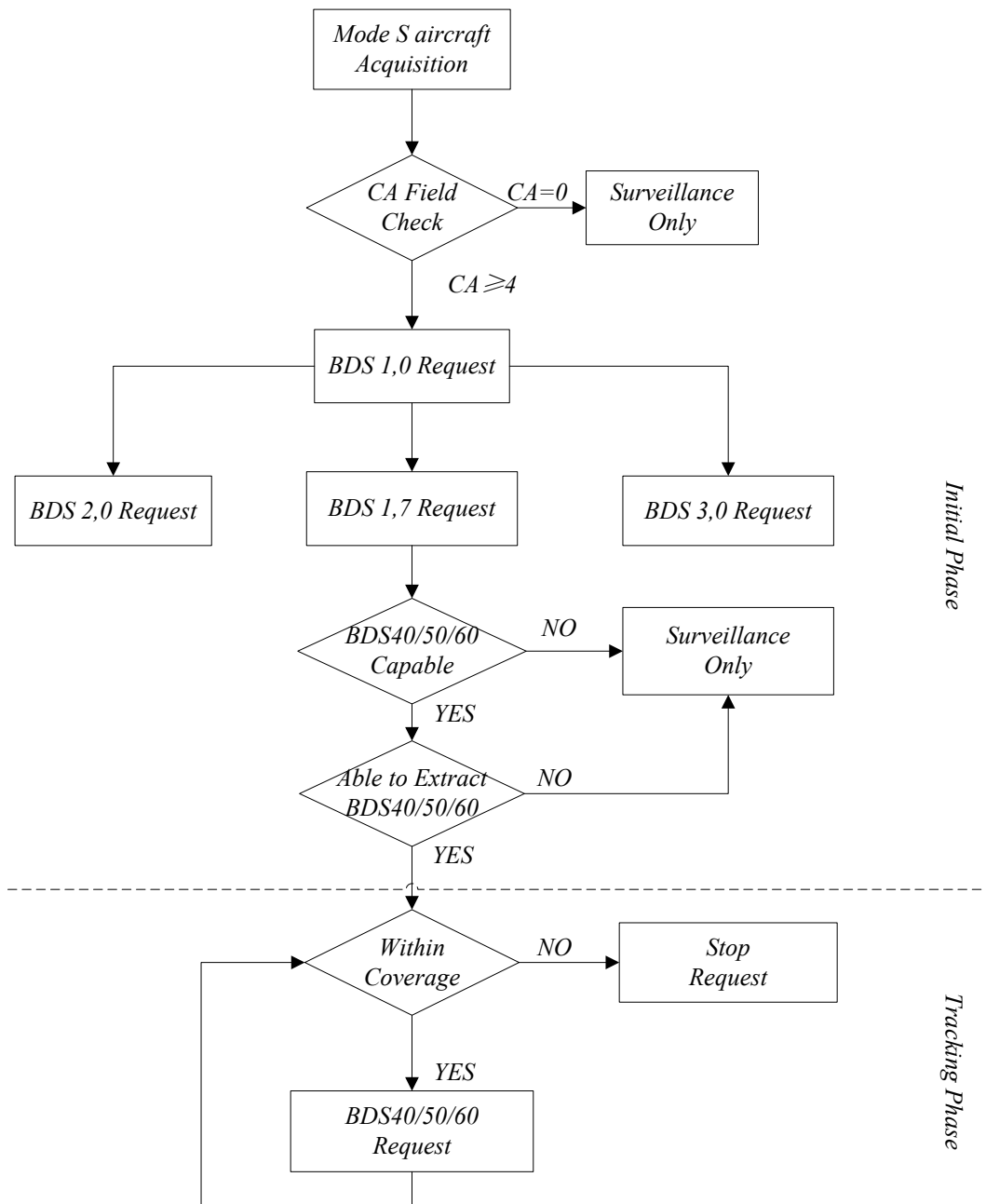


Figure.7-2 The Typical Procedure of DAPs Extraction

Given that the Mode S transponder's CA value is 4 or greater, the second processing step for any Mode S data link application is to extract the transponder's Mode S data link capability report register BDS code 1,0. Bits in this register indicate the support of such Mode S data link functions as aircraft identification (register BDS code 2,0), ACAS (register BDS code 3,0), common-usage capability (register BDS code 1,7) etc. The Mode S-Specific services capability bit in register BDS code 1,0 indicates whether the avionics installation supports further data link functions. If this bit is set, the Mode S data link application would next extract the common-usage capability register BDS code 1,7. All of the registers involved with the EHS application have bit flags assigned in this register BDS code 1,7. If the bit flag is set, it indicates that the corresponding register has been updated in a timely manner and contains valid data which can be extracted by the interrogator. The processing protocol is sufficient initialization for

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basic data link applications such as ELS, EHS since all their status and configuration information is available from register BDS code 1,0 and register BDS code 1,7.

So, the Mode S interrogator should transmit the selective interrogation to elicit the Mode S transponder reply with the specific formats and Comm-B data contained in the corresponding registers.

Normally, the more Comm-B data requested by the Mode S interrogator, the more information can be extracted from the aircraft transponder registers. It will also help the ATC controller get the aircraft's flight status and flight intention. However, there should be some necessary limitations for the Comm-B data request to avoid the phenomenon of Comm-B data discontinuity because of the limited Roll-Call interrogation duration.

It is suggested that the number, periodicity and priority of BDS data extraction rule be reasonably and effectively implemented according to the requirements and the number of aircraft in the airspace. The scientific strategy can ensure the ATC controller gets Comm-B data timely and effectively.

7.3.5 Mode S SSR DAPs Extraction using AICB Protocol

The AICB procedure is initiated by a Mode S transponder for transmitting a single Comm-B segment from the aircraft installation.

Any changes in the contents of ACAS (register BDS code 3,0) triggers a downlink message via the air-initiated Comm-B broadcast protocol including the updated register contents.

An AICB sequence shall start upon the acceptance of a message intended for delivery to the ground sensor. After receipt of this message, the transponder shall set a valid downlink request code of surveillance or Comm-B reply. On receipt of this message with a valid downlink request code, the interrogator could start to extract the message.

AICB messages are announced by the transponder and are transmitted in a subsequent reply only after authorization by the interrogator. AICB messages are announced to all interrogators and can be extracted by any interrogator. The Mode S data link application should update the aircraft's "state" values with the new ones. The changed state might result in discontinuance (or reinstatement) of certain Mode S data link functions. Mode S transponder AICB broadcast messages are held active in the transponder for 18 seconds after the triggering event. Any Mode S sensor can extract the broadcast information.

7.3.6 Mode S SSR DAPs Extraction using Comm-B Broadcast

A Comm-B broadcast is a message directed to all active interrogators in view. Messages are available for 18 seconds unless a waiting AICB interrupts the cycle. Interrogators have no means to cancel the Comm-B broadcast.

Currently, only registers of datalink capability report (register BDS code 1,0) and aircraft identification (register BDS code 2,0) make use of the Comm-B Broadcast.

7.4 Provision of ADS-B DAPs using extended squitter

7.4.1 Working Principles

The "1090 Extended Squitter" is a spontaneous broadcast transmission by the Mode S transponder on the 1090 MHz frequency not initiated by an interrogation on 1030 MHz. The "Automatic Dependent Surveillance – Broadcast (ADS-B)" is a function of airborne or surface aircraft, or other surface vehicles

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operating in the airport surface area, that periodically transmits its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information via a data link.

The 1090 Extended Squitter allows the transmission of ADS-B messages by means of 1090 Extended Squitter via 1090 MHz. The ADS-B message is formatted data that conveys information used in the development of ADS-B reports that can be used for air traffic management activity. The ADS-B reports can support improved use of airspace, surface surveillance, and enhanced safety such as conflict management.

There are four defined standards for the ADS-B 1090 ES applications. These standardizations were consistent with RTCA/DO-260, RTCA/DO-260A, RTCA/DO-260B and RTCA/DO-260C were termed 1090 ES Version 0, Version 1, Version 2 and Version 3. (1090 ES Version 3 has just been released in December 2020.)

The differences between the first three versions are mainly in the following two areas: (a) its specification of the ADS-B “event driven” transponder register set, and (b) how available avionics surveillance accuracy is specified.

7.4.2 ADS-B Message content

The Mode S transponder has 255 BDS registers. Each register stores aircraft parameters, message or data derived from FMS or other sensors. Some specific registers are defined for the ADS-B application so that related messages can be delivered via ADS-B message broadcast activity.

Table 7-2 Registers Related to ADS-B Application

Register	Content		
BDS code 0,5	Version0	Version1	Version2
	Airborne Position Message		
	Single Antenna Flag		NIC Supplement-B
	Airborne Position		
	Pressure Altitude		
	GNSS Height		
	Surveillance Status		
BDS code 0,6	Version0	Version1	Version2
	Surface Position Message		
	Ground Track	Heading	
	Surface Position		
	Movement		
BDS code 0,8	Version0	Version1	Version2
	Aircraft Identification and Type Message		
	Aircraft Category		
	Aircraft Identification		
BDS code 0,9	Version0	Version1	Version2
	Airborne Velocity Message		
	NUC _R	NAC _v	
	IFR Capability Flag		-
	Subtypes 1 and 2:Velocity Over Ground		Subtypes 3 and 4:Airspeed and Heading

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	Ground Speed Vector		Air Speed			
			Heading			
	Intent Change Flag					
	Ground Speed Vector					
	Vertical Rate					
	Difference from Baro Altitude					
BDS code 6,1	Version0	Version1		Version2		
	Aircraft Status Message					
	Subtype 1:Emergency/Priority Status			Subtype 2:1090ES TCAS RA Broadcast		
	Emergency Status			ACAS RA Report		
	-		Mode A Code			
	BDS code 6,2	Version 0	Version 1		Version 2	
Current/Next Trajectory Change Point(TCP) Message		Target State and Status Information Message				
TCP data		Target Altitude		Selected Altitude		
		-		SIL Supplement		
				Barometric Pressure Setting		
		Track Heading / Track Angle		Selected Heading		
		Emergency/Priority Status		Mode Engaged (Autopilot VNAV Altitude Approach LNAV)		
		Capability/Mode Code		TCAS Operational		
		NAC _P 、 SIL、 NIC _{BARO}				
BDS code 6,3		Version 0	Version 1		Version 2	
	Current/Next Trajectory Change Point Message(TCP+1)	Aircraft Operational Status Message		-		
		Subtype 0	Subtype 1			
	TCP+1 Data	Airborne Capability Class	Surface Capability Class			
			Length/Width Codes			
		NIC _{BARO}	TRK/HDG			
		Operational Mode OM				
		Version Number				
		NIC Supplement				
		NAC _P 、 SIL				
		HRD				
	BDS code 6,4	Version 0	Version 1			Version 2
		Aircraft Operational	-			

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		Coordination Message	-		
		Paired Address			
		Runway Threshold Speed			
		Roll Angle			
	BDS code 6,5	Version 0	Version 1	Version 2	
		Aircraft Operational Status Message	-	Aircraft Operational Status Message	
		CC	-	Subtype = 0	Subtype = 1
				Airborne Capability Class	Surface Capability Class
					Length/Width
				Airborne Operational Mode	Surface Operational Mode
		OM		GVA	-
				NIC _{BARO}	TRK/HDG
				Version Number	
				NIC Supplement-A	
				NAC _P , SIL	
				SIL Supplement	
				HRD	

As shown in the above table, all the versions of 1090 ES application involve the 7 basic registers (Airborne Position, Surface Position, ES Status, ES Identification and Category ES Airborne Velocity ES Event Driven Register and ES Aircraft Status). The remaining registers (BDS code 6,2, BDS code 6,3, BDS code 6,4) in the table have different definitions and applications for the three versions of 1090 ES application. Generally, for version 0, only five registers (BDS code 0,5, code 0,6, code 0,8, code 0,9 and BDS code 6,1) will be broadcast. In addition to the above five registers, version 1 will also broadcast message about BDS code 6,2 and code 6,3, while version 2 will broadcast message about BDS code 6,2 and code 6,5 additionally.

Table 7-3 ADS-B Message

Version	Common usage ADS-B Message
0,1,2	ES Airborne Position
	ES Surface Position
	ES Identification and Category
	ES Airborne Velocity
	ES Aircraft Status / Type Code=28
1,2	Target State and Status Information / BDS code 6,2/Type Code=29
1	Aircraft Operational Status / BDS code 6,3/Type Code=31 for version 1
2	Aircraft Operational Status /BDS code 6,5/Type Code=31 for version 2

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The three versions of the ADS-B application have different definitions of surveillance accuracy and the application of “event-driven” register messages. Therefore, the prerequisite for the correctly decoding the surveillance accuracy information and “event-driven” messages is the determination of the 1090 ES version.

There are two steps to check the ADS-B version, due to the fact that ADS-B version information in version 0 is not included in any message. **Step 1:** Check whether an aircraft is broadcasting ADS-B messages with Aircraft Operational Status message (Type Code=31) at all. If no message is ever reported, it is safe to assume that the version is equal to “0”. **Step 2:** If messages with Type Code =31 are received, check the version numbers located in the bits 41–43 in ME (or bits 73–75 in the message). The bits “001” correspond to version 1 and “010” to version 2 respectively.

7.4.3 ADS-B message Transmission Broadcast rate

The maximum ADS-B Message transmission rate shall not exceed 6.2 transmitted messages per second averaged over any 60 second interval. **There are periodic messages which are broadcast in the periodic manner and event-driven messages which are broadcast following the event-driven protocol. The event-driven protocol limits event-driven message transmissions to 2 per second in any second.**

a) **Airborne position Message (Version 0, 1, 2) is a periodic message, and** shall be emitted at random intervals that are uniformly distributed over the range from 0.4 to 0.6 seconds.

b) **Surface position Message (Version 0, 1, 2) is a periodic message, and** shall be emitted using one of two rates (high or low rate). The low rate is used when the aircraft is stationary, the high rate is used when the aircraft is moving. When the high squitter rate has been selected, the transmission interval of the surface position message obeys a uniform distribution within the interval of 0.4 to 0.6 seconds, and when the low squitter rate is used, it shall be emitted at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds.

c) **Aircraft identification Message (Version 0, 1, 2) is a periodic message,** which transmission interval follows a uniform distribution over 4.8 to 5.2 seconds when the aircraft is reporting the airborne position message, or when the aircraft is reporting the surface position message at the high rate (moving). When the surface position message is being broadcasted at the low rate (stationary), the message shall be emitted at random intervals that are uniformly distributed over the range of 9.8 to 10.2 seconds.

d) **Airborne velocity Message ((Version 0, 1, 2) is a periodic message, and** shall be emitted at random intervals that are uniformly distributed over the range from 0.4 to 0.6 seconds.

e) **Target State and Status Message (Version 1, 2) is delivered using the event-driven protocol in version 1 and is periodic message in version 2, and** shall be initiated only when the aircraft is airborne and when target state (vertical or horizontal) information is available and valid. The TSS Message shall be broadcast at random intervals with the uniformly distributed over the range of 1.2 to 1.3 seconds.

f) **Aircraft Operational Status Message –Airborne is delivered using the event-driven protocol in version 1 and is periodic message in version 2, and** shall be emitted for a period of 24 seconds at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds, when the Target State and Status (TSS) Message is not being broadcast and there has been a change within the past 24 seconds in the value of one or more of the specific parameters (*TCAS Operational/TCAS RA Active/NACP/SIL for Version 1 and TCAS RA Active/NACP/SIL/NIC_{SUPP} for Version 2*) included in the Operational Status Message.

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For other case when there is not any change within the past 24 seconds in the value of the specific parameters mentioned previous paragraph, the transmission interval of the message obeys a uniform distribution within the interval of 2.4 to 2.6 seconds

g) **Aircraft Operational Status Message –Surface is delivered using the event-driven protocol in version 1 and is periodic message in version 2, and** shall be always broadcast at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds for **Version 1**. For **Version 2**, the Surface Aircraft Operational Status Messages shall be broadcast at random intervals that are uniformly distributed over the range of 4.8 to 5.2 when the aircraft is on-ground and not moving. If the Aircraft is moving and there has been no change in the specific parameters (*NIC_{SUPP} / NAC / SIL*) then the message shall be broadcast at random intervals that are uniformly distributed over the range of 2.4 to 2.6 seconds for Version 2. When the Version 2 aircraft is on-ground and moving and there has been a change in the parameters mentioned above then the message shall be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds.

h) **Extended Squitter Aircraft Status message (Version 0)** is an event-driven message, and shall be broadcast at random intervals that are uniformly distributed over the range of 0.8 to 1.2 seconds for the duration of the emergency condition (temporary or permanent). If the Mode A Code is changed to 7500, 7600 or 7700, the duration of emergency condition shall be permanent. If the Mode A Code is changed to any other value, the emergency condition shall be temporary, and duration is equal to 18 seconds (TC).

i) **Extended Squitter Aircraft Status message (Version 1) is an event-driven message, and the transmission rate varies depending on whether the TSS Message is not being broadcast, versus being broadcast.**

In the case where the TSS Message is not being broadcast, the Extended Squitter Aircraft Status message shall be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds for the duration of the emergency condition. It shall be broadcast at random intervals that are uniformly distributed over the range of 2.4 to 2.6 seconds for the duration of the emergency condition, when the TSS Message is being broadcast,

j) **Extended Squitter Aircraft Status message with Subtype=1 (Version 2)** is an event- driven message, and shall be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds for the duration of the emergency condition, or the Message shall not be broadcast (no emergency condition established), When the Mode A Code transmission is disabled (be set to Mode S Conspicuity Code “1000”).

When the Mode A Code transmission is enabled, the Aircraft Status message with Subtype=1 shall be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds for a duration of 24 ± 1 seconds following a Mode A Code change by the pilot

In the absence of conditions above for version 2, the Message shall be broadcast at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds.

The Aircraft Status Message with Subtype=2 (TCAS RA Broadcast) for version 2 shall be broadcast at random intervals that are uniformly distributed over the range of 0.7 to 0.9 seconds. The transmission shall be terminated 24 ± 1 seconds after the *Resolution Advisory Termination* (RAT) flag transitions from ZERO (0) to ONE (1).

7.5 Application of the Mode S DAPs in ATM Automation System

7.5.1. Implementation of the General DAPs information

General DAPs information refers to the information that both Mode S SSR, MLAT and ADS-B can provide. This information from aircraft can be beneficial to the ATM automation system:

a) ICAO 24-bit Aircraft Address/Aircraft Identification

- 1) The ATM automation system should collect the real aircraft address/aircraft identification from the received message, and the aircraft address/aircraft identification can be shown on the control HMI to identify the aircraft.
- 2) The ATM automation system can use the aircraft address/aircraft identification to correlate an aircraft's track with the flight plan, so the use of aircraft address/aircraft identity can alleviate the shortage of Mode 3/A code. Correlation between track and flight plans is normally based on either the 24-bit aircraft address, aircraft identification, or the Mode 3/A code. The correlation will depend on their weights and priority.
- 3) The ATM automation system can also utilize the aircraft address/aircraft identification to improve the tracking function.
- 4) The ATM automation system could provide DUPE warning between aircrafts which have the same ICAO 24-bit aircraft address, same aircraft identification or the same Mode 3/A code.

b) Altitude reporting in 25ft interval

The ATM automation system can collect aircraft altitude reporting in 25ft increments and provides valuable improvements to the quality of safety nets. The improvements should reduce the number of nuisance alerts and enhance the integrity of separation assurance.

c) Selected Altitude

- 1) The ATM automation system can collect the selected altitude of the aircraft from Mode S SSR DAPs BDS 4,0 or ADS-B DAPs BDS 6,2 (Version 2) that can be shown to the controller to improve the situational awareness of the controller.
- 2) The ATM automation system can generate a SFL Mismatch Alarm when the SFL chosen by the crew does not match the cleared altitude given by the controller (CFL), alerting the controller to take appropriate action to remedy the issue. A SFL Mismatch Alarm shall be presented to the responsible controller as an indication in the coupled/correlated surveillance track label and in the associated flight strip.
- 3) The ATM automation system can also utilize the SFL to improve the accuracy of the safety net.

In MTCD function, the ATM automation system can use the selected altitude as the target climbing/descending altitude in the flight look-ahead time, and calculate the possibility of conflict with the predicted flight trajectories of other flights in the airspace through trajectory prediction. Calculations involving SFL could be more accurate, and improve the performance of MTCD.

In MSAW function, the ATM automation system generally provides MSAW warning by using track data (heading and rate of climb/descent and mode c). The ATMs use of CFL or SFL can enhance the MSAW algorithms use of vertical data to predict MSAW alerts and reduce the number of false alerts.

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d) Barometric Pressure Setting

The ATM automation system can collect the barometric data of the aircraft from Mode S SSR DAPs BDS 4,0 or ADS-B DAPs BDS 6,2 (Version 2) and provide this information to the controller. The system can provide a warning when the barometric data transmitted by the aircraft does not match the parameter of the area where the aircraft is operating.

e) Ground Speed, True Track Angle, Magnetic Heading, True Airspeed

- 1) The ATM automation system can collect Ground Speed, True Track Angle from Mode S SSR DAPs BDS 4,0 or ADS-B DAPs BDS 0,9 and 0,6, True Airspeed from Mode S SSR DAPs BDS 5,0 or ADS-B DAPs BDS 0,9 (if ground speed is unavailable), Magnetic Heading from Mode S SSR DAPs BDS 6,0 or ADS-B DAPs BDS 0,9 (if ground speed is unavailable). The system may provide the display of some of the information to the controller to improve the situational awareness of the controller. This information can be displayed in various ways (e.g., a DAP Window) as offline defined, according to the requirement of the controllers. Display of some parameters provides a clearer picture to the controllers generating a reduction in radio calls with the pilot, so the R/T usage between the controller and individual aircraft under service is reduced.
- 2) The system can make use of DAPs kinematics parameters for consistency checking, and perform a more precise tracking function.
- 3) The system can utilize the kinematics information of the aircraft to improve the accuracy of safety net functions, (e.g., Short-Term Conflict Alert (STCA)), through the provision of more accurate aircraft tracks.
- 4) The system may use True track angle, Magnetic Heading, True Airspeed and Ground Speed to calculate a wind direction and speed of a specific area, which will enable the updating of forecast winds and improve trajectory modeling in the system. The system may also show the wind information to the controller to improve the situational awareness of the controller.

f) Barometric Altitude Rate

The ATM automation system can collect the vertical rate data of the aircraft from Mode S SSR DAPs BDS 4,0 or ADS-B DAPs BDS 0,9 to improve the precision of the compute altitude and the accuracy of the related alert. The system can make use of the data to realize an optimized CFL protection in STCA and MSAW analysis function.

g) Indicated Air Speed

The ATM automation system can acquire indicated airspeed of the aircraft from Mode S SSR DAPs BDS 6,0 or ADS-B DAPs BDS 0,9 (if ground speed is unavailable), allow ATC to monitor the aircrew compliance with the controller's instructions, and if required provide a warning to the controller when there is a mismatch.

h) ACAS Resolution Advisory Report

Some of the ATM automation system can collect the ACAS Resolution Advisory Report from Mode S SSR DAPs BDS 3,0 or ADS-B DAPs BDS 6,5 (Version 2). The ACAS Resolution Advisory information can be shown in the system to improve situational awareness of the controller. On receipt of ACAS Resolution Advisory notification, a prominent notification is displayed in a field that may be acknowledged. The indication is removed when the ACAS RA is resolved.

Note: The display of ACAS Resolution Advisory Report in ATM automation system can be turned on or turned off by a user, and it's use if not recommended by IFATCA. The user is suggested to do the relevant safety evaluation before applying this function.

7.5.2. Mode S SSR DAPs

Mode S SSR DAPs information refers to the information that only Mode S SSR can provide. This following information of aircraft can be beneficial to the ATM automation system:

- a) Roll Angle, Track Angle Rate,
 - 1) The ATM automation system can collect these parameters from Mode S SSR DAPs BDS 5,0 and may allow the display of some of the information to the controller to improve the situational awareness of the controller. This information can be displayed in various ways (e.g., a DAP Window) as offline defined, according to the requirement of the controllers. Display of some parameters provides a clearer picture to the controllers generating a reduction in radio calls with the pilot, so the R/T usage between the controller and individual aircraft under service is reduced.
 - 2) The system can make use of DAPs kinematics parameters for consistency checking, and perform a more precise tracking function.
 - 3) The system can utilize the kinematics information of the aircraft to improve the accuracy of safety net functions, (e.g., Short-Term Conflict Alert (STCA)), through the provision of more accurate aircraft tracks.
 - 4) The system may use True track angle, Magnetic Heading, True Airspeed and Ground Speed to calculate a wind direction and speed of a specific area, which will enable the updating of forecast winds and improve trajectory modeling in the system. The system may also show the wind information to the controller to improve the situational awareness of the controller.

- b) Inertial Vertical Velocity

The ATM automation system can acquire the vertical rate data of the aircraft from Mode S SSR DAPs BDS 6,0 to improve the precision of the compute altitude and the accuracy of the related alert. The system can make use of the data to realize an optimized CFL protection in STCA and MSAW analysis function.

- c) Mach Number

The ATM automation system can acquire Mach number of the aircraft from Mode S SSR DAPs BDS 6,0. This information can allow ATC to monitor the aircrew compliance with the controller's instructions, and if required provide a warning to the controller when there is a mismatch.

- d) Flight status (airborne/on the ground)

The ATM automation system can collect the flight status of the aircraft from reply of the Mode S SSR Roll-Call interrogation. Whether the aircraft is airborne or on the ground can be shown in the system to improve the situational awareness of the controller. Also, the flight status can be used to filter the aircraft on the ground in the system if necessary.

7.5.3. ADS-B DAPs

- a) Aircraft emitter category

The emitter category can be acquired from ADS-B DAPs BDS 0,8 can be provided information about the type of vehicle to the controller by the ATM automatic system. The system can provide a warning to the controller when the information transmitted by the aircraft does not match the Flight Plan.

- b) GNSS information (latitude, longitude, height, altitude, velocity, vertical rate, accuracy and integrity of GNSS information)
- 1) The precision of aircraft position in GNSS information should be higher than normal radars. The ATM automation can make use of DAPs GNSS information to perform a more precise tracking function.
 - 2) The ATM automation system can utilize the GNSS information in different ways or display in different symbols to the controller based on the accuracy and integrity values of current GNSS information received in the messages.
 - 3) In order to meet the requirements of ICAO Annex 6 and Annex 10 for aircraft RVSM altitude maintenance performance monitoring, the geometric altitude in ADS-B (using as the real altitude of aircraft operation), can be compared with the air pressure altitude (Mode C) to analyze the aircraft altitude keeping performance. The comparison verifies whether the aircraft is flying according to the selected altitude setting by the crew, and validates the continual compliance for RVSM altitude monitoring.
 - 4) Airborne horizontal position/Geometric altitude can be used in data analysis. Based on flight trajectory, an analyzer can classify different trajectory models, view different traffic pattern, find abnormal trajectory, analyze the operation efficiency of traffic flow, and predict the flight time of future trajectory.
- c) Selected Heading/Target Heading
- 1) The ATM automation system can use the selected heading/target heading of the aircraft, and may display the information to the controller to improve the situational awareness of the controller.
 - 2) The ATM automation system can generate a heading Mismatch Alarm when the selected heading/target heading does not match the heading given by the controller, alerting the controller to take appropriate action to remedy the issue.
 - 3) The ATM automation system can also utilize the selected heading/target heading to improve the accuracy of the safety net.

7.6 Flight Planning

7.6.1 ICAO Flight Plan Item 7 - Aircraft Identification

ACID must be accurately recorded in item 7 of the ICAO Flight Plan form as per the following instructions:

Aircraft Identification, not exceeding 7 alphanumeric characters and without hyphens or symbols is to be entered both in item 7 of the flight plan and replicated exactly when set in the aircraft (for transmission as Flight ID) as follows:

Either,

- a) The ICAO designator for the aircraft operating agency followed by the flight identification (e.g., KLM511, NGA213, JTR25), when in radiotelephony the call sign to be used by the aircraft will consist of the ICAO telephony designator for the operating agency followed by the flight identification (e.g., KLM 511, NIGERIA213, JESTER25).

Or,

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-
- b) The nationality or common mark registration marking of the aircraft (e.g., EIAKO, 4XBCD, N2567GA), when:
- 1) in radiotelephony the callsign used by the aircraft will consist of this identification alone (e.g., CGAJS), or preceded by the ICAO telephony designator for the operating agency (e.g., BLIZZARD CGAJS),
 - 2) the aircraft is not equipped with a radio.

Note 1: No zeros, hyphens, dashes or spaces are to be added when the Aircraft Identification consists of less than 7 characters.

Note 2: Appendix 2 to ICAO DOC4444 (PANS-ATM 16th edition, 2016) refers.

Note 3: Standards for nationality, common and registration marks to be used are contained in Annex 7, section 3.

Note 4: Provisions for the use of radiotelephony call signs are contained in Annex 10, Volume II, Chapter 5. ICAO designators and telephony designators for aircraft operating agencies are contained in Doc 8585 — Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services.

7.6.2 Equipment (Surveillance Equipment /SSR Equipment)

- a) ICAO Flight Plan Item 10 – Surveillance Equipment and Capabilities

When an aircraft is equipped with a Mode S Transponder, appropriate Mode S designators shall be entered in item 10 of the flight plan to indicate that the flight is capable of transmitting Mode S DAPs messages.

These are defined in ICAO DOC 4444 as follows:

‘N’ No surveillance equipment for the route to be flown is carried, or the equipment is unserviceable

SSR Mode A and C

‘A’ Mode A transponder

‘C’ Mode A and Mode C transponder

SSR Mode S

‘E’ Mode S transponder, including aircraft identification, pressure-altitude and extended squitter (ADS-B) capability

‘H’ Mode S transponder, including aircraft identification, pressure-altitude and enhanced surveillance capability

‘I’ Mode S transponder, including aircraft identification, but no pressure-altitude capability

‘L’ Mode S transponder, including aircraft identification, pressure-altitude, extended squitter (ADS-B) and enhanced surveillance capability

‘P’ Mode S transponder, including pressure-altitude, but no aircraft identification capability

‘S’ Mode S transponder, including both pressure altitude and aircraft identification capability

‘X’ Mode S transponder with neither aircraft identification nor pressure-altitude capability

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Note: Enhanced surveillance capability is the ability of the aircraft to down-link aircraft derived data via a Mode S transponder.

b) ICAO Flight Plan Item 18 – Other Information

Where required by the appropriate authority the ICAO AA (24 Bit Code) may be recorded in Item 18 of the ICAO flight plan, in hexadecimal format as per the following example:

CODE/7C432B

Members or states should note that use of hexadecimal code may be prone to human error and is less flexible in regard to airframe changes for a notified flight.

7.6.3 Inconsistency between Mode S Flight Planning and Surveillance Capability

Inconsistency between flight planning of Mode S and surveillance capability of an aircraft can impact ATC planning and situational awareness. States are encouraged to monitor for consistency between flight plan indicators and actual surveillance capability. Where discrepancies are identified aircraft operators should be contacted and instructed to correct flight plans, or general advice (as appropriate to the operational environment and type of flight planning problems) should be issued to aircraft operators.

Advice to Operators:

Concerning inconsistency between Mode S Flight Planning and Surveillance Capability:

- a) ICAO AA (24 Bit Code) not submitted, or submitted incorrectly.
- b) Mode S and surveillance capabilities indicators incorrectly.

The flight planning requirements and relevant designators for aircraft are described in local document reference or ICAO DOC 4444 Appendix 2. The capability of the aircraft transponder and ADS-B capability will typically be available in the transponder manual or the aircraft flight manual for the aircraft. If in doubt, consult the transponder manual, aircraft flight manual or the Licensed Aircraft Maintenance Engineer.

7.6.4 Setting Flight ID in Cockpits

a) Flight ID Principles

The Flight ID is the equivalent of the aircraft callsign and is used in both Mode S SSR and ADS-B technology. Up to seven characters long, it is usually set in airline aircraft by the flight crew via a cockpit interface. It enables air traffic controllers to identify an aircraft on a display and to correlate a radar or ADS-B track with the filed flight plan ACID. Flight ID is critical, so it must be entered carefully. Punching in the wrong characters can lead to ATC confusing one aircraft with another.

The Flight ID entered in the transponder exactly must match the ACID entered in the flight plan.

Intuitive correlation between an aircraft's flight identification and radio callsign enhances situational awareness and communication. Airlines typically use a three letter ICAO airline code in flight plans, NOT the two letter IATA codes.

b) Setting Flight ID

The callsign dictates the applicable option below for setting Mode S or ADS-B Flight ID:

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- 1) The flight number using the ICAO three-letter designator for the aircraft operator if a flight number callsign is being used (e.g., QFA1 for Qantas 1, THA54 for Thai 54).
- 2) The nationality and registration mark (without hyphen) of the aircraft if the callsign is the full version of the registration (e.g., VHABC for international operations).
- 3) The registration mark alone of the aircraft if the callsign is the abbreviated version of the registration (e.g., ABC for domestic operations).
- 4) The designator corresponding to a particular callsign approved by the ANSP or regulator (e.g., SPTR13 for firepotter 13).
- 5) The designator corresponding to a particular callsign in accordance with the operations manual of the relevant recreational aircraft administrative organization (e.g., G123 for Gyroplane 123).

Note: More information of Flight plan for 1090 MHz ADS-B can refer to section 9.10 of AIGD.

7.7 Contingency Plan

ANSPs should prepare appropriate contingency plans in the event of a system failure that prevents the use of Mode S DAPs.

8. TRAINING AND COMPETENCY

8.1 Introduction

Training and development play an important role in the effectiveness of organizations and to the experiences of people in work. Training on DAPs has implications in improving productivity, aviation safety and personal development. The primary goal of the training is to develop and maintain an appropriate level of trust in DAPs related module, i.e., to make ATC and ATSEP aware of the likely situations where DAPs will be effective and, more importantly, situations in which DAPs will not be so effective (e.g., sudden, unexpected maneuvers).

8.2 Training of an Air Traffic Controller (ATC) in DAPs

With the inclusion of DAPs into surveillance and ATM automation system, an ATC training plan should adopt a modular approach. This approach progressively introduces various features, functionality of the new system on one hand and allows for integration with the ATC operational procedures. Additional benefits include shorter, logical self-contained units, clear attainable goals, better evaluation of training effectiveness and simplified self-assessment.

The ANSP should develop familiarization and rating focused training to ATC prior to adoption of DAPs in Surveillance and ATM automation systems.

The ANSP should ensure that all ATC concerned are assessed as competent for the use of the relevant DAPs module.

8.3 Training of an ATSEP in DAPs

- a) The ANSP should develop an ATSEP training programme that is acceptable to the ANS Regulator prior to its implementation.
- b) As a minimum, the training programme should comprise three levels as described below:
 - 1) Level 1 (Basic training). This should comprise training on the basic Surveillance and ATM automation systems operating in the State and their impacts on the safety of aircraft operations. The ANSP should ensure every ATSEP undergoes the basic training.
 - 2) Level 2 (Qualification training). This should comprise training to develop knowledge and skills on Surveillance and ATM automation systems. The ANSP should ensure each ATSEP is trained in one or more domains depending on their job scope.
 - 3) Level 3 (Specialized training). This should comprise training on specific Surveillance and ATM automation systems installed in the State, followed by on-the-job training.
- c) The ANSP should conduct a yearly review of the training plan for each ATSEP at the beginning of the year to identify any gaps in competency or changes in training requirements and priorities the type of training required for the coming year in regards of DAPs development.
- d) The ANSP should keep records of individual ATSEP training, competency assessment and approval history, where applicable, and associated documents. The records should be kept at least until the Surveillance and ATM automation system of which the ATSEP was trained on is no longer in use with the ANSP.

- e) The individual training records for each of ATSEP should include a training plan detailing the courses completed as well as the time-frame for attending future courses as required under his/her training plan.

8.4 Competency Assessment of an ATSEP in DAPs

- a) The ANSP should develop an assessment methodology to determine the competency of an ATSEP in accordance with the competency framework developed in PANS-Training and which should be adapted to suit the local context.
- b) The ANSP may select a person to be a competency assessor only if the person –
 - 1) is an ATSEP approved in accordance with paragraph 8.3 for the particular Surveillance and ATM automation system; and
 - 2) has received adequate training in the conduct of competency assessment, practical checks and oral questionings.
- c) A competency assessor should not conduct a competency assessment on an ATSEP who is under the direct supervision of the competency assessor unless the assessment is done in the presence of a second independent assessor.
- d) The assessment methodology should include a process for on-going competency checking and refresher training to ensure retention of competence.

9. SPECIFIC EXAMPLES ON MODE S DAPs APPLICATION

9.1 Use of Selected Altitude

Since August 2013, Mode S data processing functions have been implemented in Chengdu ATM automation system. The system uses the select altitude data extracted from the Mode S DAPs to provide an optimized CLAM alert for controllers. The system will generate the alert when the SFL chosen by the crew does not match the cleared altitude recorded in the ATM automation system. And a time delay parameter is predefined for the response time of the flight after controllers' input to the ATM automation system (typically at the time of instruction given to the pilot).

Thanks to this new kind of alert, controllers have a better awareness of the intention of the airplanes and may discover the crew's mis-operation much earlier than the traditional CLAM, and then take actions timely to avoid the potential conflict.

In April 2017, an A320 aircraft was maintaining level flight at 27600 feet with another flight flying nearby at 26600 feet. Suddenly, the crew set an error altitude 22600 feet. The ATM automation system triggered the alert immediately even before the aircraft began to descend. The controller quickly noticed the alert and informed the crew in time. The aircraft successfully stopped descend at 27400 feet.

9.2 Use of ACAS RA

With the advancement of the ASTERIX standards and DAPs application, an ATM system can handle the derived data from Aircraft, which is detected, received and transmitted through the Mode S Radar, ADS-B station, and WAM sensors. In the event that an Airborne Collision Avoidance System (ACAS) Resolution Advisory (RA), the ATM system is able to provide a visual and aural alarm warning and indicative pilot intention to the controller.

Resolution Advisory (RA) alerting function works as follows:

- A resolution advisory is present when, in the subfields I048/260, I020/260, I021/260, I021/260 or I062/380 subfield #12(ACS), the bits are set as follows:
 - the first bit of the ARA field set to 1 and the RAT bit set to 0 or,
 - the first bit of the ARA field set to 0, the MTE bit set to 1 and the RAT bit set to 0.
- A resolution advisory is removed when:

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-
- the ACAS RA report subfield (I048/260, I020/260, I021/260 or I062/380 subfield #12(ACS)) contains the RAT bit set to 1, or
 - An ACAS RA report is not received in the relevant Data Item of the ASTERIX report.

Besides, the Resolution Advisory Intention is populated base on the PILOT selection and according to the following table:

MTE (60)	ARA (41)	42	43	44	45	46	47	RA Selection	RA Intention
1	0	Any	0	Any	1	Any	Any	Descend	Positive descend (Descent to avoid the threat)
1	0	Any	1	Any	0	Any	Any	Climb	Positive climb (Climb to avoid the threat)
1	0	Any	0	Any	0	Any	Any	Other	Other

*NOTE1: ACAS Airborne Collision Avoidance System, applied in the EURO Aviation System, has the same meaning as TCAS abbreviated to Traffic Alert and Collision Avoidance System in the USA Aviation System

*NOTE2: The function and the matters needing attention related to ACAS Resolution Advisory Report in ATM automation system, please refer to 7.4.1 e).

9.3 Use of Mode-S DAPs data for weather forecast

Meteorological Research Institute (MRI) and Electronic Navigation Research Institute (ENRI) conducted experiments for improving weather forecast accuracy utilizing Mode S DAPs data. In the experiments, horizontal wind and temperature were estimated from the data in registers BDS code 5,0 and BDS code 6,0 listed below.

Table 9-1 DAPs information for weather forecast

Register	Name	Data Item
BDS code 5,0	Track and turn report	True Track Angle
		Ground Speed

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		True Airspeed
BDS code 6,0	Heading and speed report	Magnetic Heading
		Mach Number

The temperature is the function of Mach number and true airspeed. To estimate horizontal wind speed and direction, calculating zonal wind speed and meridional wind speed from ground speed, true airspeed, true track angle and true heading angle. The true heading angle is obtained from magnetic heading angle and magnetic declination which is given by a quadratic equation of aircraft position. Then the wind and temperature as observation data were used to produce the initial fields of the numerical model, resulting in the improvements of weather forecast accuracy.

The results of the experiments indicate that Mode S DAPs data have the potential to improve forecasts of rainfalls and shear-lines. For details, please refer to the IP11 presented by Japan at the Mode S DAPs/3.

9.4 Use of Barometric Pressure Setting

When the aircraft is below the transition level the pilot is required to set barometric pressure setting in altimeter to local QNH/QFE. Wrong barometric pressure setting (especially QNH higher than actual) can lead to cleared flight level deviation or more serious controlled flight into terrain, as the pilot sees higher altitude on his altimeter and the flight management system determines the lower target altitude base on barometric pressure setting and selected altitude. Every millibar of barometric pressure setting error may add 30 feet of error to altimeter and target altitude.

Constantly checking if the barometric pressure setting in DAPs is consistent with the airport's QNH can alert the controller to avoid similar situations. In Feb 2021, an aircraft was cleared to descend to 7000 feet. The pilot set the right selected altitude, but forgot to set barometric pressure setting. At that time, the airport QNH was 1013, while the crew barometric pressure setting was 1118.5. An alarm system notified the controller of this situation. The error was corrected after the controller prompted the pilot preventing a dangerous situation.

9.5 Application of geometric height of ADS-B in analysis of Height-Keeping-Performance in RVSM

TVE, AAD and ASE are important indicators reflecting the height keeping performance of aircraft, which can be calculated based on ADS-B data, the definitions of TVE, AAD, ASE and FTE in Doc 9574 are as followed:

***Total vertical error (TVE).** The vertical geometric difference between the actual pressure altitude flown by an aircraft and its assigned pressure altitude (flight level).*

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Assigned altitude deviation (AAD). The difference between the transponder Mode C altitude and the assigned altitude/flight level.

Altimetry system error (ASE). The difference between the altitude indicated by the altimeter display, assuming a correct altimeter barometric setting, and the pressure altitude corresponding to the undisturbed ambient pressure.

Flight technical error (FTE). The difference between the altitude indicated by the altimeter display used to control the aircraft and the assigned altitude/flight level.

The section 4.10 of Appendix A of Doc 9574 outlines the method for estimating ASE. The description is as followed:

An aircraft's actual ASE at any time is the difference between its actual TVE and contemporaneous actual FTE. Given a measure of TVE and a contemporaneous AAD for the aircraft, the difference between TVE and AAD provides an estimate of ASE.

Figure 9-1 shows the relationship between the vertical errors. As noted in Doc 9574, correspondence error can be negligible when estimating ASE, so RMAs only estimates TVE, AAD and AES usually.

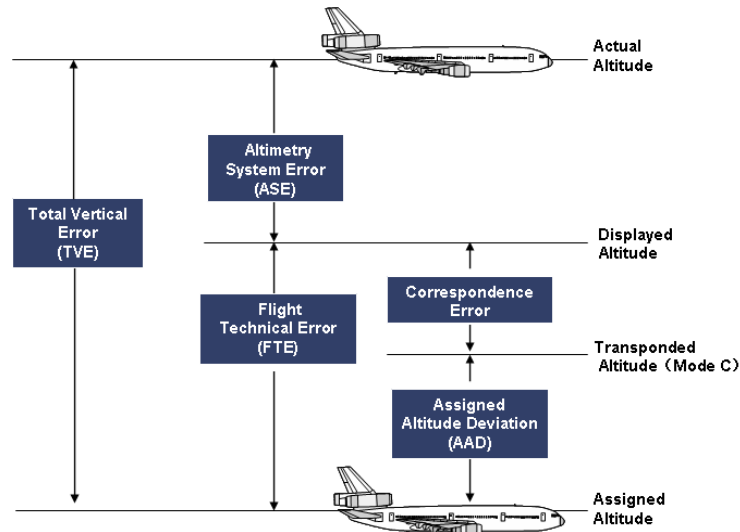


Figure 9-1: Relationship between the vertical errors

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Figure 9-2 shows the calculation process of TVE, AAD and ASE based on ADS-B data. It should be known that the aircraft actual geometric altitude and Mode C pressure altitude are included in ADS-B data. For assigned pressure altitude, it can be inferred from Mode C pressure altitude. And for the corresponding geometric altitude, it can be calculated by combining the inferred assigned pressure altitude/FL and the MET data. The difference between aircraft actual geometric altitude and geometric altitude of the inferred assigned pressure altitude/FL is TVE, the difference between inferred assigned pressure altitude/FL and Mode C pressure altitude is AAD, and the difference between TVE and AAD is ASE.

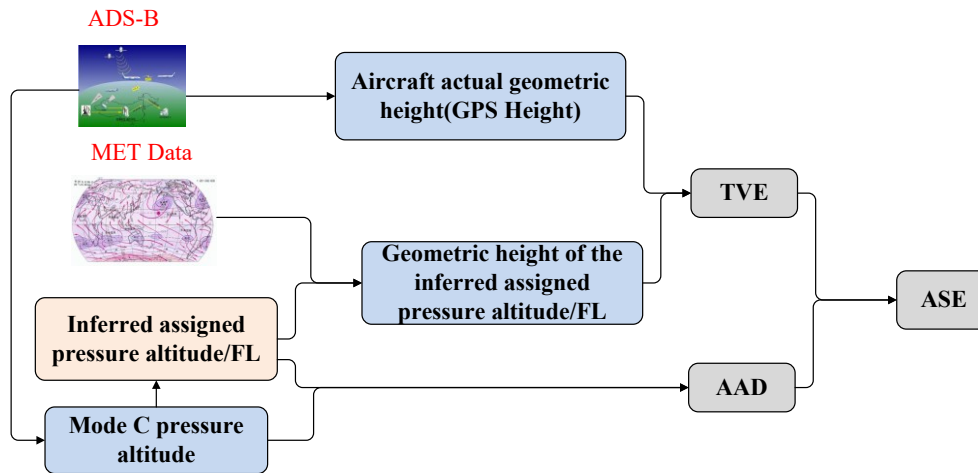


Figure 9-2: Calculation process of TVE, AAD and ASE based on ADS-B

In 9574, the error ranges of TVE, AAD and ASE are defined at the same time

- 1) $TVE \geq 90 \text{ m (300 ft)}$.
- 2) $ASE \geq 75 \text{ m (245 ft)}$; and
- 3) $AAD \geq 90 \text{ m (300 ft)}$.

APPENDIX 1: Mode S DAPs Analysis

a) Data Recording Configuration

Figure 1 represents an example of a configuration for data recording. The Mode S sensor sends interrogations to an individual aircraft using a unique ICAO 24-bit aircraft address. The Mode S transponder has 255 BDS Registers. Each register stores aircraft parameters data derived from FMS or other sensors. The messages can be readout on demand by a ground interrogator, in addition to/or being broadcasted.

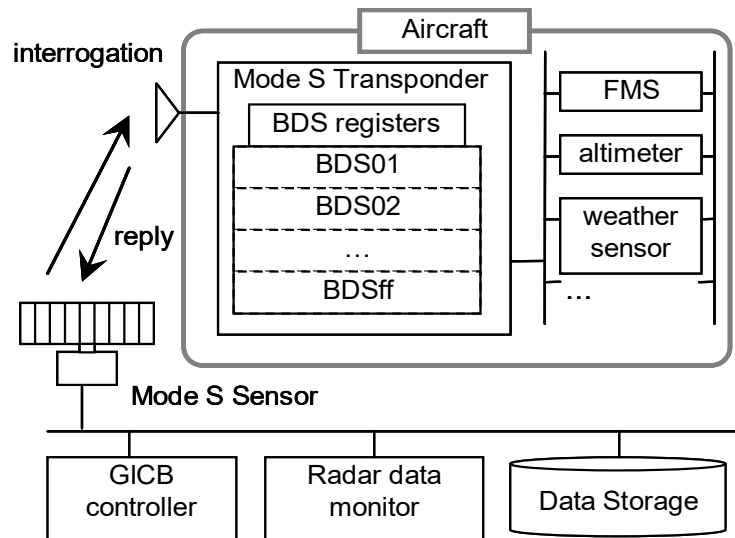


Figure1 - Example of Data Recording Configuration

b) Data Analysis

As described above section, erroneous DAPs data have been observed due to failure or improper setting/installation of Mode S avionics equipment. Bad data hinders the use of DAPs by the ATM service. To employ DAPs for ATM services, the reliability of DAPs is important. Therefore, it is necessary to analyze the recorded data to ensure reliability of the DAPs data.

If a controller finds some problem during the application of the Mode S DAPs, the ATS providers can analyze the recorded data to find the exact reason which caused the problem. If the ATS equipment has a fault which caused the problem, the ATS provider should implement a solution as soon as possible. If the ATS

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provider proves that the problem is caused by an avionics fault, then the problem should be reported to the appropriate party to solve the problem. The ATS providers need to devise mechanisms and procedures to address identified faults.

ATS providers should develop systems to analyze the routine recorded data. From the analyses, ATS providers can provide more information of the transponder's performance such as SI capability, datalink capability etc. The information can be used to improve the capability of the operation of Mode S DAPs equipment. By analyzing the recorded data, advice on avionics anomalies and faults, which have been detected, can be passed onto the regulators and the aircraft operators.

c) DAPs Data Validation

To ensure that Mode S DAPs are operating in conformance with the ICAO requirements, validating DAPs data is highly recommended. It has been noted that there are some drawbacks in the traditional methodology of executing tests for aircraft on the ground as follows:

- 1) Avionics for DAPs consist of several devices and functional blocks. They are interconnected, and the configuration is complicated.
- 2) Avionics and configuration differ depending on each aircraft.
- 3) It is difficult to cover the possible test patterns completely.
- 4) Ground test methodology would not detect failures or anomalies that occur after the testing.

Responding to these drawbacks, MIT Lincoln Laboratory developed and proposed a DAPs validation methodology, which monitors DAPs data received from actual flying aircraft to detect erroneous data. The MIT validation methodology is mainly categorized by two groups, static value tests and dynamic value tests.

Static value tests are executed to detect erroneous values of the bits and fields in BDS registers which do not change during a flight. Those bits and fields represent the avionics system's configuration, capability, and status information. These tests verify that those bits and fields are proper values in compliance with the ICAO regulations for DAPs applications. Table 1 shows an example of static value tests. As can be seen by the table, failed data were detected in each BDS register test. For BDS Register 20₁₆, failed data with wrong character coding were caused not due to equipment problem, but to faulty data input.

Table 1 Example of Static Value Tests

BDS Register	Test Item	Total Count		Aircraft	
		Executed	Failed	Executed	Failed

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BDS code 1,0	Aircraft identification capability flag = '1'	544,980	7,183	3,615	146
BDS code 2,0	Each character conforms to ICAO 6-bit character coding	737,993	1,516	3,596	144
BDS code 4,0	Unavailable data fields are set at zero	54,248,802	1,755	3,614	4

Dynamic value tests validate the values which dynamically change according to aircraft motion, such as aircraft speed and track angle. The tests compare the DAPs values with equivalent data like radar-measured positions. If the difference between DAPs values and radar-derived parameters exceeds the acceptability threshold, the DAPs value is accounted as an error. Figure 2 represents an example of dynamic value tests. This figure indicates that ground speed differences between DAPs data and radar-derived data fall inside the threshold range.

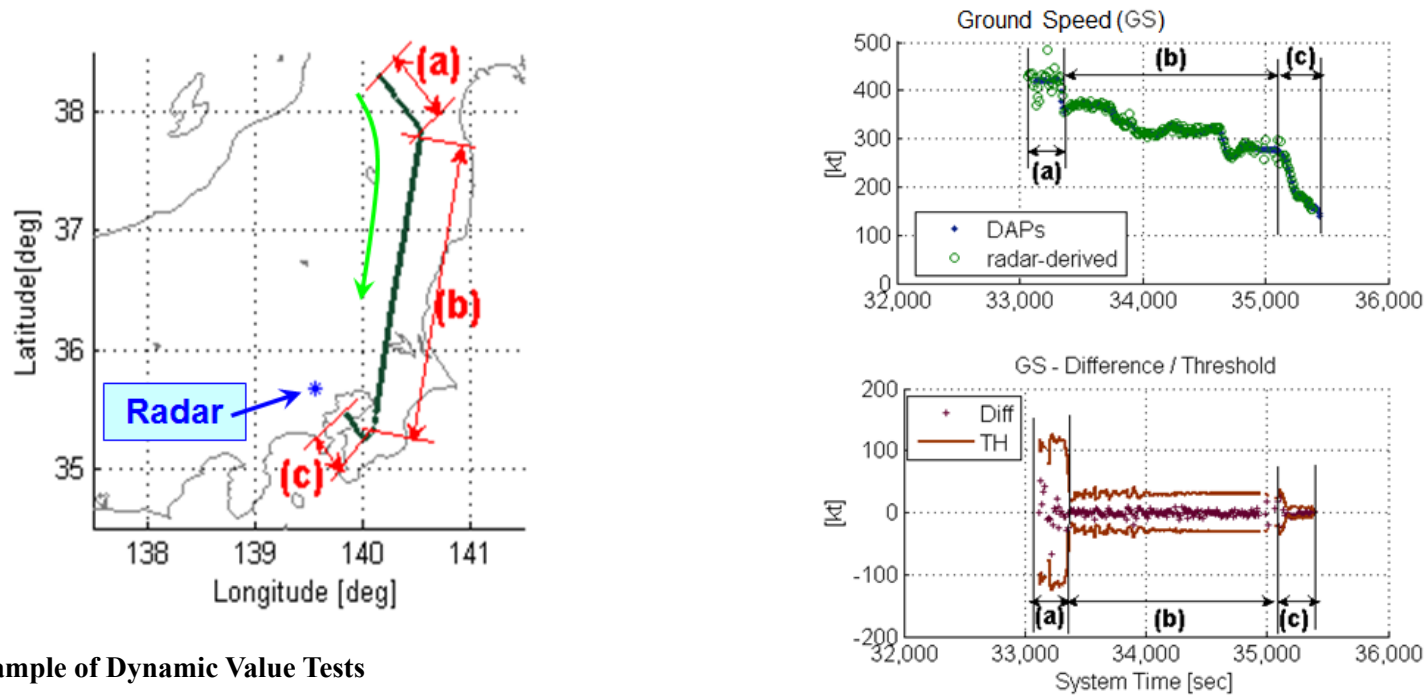


Figure 2 - Example of Dynamic Value Tests

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APPENDIX 2: LIST OF IDENTIFIED ISSUES

Ref.	Issue	Cause	Safety Implications to ATC (Yes / No)	Recommendations
1.	Wrong ground bits in DAPs led to the track decoupling from the flight plan	Through joint investigation with the airlines, it found that parts of the aircraft A were exchanged with another aircraft B for test. The malfunction part was discovered when the wrong ground bits data was found coming from the aircraft B.	Yes The wrong ground bits in DAPs could make ATM automation system display track decoupled with flight plan	
2.	Wrong aircraft identification	Many cases of wrong aircraft identification were found at the beginning of mode S operation. All related data collected and sent to the relevant airlines by the management department. Through joint investigation with the airlines, it was found that the issue is normally due to pilot's error.	Yes Wrong aircraft identification could lead to wrong flight plan coupling.	Through the joint efforts of ATMB and the airlines, the aircraft identification data became more and more accurate.
3.	Wrong Barometric Pressure	Barometric Pressure, such as BARO or QNH, is available in Mode S BDS code 4,0. Initial testing found that data above the transition level for some aircraft types would not be useful due to a mismatch between what the crew set in the cockpit, and what the aircraft Downlinked.	Yes There will display a wrong Barometric Pressure with aircraft in ATM automation system.	EASA Safety Information Bulletin SIB-2016-05R2 ("Incorrect Downlink Barometric Pressure Settings") covers this issue.
4.	Different processing between Mode A/C and Mode S Altitude	Currently, the altitude accuracy of Mode A/C radar is 100ft, while that of Mode S radar is 25ft. The altitude tracking, and display mechanism of ATM automation systems could be received both precisions altitude data.	Yes In Mode S radar and Mode, A/C radar overlapped area, the ATM automation systems might display an altitude jumping.	The altitude tracking, and display mechanism of ATM automation systems need to be optimized to avoid altitude jumping.

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5.	Mode S interrogators request the aircraft transponder registers too frequently in busy airspace	If Mode S interrogators request the aircraft transponder registers too frequently in busy airspace, it may appear that the transponder registers information cannot complete the whole transmission process. The BDS parameters requesting rule needs to be set by the Mode S interrogator reasonably.	Yes ATM automation system would display track delay or intermittent interruption of radar data.	The data transmission rate of Mode S radar to feed ATM automation system needs to be selected reasonably to meet the requirements of ATC operations in busy airspace to prevent track delay or intermittent interruption of radar data.
6.	Mode S DAPs data does not correspond to the content of the requested register	It has been noted that from time to time Mode S DAPs data does not correspond to the content of the requested register. For example, the content of BDS code 5,0 is received when extracting BDS code 4,0. This phenomenon is called “BDS swap”. Table 1 represents an example data of BDS swap. The table shows the data of BDS code 0,5/4,0/5,0 data downlink from an aircraft in three sequential scans. As can be seen by the table, BDS swap occurred at 08:05:45.	Yes Wrong information could display to controller.	Different options can be implemented to decrease the impact of such as: 1. limit the number of radars extracting aircraft registers 2. implement specific filters in radar or in the surveillance data processing to discard the erroneous data (e.g. when two different registers are received with the same content they are both discarded)

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7.	Duplicated aircraft address	One case was related to a local airline, wrong spare parts of the airplane were installed by mistake during maintenance. The airline replaced the spare parts after being informed. Another case was military aircraft. Another reason has been observed that in many cases the 24-bit aircraft address transmitted by the aircraft does not match its nationality (i.e. its State of Registry's block) or is otherwise incorrectly configured in the transponder. Care needs to be taken to ensure that the registration and the 24-bit address of every aircraft are processed and assigned simultaneously by the regulatory authority, and reporting mechanisms are in place to rectify incorrect configurations.	Yes The possible consequences are as follows: 1. An aircraft may be locked out in error, if it is the same beam. This may result in a new aircraft not being detected when it enters Mode S radar coverage. 2. Possible track label swap for crossing aircraft, this may result in incorrect labeling of an aircraft on the Radar screen. 3. In the technical operation of Mode S Elementary surveillance, duplicated address may result in the possible loss of a track when the two aircraft are crossing due to the interrogation scheduling within the ground station.	According to Annex 10, the aviation authority of each State is responsible for assigning 24-bit addresses to all aircraft in its registry using the block allocated by ICAO to that State. The duplicate address should be detected and reported. Without duplicate address detection, if an aircraft enters the range of the Mode S SSR with the same ICAO 24-bit address as that of an existing target, the information of the new aircraft could be erroneously associated with the existing target. Once the Mode S DAPs System detect more than one aircraft is transmitting the same ICAO 24-address, it will initiate a duplicate address report and a duplicate address condition shall be declared, and when receive new information of this address, the system should associate the information by ID or position but not the address.
8.	incorrect aircraft address in flight plan	Although the overwhelming majority aircrafts are equipped with Mode S transponders, many flight plans are not filed with the correct aircraft address in item 18.	Yes This affects the function of aircraft address correlation in ATM automation system.	

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9.	incorrect wind speed and direction	Aircrew round the system output figures from Spot Wind data was the main reason for variations by crew response. e.g. Recorded wind 283/42kts, crew response 280/40kts.	No	
10.	empty ACAS RA message	ASTERIX message “I048/260, ACAS Resolution Advisory Report” indicates that airplane is in ACAS RA condition. In some cases, all zero I048/260 reports are received in the ATM automation system through Mode S radar.	Yes ATM automation system may generate false ACAS alarm from Empty RA message.	ACAS message handling feature at ATM system must be checked on at its installation stage following the ACAS message flow
11.	erroneous SFL information	It is noticed ATM automation system could receive erroneous SFL information due to the BDS swap problem and other reasons.	Yes ATM automation system may generate false SFL mismatch alarm due to the erroneous SFL information.	ATM automation system could use multiple data sources to check the SFL data.
12.	Incorrect ACAS RA information	Many cases of incorrect ACAS RA information were found at the Mode S operation. After analysis the incorrect ACAS RA data, the reason is so called “BDS Swap” and only the old type of Mode S radar has the “BDS Swap” problem.	Yes Wrong information could display to controller.	Short term solution: Reject data (BDS content and/or reply) in case of difference between UF and DF. Reject BDS content (BDS 1,0; 2,0 and 3,0) in case of first byte error. Medium /long term solution: "Overlay" function is introduced in the fifth edition of Volume IV of ICAO document annex 10. the DP (data parity) field is designed to replace the AP field to check the BDS register number in the downlink DF20 / 21. It aims to solve BDS swap problem from the source.

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Table 1 Example Data of BDS Swap

BDS Register	Time of Scan		
	08:05:35	08:05:45 (BDS swap occurred)	08:05:55
BDS code 0,5	605f80c056966f	a3280030a40000	605f845303ce8d
BDS code 4,0	a3280030a40000	a3280030a40000	a3280030a40000
BDS code 5,0	fff8cf1f800489	a3280030a40000	ffb8cf1f80048a

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APPENDIX 3: A Brief Introduction of Mode S SSR DAPs Data Source

1. Introduction

1.1 During the 2nd meeting of ICAO APAC Mode S DAPs WG, China presented an information paper regarding the Mode S DAPs data source, the meeting was of the view that the content of the paper will help in the understanding of the basic mechanism of avionics relevant to surveillance application and implementation of DAPs.

-Refer to Mode S DAPs WG/2 IP05 “Preliminary Study of DAPs Data Sources”

1.2 The Mode S DAPs provides useful information on aircraft that will enhance ATM operations. More attention should be paid when introducing Mode S DAPs and it's important to clearly understand what these parameters are and where these parameters come from. This text provides give some brief information about the parameters.

2. Mode S SSR DAPs ELS and EHS

2.1 Mode S DAPs-based surveillance includes ELS (Elementary Surveillance) and EHS (Enhanced Surveillance).

2.2 Most of the ELS parameters are capability parameters of the aircraft, hence are static. They can be used for improved aircraft identification, and have less direct impact on ATC operations. The ELS parameters are shown in Table 2.1.

Table 2.1 ELS Parameters Information

	Register	DAP Set	Bits	Units	Quantity	Range
ELS		24-Bit Aircraft Address (AA)	NA	NA	NA	NA
		Transponder Capability (CA)	NA	NA	NA	NA
		Flight Status (FS)	NA	NA	NA	NA
		Altitude Reporting in 25ft	NA	ft	25	[-1000, 50175]
	BDS 1,0	Datalink Capability Report	56	NA	NA	NA
	BDS 1,7	Common GICB Capability Report	56	NA	NA	NA
	BDS 2,0	Aircraft Identification Report	56	NA	NA	NA
	BDS 3,0	ACAS Resolution Advisory Report	9-22	NA	NA	NA

2.3 EHS parameters are more related to the aircraft's intention and status, and most of them are dynamic. The implementation of EHS parameters has a larger impact on controllers. The EHS parameters are shown in Table 2.2.

Table 2.2 EHS Parameters Information

	Register	DAP Set	Bits	Units	Quantity	Range
EHS	BDS 4,0	Selected Altitude (MCP/FCU)	2-13	ft	16	[0, 65520]
		Selected Altitude (FMS)	15-26	ft	16	[0, 65520]
		Barometric Pressure Setting	28-39	mb	0.1	[0, 410]

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BDS 5,0	Roll Angle	3-11	dg	45/256	[-90, +90]
	True Track Angle	14-23	dg	90/512	[-180, +180]
	Ground Speed	25-34	kt	2	[0, 2046]
	Track Angle Rate	37-45	dg/s	8/256	[-16, +16]
	True Airspeed	47-56	kt	2	[0, 2046]
BDS 6,0	Magnetic Heading	3-12	dg	90/512	[-180, +180]
	Indicated Airspeed	14-23	kt	1	[0, 1023]
	Mach No	25-34	NA	2.048/512	[0, 4.092]
	Barometric Altitude Rate	37-45	ft/min	32	[-16384, +16352]
	Inertial Vertical Velocity	48-56	ft/min	32	[-16384, +16352]

3. Mode S SSR DAPs Data System

3.1 The ELS and EHS parameters originate from various sensors and cockpit settings. After being organized by the avionics systems, the information is being sent to the transponder through standard aircraft data buses, and subsequently formatted by the transponder and stored inside the relevant Binary Data Storages (BDS). The ground-based surveillance system could downlink desired DAPs by specific Mode S GICB (Ground Initiated Comm-B) protocol.

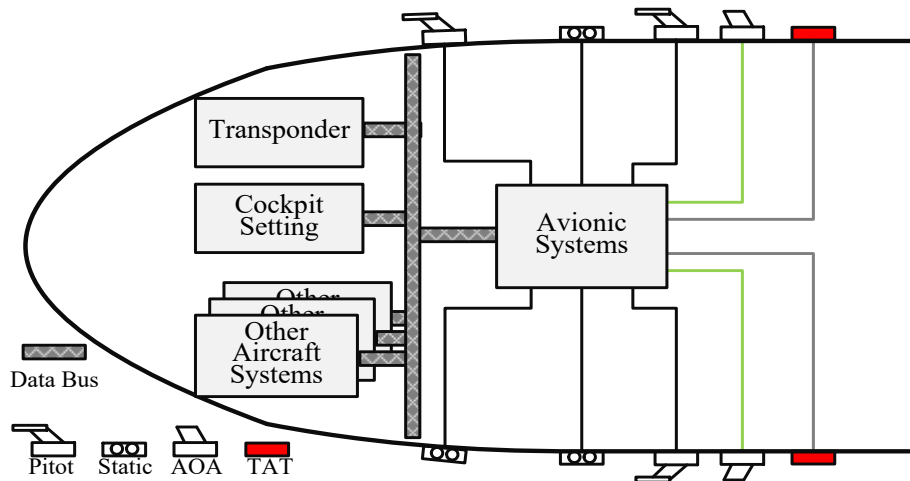


Figure 3.1 Typical DAPs Data Source Block Diagram

Transponder and TCAS Computer

3.2 The most common standard of the civil aircraft transponder, the Mark 4 Air Traffic Control Transponder, is based on the ARINC 718A standard. There are 3 main interface plugs defined on the rear panel, namely TP (Top Plug), MP (Middle Plug), and BP (Bottom Plug).

3.3 The airborne collision avoidance system, Traffic Computer TCAS and ADS-B Functionality, is based on the ARINC 735B standard. There are 6 main interface plugs defined on the rear panel, namely LTP (Left Top Plug), LMP (Left Middle Plug), LBP (Left Bottom Plug), RTP (Right Top Plug), RMP (Right Middle Plug) and RBP (Right Bottom Plug).

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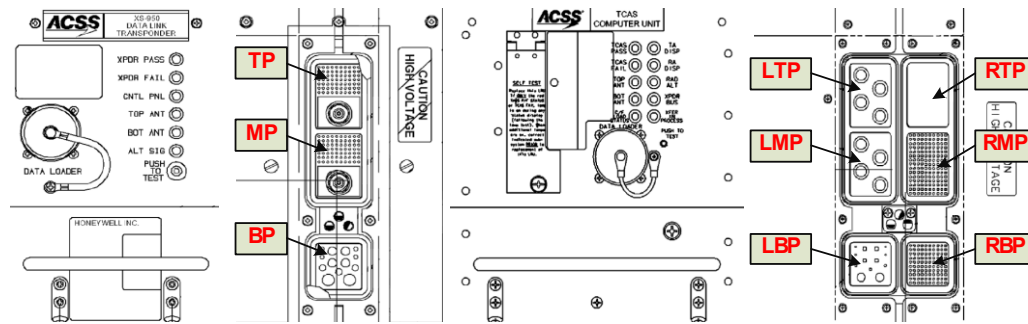


Figure 3.2 Transponder and TCAS Computer Examples from ACSS

Data Bus

3.4 The most common data bus, the Digital Information Transfer System, is based on the ARINC 429 standard. The standard defines the data transfer between most of the avionics systems. There are also other standards such as the ARINC 629 used on Boeing B777, Airbus A330 and A350, as well as the ARINC 664 (AFDX, Avionics Full Duplex Switched Ethernet) used on A380 and B787.

Avionics and DAPs Data

3.5 The Aircraft Address (AA) is a parameter programmed into the aircraft frame after the address is allocated by the State registration authority. Normally there are 2 ways to program this parameter, one is to program the pins of the MP (connected for “1”, open for “0”), and the other is to use Aircraft Personality Module (ARINC 607) to store the address, and then interface to the MP.

Note: For more detailed information about Aircraft Address, refer to ARINC 718A Attachment 2B. For APM implementation guidelines, refer to ARINC 718A Attachment 9.

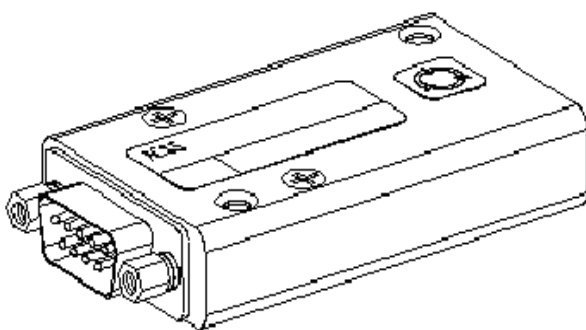


Figure 3.3 APM Example from ACSS

3.6 The Transponder Capability (CA) is a result of the combination of on-the-ground status and transponder capability level. Normally the on-the-ground status is automatically indicated by the weight sensor fitted on the aircraft, but some GA planes use manual means to indicate the status by switching the transponder knob to the GND option. The transponder receives on-the-ground status from the TP pins (5J and 5K), make validation of the status with Ground Speed, Radio Altitude or Airspeed, and then announce the status. The transponder capability level is a static value which is fixed after manufacturing.



Figure 3.4 TT31 Mode S Transponder from TRIG

3.7 The Flight Status (FS) is a result of combination of the on-the-ground status, SPI, and Alert. The on-the-ground is the same as in 3.6, the SPI is from pushing IDENT function button of the transponder by pilot, and the Alert is produced by changing Mode A code (If changed to 7500, 7600, 7700, that's permanent alert; and if changed to other codes, that's 18 seconds temporary alert).

3.8 The Common Usage GICB Capability Report is generated by the transponder itself by detecting the corresponding input data availability, and then set the corresponding bit related to that GICB register.

3.9 The main source of Aircraft Identification is from FMS, input by pilot through Flight ID (or Flight No) menu, and the related data transmitted to transponder by specific data bus (ARINC 429 Labels 233~237). If the Flight ID is empty, then the Aircraft Registration data may be provided within another data bus (ARINC 429 Labels 301-303).

3.10 According to TCAS standard (ARINC 735B Chapter 3.3.4.1), the Datalink Capability Report and the Resolution Advisories Report are sent to the Transponder from TCAS Computer by specific protocol (TGD-TCAS to Transponder data transfer protocol, and Transponder to TCAS data transfer protocol is named XGD. The data bus used is ARINC 429 Label 270). The data are sent from RMP of the TCAS Computer to TP of the Transponder, related pins refer to Figure 3.5.

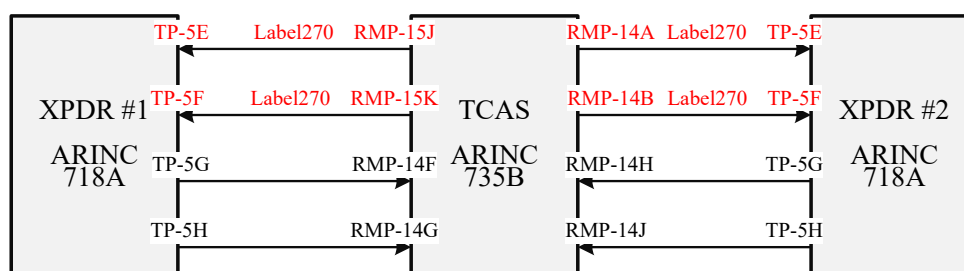


Figure 3.5 Illustrations of Datalink Capability and RA Report Transfer

3.11 There are 2 kinds of Selected Altitude, one is from MCP/FCU (Boeing's Mode Control Panel and Airbus's Flight Control Unit), and the other is from FMS (Flight Management System). The first one is set by the pilot in response to a controller's instruction during the flight, the second one is calculated by the FMS automatically to achieve the best cost-efficient.

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Figure 3.6 MCP of Boeing B787 & FCU of Airbus A380

3.12 The Barometric Pressure Setting (BPS) is also located in the MCP/FCU, and set by the pilot rotating the knob to the pressure value comes from the aerodrome's ATIS (Automatic Terminal Information System).

3.13 The other parameters mainly come from the sensors onboard the aircraft, the sensors are organized in 3 groups, the air data sensors, the inertial sensors and the magnetic sensor.

3.14 The air data sensors are used to sense the medium through which the aircraft is flying, including pitot (static) probe, static port, temperature sensor, angle of attack sensor. Typical sensed parameters are total pressure (Pt), static pressure (Ps), pressure changing rate, air temperature (TAT), and angle of attack. Derived data includes Barometric Altitude (ALT), Indicated Airspeed (IAS), Vertical Speed (VS), Mach (M), Static Air Temperature (SAT), Total Air Temperature (TAT), True Airspeed (TAS) and Angle of Attack (AOA). The simplest system provides ALT and IAS.



Figure 3.7 Air Data Sensors and Integrated Sensor on Airbus A380

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3.15 The inertial sensors are used to detect the motion of the aircraft in a universal reference system, including position gyroscopes, rate gyroscopes and accelerometers. By detection of the 3D dynamic of the aircraft, derived data includes Ground Speed (GS), Wind Speed, Wind Direction, True Track Angle, Roll Angle, and Track Angle Rate and so on.

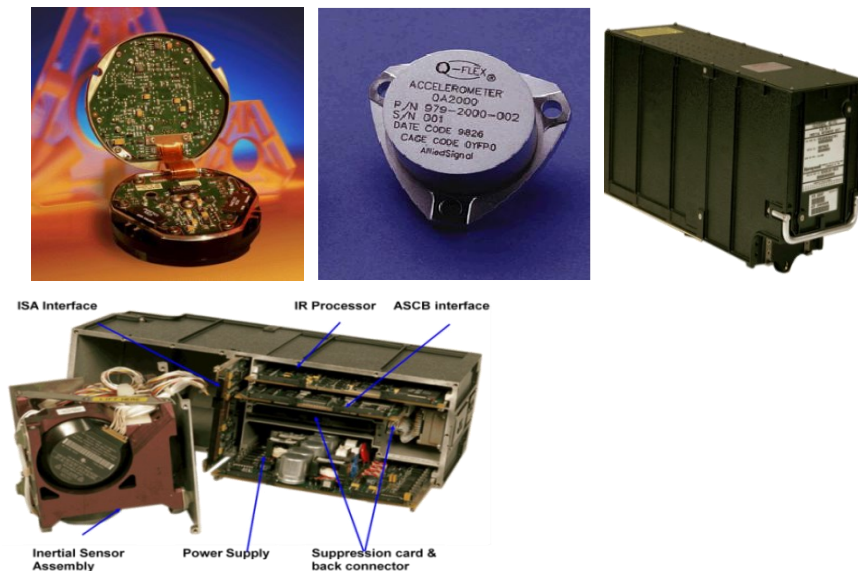


Figure 3.8 Gyro, Accelerometer and LASEREF IV IRU from Honeywell

3.16 The magnetic sensor is used to sense the direction and to find the magnetic north, and give out the main parameter of Magnetic Heading. The world magnetic model is show below:

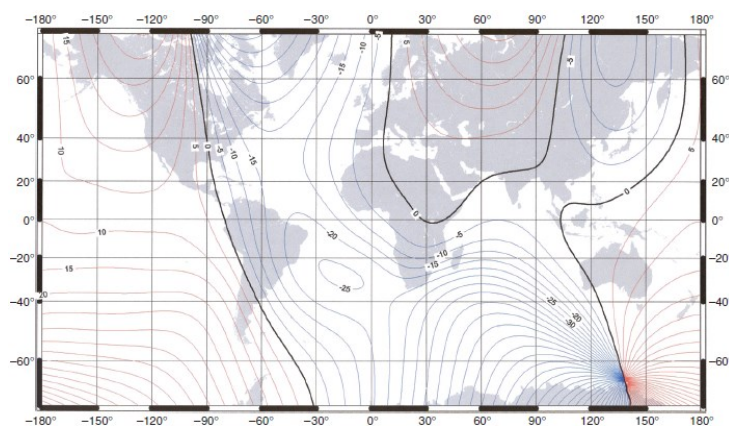


Figure 3.9 World Magnetic Model 2000

3.17 Some airplane platform uses an integrated solution to process these data, each air data sensor is connected with an Air Data Module (ADM) which converts the analog data to digital data and make the compensation of the instrumental and positional error. These data then feed to the input of Air Data Inertial Reference Systems (ADIRS) to calculate all the parameters mentioned before. And after that the parameters are sent to transponder and other avionics systems by the Data Bus.

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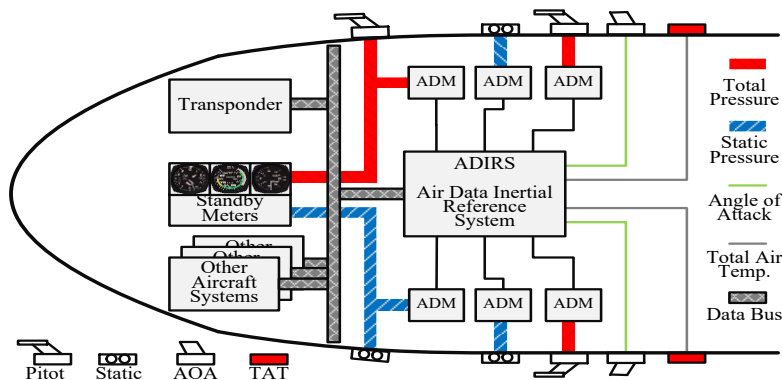


Figure 3.10 Typical ADIRS Architecture

3.18 The most commonly used data bus for parameters from ADIRS is ARINC 429 (and the newest evolution is AFDX invented by Airbus and implemented in various new aircrafts like A380 and B787), and the standard ARINC 429 Labels used by these parameters are as follows:

Table 3.1 ADIRS Parameters Used Labels of ARINC 429

No	DAP Item	Label
1	Mach No.	205
2	Indicated Air Speed	206
3	True Air Speed	210
4	Barometric Altitude Rate	212
5	Ground Speed	312
6	True Track Angle	313
7	Magnetic Heading	320
8	Roll Angle	325
9	Track Angle Rate	335*
10	Inertial Vertical Velocity	365

**Note: This label in GAMA configuration is not used for Track Angle Rate*

3.19 By using these parameters, the aircraft dynamic is illustrated as in Figure 3.11.

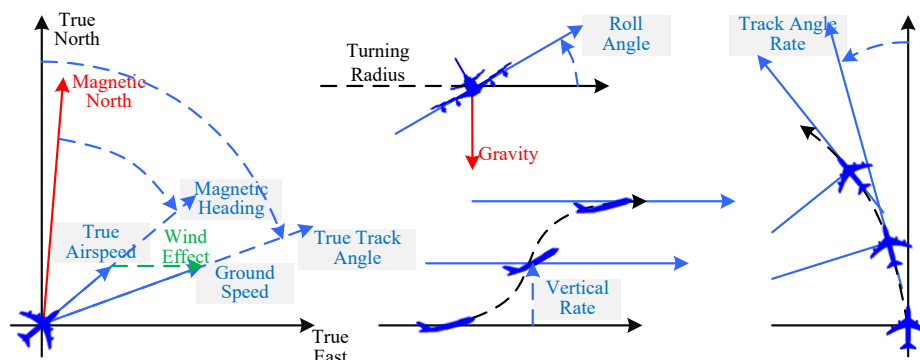
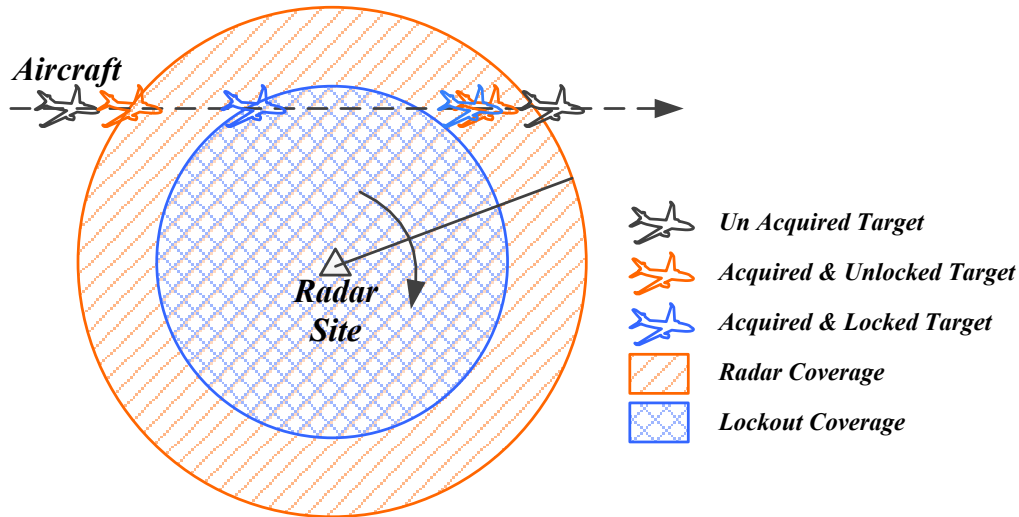


Figure 3.11 Illustration of Aircraft Dynamic

APPENDIX 4: Mode S Parameter Set

Radar Coverage R

1.1 The Mode S radar coverage is defined as the farthest target the radar will process. If the Mode S radar uses a lockout map, the difference of the two coverage ranges should be noticed.



1.2 The radar coverage will decide the minimal All-Call period, this is to say, the time of All-Call period should:

$$T \geq \frac{R * 2 * 1852}{3 * 10^8}$$

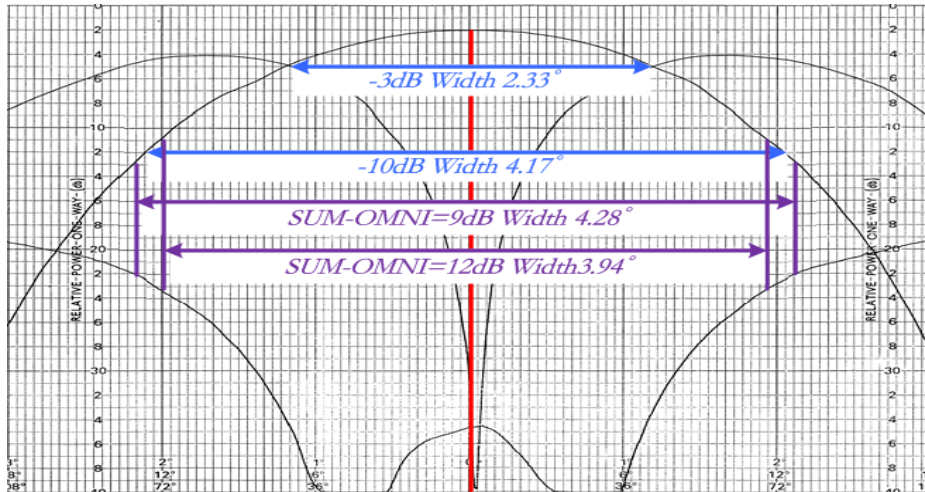
Antenna Period T_a

2.1 The antenna period is the time of a successful antenna rotation, this time actually has very important influence of the total time resource of the radar. Lower antenna rotation speed will provide rich antenna period, hence time resource of the radar. The most commonly used antenna period is 4000ms (15rpm) and 6000ms (10rpm) for terminal surveillance radar.

Antenna Beamwidth B

3.1 Most of the secondary surveillance radar uses the same LVA antenna, the beam is more or less the same, and the standard interrogation beam has a -3dB width of $2.45^\circ \pm 0.25^\circ$. In Mode S interrogation, the suppression requirement actually allow to use a wider beam width than -3dB width, most of the radar choose 3.8° or roughly the -10dB beam width.

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Time on Target T_t

4.1 The time on target is the total time amount the radar beam covers the target during one scan, it defines the time resource upper limit for one dedicated target, it is determined by both the antenna period and the beamwidth, and the relation is as follows:

$$T_t = \frac{T_a}{360} * B$$

4.2 It should be noticed that during a mix air operation (Conventional targets and Mode S targets flying in the same area in the same time), there is a need for the Necessary Transaction. That is during an antenna scan, there should be at least 4 transactions between the radar and the conventional target, in order not to miss conventional target.

All-Call Period T_{ac} and Roll-Call Period T_{rc}

5.1 The All-Call period and Roll-Call period setting are different radar by radar, but there should be some principles:

- 1) All-Call period should long enough to allow the coverage requirement.
- 2) During the time on target, the Necessary Transaction should be guaranteed.
- 3) Time resource should allocate to Roll-Call as much as possible; and
- 4) Algorithm should be used to optimize the scheduling in the Roll-Call period.

Mode Interlace Pattern MIP

6.1 Mode Interlace Pattern defines the radar operating mode setting. The setting is related to the specific radar environment, hence there is no standard MIP.

6.2 All the modes Mode S radar can use is listed in the following table:

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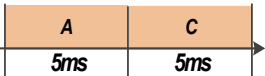
No.	Mode	Description	Pulse Used
1	A	Mode A interrogation	8μs between P1 and P3
2	C	Mode C interrogation	21μs between P1 and P3
3	A _S	Mode A Only All-Call	8μs between P1 and P3, and short P4
4	C _S	Mode C Only All-Call	21μs between P1 and P3, and short P4
5	S _L	Mode ACS All-Call	8μs, 21μs between P1 and P3, and Long P4
6	S _{PO}	Mode S Only All-Call P for PR, O for LO	2μs between P1 and P2, and P6 UF11 inside P6
7	R	Mode S Roll-Call	2μs between P1 and P2, and P6 UF0/4/5/16/20/21 inside P6

6.3 For a specific MIP, the describe phraseology defines as follows, and also one example is listed below:

Mode[Time]/ Mode[Time]/ Mode[Time]/.....

Note: The All-Call and Roll-Call periods are separated by “/”, the “Mode” is one of the Modes listed above, and the “[Time]” stands for the duration of the periods.

6.4 An example is show as follows:

No.	Mode	MIP
1	Conventional	A[5.0]/C[5.0]
		 Mode A and Mode C repeat, both durations are 5ms
2	Mode S #1	S _{1/2} A _S [5.0]/S _{1/2} C _S [5.0]/R[10.0]
		 2All-Call periods and 1 Roll-Call period repeat, All-Call duration is 5ms, Roll-Call duration is 10ms In the first All-Call, the PR=1/2, and use Mode A with short P4 In the second All-Call, the PR=1/2, and use Mode C with short P4
3	Mode S #2	S _{1/2} A _S [5.0]/R[10.0]/S _{1/2} C _S [5.0]/R[10.0]
		 1All-Call,1Roll-Call,1All-Call,1Roll-Call repeat, All-Call duration is 5ms, Roll-Call duration is 10ms In the first All-Call, the PR=1/2, and use Mode A with short P4 In the second All-Call, the PR=1/2, and use Mode C with short P4

Interrogation Repetition Frequency **IRF**

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7.1 The Mode S introduced the Roll-Call period, which makes the interrogation repetition frequency a little bit different from the Conventional Mode. There is a need to define the interrogation repetition frequency by Mode IRF_{Mode}. Normally use IRF stands for the IRF_{AC} of Conventional mode and IRF_S of the Mode S All-Call. One example is listed below:

No.	MIP	IRF
1	A[5.0]/C[5.0]	IRF_A=100Hz IRF_C=100Hz IRF_{AC}=200Hz
2	S_{1/2}A_s[5.0]/R[10.0]/S_{1/2}C_s[5.0]/R[10.0]	IRF_A=33.3Hz IRF_C=33.3Hz IRF_{AC}=66.7Hz IRF_S=66.7Hz IRF_R=66.7Hz

DAPs Extraction Strategy

8.1 The DAPs extraction strategy normally includes the BDS number, extraction priority, extraction period, and re-extraction.

1) BDS number stands for the setting of the number of BDSs which radar is going to extract. It doesn't include the ELS registers, these registers should not be extracted periodically.

2) Extraction priority stands for the priority of each BDS when the radar is performing extraction, the priority should be in accordance to the user's needs;

3) Extraction period stands for the period of the dedicated BDS extraction, normally described by the antenna scan number.

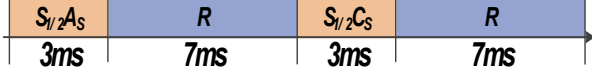
4) Re-extraction stands for the function of re-extraction of the dedicated BDS in the same beam dwell when the extraction is failed, but it's not recommended to use re-extraction more than 2 times.

Mode S Parameter Set Example

9.1 The following is an example of the Mode S Parameter Set:

No.	Parameter	Unit	Value	Note
1	R Coverage Range	NM	200	Equivalent All-Call Time $\frac{200 * 2 * 1852}{3 * 10^8} * 10^3 \approx 2.47ms$
2	Ta Antenna Period	ms	3800	Antenna Rotation Period
3	B Work Beamwidth	°	3.8	Mode S Work Beamwidth Normally Greater Than -3dB width of 2.45°
4	Tt Time on Target	ms	40.1	The Time on Target In One Scan $\frac{3.8}{360} * 3800 \approx 40.1ms$

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5	Tac All-Call Period	ms	3.0	Equivalent Coverage Range $\frac{3 * 10^8 * 3.0 * 10^{-3}}{1852 * 2} \approx 243\text{NM}$
6	Trc Roll-Call Period	ms	7.0	This Period Related To The Extraction Efficiency
7	MIP	—	—	$S_{1/2}A_s[3.0]/R[7.0]/S_{1/2}C_s[3.0]/R[7.0]$ 
8	IRF _{AC}	Hz	100	Interrogation Repetition Frequency of Mode S All-Call
9	DAPs Extraction	—	—	No. of BDS: 3 (BDS 4,0 5,0 6,0) Extra. Priority: BDS 4,0 6,0 5,0 Extra. Period: 1 Scan Re-Extraction: Yes

APPENDIX 5: Radio Frequency (RF) Measurements and Analysis

The following is excerpted from ICAO Doc 9924 Aeronautical Surveillance Manual (Third Edition 2020), Appendix M: Interference Considerations.

1. Overview

1.1 The 1030 and 1090 MHz frequency bands form the worldwide RF network, which enables the cooperative surveillance of mobile vehicles involved in ATM including airborne vehicles (aircraft) and ground vehicles (e.g., specific vehicles operating on airport surface in critical areas). It is utilized to support civil and military (IFF) air-ground surveillance applications, air-air surveillance applications and collision avoidance applications.

1.2 In general, the 1030/1090 MHz network is robust in its ability to support the systems that utilize it but as more systems are added, performance of one or more of these systems may degrade to unacceptable levels. Since many systems are safety critical in nature, protecting the 1030/1090 MHz spectrum from reaching unacceptable utilization is paramount.

1.3 Capacity of the system is impacted by the number and types of users. Aircraft density and the number and type of interrogators directly influence the activity on these links. Information extraction from ground and aircraft to aircraft interrogators increases the activity of these RF links. High density airspace is a particular challenge as these locations tend to contain accompanying higher density of ground interrogators. The systems that utilize the 1030/1090 MHz bands have standards that limit their impact to protect the performance of all users and provide robust capacity to the system. However, available capacity can be limited in the highest density areas of the world.

1.4 Therefore, it is necessary to monitor the usage of the 1030/1090 RF network, as is required for any telecommunication network, in order to regulate its use. Such monitoring should support the determination of the remaining margin of the network. It should help identify the sources of the utilization and whether the limits are being reached by misuse of some systems operating in a non-conforming or inefficient manner to the detriment of the good operation of the other systems using the same network.

2. Radio frequency (RF) measurements

2.1 Measurements need to provide information to answer the following questions:

- a) what is the probability that a transponder correctly receives and decodes an interrogation sent on 1030 MHz (the utilization of the 1030 MHz frequency);
- b) what is the probability that a transponder is available to receive and decode interrogations and is able to reply (the availability of the transponder); and

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- c) what is the probability that a 1090 MHz message is correctly received by a 1090 MHz receiver, which is impacted by overlaps of messages on 1090 MHz (the utilization of the 1090 MHz frequency).

2.2 Measurement methodologies

2.2.1 Data produced by RF measurement activities is recommended to include a minimum set of information that can adequately characterize the RF environment of the geographical area under assessment and support comparison to other measurements. Additionally, the data is intended to support comparison to other data collection measurements in other geographical areas which can provide insight to areas with high or unusual activity and help identify areas that warrant further investigation. To allow comparison between different measurements performed in different locations around the world, it is very important to define the types and the conditions of measurements. Measurements can be made from the ground and/or from the air. Each of them provides critical insight into the 1030/1090 MHz utilization.

2.2.2 Airborne measurements provide a larger area of measurement but are more difficult to conduct and result in higher cost. The airborne measurements provide both the ability to characterize ground sensor operations (1030 MHz) and transponder occupancy. Providing a 1030 MHz measurement enables the detection of all types of interrogations to which a transponder is receiving, i.e., interrogations to which a transponder does or does not transmit a reply. Therefore, it allows an estimation of transponder occupancy at the given points of measurement. It also allows the tracking of interrogations received but not generating replies (e.g., SLS interrogations, interrogations directed to other aircraft).

2.2.3 Ground measurements are more easily accomplished, less expensive but geographically limited. They allow the verification of transponder transmissions on 1090 MHz but are limited in their ability of providing a complete understanding of the environment that airborne aircraft are experiencing. Estimates of 1030 MHz activity can be somewhat estimated from measurement of 1090 MHz replies. However, there is no way to completely account for interrogations that do not result in a reply that impact transponder occupancy.

2.3 Metrics and measurement methods

2.3.1 Frequency occupancy

2.3.1.1 Method 1, In order to allow simple comparison of signal activity received on either 1030 MHz or 1090 MHz frequency, one method is to calculate a simple time occupancy that corresponds to the amount of time that there is a signal present above a given threshold without trying to extract or even decode the content of the messages. The process can be based on the following criteria:

- 1090 MHz frequency occupancy is defined by the proportion of time that there is a signal above the MTL (-84 dBm) for pulses greater than 0.3 microseconds in duration; and
- 1030 MHz frequency occupancy is defined by the proportion of time that there is a

signal above the MTL (-74 dBm) for pulses greater than 0.3 microseconds in duration.

2.3.1.2 Method 2, which analyses the signal received on 1090 MHz, would be determined by decoding of, and counting the number of signals for, different types of messages. The 1090 MHz frequency band occupancy can also be estimated using a predefined occupancy time for each type of message. This message occupancy time is defined as the time there is a signal transmitted on the frequency, i.e., a pulse is transmitted. It signifies how long the transmission is occupying the frequency and therefore possibly interfering with another signal. The table below provides the values to be used to estimate the effective occupancy time and allow comparison between different measurements/estimations made by different authorities.

<i>Type of message</i>	<i>Time occupancy in μs</i>
Mode A/C reply	4.05 (9*0.45)
Short Mode S reply or squitter	30 (60*0.5)
Long Mode S reply or Extended Squitter	58 (116 *0.5)

2.3.1.3 Note that the occupancy of a Mode A/C reply depends on the number of pulses transmitted in each reply. For this calculation, an average value of 9 pulses (2 framing + 7 code pulses) has been used. This is sufficient to provide a first order estimation for comparison with the occupancy of other signal types.

2.3.1.4 The calculation of the number of replies of a given type multiplied by their corresponding time occupancy enables characterizing the impact of different message types on the frequency. Since this uses a fixed defined time occupancy for each type of message, the occupancy determined using this method, in general, will be lower than the occupancy computed using method 1 above, since it can be expected that interfering pulses that may occur during a detected message are not accounted for using method 2.

2.3.1.5 Method 3 is similar to the previous methods. An alternate occupancy calculation is based on the number of signals received on 1030 and 1090 MHz, which are decoded and from which signal rates are determined. However, the occupancy considers the entire signal length from the leading edge of the first pulse until the trailing edge of the last pulse as the time duration regardless of whether and how many intermediate pulses are transmitted. The rationale behind this method is that in RF high-density areas, multiple signal garbling is likely to occur and therefore pulse gaps are unpredictably filled. The determination of the band occupancy is based on the signal durations, as shown in table below.

<i>Type of message</i>	<i>1030 MHz signal duration</i>	<i>1090 MHz signal duration</i>
Mode 1	3.8 μs	20.75 μs
Mode 2	5.8 μs	20.75 μs
Mode 3/A	8.8 μs	20.75 μs

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Mode C	21.8 μ s	20.75 μ s
Mode C (Whisper/Shout)	23.8 μ s	20.75 μ s
Mode A only All Call	10.8 μ s	20.75 μ s
Mode C only All-Call	23.8 μ s	20.75 μ s
Mode A/Mode S All-Call	11.6 μ s	20.75 μ s or 64 μ s
Mode C/Mode S All-Call	24.6 μ s	20.75 μ s or 64 μ s
Mode C only All-Call (W/S)	25.8 μ s	20.75 μ s
Mode A only All-Call (W/S)	12.8 μ s	20.75 μ s
Short Mode S	19.75 μ s	64 μ s
Long Mode S	33.75 μ s	120 μ s

2.3.2 Determination of transponder reply and broadcast activity

2.3.2.1 By analyzing the transmissions made by a transponder, it is possible to verify if a transponder is transmitting above the minimum capabilities specified in Annex 10, Volume IV. The number of messages can be counted over 1 second and 100 msec sliding windows. The peak rates (i.e., the interval with the highest number of messages) detected over a given interval (e.g. 1 minute) can be compared to the values defined in Annex 10, Volume IV. Such information provides a good overall estimate of transponder activity caused by interrogators and makes possible the detection and further analysis of unexpected activity on the channel.

2.3.2.2 One method to estimate the number of messages transmitted by individual aircraft is by counting the number of messages received by a 1090 MHz receiver for aircraft in the vicinity of the receiver with a good link budget. However, achieving sufficient decoding performance is difficult but this method lends itself to a long-term ground-based monitoring system.

2.3.2.3 Another method is to conduct flight tests and detect and record the transmissions made by the operational transponder installed on the test aircraft. This is a good way to determine with high confidence the activity of an individual transponder in the environment. Decoding ownship replies is more accurate than attempting to analyses all the replies transmitted by all the other aircraft because the transmissions are received at high power, thereby reducing the problem of degarbling with other transmissions.

3. Additional data

3.1 Considering additional data such as aircraft environment and traffic density is desirable to assist in understanding the RF measurements that are obtained by the various methods previously identified. RF activity is a function of the number of systems operating, which includes the number and types of interrogators operating on the 1030 MHz frequency as well as the number and equipment of aircraft operating in the geographical area surrounding the measurement location.

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3.2 Data to describe the aircraft environment during a measurement activity is helpful to understand the relationship between the RF measurements and the aircraft traffic in the surrounding area. Traffic density and traffic patterns influence the RF activity in any given area or region. Determining the aircraft environment may require collecting and recording data from one or more ground SSRs. Data in time intervals of 10 to 15 minutes is suggested. To some extent, aircraft information can be determined by the RF measurement system itself. Mode S equipped aircraft can be detected by 1090 MHz reply via the 24-bit aircraft address and additionally the position of many aircraft can be determined by extended squitter data. ACAS equipage can be determined from 1030 MHz TCAS broadcast data, extended squitter as well as DF 0/16 reply content. These methods are limited to the receiver range of the measurement system but enable determining the nearby aircraft environment.

3.3 Information to describe the ground interrogator environment during a measurement activity is helpful to understand the relationship between the RF measurements and the number of interrogators in the surrounding area. Ground interrogators vary in characteristics that influence the impact to the RF environment. The expected RF contribution from ground interrogators can be predicted based on their characteristics such as PRF, scan rate, mode interlace pattern, beamwidth, power, etc. Although there is no way to associate measured 1030 MHz Mode A/C or Whisper-Shout interrogations to a given ground interrogator without detailed analysis of interrogation timing, particularly in the mainbeam, Mode S interrogator All-Call activity can be associated via the II/SI codes. There are many factors that influence overall RF activity with Mode S since ground interrogators may be extracting many GICB registers that increase the contribution of Mode S FRUIT caused by ground interrogators. It is possible to associate All-Call interrogations with UF 4, 5, 20 and 21 interrogations by examining mainbeam activity of detected Mode S ground interrogators.

3.4 Additional data that can be helpful in assessing the RF activity in a given region is the use of interrogation and reply data that is broadcast on extended squitter by so equipped aircraft. The capability to broadcast interrogation and reply data is incorporated into the future version of 1090 MHz extended squitter as a means of collecting useful 1030 and 1090 MHz activity data. The interrogation data is useful in conjunction with flight test measurements as it provides insight to the interrogation activity at different locations in addition to own aircraft. The reply data counts from the broadcasting aircraft enable comparison to the own aircraft rates as a function of time. For the purpose of ground monitoring of RF activity over time, decoding of the interrogation and reply monitoring extended squitter messages can be used for long term assessment of RF activity and enable capture of unusual or excessive RF activity events.

Terms of Reference of Mode S and DAPs Working Group

Working Arrangement of the Mode S and DAPS WG

Membership: The Mode S and DAPS WG shall be composed of experts involved in technical and operation of surveillance services as well as operational experts. Member States of SURICG are encouraged to volunteer to form this Working Group. The working group shall normally invite representatives of International Organizations recognized by the ICAO Council and Industry Partners as required by the group which represent important civil aviation interests to participate in its work in a consultative capacity.

Meetings: The Mode S and DAPS WG shall convene annually with at least one face-to-face meeting per year and supplemented with WebEx meetings as required. The outcome of the meetings shall be reported to the SURICG.

Schedule and delivery: Subject to the extent of prioritized applications considered by the Mode S and DAPS WG, the schedule for delivery of the working group shall be 4 +2 years after initiation of the Mode S DAPS WG (28 March 2018). The delivery point(s) will be nominated by SURICG through discussion. The Mode S and DAPS WG shall report to the APANPIRG via the SURICG.

Terms of Reference. See next section.

Term of Reference

The Objectives of Mode S and DAPs Working Group are to:

- 1) Ensure harmonized implementation of Mode S and DAPs in the Asia and Pacific Regions according to Surveillance Strategy adopted by APANPIRG;
- 2) Facilitate the implementation of Mode S and DAPs application in the Asia and Pacific Regions using the project management principles where appropriate to maximize its benefit to region; and
- 3) Review, identify and address major issues in technical, operational and regulatory aspects to facilitate the Mode S and DAPs implementation in the Asia and Pacific Regions.

Deliverables to meet the Objectives:

- 1) Progress report to be submitted to SURICG addressing the Mode S and DAPs Working Group deliverables (listed in 2 to 7 below);
- 2) To study and identify applicable Mode S and DAPs applications in the Asia and Pacific Regions considering:
 - Concept of use/operation;
 - Cost of system;
 - Requirement of surveillance systems (focusing on radar);
 - Matching functionality in ATC-ATM automation system;
 - Other currently available or emerging technologies;
 - ICAO Global Air Navigation Plan (GANP) and Aviation System Block Upgrades (ASBU); and
 - Evaluation method for Mode S and DAPs performance.
- 3) To identify and develop the regional requirements of Mode S and DAPs capability in the area of aircraft equipage, surveillance systems (focusing on radar) and ATC-ATM automation system, taking into account the relevant performance expectations of the Asia/Pacific Seamless ANS Plan;

- 4) To develop roadmap for Mode S and DAPs application in the Asia and Pacific Regions taking into account of:
- Available equipment standards;
 - Readiness of airspace users and ATS providers; and
 - Development of standardized and systematic approach to Mode S and DAPs application.
- 5) To develop guidance materials to assist States and airspace users (where applicable) on the use of Mode S and DAPs in the Asia and Pacific Regions;
- 6) To encourage research and development, trials and demonstrations in the field of Mode S and DAPs application; and
- 7) Draft Conclusions and Decisions to be formulated relating to matters in the field of Mode S and DAPs that come within the scope of the SURICG work plan.

[Note: Mode S and DAPS Working Group will report to SURICG and SURICG will coordinate with CNS Sub-group.]

Current Members: The working group is currently comprised of representatives from Australia, Cambodia, China, Hong Kong China, India, Indonesia, Japan, Republic of Korea, Malaysia, Nepal, New Zealand, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Viet Nam, and is led by China and Singapore.

Term of Reference

		Efforts thus far
The Objectives of Mode S and DAPs Working Group are to:		
1	Ensure harmonized implementation of Mode S and DAPs in the Asia and Pacific Regions according to Surveillance Strategy adopted by APANPIRG;	a) Planning of II/SI code assignment in progress. b) Encouraged Mode S forward fit. c) Guidance material on the implementation of DAPs applications in ATM systems is created.
2	Facilitate the implementation of Mode S and DAPs application in the Asia and Pacific Regions using the project management principles where appropriate to maximize its benefit to region; and	High level principle is in the draft guidance material.
3	Review, identify and address major issues in technical, operational and regulatory aspects to facilitate the Mode S and DAPs implementation in the Asia and Pacific Regions.	a) Guidance material on measurement of frequency occupancy is created. b) Guidance material to address technical and operational issues is created. c) Guidance material to address regulatory issues is created.
Deliverables to meet the Objectives:		
1	Progress report to be submitted to SURICG addressing the Mode S and DAPs Working Group deliverables (listed in 2 to 7 below);	
2	To study and identify applicable Mode S and DAPs applications in the Asia and Pacific Regions considering: - Concept of use/operation - Cost of system - Requirement of surveillance systems (focusing on radar) - Matching functionality in ATC/ATM automation system - Other currently available or emerging technologies; - ICAO Global Air Navigation Plan (GANP) and Aviation System Block Upgrades (ASBU); - Evaluation method for Mode S and DAPs performance.	a) Guidance material on the implementation of DAPs applications in ATM systems is created. b) Means to test and validate DAPs are in the guidance document.
3	To identify and develop the regional requirements of Mode S and DAPs capability in the area of aircraft equipage, surveillance systems (focusing on radar) and ATC/ATM automation system, taking into account the relevant performance expectations of the Asia/Pacific Seamless ATM Plan;	a) Planning of II/SI code assignment in progress. b) Encouraged Mode S forward fit. c) Guidance material on the implementation of DAPs applications in ATM systems is created.
4	To develop roadmap with a view to formulate mandates for Mode S and DAPs application in the Asia and Pacific Regions taking into account of: - Available equipment standards - Readiness of airspace users and ATS providers - Development of standardized and systematic approach to Mode S and DAPs application;	Road map created.

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5	To develop guidance materials to educate States and airspace users (where applicable) on the use of Mode S and DAPs in the Asia and Pacific Regions:	Guidance material to educated States is created. No need for guidance material for airspace users identified yet.
6	To encourage research and development, trials and demonstrations in the field of Mode S and DAPs application; and	Research and development activities are being shared in the Working Group. These include: a) Deriving weather related information from DAPs; b) Detection of BDS swab.
7	Draft Conclusions and Decisions to be formulated relating to matters in the field of Mode S and DAPS that come within the scope of the SURICG work plan.	On going.

NOTES ON THE PRESENTATION OF THE PROPOSED AMENDMENT

1. The text of the amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:

a) ~~Text to be deleted is shown with a line through it.~~	text to be deleted in
b) New text to be inserted is highlighted with grey shading.	new text to be inserted in
c) ~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.	new text to replace existing text

REVISED SURVEILLANCE STRATEGY FOR THE APAC REGION

Considering that:

1. States are implementing CNS/ATM systems to gain safety, efficiency and environmental benefits, and have endorsed the move toward satellite and data link technologies;
2. The future air traffic environment will require increased use of aircraft-derived surveillance information for the implementation of a seamless automated air traffic flow management system;
3. The 11th Air Navigation Conference endorsed the use of ADS-B as an enabler of the global air traffic management concept and encouraged States to support cost-effective early implementation of ADS-B applications;
4. The 12th Air Navigation Conference endorsed the ICAO Aviation System Block Upgrades (ASBU) Framework with Modules specifying effective use of ADS-B/MLAT and associated communication technologies in bridging surveillance gaps and its role in supporting future trajectory-based ATM operating concepts. Cooperation between States is the key to achieve harmonized ATM system operations;
5. The 13th Air Navigation Conference endorsed the multilayer structure for the GANP, the ASBU and initial version of basic building block (BBB) frameworks and its change management process, which are available in an interactive format as part of the web-based GANP Portal. This allows ICAO to incorporate a flexible framework for new/emerging surveillance-related concepts such as space based ADS-B into future editions of the GANP;
6. APANPIRG has decided to use the 1090MHz Extended Squitter data link for ADS-B air-ground and air-air applications in the Asia/Pacific Region;
7. Use of surveillance systems that do not require GNSS will continue to meet many critical surveillance needs for the foreseeable future;
8. SARPs, PANS and guidance material for the use of ADS-B have been developed;
9. Availability of new technologies, such as space based ADS-B which is now operationally used by some States;
10. Mode S and ADS-B avionics (including DAPs) and processing systems are available;

11. ADS-B IN applications and equipment are now available in commercial airliners and ICAO ASBUs include ADS-B IN applications;
12. There are continuing significant pressures on the radio spectrum for purposes outside aviation, particularly in the primary radar spectrum; and
13. ADS-B security issues are addressed by the ADS-B regional guidance material and security issues of Mode S surveillance may need to be further considered in the future.

THE SURVEILLANCE STRATEGY FOR THE ASIA/PACIFIC REGION IS TO:

1. Minimize the reliance upon pilot position reporting, particularly voice position reporting, for surveillance of aircraft;
2. Maximize the use of ADS-B on major air routes and in terminal areas, giving consideration to the mandatory carriage of ADS-B Out as specified in *Note 1* and use of ADS-B for ATC separation service;
3. Reduce the dependence on Primary Radar for area surveillance, consider the ongoing need for primary radars in terminal areas with a view to reducing primary surveillance coverage or use of phased array radar or other technologies with coverage focusing on areas of concern, and the potential use of alternate technologies or procedures (e.g. transponder veil regulations);
4. Encourage deployment of Mode S systems instead of Mode A/C only radars when replacement is required;
5. Provide maximum contiguous ATS surveillance coverage of air routes using 1090MHz Extended Squitter (1090ES) ADS-B, Wide Area Multilateration and Mode S SSR to meet operational and safety requirements;
6. Make full use of aircraft Mode S capabilities, where suitable surveillance systems and ATM automation systems are available, to reduce reliance on 4-digit octal codes. Mode S capabilities such as DAPs should also be considered for use to support ATM services where appropriate;
7. Make use of alternative technologies where technical constraint or comparative cost benefit analysis does not support the use of ADS-B, SSR or Multilateration;
8. Make use of Multilateration and/or ADS-B for surface, terminal and area surveillance where appropriate, feasible and cost effective;
9. Monitor ADS-B OUT developments such as Version 3 (DO-260C) MOPS development, and Version 2 (DO260B) equipage in the APAC region. At an appropriate time (circa 2020) APAC States should review progress and consider development of transition plans where cost/benefit studies indicate positive advantages for the region;
10. Monitor ADS-B IN development and cost benefits to ensure that APAC States are able to take advantage of ADS-B IN benefits when appropriate, through procedures, rules and ATC automation capabilities;

11. To the extent possible, implement ADS-B in the non-radar environment as a priority. In the radar or other surveillance environment, use ADS-B to supplement or replace existing surveillance coverage, subject to local factors and risk assessment;
12. Make use of surveillance capability to support the GADSS as appropriate;
13. Implementation of surveillance capability should also include consideration of contingency surveillance requirements ^{Note 2} and multilayer surveillance provision should be implemented to enhance the availability of surveillance services;
14. Monitor development of surveillance systems to support integration of UAS including new technology capable to detect non cooperative targets such as UAS.
15. Encourage sharing of surveillance data, utilizing provisions in the Region such as CRV, to improve safety and efficiency in air traffic management with a justifiable cost; and
16. Monitor potential congestion on 1090 MHz by means of routine measurements of channel occupancy, at both terrestrial and airborne levels, and monitor the availability of 24-bit aircraft address

Note 1:

- a) *Version 0 ES as specified in Annex 10, Volume IV, Chapter 3, Paragraph 3.1.2.8.6 (up to and including Amendment 82 to Annex 10) and Chapter 2 of Technical Provisions for Mode S Services and Extended Squitter (ICAO Doc 9871) (Equivalent to DO260) to be used till at least 2020.*
- b) *Version 1 ES as specified in Chapter 3 of Technical Provisions for Mode S Services and Extended Squitter (ICAO Doc 9871) (Equivalent to DO260A);*
- c) *Version 2 ES as specified in Chapter 4 of Technical Provisions for Mode S Services and Extended Squitter (ICAO Doc 9871) (Equivalent to DO260B).*
- d) *States/Administrations in APAC region are strongly encouraged to mandate aircraft with a maximum take-off mass exceeding 5 700 kg or having a maximum cruising true airspeed capability greater than 250 knots, to be equipped with ADS-B OUT avionics compliant with Version 2 ES (DO-260B) or later version with date of manufacture on or after 1 January 2020.*

Note 2:

Contingency surveillance requirements are requirements to handle contingency situations in surveillance thus retain capacity to continue providing/using air navigation services. Such situations include but are not limited to the followings:

- *failure of surveillance system or infrastructure such as ground stations or GNSS failure;*
- *avionics failure or equipped aircraft transmitting bad data in flight with good data integrity indicators.*



**INTERNATIONAL CIVIL AVIATION ORGANIZATION
ASIA AND PACIFIC OFFICE**

**ADS-B IMPLEMENTATION AND
OPERATIONS GUIDANCE DOCUMENT**

Edition 15.0 - August 2022

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Appendix 1 – An Example of Commissioning Checklist

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Appendix 4 – An Example of Advice to Operators Concerning Inconsistency between ADS-B Flight Planning and Surveillance Capability

Appendix 5 – Checklist of Common Items or Parameters for the Monitoring of ADS-B System

Appendix 6 – Baseline ADS-B Service Performance Parameters

Appendix 7 – Guidance Material on Generation, Processing and Sharing of ASTERIX Category 21 ADS-B Messages

Appendix 8 – ICAO Guidance Material on 1 090 Mhz Spectrum Issues and Proper Management of 24-Bit Aircraft Addresses Associated with Unmanned Aircraft

1. INTRODUCTION

The Eleventh ICAO Air Navigation Conference held in 2003 recommended that States recognize ADS-B as an enabler of the global ATM concept bringing substantial safety and capacity benefits; support the cost-effective early implementation of it; and ensuring it is harmonized, compatible and interoperable with operational procedures, data linking and ATM applications.

The Twelve ICAO Air Navigation Conference held in 2012 endorsed the Aviation System Block Upgrades (ASBU) to provide a framework for global harmonization and interoperability of seamless ATM systems. Among the Block Upgrades, the Block 0 module “Initial Capability for Ground Surveillance” recommends States to implement ADS-B which provides an economical alternative to acquire surveillance capabilities especially for areas where it is technically infeasible or commercially unviable to install radars.

This ADS-B Implementation and Operations Guidance Document (AIGD) provides guidance material for the planning, implementation and operational application of ADS-B technology in the Asia and Pacific Regions.

The procedures and requirements for ADS-B operations are detailed in the relevant States’ AIP. The AIGD is intended to provide key information on ADS-B performance, integration, principles, procedures and collaboration mechanisms.

The content is based upon the work to date of the APANPIRG ADS-B Study and Implementation Task Force (SITF), the Surveillance Implementation Coordination Group (SURICG) and various ANC Panels developing provisions for the operational use of ADS-B. Amendment to the guidance material will be required as new/revised SARPs and PANS are published.

1.1 ARRANGEMENT OF THE AIGD

The AIGD consists of the following Parts:

Section 1	Introduction
Section 2	Acronyms and Glossary of Terms
Section 3	Reference Documents
Section 4	ADS-B Data
Section 5	ADS-B Implementation
Section 6	Template of Harmonization Framework for ADS-B Implementation
Section 7	System Integrity and Monitoring
Section 8	Reliability and Availability Considerations
Section 9	ADS-B Regulations and Procedures
Section 10	Security Issues Associated with ADS-B

1.2 DOCUMENT HISTORY AND MANAGEMENT

This document is managed by the APANPIRG. It was introduced as draft to the first Working Group meeting of the ADS-B SITF in Singapore in October 2004, at which it was agreed to develop the draft to an approved working document that provides implementation guidance for States. The first edition was presented to APANPIRG for adoption in August 2005. It is intended to supplement SARPs, PANS and relevant provisions contained in ICAO documentation and it will be regularly updated to reflect evolving provisions.

1.3 COPIES

Paper copies of this AIGD are not distributed. Controlled and endorsed copies can be found at the following web site: <http://www.icao.int/APAC/Pages/edocs.aspx>

Copy may be freely downloaded from the web site, or by emailing APANPIRG through the ICAO Asia and Pacific Regional Office who will send a copy by return email.

1.4 CHANGES TO THE AIGD

Whenever a user identifies a need for a change to this document, a Request for Change (RFC) Form (see Section 1.6 below) should be completed and submitted to the ICAO Asia and Pacific Regional Office. The Regional Office will collate RFCs for consideration by the Surveillance Implementation Coordination Group.

When an amendment has been agreed by a meeting of the Surveillance Implementation Coordination Group then a new version of the AIGD will be prepared, with the changes marked by an “|” in the margin, and an endnote indicating the relevant RFC, so a reader can see the origin of the change. If the change is in a table cell, the outside edges of the table will be highlighted; e.g.:

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Final approval for publication of an amendment to the AIGD will be the responsibility of APANPIRG.

1.5 EDITING CONVENTIONS (Intentionally blank)

1.7 AMENDMENT RECORD

Amendment Number	Date	Amended by	Comments
0.1	24 December 2004	W. Blythe H. Anderson	Modified draft following contributions from ADS-B SITF Working Group members. Incorporated to TF/3 Working Paper #3.
0.2 (1.0)	24 March 2005	H. Anderson	Final draft prepared at ADS-B SITF WG/3
0.3 (1.1)	03 June 2005	Nick King	Amendments following SASP WG/WHL meeting of May 2005
0.4	15 July 2005	CNS/MET SG/9	Editorial changes made
1.0	26 August 2005	APANPIRG/16	Adopted as the first Edition
2.0	25 August 2006	Proposed by ADS-B SITF/5 and adopted by APANPIRG/17	Adopted as the second Edition
3.0	7 September 2007	Proposed by ADS-B SITF/6 and adopted by APANPIRG/18	Adopted as the second amendment (3 rd edition)
4.0	5 September 2011	Proposed by ADS-B SITF/10 and adopted by APANPIRG/22	Adopted amendment on consequential change to the Flight Plan and additional material on the reliability and availability for ADS-B ground system
5.0	14 September 2012	Proposed by ADS-B SITF/11 and adopted by APANPIRG/23	Included sample template on harmonization framework
6.0	June 2013	Proposed by ADS-B SITF/12 and adopted by APANPIRG/24	Revamped to include the latest ADS-B developments and references to guidance materials on ADS-B implementation
7.0	September 2014	Proposed by ADS-B SITF/13 and adopted by APANPIRG/25	(i) Included guidance materials on monitoring and analysis of ADS-B equipped aircraft (ii) Included guidance materials on synergy between GNSS and ADS-B (iii) Revised ATC Phraseology (iv) Included clarification on Flight Planning
8.0	September 2015	Proposed by ADS-B SITF/14 and adopted by APANPIRG/26	(i) Updated the guidance materials on monitoring and analysis of ADS-B equipped aircraft (ii) Updated the categories of reported ADS-B avionics problems (iii) Updated the guidance materials on ADS-B flight plan (iv) Updated the guidance materials on disabling ADS-B transmissions (v) Remove reference to operational

			approval for use of ADS-B Out by ATC
9.0	September 2016	Proposed by ADS-B SITF/15 and adopted by APANPIRG/27	(i) Included a list of additional functional requirements for ADS-B integration (ii) Addition of a checklist of common items or parameters for monitoring of ADS-B System (iii) Amendment to emphasize the issue on potential incorrect processing of DO-260B downlinks by ADS-B ground stations during upgrade (iv) Updated the list of known ADS-B avionics problems (v) Included a general recommendation of technical solution on acquisition of Mode 3/A code information via Mode S downlink for DO-260 aircraft in ADS-B implementation with Mode A/C SSR environment
10.0	June 2017	Proposed by SURICG/2	(i) Updated “B787 position error with good NUC” in the list of known ADS-B avionics problems. (ii) Included new problem type “Incorrect Ground Bit Setting in ADS-B Avionics Downlink Data” and “A350 ADS-B on-ground performance” in the list of known ADS-B avionics problems. (iii) Amendment to the template for ADS-B Mandate / Regulations for Aircraft Avionics. (iv) Included a general recommendation to use ADS-B in overcoming the limitations of Mode A/C radar technology. (v) Included a general recommendation on carrying out ICAO Aircraft Address Monitoring (vi) Aligned to replace NACp for NAC throughout the document (vii) Aligned to use ICAO Aircraft Address throughout the document
11.0	April 2018	Proposed by SURICG/3	(i) Editorial Updates – including /replacing ADS-B SITF with SURICG (Sections 1, 1.4, 2.1, 7.5.1, 7.5.5, 7.5.6, 7.6, 7.8.2) (ii) Correction of HPL Definition (Section 2.2) (iii) Update of reference documents as in Attachment 2 of WP/02 (iv) Include reference to APRD (Section

			7.5.1) (v) Update of sample regulations (Section 9.2) (vi) Update in Position Reporting Performance (Section 9.3.2) (vii) Update in GNSS Integrity Prediction Service (Section 9.3.3) (viii) Update name of RASMAG in Sharing of ADS-B Data (Section 9.3.4) (ix) Clarification of reporting rate requirements (Section 9.4.1) (x) Use of Ident during ADS-B emergencies.(Section 9.12) (xi) Appendix 1 missing from Version 10 – reinstate. (xii) Appendix 2 – update for available APRD. (xiii) Update to B787 service bulletin status. (Attachment A in Appendix 2) (xiv) replace "Date UTC" to "Start Time/Date UTC", replace "Time UTC" to "End Time/Date UTC" and related contents in the Report Form (Section 7.8.1) (xv) replace description of "Date UTC" as "UTC Time/Date when the event occurred", replace description of "Time UTC" as "UTC Time/Date when the event ended" as sometimes the problem will lasts across mid-night. (Section 7.8.2) (xvi) In Remote Control & Monitoring (RCMS) part, suggest to replace "ASTERIX Output Load" to "ASTERIX Output Load and Link Status" (Appendix 5) (xvii) Update on DO260A EMG issue (Section 9.12) (xviii) Update the link to the Guidance Material on generation, processing and sharing of ASTERIX (Section 4) (xix) Reference to Space based ADS-B and ATC automation as in WP12 is added under 5.1.4.4.6 (xx) Updated Section 4Managing the Problem in Appendix 2 to incorporate the General mechanism and procedure for blacklisting aircraft (xxi) Updated the Attachment A to Appendix 2 – List of known ADS-B avionics problems (xxii) Added Appendix 6 – Baseline ADS-B Service Performance Parameters
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			(xxiii) Added Appendix 7 – Guidance Material on Generation, Processing and Sharing of ASTERIX Category 21 ADS-B Messages
12.0	April 2019	Proposed by SURICG/4	(i) Added procedures on handling GPS time and week counters rollover (Section 9.13) (ii) Added two new problem types to Attachment A of Appendix 2 “List of known ADS-B avionics problems”, including: ○ Rockwell TSS-4100 Geometric Altitude Reporting as Pressure Altitude ○ Improper NACv reporting (iii) Updated the status of known ADS-B avionics problems in Attachment A of Appendix 2 “List of known ADS-B avionics problems”, including: ○ B787 position error with good NIC ○ Rockwell TSS-4100 track extrapolation issue ○ Embraer 170 track jumping issue ○ Airbus Single Aisle production wiring issue ○ Boeing 777-300ER production wiring issue
13.0	September 2020	Proposed by SURICG/5	(i) Updated the status of known ADS-B avionics problems in Attachment A of Appendix 2 “List of known ADS-B avionics problems”, including B787 NACv = 0 Issue (ii) Updated Section 5.1.4.5.1 on ICAO Aircraft Address Monitoring (iii) Added the following new sections: ○ Use of ADS-B for Airport Surface Movement (Section 9.3.6) ○ 1090 Mhz Spectrum and 24-bit Aircraft Address Issue with Unmanned Aircraft Systems (UAS) (Section 9.3.7) ○ Measures for Enhancing the Security of ADS-B (Section 10.3) ○ Time Difference of Arrival

			(TDOA) Based Position Verification Method (Section 10.3.1)
14.0	August 2021	Proposed by SURICG/6	(i) Added the following new issue to the “List of known ADS-B avionics problems” in Attachment A of Appendix 2 ○ Honeywell Primus II RCZ Issue
15.0	May 2022	Proposed by SURICG/7	(i) Added Section 9.3.8 on Methodologies to Avoid or Reduce 1090 MHz Congestion (ii) Added Section 10.3.2 on Appropriate Implementation of a Decoding Method of CPR

2. ACRONYM LIST & GLOSSARY OF TERMS

2.1 ACRONYM LIST

ACID	Aircraft Identification
ADS-C	Automatic Dependent Surveillance - Contract
ADS-B	Automatic Dependent Surveillance - Broadcast
AIGD	ADS-B Implementation and Operations Guidance Document
AIP	Aeronautical Information Publication
AIT	ADS-B Implementation Team
AMSL	Above Mean Sea Level
APANPIRG	Asia/Pacific Air Navigation Planning and Implementation Regional Group
APRD	ADS-B Avionics Problem Reporting Database
ARINC	Aeronautical Radio Incorporated
ATC	Air Traffic Control (or Air Traffic Controller)
ATM	Air Traffic Management
ATS	Air Traffic Services
ATSP	ATS Provider
ATSU	ATS unit
CNS	Communications, Navigation, Surveillance
CRC	Cyclic Redundancy Check
CDTI	Cockpit Display Traffic Information
DAIW	Danger Area Infringement Warning
FIR	Flight Information Region
FLTID	Flight Identification
FMS	Flight Management System
FOM	Figure of Merit used in ASTERIX messaging
GPS	Global Positioning System (USA)
HPL	Horizontal Protection Level
ICAO	International Civil Aviation Organization
MSAW	Minimum Safe Altitude Warning
MTBF	Mean Time Between Failures
MTCA	Medium Term Conflict Alert
MTTR	Mean Time To Restore
NACp	Navigation Accuracy Category
NIC	Navigation Integrity Category
PRS	Problem Reporting System
RAI	Restricted Area Intrusion
RAM	Route Adherence Monitoring
RAIM	Receiver Autonomous Integrity Monitoring
RFC	Request for Change
RNP	Required Navigation Performance
SIL	Source Integrity Level
SITF	Study and Implementation Task Force
STCA	Short Term Conflict Alert
SURICG	Surveillance Implementation Coordination Group

2.2 GLOSSARY OF TERMS

ADS-B In	An ADS-B system feature that enables the display of real time ADS-B tracks on a situation display in the aircraft cockpit.
ADS-B Out	An ADS-B system feature that enables the frequent broadcast of accurate aircraft position and vector data together with other information.
Asterix 21	Eurocontrol standard format for data message exchange
FOM (Figure of Merit)	A numeric value that is used to determine the accuracy and integrity of associated position data.
HPL (Horizontal Position Limit)	The containment radius within which the true position of the aircraft will be found for 99.999% of the time, or the probability indicated by the reported SIL value (DO-260A/B).
NACp (Navigational Accuracy Category)	Subfield used to announce the 95% accuracy limits for the horizontal position data being broadcast.
NIC (Navigational Integrity Category)	Subfield used to specify the containment radius integrity associated with horizontal position data.
NUCp (Navigation Uncertainty Category)	A numeric value that announces the integrity of the associated horizontal position data being broadcast.
SIL (Source Integrity Level)	Subfield used to specify the probability of the true position lying outside the containment radius defined by NIC without being alerted.

3. REFERENCE DOCUMENTS

Id	Name of the document	Reference	Date	Origin	Domain
1	Annex 2: Rules of the Air	Tenth Edition Including Amendment 43 dated 10/11/16	July 2005	ICAO	
2	Annex 4: Aeronautical Chart	Eleventh Edition including Amendment 59 dated 10/11/16	July 2009	ICAO	
3	Annex 10: Aeronautical Telecommunications, Vol. IV – Surveillance Radar and Collision Avoidance Systems	Fifth Edition	July 2014	ICAO	
4	Annex 11: Air Traffic Services	Fourteenth Edition	July 2016	ICAO	
5	Annex 15: Aeronautical Information Services	Fifteenth Edition	July 2016	ICAO	
6	PAN-ATM (Doc 4444/ATM501)	Sixteenth Edition	November 2016	ICAO	
7	Air Traffic Services Planning Manual (Doc 9426/AN924)	First Edition including Amendment 4 30/12/92	1984	ICAO	
8	Manual on Airspace Planning Methodology for the Determination of Separation Minima (Doc 9689/AN953)	First Edition including Amendment 1 dated 30/8/02	1998	ICAO	
9	Doc 9859 Safety Management Manual (SMM)	Third Edition	2013	ICAO	
10	Technical Provisions for Mode S Services and Extended Squitter (Doc 9871/AN460)	Second Edition including Amendment 1 dated 09/01/17	2012	ICAO	
11	Aeronautical Surveillance Manual (Doc 9924)	Second Edition	2017	ICAO	
12	ICAO Circular 326 AN/188 “Assessment of ADS-B and Multilateration Surveillance to Support Air Traffic Services and Guidelines for Implementation”.	First Edition	2012	ICAO	
13	Regional Supplementary Procedures (Doc 7030)	Fifth Edition including Amendment 9 dated 25/04/14	2008	ICAO	
14	Minimum Operational Performance Standards (MOPS) for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B) – including Change 1	RTCA DO-260 September 13, 2000 Change 1 to RTCA DO-260	2000 2006	RTCA	

		June 27, 2006			
15	Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)	RTCA DO-260A April 10, 2003	2003	RTCA	
	Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B) – Change 1	RTCA DO-260A Change 1 June 27, 2006	2006		
	Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B) – Change 2	RTCA DO-260A Change 2 December 13, 2006	2006		
16	Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services (TIS-B)	RTCA DO-260B December 2, 2009	2009	RTCA	
	Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B) – Corrigendum 1	RTCA DO-260B December 13, 2011	2011		

4. ADS-B DATA

APANPIRG has decided to use 1090MHz Extended Squitter data link for ADS-B data exchange in the Asia and Pacific Regions. In the longer term an additional link type may be required.

To ensure interoperability of ADS-B ground stations in the Asia Pacific (ASIA/PAC) Regions, during the 16th APANPIRG Meeting held in August 2005, the ASTERIX Category 21 version 0.23 (V0.23) which had incorporated DO260 standard was adopted as the baselined ADS-B data format for deployment of ADS-B ground stations and sharing of ADS-B data in the ASIA/PAC Regions. At this time, DO260A and DO260B standards were not defined.

This baselined version provides adequate information so that useful ATC operational services, including aircraft separation, can be provided. V0.23 can be used with DO260, DO260A and DO260B ADS-B avionics/ground stations to provide basic ATC operational services. However, V0.23 cannot fully support the more advanced capabilities offered by DO260A and DO260B.

As the avionics standards changed through the different versions of DO260, the ADS-B ground station processing also needed to change, so that downlinks received from aircraft would be correctly interpreted in construction of the ASTERIX Category 21 messages. It is important that States with “older generation” ADS-B ground stations designed to support DO260 or DO260A, take action to upgrade to support the latest ADS-B avionics standard as well as the older standards. DO260B avionics will become more common in the Asia Pacific region as the FAA and European ADS-B mandates for 2020 require this version.

States intending to implement ADS-B surveillance and share ADS-B data with others might consider to adopt a more updated version of ASTERIX in order to make use of the advanced capabilities offered by DO260A and DO260B compliant avionics.

A guidance material on generation, processing and sharing of ASTERIX Cat. 21 ADS-B messages is provided at **Appendix 7** for reference by States.

In this guidance material, the ADS-B data contained inside ASTERIX Cat 21 are classified as Group 1 (mandatory), Group 2 (Desirable) and Group 3 (Optional). It is required to transmit all data that are operationally desirable (Group 2), when such data are received from the aircraft, in addition to the data that are mandatory (Group 1) in ASTERIX messages. Whether Group 3 optional data will need to be transmitted or not should be configurable on item-by-item basis within the ADS-B ground station depending on specific operational needs.

It is considered necessary that all data that are mandatory in ASTERIX messages (i.e. Group 1 data items) and operationally desirable (i.e. Group 2 data items) when such data are received from aircraft, should be included in data sharing. In the event that the data have to be filtered, the list of optional data items (i.e. Group 3 data items) needs to be shared will be subject to mutual agreement between the two data sharing parties concerned.

5. ADS-B IMPLEMENTATION

5.1 INTRODUCTION

5.1.1 Planning

There are a range of activities needed to progress ADS-B implementation from initial concept level to operational use. This section addresses the issues of collaborative decision making, system compatibility and integration, while the second section of this chapter provides a checklist to assist States with the management of ADS-B implementation activities.

5.1.2 Implementation team to ensure international coordination

5.1.2.1 Any decision to implement ADS-B by a State should include consultation with the wider ATM community. Moreover, where ADS-B procedures or requirements will affect traffic transiting between states, the implementation should also be coordinated between States and Regions, in order to achieve maximum benefits for airspace users and service providers.

5.1.2.2 An effective means of coordinating the various demands of the affected organizations is to establish an implementation team. Team composition may vary by State or Region, but the core group responsible for ADS-B implementation planning should include members with multidiscipline operational expertise from affected aviation disciplines, with access to other specialists where required.

5.1.2.3 Ideally, such a team should comprise representatives from the ATS providers, regulators and airspace users, as well as other stakeholders likely to be influenced by the introduction of ADS-B, such as manufacturers and military authorities. All identified stakeholders should participate as early as possible in this process so that their requirements can be identified prior to the making of schedules or contracts.

5.1.2.4 The role of the implementation team is to consult widely with stakeholders, identify operational needs, resolve conflicting demands and make recommendations to the various stakeholders managing the implementation. To this end, the implementation team should have appropriate access to the decision-makers.

5.1.3 System compatibility

5.1.3.1 ADS-B has potential use in almost all environments and operations and is likely to become a mainstay of the future ATM system. In addition to traditional radar-like services, it is likely that ADS-B will also be used for niche application where radar surveillance is not available or possible. The isolated use of ADS-B has the potential to foster a variety of standards and practices that, once expanded to a wider environment, may prove to be incompatible with neighbouring areas.

5.1.3.2 Given the international nature of aviation, special efforts should be taken to ensure harmonization through compliance with ICAO Standards and Recommended Practices (SARPs). The choice of systems to support ADS-B should consider not only the required performance of individual components, but also their compatibility with other CNS systems and prevailing avionics standards.

5.1.3.3 The future concept of ATM encompasses the advantages of interoperable and seamless transition across flight information region (FIR) boundaries and, where necessary, ADS-

B implementation teams should conduct simulations, trials and cost/benefit analysis to support these objectives.

5.1.4 Integration

5.1.4.1 ADS-B implementation plans should include the development of both business and safety cases. The adoption of any new CNS system has major implications for service providers, regulators and airspace users and special planning should be considered for the integration of ADS-B into the existing and foreseen CNS/ATM system. The following briefly discusses each element.

5.1.4.2 Communication system

5.1.4.2.1 The communication system is an essential element within CNS. An air traffic controller can now monitor an aircraft position in real time using ADS-B where previously only voice position reports were available. However, a communication system that will support the new services that result from the improved surveillance may be necessary. Consequently, there is an impact of the ongoing ADS-B related work on the communication infrastructure developments.

5.1.4.3 Navigation system infrastructure

5.1.4.3.1 ADS-B is dependent upon the data obtained from a navigation system (typically GNSS), in order to enable its functions and performance. Therefore, the navigation infrastructure should fulfill the corresponding requirements of the ADS-B application, in terms of:

- a) Data items; and
- b) Performance (e.g. accuracy, integrity, availability etc.).

5.1.4.3.2 This has an obvious impact on the navigation system development, which evolves in parallel with the development of the surveillance system.

5.1.4.4 Other surveillance infrastructure

5.1.4.4.1 ADS-B may be used to supplement existing surveillance systems or as the principal source of surveillance data. Ideally, surveillance systems will incorporate data from ADS-B and other sources to provide a coherent picture that improves both the amount and utility of surveillance data to the user. The choice of the optimal mix of data sources will be defined on the basis of operational demands, available technology, safety and cost-benefit considerations.

5.1.4.4.2 ADS-B is one of the cost-effective means in complementing and overcoming limitations of Mode A/C radars, including false targets, aircraft positions temporarily not displayed and split tracks, which could cause aircraft display issues on radar screens for ATC irrespective of brands of Air Traffic Management System being used. Within busy airspace, aircraft could be managed at close lateral distance while vertically separated. In such situation, Mode A/C radars sometimes provide garbled detection, in the form of false targets due to overlapping replies from two or more aircraft. In the case of ADS-B, ADS-B data are broadcast in an omni-directional,

random and periodic intervals without suffering from the same issue. In addition, automatic data validation is usually done at ADS-B receivers to ensure integrity of ADS-B information received from the aircraft.

- 5.1.4.4.3 A guidance material on issues to be considered in ATC multi-sensor fusion processing including integration of ADS-B data is provided on the ICAO website <http://www.icao.int/APAC/Pages/edocs.aspx> for reference by States.
- 5.1.4.4.4 Acquisition of Mode 3/A code for DO-260 aircraft through Mode S downlink

There is a potential problem for some of the air traffic management systems (ATMS) for fusion of ADS-B targets with Mode A/C SSR targets, because a common identifier to the aircraft, Mode 3/A code, is not available through ADS-B. Then ATMS can only rely on proximity analysis of aircraft position and Mode C altitude to determine whether detections from two distinct types of surveillance sources belong to the same aircraft. This matching technique might introduce ambiguity in associating ADS-B with Mode A/C SSR targets for fused display.

States may consider enhancing their ADS-B ground stations to listen to Downlink Format 5 and 21 (DF 5 and 21) of Mode S interrogation replies which carry the Mode 3/A code of the same aircraft. As a result, ADS-B target reports of the same DO-260 aircraft can be filled with Mode 3/A code acquired from Mode S downlink to facilitate matching with Mode A/C SSR targets before transmitting to the ATMS.

The transmission of DF 5 and DF 21 messages from a Mode S aircraft requires to be triggered by ground-based Mode S interrogators, either through active or passive interrogation. For active interrogation, Mode S interrogators can be installed alongside with ADS-B ground stations for actively triggering DF 5 and DF 21 messages transmission from the aircraft. The interrogators shall follow ICAO standard to perform periodic all-call and roll-call to the aircraft in range. For passive interrogation, the ADS-B ground stations will only passively listen to the DF messages from the aircraft for acquiring the Mode 3/A code. It is required to ensure that Mode S interrogations are performed by external systems, such as A-SMGCS, MLAT system or Mode S radar under their coverage.

The above provides an interim solution during transition from Mode A/C SSR to Mode S SSR. After upgrading to Mode S SSR, ATMS can have an alternative means to make use of Flight ID or ICAO Aircraft Address to perform association between ADS-B and Mode S radar targets without ambiguity.

- 5.1.4.4.5 A guidance material on processing and displaying of ADS-B data at air traffic controller positions is provided on the ICAO website "<http://www.icao.int/APAC/Pages/edocs.aspx>" for reference by States.
- 5.1.4.4.6 Most of the ATC automation systems that support terrestrial ADS-B will also support space-based ADS-B without modifications. For more guidance, reference can be made to WP/12 on "ATC Automation Requirement and Space-based ADS-B" delivered during 3rd meeting of the SURICG.

5.1.4.5 Additional Functional Requirements for ADS-B Integration

5.1.4.5.1 The following list of functions could be considered by each individual States to see whether they are suitable for their own operational needs or applicable to local environment from ADS-B integration point of view:

- The priority of ADS-B sensor position data vs radar data could be adaptable;
- For ADS-B aircraft, receipt of the Mode S conspicuity code could trigger use of the Flight ID / ICAO Aircraft Address for flight plan correlation;
- If, due to sensor or aircraft capability limitation, no SSR code is received for an aircraft, the system could use Flight ID/ ICAO Aircraft Address for track correlation;
- For correlation based on Flight ID, the received ID could exactly match the ACID of the flight plan;
- For correlation based on ICAO Aircraft Address, the received address could match the address entered in the flight plan item 18 CODE/ keyword;
- The system could generate an alert for a correlated flight for which the Flight ID from the track does not match the flight plan ACID and/or the ICAO Aircraft Address from the track does not match the code given in the flight plan Item 18 CODE/ keyword;
- The system could allow the setting of ADS-B above or below the radar sources within the Surveillance Data Processor Tile Set on a per-tile basis;
- Priority could only apply to data received at or above the adapted NUCp, NACp, NIC, and/or SIL thresholds;
- The system could be configurable to either discard ADS-B data or display the track with an indication of ADS-B degradation if the received NUCp, NACp, NIC, or SIL is below an adapted threshold;
- If the system is configured to display the degraded track, the degraded position and status could only be displayed if there are no other surveillance sources available;
- The system could allow the adaptation of ADS-B emergency codes to map to special Mnemonics;
- The system could include an adaptable Downlinked Aircraft Parameters (DAP) field that invokes a popup with the following information from Mode-S and ADS-B aircraft:
 - Magnetic Heading
 - True Track Angle

- Indicated Airspeed/Mach Number
 - Groundspeed
 - Track Angle Rate
 - True Airspeed
 - Roll Angle
 - Selected Altitude
 - Vertical Rate
- The system could generate a conformance alert if the Selected Altitude and the Cleared Flight Level do not match.
 - The system could monitor¹ the ICAO Aircraft Address of individual aircraft and generate alert for the following cases:
 - ICAO Aircraft Address does not match with that specified in flight plan ICAO Aircraft Address is all 0 or F (expressed in hexadecimal)
 - ICAO Aircraft Address is not defined in ICAO's allocation
 - Duplicate ICAO Aircraft Address detected within single sensor in the same time-frame
 - Duplicate ICAO Aircraft Address detected within multi-sensors in the same time-frame ICAO Aircraft Address changes during the flight
 - Aircrafts whose state identification number is not match with the state information registered in its flight plan
 - Aircrafts whose state identification number is not defined in SARPs (Annex 10)
 - Mode-S transponder of which P4 pulse was not detected
 - Mode-A/C transponder replied to Mode-S all call

5.1.5 Coverage Predictions

- 5.1.5.1 Reliable and robust analysis and planning of ADS-B coverage to support seamless ATM initiative requires accurate and reliable coverage modelling. States should ensure that surveillance engineering/technical teams are provided with modelling tools to provide accurate and reliable coverage predictions for ATM planning and analysis.

¹ Monitoring could be done by ATM system or other systems of the States/Administration

5.2 IMPLEMENTATION CHECKLIST

5.2.1 Introduction

The purpose of this implementation checklist is to document the range of activities that needs to be completed to bring an ADS-B application from an initial concept to operational use. This checklist may form the basis of the terms of reference for an ADS-B implementation team, although some activities may be specific to individual stakeholders. An example of the checklist used by AirServices Australia is given at Appendix 1.

5.2.2 Activity Sequence

The activities are listed in an approximate sequential order. However, each activity does not have to be completed prior to starting the next activity. In many cases, a parallel and iterative process should be used to feed data and experience from one activity to another. It should be noted that not all activities will be required for all applications.

5.2.3 Concept Phase

a) construct operational concept:

- 1) purpose;
- 2) operational environment;
- 3) ATM functions; and
- 4) infrastructure;

b) identify benefits:

- 1) safety enhancements;
- 2) efficiency;
- 3) capacity;
- 4) environmental;
- 5) cost reductions;
- 6) access; and
- 7) other metrics (e.g. predictability, flexibility, usefulness);

c) identify constraints:

- 1) pair-wise equipage;
- 2) compatibility with non-equipped aircraft;
- 3) need for exclusive airspace;
- 4) required ground infrastructure;
- 5) RF spectrum;
- 6) integration with existing technology; and
- 7) technology availability;

d) prepare business case:

- 1) cost benefit analysis; and
- 2) demand and justification.

5.2.4 Design Phase

a) identify operational requirements:

- 1) security; and
 - 2) systems interoperability;
- b) identify human factors issues:
- 1) human-machine interfaces;
 - 2) training development and validation;
 - 3) workload demands;
 - 4) role of automation vs. role of human;
 - 5) crew coordination/pilot decision-making interactions; and
 - 6) ATM collaborative decision-making;
- c) identify technical requirements:
- 1) standards development;
 - 2) prevailing avionics standards;
 - 3) data required;
 - 4) functional processing;
 - 5) functional performance; and
 - 6) required certification levels;
- d) equipment development, test, and evaluation:
- 1) prototype systems built to existing or draft standards/specifications;
 - 2) developmental bench and flight tests; and
 - 3) acceptance test parameters; and
 - 4) select and procure technology;
- e) develop procedures:
- 1) pilot and controller actions and responsibilities;
 - 2) phraseologies;
 - 3) separation/spacing criteria and requirements;
 - 4) controller's responsibility to maintain a monitoring function, if appropriate;
 - 5) contingency procedures;
 - 6) emergency procedures; and
 - 7) develop AIP and Information documentation
- f) prepare design phase safety case:
- 1) safety rationale;
 - 2) safety budget and allocation; and
 - 3) functional hazard assessment.

5.2.5 Implementation phase

- a) prepare implementation phase safety case;
- b) conduct operational test and evaluation:
- 1) flight deck and ATC validation simulations; and
 - 2) flight tests and operational trials;
- c) obtain systems certification:

- 1) aircraft equipment; and
 - 2) ground systems;
 - d) obtain regulatory approvals:
 - 1) air traffic certification of use;
 - e) implementation transition:
 - 1) Promulgate procedures and deliver training
 - 2) continue data collection and analysis;
 - 3) resolve any unforeseen issues; and
 - 4) continue feedback into standards development processes;
 - f) performance monitoring to ensure that the agreed performance is maintained.
- 5.2.5.1 Once the implementation project is complete, ongoing maintenance and upgrading of both ADS-B operations and infrastructure should continue to be monitored, through the appropriate forums.

6. HARMONIZATION FRAMEWORK FOR ADS-B IMPLEMENTATION

6.1 BACKGROUND

6.1.1 It is obvious that full benefits of ADS-B will only be achieved by its harmonized implementation and seamless operations. During the 6th meeting of ADS-B SEA/WG in February 2011, Hong Kong, China initiated to strengthen collaboration among concerned States/Administrations for harmonized ADS-B implementation and seamless operations along two ATS routes L642 and M771 with major traffic flow (MTF). An ad-hoc workgroup comprising concerned CAAs/ANSPs from Hong Kong, China, Mainland China, Vietnam and Singapore was subsequently formed to elaborate and agree on a framework regarding implementation timelines, avionics standards, optimal flight levels, and ATC and engineering handling procedures. As a coherent effort, ADS-B implementation along ATS routes L642 and M771 has been harmonized while Hong Kong, China and Singapore have published respective Aeronautical Information Circulars and Airworthiness Notices on ADS-B mandates for these two routes with effect on 12 December 2013.

6.1.2 It is considered that the above implementation framework for ATS routes L642/M771 would serve as a useful template for extension to other high density routes to harmonize ADS-B implementation. Paragraph 6.2 shows the detailed framework.

6.2 TEMPLATE OF HARMONIZATION FRAMEWORK FOR ADS-B IMPLEMENTATION

Harmonization Framework for ADS-B Implementation along ATS Routes L642 and M771			
No.	What to harmonize	What was agreed	Issue / what needs to be further discussed
1	Mandate Effective	Singapore (SG), Hong Kong (HK), China (Sanya) : 12 Dec 2013 Vietnam (VN) : to be confirmed	
2	ATC Operating Procedures	No need to harmonize	Refer to SEACG for consideration of the impact of expanding ADS-B surveillance on ATC Operating Procedures including Large Scale Weather procedures.
3	Mandate Publish Date	No need to harmonize	To publish equipment requirements as early as possible.

4	Flight Level	SG, HK, CN : - At or Above FL290 (ADS-B airspace) - Below FL290 (Non-ADS-B airspace) VN to be confirmed	
5	Avionics Standard (CASA/AMC2024)	SG - CASA or AMC2024 or FAA AC No. 20-165 HK - CASA or AMC2024 or FAA AC No. 20-165 VN - CASA or AMC2024 or FAA AC No. 20-165 CN - CASA or AMC2024 or FAA AC No. 20-165	ADS-B Task Force agreed that DO260B will be accepted as well. SG, HK, and CN agreed their ADS-B GS will accept DO260, DO260A and DO260B by 1 July 2014 (Note 1)
6	Flight Planning	Before 15 Nov 2012, as per AIGD On or after 15 Nov 2012, as per new flight plan format	
7	Aircraft Equippage		
7a)	Procedures if Aircraft Not Equipped or Aircraft without a Serviceable ADS-B Transmitting Equipment before Flight	SG, HK, CN : FL280 and Below VN to be confirmed	

7b)	Aircraft Equipped but Transmitting Bad Data (Blacklisted Aircraft)	For known aircraft, treat as non ADS-B aircraft.	Share blacklisted aircraft among concerned States/Administration
8	Contingency Plan		
8a)	Systemic Failure such as Ground System / GPS Failure	Revert back to current procedure.	
8b)	Avionics Failure or Equipped Aircraft Transmitting Bad Data in Flight	Provide other form of separation, subject to bilateral agreement. From radar/ADS-B environment to ADS-B only environment, ATC coordination may be able to provide early notification of ADS-B failure.	Address the procedure for aircraft transiting from radar to ADS-B airspace and from ADS-B to ADS-B airspace.
9	Commonly Agreed Route Spacing	SEACG	Need for commonly agreed minimal in-trail spacing throughout.

Note 1: Also included two ADS-B GS supplied by Indonesia at Matak and Natuna

7. SYSTEM INTEGRITY AND MONITORING

7.1 INTRODUCTION

The Communications, Navigation, Surveillance and Air Traffic Management (CNS/ATM) environment is an integrated system including physical systems (hardware, software, and communication networks), human elements (pilots, controllers and engineers), and the operational procedures for its applications. ADS-B is a surveillance system that may be integrated with other surveillance technologies or may also operate as an independent source for surveillance monitoring within the CNS/ATM system.

Because of the integrated nature of such system and the degree of interaction among its components, comprehensive system monitoring is recommended. The procedures described in this section aim to ensure system integrity by validation, identification, reporting and tracking of possible problems revealed during system monitoring with appropriate follow-up actions.

These procedures do not replace the ATS incident reporting procedures and requirements, as specified in PANS-ATM (Doc 4444), Appendix 4; ICAO's Air Traffic Services Planning Manual (Doc 9426), Chapter 3; or applicable State regulations, affecting the reporting responsibilities of parties directly involved in a potential ATS incident.

7.2 PERSONNEL LICENSING AND TRAINING

Prior to operating any element of the ADS-B system, operational and technical personnel shall undertake appropriate training as determined by the States, including compliance with the Convention on International Civil Aviation where applicable.

Notwithstanding the above requirement and for the purposes of undertaking limited trials of the ADS-B system, special arrangements may be agreed between the operator and an Air Traffic Services Unit (ATSU).

7.3 SYSTEM PERFORMANCE CRITERIA FOR AN ATC SEPARATION SERVICE

A number of States have introduced ADS-B for the provision of Air Traffic Services, including for surveillance separation. The ICAO Separation and Airspace Safety Panel (SASP) has completed assessment on the suitability of ADS-B for various applications including provision of aircraft separation based on comparison of technical characteristics between ADS-B and monopulse secondary surveillance radar. It is concluded that that ADS-B surveillance is better or at least no worse than the referenced radar, and can be used to provide separation minima as described in PANS-ATM (Doc 4444) whether ADS-B is used as a sole means of ATC surveillance or used together with radar, subject to certain conditions to be met. The assessment result is detailed in the ICAO Circular 326 AN/188 "Assessment of ADS-B and Multilateration Surveillance to Support Air Traffic Services and Guidelines for Implementation".

Regarding the use of ADS-B in complex airspace (as discussed in ICAO Circular 326), complex airspace may be considered to be airspace with the following characteristics:

- Higher aircraft density
- Higher route crossing point density
- A higher mixture of different aircraft performance levels
- A higher rate of aircraft manoeuvring (as distinct from straight and level flight).

The following recommendations need to be considered:

1. Whether complex or not, States are urged to consider whether the current or required surveillance system performance is better, equivalent or worse than the SASP reference.
2. If the current or required surveillance system used by a State is lower or equivalent in performance than the reference MSSR used in Circular 326 Appendix A, then that State may use the Appendix C performance criteria.
3. If the current or required surveillance system used by a State is higher performance than the reference MSSR used in Circular 326 Appendix A, then the State must ensure that the ADS-B system achieves the more demanding performance.
4. State should undertake, in all cases, a safety assessment that ensures that any additional risks and safety requirements already identified for the airspace where ADSB or MLAT is to be implemented, or any newly identified risks, are effectively controlled and risk is reduced to an acceptable level.

States intending to introduce ADS-B separation minima shall comply with provisions of PANS-ATM, Regional Supplementary Procedures (Doc 7030) and Annex 11 paragraph 3.4.1. States should adopt the guidelines contained in this document unless conformance with PANS-ATM specifications requires change.

7.4 ATC SYSTEM VALIDATION

7.4.1 Safety Assessment Guidelines

To meet system integrity requirements, States should conduct a validation process that confirms the integrity of their equipment and procedures. Such processes shall include:

- a) A system safety assessment for new implementations is the basis for definitions of system performance requirements. Where existing systems are being modified to utilize additional services, the assessment demonstrates that the ATS Provider's system will meet safety objectives;
- b) Integration test results confirming interoperability for operational use of airborne and ground systems; and
- c) Confirmation that the ATS Operation Manuals are compatible with those of adjacent providers where the system is used across a common boundary.

7.4.2 System safety assessment

The objective of the system safety assessment is to ensure the State that introduction and operation of ADS-B is safe. This can be achieved through application of the provisions of Annex 11 paragraph 2.27 and PANS-ATM Chapter 2. The safety assessment should be conducted for initial implementation as well as any future enhancements and should include:

- a) Identifying failure conditions;
- b) Assigning levels of criticality;
- c) Determining risks/ probabilities for occurrence;
- d) Identifying mitigating measures and fallback arrangements;
- e) Categorising the degree of acceptability of risks; and

- f) Operational hazard ID process.

Following the safety assessment, States should institute measures to offset any identified failure conditions that are not already categorized as acceptable. This should be done to reduce the probability of their occurrence to a level as low as reasonably practicable. This could be accomplished through system automation or manual procedures.

Guidance material on building a safety case for delivery of an ADS-B separation service is provided on the ICAO APAC website “<http://www.icao.int/APAC/Pages/edocs.aspx>” for reference by States.

7.4.3 Integration test

States should conduct trials with suitably equipped aircraft to ensure they meet the operational and technical requirements to provide an ATS. Alternatively, they may be satisfied by test results and analysis conducted by another State or organization deemed competent to provide such service. Where this process is followed, the tests conducted by another State or organization should be comparable (i.e. using similar equipment under similar conditions). Refer also to the *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc9689).

7.4.4 ATS Operation Manuals

States should coordinate with adjacent States to confirm that their ATS Operation Manuals contain standard operating procedures to ensure harmonization of procedures that impact across common boundaries.

7.4.5 ATS System Integrity

With automated ATM systems, data changes, software upgrades, and system failures can affect adjacent units. States shall ensure that:

- a) A conservative approach is taken to manage any changes to the system;
- b) Aircrew, aircraft operating companies and adjacent ATSU(s) are notified of any planned system changes in advance, where that system is used across a common boundary;
- c) ATSUs have verification procedures in place to ensure that following any system changes, displayed data is both correct and accurate;
- d) In cases of system failures or where upgrades (or downgrades) or other changes may impact surrounding ATS units, ATSUs should have a procedure in place for timely notification to adjacent units. Such notification procedures will normally be detailed in Letters of Agreement between adjacent units; and
- e) ADS-B surveillance data is provided with equal to or better level of protection and security than existing surveillance radar data.

7.5 SYSTEM MONITORING

During the initial period of implementation of ADS-B technology, routine collection of data is necessary in order to ensure that the system continues to meet or exceed its performance, safety and interoperability requirements, and that operational service delivery and procedures are working as intended. The monitoring program is a two-fold process. Firstly, summarised statistical data should be

produced periodically showing the performance of the system. This is accomplished through ADS-B Periodic Status Reports. Secondly, as problems or abnormalities arise, they should be identified, tracked, analyzed and corrected and information disseminated as required, utilizing the ADS-B Problem Report.

Guidance materials on monitoring and analysis of ADS-B Avionics Performance are given at Appendix 2. Checklist of common items or parameters that could be considered for monitoring is summarized at Appendix 5 for reference.

7.5.1 Problem Reporting System (PRS)

The Problem Reporting System is tasked with the collection, storage and regular dissemination of data based on reports received from SURICG members. The PRS tracks problem reports and publish information from those reports to SURICG members. Problem resolution is the responsibility of the appropriate SURICG members.

The PRS Administrator shall:

- a) prepare consolidated problem report summaries for each SURICG meeting;
- b) collect and consolidate ADS-B Problem Reports; and
- c) maintain a functional website (with controlled access) to manage the problem reporting function.

The PRS is managed through the Asia Pacific ADS-B Avionics Problem Reporting Database (APRD) which is accessible to authorized users via <https://applications.icao.int/ADSB-APRD/login.aspx>.

7.5.2 The monitoring process

When problems or abnormalities are discovered, the initial analysis should be performed by the organization(s) identifying the problem. In addition, a copy of the problem report should be entered in to the PRS which will assign a tracking number. As some problems or abnormalities may involve more than one organization, the originator should be responsible for follow-up action to rectify the problem and forward the information to the PRS. It is essential that all information relating to the problem is documented and recorded and resolved in a timely manner.

The following groups should be involved in the monitoring process and problem tracking to ensure a comprehensive review and analysis of the collected data:

- a) ATS Providers;
- b) Organizations responsible for ATS system maintenance (where different from the ATS provider);
- c) Relevant State regulatory authorities;
- d) Communication Service Providers being used;
- e) Aircraft operators; and

- f) Aircraft and avionics manufacturers.

7.5.3 Distribution of confidential information

It is important that information that may have an operational impact on other parties be distributed by the authorised investigator to all authorised groups that are likely to be affected, as soon as possible. In this way, each party is made aware of problems already encountered by others, and may be able to contribute further information to aid in the solution of these problems. The default position is that all states agree to provide the data which will be de-identified for reporting and record keeping purposes.

7.5.4 ADS-B problem reports

Problem reports may originate from many sources, but most will fall within two categories; reports based on observation of one or more specific events, or reports generated from the routine analysis of data. The user would document the problem, resolve it with the appropriate party and forward a copy of the report to the PRS for tracking and distribution. While one occurrence may appear to be an isolated case, the receipt of numerous similar reports by the PRS could indicate that an area needs more detailed analysis.

To effectively resolve problems and track progress, the problem reports should be sent to the nominated point of contact at the appropriate organization and the PRS. The resolution of the identified problems may require:

- a) Re-training of system operators, or revision of training procedures to ensure compliance with existing procedures;
- b) Change to operating procedures;
- c) Change to system requirements, including performance and interoperability; or
- d) Change to system design.

7.5.5 ADS-B periodic status report

The ATS Providers should complete the ADS-B Periodic Status Report annually and deliver the report to the regional meeting of the SURICG. The Periodic Status Report should give an indication of system performance and identify any trend in system deficiencies, the resultant operational implications, and the proposed resolution, if applicable.

Communications Service Providers, if used, are also expected to submit Periodic Status Reports on the performance of the networks carrying ADS-B data at the annual regional meeting of the SURICG. These reports could also contain the details of planned or current upgrades to the network.

7.5.6 Processing of Reports

Each group in the monitoring process should nominate a single point of contact for receipt of problem reports and coordination with the other parties. This list will be distributed by the PRS Administrator to all parties to the monitoring process.

Each State should establish mechanisms within its ATS Provider and regulatory authority to:

- a) Assess problem reports and refer them to the appropriate technical or operational expertise for investigation and resolution;
- b) Coordinate with aircraft operators;
- c) Develop interim operational procedures to mitigate the effects of problems until such time as the problem is resolved;
- d) Monitor the progress of problem resolution;
- e) Prepare a report on problems encountered and their operational implications and forward these to the PRS;
- f) Prepare the ADS-B periodic status report at pre-determined times and forward these to the Secretary of the annual meeting of the SURICG; and
- g) Coordinate with any Communication Service Providers used.

7.6 APANPIRG

APANPIRG, with the assistance of its contributory bodies, shall oversee the monitoring process to ensure the ADS-B system continues to meet its performance and safety requirements, and that operational procedures are working as intended. The APANPIRG'S objectives are to:

- a) review Periodic Status Reports and any significant Problem Reports;
- b) highlight successful problem resolutions to SURICG members;
- c) monitor the progress of outstanding problem resolutions;
- d) prepare summaries of problems encountered and their operational implications; and
- e) assess system performance based on information in the PRS and Periodic Status Reports.

7.7 LOCAL DATA RECORDING AND ANALYSIS

7.7.1 Data recording

It is recommended that ATS Providers and Communication Service Providers retain the records defined below for at least 30 days to allow for accident/incident investigation processes. These records should be made available on request to the relevant State safety authority. Where data is sought from an adjacent State, the usual State to State channels should be used.

These recordings shall be in a form that permits a replay of the situation and identification of the messages that were received by the ATS system.

7.7.2 Local data collection

ATS providers and communications service providers should identify and record ADS-B system component failures that have the potential to negatively impact the safety of controlled flights or compromise service continuity.

7.7.3 Avionics problem identification and correction

ATS providers need to develop systems to:

- a) detect ADS-B avionics anomalies and faults
- b) advise the regulators and where appropriate the aircraft operators on the detected ADS-B avionics anomalies and faults
- c) devise mechanisms and procedures to address identified faults

Regulators need to develop and maintain systems to ensure that appropriate corrective actions are taken to address identified faults.

7.8 ADS-B PROBLEM REPORT

7.8.1 Report Form			PRS #
Start Time/Date UTC		End Time/Date UTC	
Registration		Aircraft ID	
Flight ID		ICAO Aircraft Address	
Aircraft Type			
Flight Sector/ Location			
ATS Unit			
Description / additional information			
Originator		Originator Reference number	
Organization			

7.8.2 Description of Fields

Field	Meaning
Number	A unique identification number assigned by the PRS Administrator to this problem report. Organizations writing problem reports are encouraged to maintain their own internal list of these problems for tracking purposes. Once the problems have been reported to the PRS and incorporated in the database, a number will be assigned by the PRS and used for tracking by the SURICG.
Start Time/Date UTC	UTC time/date when the event occurred.
End Time/Date UTC	UTC time/date when the event ended.
Registration	Registration number (tail number) of the aircraft involved.
Aircraft ID (ACID)	Coded equivalent of voice call sign as entered in FPL Item 7.
ICAO Aircraft Address	Unique ICAO Aircraft Address expressed in Hexadecimal form (e.g. 7432DB)
Flight ID (FLTID)	The identification transmitted by ADS-B for display on a controller situation display or a CDTI.
Flight Sector/Location	The departure airport and destination airport for the sector being flown by the aircraft involved in the event. These should be the ICAO identifiers of those airports. Or if more descriptive, the location of the aircraft during the event.
Originator	Point of contact at the originating organization for this report (usually the author).
Aircraft Type	The aircraft model involved.
Organization	The name of the organization (airline, ATS provider or communications service provider) that created the report.
ATS Unit	ICAO identifier of the ATC Center or Tower controlling the aircraft at the time of the event.
Description	This should provide as complete a description of the situation leading up to the problem as is possible. Where the organization reporting the problem is not able to provide all the information (e.g. the controller may not know everything that happens on the aircraft), it would be helpful if they would coordinate with the other parties to obtain the necessary information. The description should include: • A complete description of the problem that is being reported • The route contained in the FMS and flight plan • Any flight deck indications • Any indications provided to the controller when the problem occurred • Any additional information that the originator of the problem report considers might be helpful but is not included on the list above If necessary to contain all the information, additional pages may be added. If the originator considers it might be helpful, diagrams and other additional information (such as printouts of message logs) may be appended to the report.

7.9 ADS-B PERFORMANCE REPORT FORM

Originating Organization			
Date of submission		Originator	
Report Period			
TECHNICAL ISSUES			
OPERATIONAL ISSUES			
GENERAL COMMENTS			

8. RELIABILITY & AVAILABILITY CONSIDERATIONS

Reliability and Availability of ADS-B systems should normally be equivalent or better than the reliability and availability of radar systems.

Guidance material on Reliability and Availability standards for ADS-B systems and supporting voice communications systems are included in the document “Baseline ADS-B Service Performance Parameters” at **Appendix 6**.

The “Baseline ADS-B Performance Parameters” document contains three Tiers of service performance parameters with different reliability and availability standards for each Tier. The appropriate Tier should be selected for the type of ADS-B service intended:

- (a) Tier 1 standards are for a high performance traffic separation service;
- (b) Tier 2 standards are for a traffic situational awareness service with procedural separation; and
- (c) Tier 3 standards are for a traffic advisory service (flight information service)

To achieve high operational availability of ADS-B systems to support aircraft separation services, it is necessary to operate with duplicated/redundant systems. If one system fails, the service continues using an unduplicated system. This is acceptable for a short period, whilst the faulty system is being repaired, because the probability of a second failure during the short time window of repairing is low.

However, it is necessary to ensure that the repair does not take too long. A long repair time increases the risk of an unexpected failure (loss of service continuity); which in turn, introduces potential loss of service (low availability) and loss of aircraft operational efficiency and/or safety impacts.

Checklist of common items or parameters that could be considered for monitoring is summarized at Appendix 5 for reference.

8.1 Reliability

8.1.1 Reliability is a measure of how often a system fails and is usually measured as Mean Time Between Failure (MTBF) expressed in hours. Continuity is a measure equivalent to reliability, but expressed as the probability of system failure over a defined period. In the context of this document, failure means inability to deliver ADS-B data to the ATC centre. I.e: Failure of the ADS-B system rather than an equipment or component failure.

8.1.2 Poor system MTBF has a safety impact because typically it causes unexpected transition from one operating mode to another. For example, aircraft within surveillance coverage that are safely separated by a surveillance standard distance (say, 5 NM) are unexpectedly no longer separated by a procedural standard distance (say 15 mins), due to an unplanned surveillance outage.

8.1.3 In general, reliability is determined by design (see para 8.3 B below)

8.2 Availability

8.2.1 Availability is a measure of how often the system is available for operational use. It is usually expressed as a percentage of the time that the system is available.

8.2.2 Poor availability usually results in loss of economic benefit because efficiencies are not available when the ATC system is operating in a degraded mode (eg using procedural control instead of say 5 NM separation).

8.2.3 Planned outages are often included as outages because the efficiencies provided to the Industry are lost, no matter what the cause of the outage. However, some organisations do not include planned outages because it is assumed that planned outages only occur when the facility is not required.

8.2.4 Availability is calculated as

$$Availability (Ao) = MTBF / (MTBF + MDT)$$

where $MTBF$ = Mean Time Between SYSTEM Failure
 MDT = Mean Down Time for the SYSTEM

The MDT includes Mean Time To Repair (MTTR), Turn Around Time (TAT) for spares, and Mean Logistic Delay Time (MLDT)

NB: This relates to the failure of the system to provide a service, rather than the time between individual equipment failures. Some organisations use Mean Time Between Outage (MTBO) rather than MTBF.

8.2.5 Availability is directly a function of how quickly the SYSTEM can be repaired. Ie: directly a function of MDT. Thus availability is highly dependent on the ability & speed of the support organisation to get the system back on-line.

8.3 Recommendations for high reliability/availability ADS-B systems

A: **System design** can keep system failure rate low with long MTBF. Typical techniques are:

- to duplicate each element and minimise single points of failure. Automatic changeover or parallel operation of both channels keeps system failure rates low. Ie: the system keeps operating despite individual failures. Examples are :
 - Separate communication channels between ADS-B ground station and ATC centre preferably using different technologies or service providers eg one terrestrial and one satellite
- Consideration of Human factors in design can reduce the number of system failures due to human error. E.g. inadvertent switch off, incorrect software load, incorrect maintenance operation.
- Take great care with earthing, cable runs and lightning protection to minimise the risks of system damage
- Take great care to protect against water ingress to cables and systems
- Establish a system baseline that documents the achieved performance of the site that can be later be used as a reference. This can shorten troubleshooting in future.
- System design can also improve the MDT by quickly identifying problems and alerting maintenance staff. Eg Built in equipment test (BITE) can significantly contribute to lowering MDT.

B: Logistics strategy aims to keep MDT very low. Low MDT depends on logistic support providing short repair times. To achieve short repair times, ANSPs usually provide a range of logistics, including the following, to ensure that the outage is less than a few days:

- ensure the procured system is designed to allow for quick replacement of faulty modules to restore operations
- provide remote monitoring to allow maintainers to identify the faulty modules for transport to site
- provide support tools to allow technicians to repair faulty modules or to configure/setup replacement modules
- provide technicians training to identify & repair the faulty modules
- provide local maintenance depots to reduce the time it takes to access to the site
- provide documentation and procedures to “standardise” the process
- use an in-country spares pool to ensure that replacement modules are available within reasonable times
- use a maintenance contract to repair faulty modules within a specified turnaround time. I.e.: to replenish the spares pool quickly.

Whilst technical training and remote monitoring are usually considered by ANSPs, sometimes there is less focus on spares support.

Difficulties can be experienced if States :

- a) Fail to establish a spares pool – because procurement of spares at the time of failure can bring extensive delays due to :
- b) obtaining funds
- c) obtaining approval to purchase overseas
- d) obtaining approval to purchase from a “sole source”
- e) difficulties and delays in obtaining a quotation
- f) delays in delivery because the purchase was unexpected by the supplier
- g) Fail to establish a module repair contract resulting in :
 - long repair times
 - unplanned expenditure
 - inability for a supplier to repair modules because the supplier did not have adequate certainty of funding of the work

Spares pool

ANSPs can establish, preferably as part of their acquisition purchase, adequate spares buffer stock to support the required repair times. The prime objective is to reduce the time period that the system operates un-duplicated. It allows decoupling of the restoration time from the module repair time.

Module repair contract

ANSPs can also enter into a maintenance repair contract, preferably as part of their acquisition purchase, to require the supplier to repair or replace and deliver failed modules within a specified time – preferably with contractual incentives/penalties for compliance. Such support contracts are best negotiated as part of the acquisition contract when competition between vendors is at play to keep costs down. Sometimes it is appropriate to demand that the support contractor also keep a certain level of buffer stock of spares “in country”.

It is strongly recommended that maintenance support is purchased under the same contract as the

acquisition contract.

The advantages of a module repair contract are:

- The price can be determined whilst in the competitive phase of acquisition – hence avoids excessive costs
- The contract can include the supplier bearing all shipping costs
- Can be funded by a define amount per year, which support the budget processes. If the costs are fixed, the supplier is encouraged to develop a reliable system minimising module repairs.
- It avoids delays and funding issues at the time of the module failure

Other typical strategies are:

- Establish availability and reliability objectives that are agreed organization wide. In particular agree System response times (SRT) for faults and system failure to ensure that MDT is achieved. An agreed SRT can help organizations to decide on the required logistics strategy including number, location and skills of staff to support the system.
- Establish baseline preventative maintenance regimes including procedures and performance inspections in conjunction with manufacturer recommendations for all subsystems
- Use remote control & monitoring systems to identify faulty modules before travel to site. This can avoid multiple trips to site and reduce the repair time
- Have handbooks, procedures, tools available at the site or a nearby depot so that travel time does not adversely affect down time
- Have adequate spares and test equipment ready at a maintenance depot near the site or at the site itself. Vendors can be required to perform analysis of the number of spares required to achieve low probability of spare “stock out”
- Have appropriate plans to cope with system and component obsolescence. It is possible to contractually require suppliers to regularly report on the ability to support the system and supply components.
- Have ongoing training programs and competency testing to ensure that staff are able to perform the required role

The detailed set of operational and technical arrangements in place and actions required to maintain a system through the lifecycle are often documented in a Integrated Logistics Support Plan.

C: Configuration Management aims to ensure that the configuration of the ground stations is maintained with integrity. Erroneous configuration can cause unnecessary outages. Normally configuration management is achieved by :

- Having clear organizational & individual responsibilities and accountabilities for system configuration.
- Having clear procedures in place which define who has authority to change configuration and records of the changes made including, inter alia
 - The nature of the change including the reason
 - Impact of the change & safety assessment

- An appropriate transition or cutover plan
- Who approved the change
- When the change was authorized and when the change was implemented
- Having appropriate test and analysis capabilities to confirm that new configurations are acceptable before operational deployment.
- Having appropriate methods to deploy the approved configuration (Logistics of configuration distribution). Suggested methods;
 - Approved configuration published on intranet web pages
 - Approved configuration distributed on approved media

D: Training & Competency plans aim to ensure that staff has the skills to safety repairs Normally this is achieved by:

- Conduct of appropriate Training Needs Analysis (TNA) to identify the gap between trainee skill/knowledge and the required skill/knowledge.
- Development and delivery of appropriate training to maintainers
- Competency based testing of trainees
- Ongoing refresher training to ensure that skills are maintained even when fault rates are low

E: Data collection & Review :

Regular and scheduled review should be undertaken to determine whether reliability/availability objectives are being met. These reviews need to consider :

- Reports of actual achieved availability & reliability
- Data regarding system failures including “down time” needs to be captured and analysed so the ANSP actually knows what is being (or not being) achieved.
- Any failure trends that need to be assessed. This requires data capture of the root cause of failures
- Any environmental impacts on system performance, such coverage obstructions such as trees, planned building developments, corrosion, RFI etc. Changes in infrastructure may also be relevant including air conditioning (temperature/humidity etc.) and power system changes.
- System problem reports especially those that relate to software deficiencies (design)
- System and component obsolescence
- Staff skills and need for refresher training

9. ADS-B REGULATIONS AND PROCEDURES

9.1 INTRODUCTION

ADS-B involves the transmission of specific data messages from aircraft and vehicle systems. These data messages are broadcast at approximately 0.5 second intervals and received at compatible ground stations that relay these messages to ATSU(s) for presentation on ATS situation displays. The following procedures relate to the use of ADS-B data in ATS ground surveillance applications.

The implementation of the ADS-B system will support the provision of high performance surveillance, enhancing flight safety, facilitating the reduction of separation minima and supporting user demands such as user-preferred trajectories.

9.2 ADS-B REGULATIONS

As agreed at APANPRIG 22/8, States intending to implement ADS-B based surveillance services may designate portions of airspace within their area of responsibility by:

- (a) mandating the carriage and use of ADS-B equipment; or
- (b) providing priority for access to such airspace for aircraft with operative ADS-B equipment over those aircraft not operating ADS-B equipment.

In publishing ADS-B mandate/regulations, States should consider to :

- define the ADS-B standards applicable to the State. For interoperability and harmonization, such regulations need to define both the standards applicable for the aircraft ADS-B position source and the ADS-B transmitter.
- define the airspace affected by the regulations and the category of aircraft that the regulation applies to.
- define the timing of the regulations allowing sufficient time for operators to equip. Experience in Asia Pacific Regions is that major international carriers are having high equipage rates of ADS-B avionics. However the equipage rates of ADS-B avionics for some regional fleets, business jets and general aviation are currently low and more time will be required to achieve high equipage rates.
- establish the technical and operational standards for the ground stations and air traffic management procedures used for ADS-B separation services, including the associated voice communications services.

States may refer to Appendix 3 on the template for ADS-B mandate/regulations for aircraft avionics. Some States listed below have published their ADS-B mandate/regulations on their web sites that could also be used for reference.

(a) Civil Aviation Safety Authority (CASA) of Australia
Civil Aviation Order 20.18 Compilation No. 4) 2014, Civil Aviation Order 82.1 (Compilation No. 13) ,
Civil Aviation Order 82.3 (No. 18), Civil Aviation Order 82.5 (No. 19)
<https://www.legislation.gov.au/Details/F2017C01115/Download>”

(b) Civil Aviation Department (CAD) of Hong Kong, China
Aeronautical Information Publication Supplement No. A01/16 dated 1 February 2016
“https://www.ais.gov.hk/HK_AIP/supp/A01-16.pdf”

(c) Civil Aviation Authority of Singapore (CAAS)

Aeronautical Information Publication (eAIP) Part 2 ENR 1.8 – Regional Supplementary Procedures – Section 7 – Automatic Dependent Surveillance Broadcast (ADS-B) Out exclusive airspace within parts of the Singapore FIR

“<https://fpl-1.caasaim.gov.sg/aip/2018-03-14/final/2018-03-14/html/index-en-GB.html>”

(d) Federal Aviation Administration (FAA)

ADS-B Out Performance Requirements To Support Air Traffic Control (ATC) Service, Final Rule

<http://www.gpo.gov/fdsys/pkg/FR-2010-05-28/pdf/2010-12645.pdf>

States are encouraged to mandate forward fit for newly manufactured aircraft on and after 1 January 2020, having a maximum certified takeoff weight of 5700kg or greater, or having a maximum cruising true airspeed capability of greater than 250 knots, with ADS-B avionics compliant to Version 2 ES (equivalent to RTCA DO-260B) or later version².

9.3 FACTORS TO BE CONSIDERED WHEN USING ADS-B

9.3.1 Use of ADS-B Level data

The accuracy and integrity of pressure altitude derived level information provided by ADS-B are equivalent to Mode C level data provided through an SSR sensor and subject to the same operational procedures as those used in an SSR environment. Where the ATM system converts ADS-B level data to display barometric equivalent level data, the displayed data should not be used to determine vertical separation until the data is verified by comparison with a pilot reported barometric level.

9.3.2 Position Reporting Performance

The ADS-B data from the aircraft will include a NUCp/NIC/SIL/NACp categorization of the integrity and accuracy of the horizontal position data. This figure is determined from NIC/ NACp/ SIL values for DO260A/B compliant avionics and NUC values for DO260/ED102 compliant avionics.

In general, for 5NM separation, if the HPL value used to generate ADS-B quality indicators (NUC or NIC) is greater than 2 nautical miles the data is unlikely to be of comparable quality to that provided by a single monopulse SSR. ADS-B data should not be used for separation unless a suitable means of determining data integrity is used.

The key minimum performance requirements for an ADS-B system to enable the use of a 3 NM or 5 NM separation minimum in the provision of air traffic control is provided in the ICAO Circular 326 (especially Appendix C).

ADS-B reports with low integrity may be presented on situation displays, provided the controller is alerted (e.g. by a change in symbology and/or visual alert) to the change and the implications for the provision of separation. An ANS Provider may elect not to display ADS-B tracks that fail to meet a given position reporting performance criterion.

9.3.3 GNSS Integrity Prediction Service

² Subject to endorsement by CNS/SG/22 in July 2018

ADS-B uses GNSS for position determination. As such, availability of GNSS data has a direct influence on the provision of a surveillance service.

ATS Providers may elect to use a GNSS integrity prediction service to assist in determining the future availability of useable ADS-B data. The integrity prediction service alerts users to potential future loss or degradation of the ADS-B service in defined areas. When these alerts are displayed, the system is indicating to its users that at some time in the future the ADS-B positional data may be inadequate to support the application of ADS-B separation. It is recommended that the prediction service is made available to each ATSU that is employing ADS-B to provide a separation service, to ensure that air traffic controllers are alerted in advance of any predicted degradation of the GNSS service and the associated reduction in their ability to provide ADS-B separation to flights that are within the affected area. This is similar to having advance warning of a planned radar outage for maintenance.

ADS-B should not be used to provide separation between aircraft that will be affected by an expected period of inadequate position reporting integrity.

If an unpredicted loss of integrity occurs (including a RAIM warning report from aircrew) then;

- (a) ADS-B separation should not be applied by ATC to the particular aircraft reporting until the integrity has been assured; and
- (b) The controller should check with other aircraft in the vicinity of the aircraft reporting the RAIM warning, to determine if they have also been affected and establish alternative forms of separation if necessary.

9.3.4 Sharing of ADS-B Data

ADS-B Data-sharing for ATC Operations

Member States should consider the benefits of sharing ADS-B data received from aircraft operating in the proximity of their international airspace boundaries with adjacent States that have compatible technology in an effort to maximize the service benefits and promote operational safety.

Data sharing may involve the use of the data to provide separation services if all the requirements for delivery of separation services are satisfied. In some cases, States may choose to use a lower standard that supports surveillance safety nets and situational awareness whilst operations are conducted using procedural separation standards.

Any agreement on the sharing of surveillance data should be incorporated in Letters of Agreement between the States concerned. Such agreements may also include the sharing of VHF communication facilities.

A template for ADS-B data-sharing agreement is provided on the ICAO APAC website “<http://www.icao.int/APAC/Pages/edocs.aspx>” for reference by States.

ADS-B Data-sharing for Safety Monitoring

With endorsement of the methodology by both the ICAO Separation and Airspace Safety Panel (SASP) and the Regional Airspace Safety Monitoring Advisory Group (RASMAG), ADS-B data can be used for calculating the altimetry system error (ASE) which is a measure of the height-keeping performance of an aircraft. It is an ICAO requirement that aircraft operating in RVSM airspace must undergo periodic monitoring on height-keeping performance. The existing methods to estimate aircraft ASE include use of a portable device, the Enhanced GPS

Monitoring Unit, and ground-based systems called Height Monitoring Unit/Aircraft Geometric Height Measurement Element. The use of ADS-B data for height-keeping performance monitoring, on top of providing enhanced and alternative means of surveillance, will provide a cost-effective option for aircraft operators. States are encouraged to share ADS-B data to support the height-keeping performance monitoring of airframe.

Civil/Military ADS-B Data-sharing

Civil/military data sharing arrangements, including aircraft surveillance, were a key part of civil/military cooperation in terms of tactical operational responses and increasing trust between civil and military units.

Aircraft operating ADS-B technology transmit their position, altitude and identity to all listeners, conveying information from co-operative aircraft that have chosen to equip and publicly broadcast ADS-B messages. Thus there should be no defence or national security issues with the use and sharing of such data.

Some military transponders may support ADS-B using encrypted DF19 messages, but these data are normally not decoded or used at all by civil systems. In most cases today, tactical military aircraft are not ADS-B equipped or could choose to disable transmissions. In future, increasing numbers of military aircraft will be ADS-B capable, with the ability to disable these transmissions. ADS-B data sharing should not influence the decision by military authorities to equip or not equip with ADS-B. Moreover, it is possible for States to install ADS-B filters that prevent data from sensitive flights being shared. These filters can be based on a number of criteria and typically use geographical parameters to only provide ADS-B data to an external party if aircraft are near the boundary.

A guidance material on advice to military authorities regarding ADS-B data sharing is provided on the ICAO APAC website “<http://www.icao.int/APAC/Pages/edocs.aspx>” for reference by States.

9.3.5 Synergy of ADS-B and GNSS

States intending to implement GNSS/PBN or ADS-B should consider the efficiency of implementing the other technology at the same time due to the inherent efficiencies in doing so. GNSS systems provide navigation solutions to IFR aircraft for the conduct of enroute, terminal and non-precision approaches. The use of GNSS/PBN can provide higher performance and higher safety. Transition to GNSS can avoid significant ground infrastructure costs.

ADS-B systems provide surveillance based upon GNSS position source. ADS-B provides high performance and high update surveillance for both air-air and ATC surveillance. Transition to ADS-B can avoid the costs associated with ground based radar infrastructure. ADS-B system installations rely on acceptable GNSS equipment being installed in the aircraft to provide the position source and integrity.

If the fleet is equipped with ADS-B, they will already have most of the requirements to use GNSS for navigation satisfied. Similarly, if aircraft have suitable GNSS on board, they will have a position source to support ADS-B. It is noted however, that some care is needed to ensure that the requirements of GNSS/PBN and surveillance are both satisfied.

There is significantly less cost for these systems to be installed in an aircraft at the same time. A single installation of GNSS & ADS-B will involve :

- a single design activity instead of two
- a single downtime instead of two

- installation of the connection between GPS and ADS-B transponder
- a single test, certification and aircraft flight test

For the affected aviation community (ANSP, regulator and operator), the lessons learnt and issues faced in both GNSS and ADS-B have significant commonality. This can lead to efficiencies in Industry education and training.

9.3.6 Use of ADS-B for Airport Surface Movement

Both DO321/ED-163 and the EUROCONTROL guidance for the provision of ATS using ADS-B for Airport Surface Movement state the horizontal position accuracy needs to be ≤ 10 meters at 95%, which translates into a positional accuracy of NACp = 10.

However, most of the currently deployed GNSS horizontal position sources provide values leading to either a NACp = 9 (30 meters) or a NACp = 8 (92 meters), whilst the actual position accuracy could reach 2 to 3 meters. Provided that the position source is GNSS-based, States can consider to use the following ADS-B quality indicators to determine the horizontal positional accuracy:

- DO260
 - NUCp > 6
- DO260A
 - NACp ≥ 8
 - NIC > 0
 - SIL = 2
- DO260B
 - NACp ≥ 8
 - NIC > 0
 - SIL = 3

Guidance documents recommend implementing some form of horizontal positional accuracy monitoring for using ADS-B positional data with accuracy down to NUCp > 6 or NACp ≥ 8 for airport surface movement. Visual monitoring by controllers of vehicles on taxiways and runways can be considered as an initial monitoring of the horizontal positional accuracy within the airport. In addition, States can consider to evaluate the performance of ADS-B tracks against reference tracks from proven surveillance systems, e.g. tracks from MLAT systems with certified accuracy, to show that ADS-B data is suitable for ground surveillance and falls within the requirements of international standards.

For ADS-B only tracks with quality indicators below the required accuracy, States are encouraged to keep the display of the tracks in the surveillance display with due discrimination on the track symbols in order to enhance the situation awareness of controllers.

9.3.7 1090 Mhz Spectrum and 24-bit Aircraft Address Issue with Unmanned Aircraft Systems (UAS)

Proper and efficient utilization of available bandwidth and capacity at 1 090 MHz is a key element to ensure the safe and reliable operation of aeronautical surveillance systems, including secondary surveillance radar (SSR), automatic dependent surveillance broadcast (ADS-B) and airborne collision avoidance systems (ACAS). Studies conducted by ICAO expert groups have identified certain issues and potential technical concerns to the operation of these surveillance systems in the presence of large numbers of unmanned aircraft (UA), if those UA are equipped with an ADS-B OUT transmitter on 1 090 MHz and operating at very low levels.

Recognizing issues associated with those UA which may adversely affect safety for all aircraft in the area, ICAO has developed guidance material (see Appendix 8) to assist States in validating the utilization of 1 090 MHz and for withholding 24-bit aircraft addresses to UA unless certain criteria have been met. States are encouraged to make use of the guidance material as well as any other related provisions to ensure that the surveillance capabilities being provided by the aforementioned surveillance systems.

9.3.8 Methodologies to Avoid or Reduce 1090MHz Congestion

- Make periodic measurements, say every few years so that the environment status is known.
- Reduce the number of SSR radars, especially non Monopulse and Mode A/C radars if operationally viable.
 - Convert Mode A/C to either ADS-B or Mode S
 - Some Secondary surveillance radars can be replaced by using ADS-B. e.g.: Australia removed 2 radars in the last decade in favor of ADS-B.
 - Complement existing coverage with Space based ADS-B
- Use Monopulse radars instead of old conventional radars so that the interrogation rate can be reduced
- Minimise the interrogation rate from radars and active multilateration consistent with the operational objective
- Decommission old Mode A/C radars because they allow multiple aircraft to reply to all interrogations
- Implement radar interrogation patterns to only interrogate on azimuths where additional surveillance is warranted.
- Minimise “all call” rate commensurate with operational needs
- Reduce interrogation transmit power to the minimum needed for the operational objective. Some systems allow this to be changed on different azimuths
- Avoid or reduce active multilateration if possible, and minimize transmit power commensurate with the operational objective
 - Mandate ADS-B fitment in aircraft: Multilateration position can be determined using the DF17 ADS-B message if required, so no interrogation is required
 - Gradually mandate Mode S in aircraft so that the need to interrogate Mode A/C transponders is removed eventually. Multilateration position can be determined using the DF11 message if required. A mode S interrogation still required for altitude and identity to be obtained. Mode S interrogation only triggers a single aircraft to reply.
 - Aircraft with mode A/C transponders (without Mode S require or ADS-B) require multiple interrogations with typically an omni directional antenna which makes all such aircraft to reply.
- Replace or reduce any nav aids (e.g. DME/TACAN, ICAO standard or non ICAO standard) that impinge on the 1090 MHz channel.
- Close any illegal transmissions affecting the 1090MHz band
- Take care with DAPS interrogation to ensure only wanted data is requested

9.4 Reporting Rates

9.4.1 General

The ADS-B system shall maintain a reporting rate that ensures at least an equivalent degree of accuracy, integrity and availability as specified by the performance requirements of a radar system that is used to provide a similar ATC service. The standard reporting rate is approximately 0.5 second from the aircraft, but the rate of update provided to the ATM system (for the situation display) may be less frequent (e.g. 5 seconds), provided performance requirements for the service are achieved. Reporting rate requirements are included in the document “Baseline ADS-B Service Performance Parameters” which is available at Appendix 6.

9.5 SEPARATION

9.5.1 General

ADS-B data may be used in combination with data obtained by other means of surveillance (such as radar, flight plan track, ADS-C) for the application of separation provided appropriate minima as determined by the State are applied. It should be noted that the quality of communications will have a bearing on the determination of appropriate minima.

All safety net features (MSAW, STCA, MTCA, RAM and DAIW/ RAI etc) should possess the same responsiveness as equivalent radar safety net features.

9.5.2 Identification Methods

Some of the methods approved by ICAO for establishing identification with radar, may be employed with ADS-B (see PANS-ATM chapter 8). One or more of the following identification procedures are suggested:

- a) direct recognition of the aircraft identification in an ADS-B label on a situation display;
- b) transfer of ADS-B identification;
- c) observation of compliance with an instruction to TRANSMIT ADS-B IDENT.

Note: In automated systems, the “IDENT” feature may be presented in different ways, e.g. as a flashing of all or part of the position indication and associated label.

9.5.3 ADS-B Separation

ADS-B Separation minima has been incorporated by ICAO in PANS-ATM (Doc 4444), and in Regional Supplementary Procedures (Doc 7030).

In a mixed surveillance environment, States should use the larger separation standard applicable between aircraft in the conflict pair being considered.

9.5.4 Vertical separation

9.5.4.1 Introduction

The ADS-B level data presented on the controllers situation display shall normally be derived from barometric pressure altitude. In the event that barometric altitude is

absent, geometric altitude shall not be displayed on displays used for provision of air traffic services. Geometric altitude may be used in ATM systems for other purposes.

9.5.4.2 Vertical tolerance standard

The vertical tolerances for ADS-B level information should be consistent with those applied to Mode C level information.

9.5.4.3 Verification of ADS-B level information

The verification procedures for ADS-B level information shall be the same as those employed for the verification of Mode C level data in a radar environment.

9.6 AIR TRAFFIC CONTROL CLEARANCE MONITORING

9.6.1 General

ADS-B track data can be used to monitor flight path conformance with air traffic control clearances.

9.6.2 Deviations from ATC clearances

The ATC requirements relating to monitoring of ADS-B traffic on the situation display should be similar to those contained in PANS-ATM Ch.8.

9.7 ALERTING SERVICE

For ADS-B equipped aircraft, the provision of an alerting service should be based on the same criteria as applied within a radar environment.

9.8 POSITION REPORTING

9.8.1 Pilot position reporting requirements in ADS-B coverage

States should establish voice and/or CPDLC position reporting procedures consistent with those applicable with radar for aircraft that have been identified by ATC.

9.8.2 Meteorological reporting requirements in ADS-B airspace

ATSUs may promulgate in the AIP meteorological reporting requirements that apply within the nominated FIR. The meteorological reporting data required and the transmission methods to be used by aircrew shall be specified in AIP.

9.9 PHRASEOLOGY

9.9.1 Phraseology Standard

States should use common phraseology for both ADS-B and radar where possible, and should note the requirement for ADS-B specific phraseology in some instances. States shall refer to PANS ATM Chapter 12 for ADS-B phraseology:

ADS-B EQUIPMENT DEGRADATION

ADS-B OUT OF SERVICE (appropriate information as necessary).

TO REQUEST THE CAPABILITY OF THE ADS-B EQUIPMENT

- a) ADVISE ADS-B CAPABILITY;
 - *b) ADS-B TRANSMITTER (data link);
 - *c) ADS-B RECEIVER (data link);
 - *d) NEGATIVE ADS-B.
- * Denotes pilot transmission.

Note: For (b) and (c) – the options are not available for aircraft that are not equipped.

TO REQUEST RESELECTION OF AIRCRAFT IDENTIFICATION
REENTER FLIGHT IDENTIFICATION.

Note: For some aircraft, this option is not available in-flight

TERMINATION OF RADAR AND/OR ADS-B SERVICE
IDENTIFICATION LOST [reasons] (instructions).

TO REQUEST THE OPERATION OF THE MODE S OR ADS-B IDENT FEATURE
SQUAWK IDENT.

Note: For some standalone ADS-B equipage affecting General Aviation, the option of
“TRANSMIT ADS-B IDENT” may be available

TO REQUEST AIRCRAFT SWITCHING TO OTHER TRANSPONDER OR TERMINATION
OF ADS-B TRANSMITTER OPERATION

- a) SWITCH TO OTHER TRANSPONDER
- b) STOP ADS-B TRANSMISSION. SQUAWK (code) ONLY.

Note:

a) In many cases the ADS-B transmitter cannot be operated independently of the SSR transponder and switching off the ADS-B transmission would also switch off the SSR transponder operation

b) “STOP ADS-B TRANSMISSION” applies only to aircraft that have the facility to switch off the ADS-B transmission, while maintaining SSR operation.

9.9.2 Operations of Mode S Transponder and ADS-B

It should be noted that independent operations of Mode S transponder and ADS-B will not be possible in many aircraft (e.g. where ADS-B is solely provided by 1090 MHz extended squitter emitted from the transponder). Additionally, some desirable but optional features of ADS-B transmitters may not be fitted in some aircraft. Controller training on this issue, as it relates to the following examples of radio telephony and/or CPDLC phraseology is recommended.

9.9.2.1 STOP ADSB TRANSMISSION or STOP SQUAWK

Issue: In most commercial aircraft, a common “transponder control head” is used for SSR transponder, ACAS and ADS-B functionality. In this case, a pilot who complies with the instruction to stop operation of one system will also need to stop operation of the other systems – resulting in a loss of surveillance not intended or expected by the controller.

ATC need to be aware that an instruction to “Stop ADS-B Transmission” may require the pilot to switch off their transponder that will then stop all other functions associated with the transponder operations (such as ACARs etc). Pilots need to be aware of their aircraft’s equipment limitations, the consequences of complying with this ATC instruction, and be aware of their company policy in regard to this. As with any ATC instruction issued, the pilot should advise ATC if they are unable to comply.

Recommendation: It is recommended that the concatenated phrases STOP ADSB TRANSMISSION, SQUAWK (code) ONLY or STOP SQUAWK, TRANSMIT ADSB ONLY are used. It is recommended that controller training highlights the possible consequences of **issuing** these instructions and that pilot training highlights the consequences of **complying** with this instruction. It is also recommended that aircraft operators have a clearly stated policy on procedures for this situation. Should a pilot respond with UNABLE then the controller should consider alternative solutions to the problem that do not remove the safety defences of the other surveillance technologies. This might include manual changes to flight data, coordination with other controllers and/or change of assigned codes or callsigns.

Very few aircraft provide the capability to turn off ADS-B without turning off TCAS. It is not recommended to switch off ATC transponders (& remove TCAS protection). The only action for most

pilots of aircraft transmitting misleading ADS-B data in response to ATC requests is to recycle the transponder, or switch to the alternate transponder as appropriate. Besides, aircraft that do not support ADS-B OFF should have the details included in the flight manual including the undesirability of disabling TCAS.

9.9.2.2 STOP ADSB ALTITUDE TRANSMISSION [WRONG INDICATION or reason] and TRANSMIT ADSB ALTITUDE

Issue: Most aircraft will not have separate control of ADSB altitude transmission. In such cases compliance with the instruction may require the pilot to stop transmission of all ADSB data and/or Mode C altitude – resulting in a loss of surveillance not intended or expected by the controller.

Recommendation: It is recommended that, should the pilot respond with UNABLE, the controller should consider alternative solutions to the problem that do not remove the safety defences of other surveillance data. This might include a procedure that continues the display of incorrect level information but uses pilot reported levels with manual changes to flight data and coordination with other controllers.

9.9.2.3 TRANSMIT ADS-B IDENT

Issue: Some aircraft may not be capable or the ADSB SPI IDENT control may be shared with the SSR SPI IDENT function.

Recommendation: It is recommended that controllers are made aware that some pilots are unable to comply with this instruction. An alternative means of identification that does not rely on the ADSB SPI IDENT function should be used.

9.10 FLIGHT PLANNING

9.10.1 ADS-B Flight Planning Requirement – Flight Identity

The aircraft identification (ACID) must be accurately recorded in section 7 of the ICAO Flight Plan form as per the following instructions:

Aircraft Identification, not exceeding 7 characters is to be entered both in item 7 of the flight plan and replicated exactly when set in the aircraft (for transmission as Flight ID) as follows:

Either,

- a) The ICAO three-letter designator for the aircraft operating agency followed by the flight identification (e.g. KLM511, BAW213, JTR25), when:

in radiotelephony the callsign used consists of the ICAO telephony designator for the operating agency followed by the flight identification (e.g. KLM 511, SPEEDBIRD 213, HERBIE 25).

Or,

- b) The registration marking of the aircraft (e.g. EIAKO, 4XBCD, OOTEK), when:

- 1) in radiotelephony the callsign used consists of the registration marking alone (e.g. EIAKO), or preceded by the ICAO telephony designator for the operating agency (e.g. SVENAIR EIAKO),

- 2) the aircraft is not equipped with radio.

Note 1: No zeros, hyphens, dashes or spaces are to be added when the Aircraft Identification consists of less than 7 characters.

Note 2: Appendix 2 to PANS-ATM refers. ICAO designators and telephony designators for aircraft operating agencies are contained in ICAO Doc 8585.

9.10.2 ADS-B Flight Planning Requirements

9.10.2.1 ICAO Flight Plan Item 10 – Surveillance Equipment and Capabilities

An appropriate ADS-B designator shall be entered in item 10 of the flight plan to indicate that the flight is capable of transmitting ADS-B messages.

These are defined in ICAO DOC 4444 as follows:

- B1 ADS-B with dedicated 1090 MHz ADS-B “out” capability
- B2 ADS-B with dedicated 1090 MHz ADS-B “out” and “in” capability
- U1 ADS-B “out” capability using UAT
- U2 ADS-B “out” and “in” capability using UAT
- V1 ADS-B “out” capability using VDL Mode 4
- V2 ADS-B “out” and “in” capability using VDL Mode 4

During the ADS-B SITF/13 meeting held in April 2014, clarification of the B1 and B2 descriptors was recommended as follows. This will be progressed for change to ICAO DOC 4444, but may take some time for formal adoption:

- B1 ADS-B “out” capability using 1090 MHz extended squitter
- B2 ADS-B “out” and “in” capability using 1090 MHz extended squitter

States should consider use of the revised descriptors in AIP.

9.10.2.2 ICAO Flight Plan Item 18 – Other Information

Where required by the appropriate authority the ICAO Aircraft Address (24 Bit Code) may be recorded in Item 18 of the ICAO flight plan, in hexadecimal format as per the following example:

CODE/7C432B

States should note that use of hexadecimal code may be prone to human error and is less flexible in regard to airframe changes for a notified flight.

9.10.2.3 Transponder Capabilities

When an aircraft is equipped with a mode S transponder, that transmits ADS-B messages, according to ICAO Doc 4444, an appropriate Mode S designator should also be entered in item 10; i.e.: either

- E Transponder — Mode S, including aircraft identification, pressure-altitude and extended squitter (ADS-B) capability, or
- L Transponder — Mode S, including aircraft identification, pressure-altitude, extended squitter (ADS-B) and enhanced surveillance capability.

During the ADS-B SITF/13 meeting held in April 2014, clarification of the E and L descriptors was recommended as follows. This will be progressed for change to ICAO DOC 4444, but may take some time for formal adoption:

- E Transponder — Mode S, including aircraft identification, pressure-altitude and ADS-B capability, or
- L Transponder — Mode S, including aircraft identification, pressure-altitude, ADS-B and enhanced surveillance capability.

States should consider use of the revised descriptors in AIP.

9.10.2.4 Inconsistency between ADS-B Flight Planning and Surveillance Capability

Inconsistency between flight planning of ADS-B and surveillance capability of an aircraft can impact on ATC planning and situational awareness. States are encouraged to monitor for consistency between flight plan indicators and actual surveillance capability. Where discrepancies are identified, aircraft operators should be contacted and instructed to correct flight plans, or general advice (as appropriate to the operational environment and type of flight planning problems) should be issued to aircraft operators. An example of such advice is provided at Appendix 4.

9.10.3 Setting Aircraft Identification (Flight ID) in Cockpits

(a) Flight ID Principles

The aircraft identification (sometimes called the flight identification or FLTID) is the equivalent of the aircraft callsign and is used in both ADS-B and Mode S SSR technology. Up to seven characters long, it is usually set in airline aircraft by the flight crew via a cockpit interface. It enables air traffic controllers to identify and aircraft on a display and to correlate a radar or ADS-B track with the flight plan data. Aircraft identification is critical, so it must be entered carefully. Punching in the wrong characters can lead to ATC confusing one aircraft with another.

It is important that the identification exactly matches the aircraft identification (ACID) entered in the flight notification.

Intuitive correlation between an aircraft's identification and radio callsign enhances situational awareness and communication. Airline aircraft typically use a three letter ICAO airline code used in flight plans, NOT the two letter IATA codes.

(b) Setting Flight ID

The callsign dictates the applicable option below for setting ADS-B or Mode S Flight ID:

- (i) the flight number using the ICAO three-letter designator for the aircraft operator if a flight number callsign is being used (e.g. QFA1 for Qantas 1, THA54 for Thai 54).
- (ii) the nationality and registration mark (without hyphen) of the aircraft if the callsign is the full version of the registration (e.g. VHABC for international operations).
- (iii) The registration mark alone of the aircraft if the callsign is the abbreviated version of the registration (eg ABC for domestic operations).
- (iv) The designator corresponding to a particular callsign approved by the ANSP or regulator (e.g. SPTR13 for firepotter 3).
- (v) The designator corresponding to a particular callsign in accordance with the operations

manual of the relevant recreational aircraft administrative organization (e.g. G123 for Gyroplane 123).

9.11 PROCEDURES TO HANDLE NON-COMPLANT ADS-B AIRCRAFT OR MIS-LEADING ADS-B TRANSMISSIONS

ADS-B technology is increasingly being adopted by States in the Asia/Pacific Region. Asia/Pacific Region adopted 1090 extended squitter technology. Reliance on ADS-B transmissions can be expected to increase over the coming years.

Currently a number of aircraft are transmitting ADS-B data which is misleading or non-compliant with the ICAO standards specified in Annex 10. Examples include:

- a) aircraft broadcasting incorrect message formats;
- b) aircraft broadcasting inertial positional data and occasionally indicating in the messages that the data has high integrity when it does not;
- c) using GPS sources that do not generate correct integrity data, whilst indicating in the messages that the data has high integrity;
- d) transmitting ADS-B data with changing (and incorrect) flight identity; and
- e) transmitting ADS-B data with incorrect flight identity continuously.

If the benefits of ADS-B are to flow to the aviation industry, misleading and non-compliant ADS-B transmissions need to be curtailed to the extent possible.

The transmission of a value of zero for the NUCp or the NIC or the NACp or the SIL by an aircraft indicates a navigational uncertainty related to the position of the aircraft or a navigation integrity issue that is too significant to be used by air traffic controllers.

As such, the following procedure currently stipulated in the Regional Supplementary Procedures Doc 7030³, shall be applicable in the concerned FIRs on commencement of ADS-B based surveillance services notified by AIP or NOTAM:

If an aircraft operates within an FIR where ADS-B-based ATS surveillance service is provided, and

- a) carries 1090 extended squitter ADS-B transmitting equipment which does not comply with one of the following:
 - 1) EASA AMC 20-24; or
 - 2) the equipment configuration standards in Appendix XI of Civil Aviation Order 20.18 of the Civil Aviation Safety Authority of Australia; or
 - 3) installation in accordance with the FAA AC No. 20-165 – Airworthiness Approval of ADS-B; or
- b) the aircraft ADS-B transmitting equipment becomes unserviceable resulting in the aircraft transmitting misleading information;

then:

³ SURICG/2 recommended States/Administrations to update their ADS-B Avionics Equipage Requirements to align with the template in Appendix 3

a) except when specifically authorized by the appropriate ATS authority, the aircraft shall not fly unless the equipment is:

- 1) deactivated; or
- 2) transmits only a value of zero for the NUCp or NIC or NACp or SIL

States may elect to implement a scheme to blacklist those non-compliant aircraft or aircraft consistently transmitting mis-leading ADS-B information, so as to refrain the aircraft from being displayed to ATC. Please refer Appendix 2 for guidance in implementing the blacklist scheme.

A sample template is given below for reference by States to publish the procedures to handle non-compliant ADS-B aircraft or misleading ADS-B transmissions in their ADS-B mandate/regulations:

After <insert earliest date that ADS-B may be used for any relevant operational purpose> if an aircraft carries ADS-B transmitting equipment which does not comply with :

- (a) European Aviation Safety Agency - Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHZ Extended Squitter (AMC 20-24), or
- (b) European Aviation Safety Agency - Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance Subpart D — Surveillance (SUR) (CS-ACNS.D.ADS-B), or
- (c) Federal Aviation Administration – Advisory Circular No: 20-165A (or later versions) Airworthiness Approval of Automatic Dependent Surveillance – Broadcast (ADS-B) Out Systems, or
- (d) the equipment configuration standards in Appendix XI of Civil Aviation Order 20.18 of the Civil Aviation Safety Authority of Australia.

or the aircraft ADS-B transmitting equipment becomes unserviceable resulting in the aircraft transmitting misleading information;

the aircraft must not fly unless equipment is:

- (a) deactivated; or
- (b) set to transmit only a value of zero for the NUCp or NIC or NACp or SIL.

Note:

1. It is considered equivalent to deactivation if NUCp or NIC or NACp or SIL is set to continually transmit only a value of zero.
2. Regulators should take appropriate action to ensure that such regulations are complied with.
3. ATC systems should discard ADS-B data when NUC or NIC or NACp or SIL =0.

9.12 EMERGENCY PROCEDURES

ATC surveillance systems should provide for the display of safety-related alerts and warnings, including conflict alert, minimum safe altitude warning, conflict prediction and unintentionally duplicated SSR codes and aircraft identifications.

The ADS-B avionics may transmit emergency status messages to any ADS-B ground station within coverage. The controller receiving these messages should determine the nature of the emergency, acknowledge receipt if appropriate, and initiate any assistance required. An aircraft equipped with ADS-B might operate the emergency and/or urgency mode as follows:

- a) emergency;
- b) no communications;
- c) unlawful interference;
- d) minimum fuel; and/or
- e) medical.

Selection of an emergency transponder code (e.g. 7600) automatically generates an emergency indication in the ADS-B message. However, some ADS-B transponders may only generate a generic emergency indication. That means, the specific type of emergency, e.g., communication failure, is not always conveyed to the controller in an ADS-B environment. The controller may only receive a generic emergency indication irrespective of the emergency codes being selected by the pilot.

In some early ADS-B avionics configurations, when a generic emergency indication is being transmitted, a request to “Transmit ADS-B Ident” or “Squawk Ident” may not result in the Ident indication being displayed in the ATC System. This is because the emergency and ident flags share the same data elements in the ADS-B downlink message.

Due to limitations of some ADS-B transponders, procedures should be developed for ATC to confirm the types of emergency with pilots based on operational needs of States.

In contrast to DO260 avionics, for DO-260A avionics, the transmission of an Emergency/Priority status message in the ADS-B message set will also include the original MODE A code allocated by ATC. When the aircraft resets the MODE A code to the original allocated code the ground station can retain the Emergency/Priority status in the Asterix message, for up to 100 seconds, even though the aircraft is no longer squawking an emergency code. This situation can generate confusion as to the actual status of the aircraft.

Executive control responsibility

The responsibility for control of the flight rests with the ATSU within whose airspace the aircraft is operating. However, if the pilot takes action contrary to a clearance that has already been coordinated with another sector or ATSU and further coordination is not possible in the time available, the responsibility for this action would rest with the pilot in command, and performed under the pilot’s emergency authority.

Emergency procedures

The various circumstances surrounding each emergency situation preclude the establishment of exact detailed procedures to be followed. The procedures outlined in PANS-ATM Chapter 15 provide a general guide to air traffic services personnel and where necessary, should be adapted for the use of ADS-B.

9.13 PROCEDURES TO HANDLE GPS TIME AND WEEK COUNTER ROLLOVER

The GPS system is often used in the ATC environment, including:

- to time stamp surveillance data with the “time of applicability” of the data. This allows positional data to be “extrapolated” to the time of display and allows old data to be discarded.
- to time synchronise ATC systems to the correct time, so that when it uses surveillance data, it can determine the “age” of the data.
- to time stamp recorded data and maintenance data

Thus accurate time is important to minimise incorrect positional data being presented to ATC and to ensure that valid data is not discarded – amongst other important technical roles in synchronising various computer servers in a network.

9.13.1 GPS TIME – COUNTERS AND LEAP SECONDS

The GPS navigation message contains information about the current date and time in the form of a sequential week counter (representing the number of weeks elapsed since the last time this counter was reset to zero). This counter is 10 bits long and this resets to zero every 1024 weeks (19.6 years). GPS week zero started at 00:00:00 UTC on January 6, 1980, and the week number became zero again on August 21, 1999. A rollover event occurred on 6 April 2019.

ATC systems use UTC. The difference between GPS time and UTC changes whenever a “leap second” is inserted in UTC. Wikipedia says that “one-second adjustment that is occasionally applied to civil time Coordinated Universal Time (UTC) to keep it close to the mean solar time at Greenwich, in spite of the Earth's rotation slowdown and irregularities”. This is done in coordination with the international community.

The GPS messages sent by the satellites includes the difference between GPS time and UTC, thus allowing the GPS receivers to calculate UTC.

9.13.2 GPS RECEIVER ISSUES

Each GPS receiver has firmware/software that computes UTC from the GPS time counters and from the known offset. In the past some GPS receivers have not coped well with these changes. The triggers occur very infrequently and in some cases they have not been adequately tested.

This can cause incorrect UTC time to be output following some events such as:

- Software deficiencies highlighted by the week number rollover. The rollover occurs each 19.6 years
- Deficiencies at leap second introductions (at intervals greater than 1 year)
- Loss of GPS-UTC time offset (sometimes at power off in devices not using non-volatile storage). Typically this can result in up to 15 minutes of incorrect time data until the offset is restored from the satellite messages.

Other problems such as receiver lock up (service failure) can occur when the GPS receiver is exposed to rare real world events or stimuli.

9.13.3 ATC SYSTEM RISKS AND MITIGATION

ANSPs and regulators need to be aware of the potential issues that may arise from GPS receivers that inadequately process events and stimuli.

Possible mitigations that could be considered include:

- Testing GPS receivers with a GPS test tool that simulates possible events/ stimuli
- Co-ordination with GPS receiver manufacturers
- Disconnect GPS receivers just before expected events – and check the output before reconnecting the GPS receiver. (in this case the ANSP would be relying on the ability of the ATC or surveillance system to operate for a period without the GPS synchronisation).

10. SECURITY ISSUES ASSOCIATED WITH ADS-B

10.1 INTRODUCTION

ADS-B technologies are currently “open systems” and the openness is an essential component of successful use of ADS-B. It was also noted that ADS-B transmission from commercial aircraft is a “fact of life” today. Many commercial aircraft are already equipped with ADS-B and have been transmitting data for some time.

It was noted that there has been considerable alarmist publicity regarding ADS-B security. To a large extent, this publicity has not considered the nature and complexity of ATC. Careful assessment of security policies in use today for ADS-B and other technologies can provide a more balanced view.

10.2 CONSIDERATIONS

A list of ADS-B vulnerabilities categorised into threats to Confidentiality, Integrity and Availability has been reviewed and documented into the guidance material on security issues associated with ADS-B provided on the ICAO APAC website “<http://www.icao.int/APAC/Pages/edocs.aspx>” under “Restricted Site” for reference by States. States could contact ICAO Regional Office to get access to the guidance material. The following recommendations are made to States :

- (a) While ADS-B is recognized as a key enabling technology for aviation with potential safety benefits, it is recommended that States made aware of possible ADS-B security specific issues;
- (b) It is recommended that States note that much of the discussion of ADS-B issues in the Press has not considered the complete picture regarding the ATC use of surveillance data;
- (c) For current ADS-B technology implementation, security risk assessment studies should be made in coordination with appropriate national organisations and ANSPs to address appropriate mitigation applicable in each operational environment, in accordance with ATM interoperability requirements; and
- (d) Future development of ADS-B technology, as planned in the SESAR master plan for example, should address security issues. Studies should be made to identify potential encryption and authentication techniques, taking into consideration the operational need of air to ground and air to air surveillance applications. Distribution of encryption keys to a large number of ADS-B receivers is likely to be problematic and solutions in the near and medium term are not considered likely to be deployed worldwide. Internet based encryption strategies are not deployable when ground stations are pass receivers.

10.3 MEASURES FOR ENHANCING THE SECURITY OF ADS-B

10.3.1 TIME DIFFERENCE OF ARRIVAL (TDOA) BASED POSITION VERIFICATION METHOD

One of the technologies for enhancing ADS-B security is TDOA-based position verification, which is able to mitigate false targets caused by spoofing. In a case of spoofing, the position of the emitter (attacker) is likely to differ from the position contained in the ADS-B signal. Such positional difference can be detected by means of TDOA.

When an emitter (aircraft or spoofing emitter) transmits an ADS-B signal, (at least) two receivers detect the signal and measure the time of arrival (TOA). The difference of the TOAs between the two receivers is a TDOA. Next, decoding the ADS-B signal obtains the position

contained in the signal. A calculation using the ADS-B position and the known receiver positions obtains the expected TDOA.

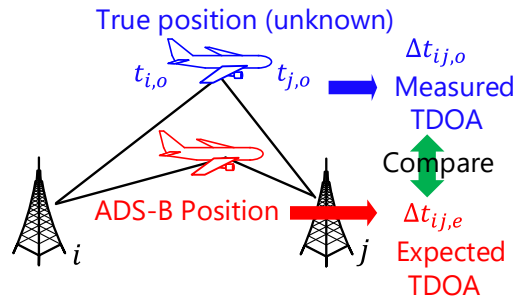


Figure 10.3.1.1 Illustration of the Procedures of TDOA method

The measured and expected TDOAs are compared. The TDOA difference is large in a case of spoofing and small in a case of a legitimate aircraft, as illustrated in Figure 10.3.1.2 (a) and (b), respectively. Therefore, a threshold can be used to make a decision; if the TDOA difference is smaller than the threshold, the position is determined as valid. If the TDOA difference is larger than the threshold, the position is determined as anomalous (spoofing).

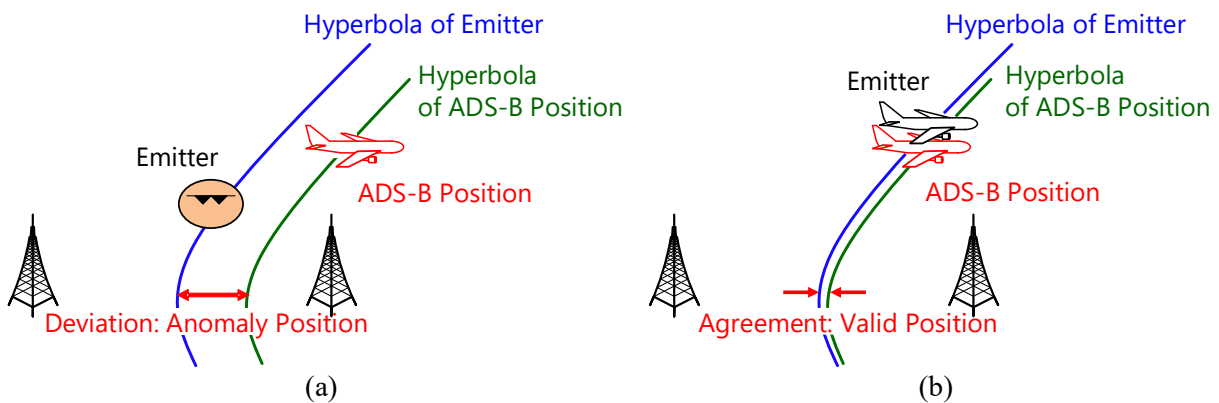


Figure 10.3.1.2 Illustration of (a) case of spoofing, and (b) case of legitimate aircraft

10.3.2 APPROPRIATE IMPLEMENTATION OF A DECODING METHOD OF CPR

CPR (Compact Position Reporting) is the format used to encode a latitude and longitude in the ADS-B position report using 1090 Extended Squitter (DF = 17, BDS = 0,5 and 0,6). There are two ways of decoding the encoded CPR:

- a) globally unambiguous decoding, which requires two signals called “even” and “odd”.
- b) locally unambiguous decoding, which requires either even or odd signal plus a reference position.

Appropriate implementation of a decoding method is important also for security aspect. In the technical standards, there are techniques available for supporting correct decoding, for example, range test and reasonableness test for CPR decoding in RTCA DO-260B. Although they are not originally intended for security purpose, reduction of false position information is expected.

The CPR reasonableness test is a technique to verify the decoded position. The basic mechanism of the reasonable test for locally unambiguous decoding is detecting a position jump from previous decoding. The criteria is available in DO-260B. The basic mechanism of the reasonable test for globally unambiguous decoding is decoding an additional pair of signal and use it for verifying the previous decoding.

The CPR reasonableness test is included in the ADS-B message decoding logic in DO-260B together with a range test, which checks whether the output of globally unambiguous decoding is within the receiver’s operational coverage. The range test and CPR reasonableness test are included also in EUROCAE ED-129B (Technical Specification for a 1090 MHz Extended Squitter ADS-B Ground System).

Commissioning Readiness		
The requirement for this form is specified in the System Management Manual (Section 11.2 of V4), C-MAN0107		
Project/Task Name	SAP Project/Task ID:	Sites or Locations affected:
Documentation prepared by:	Date:	Commissioning Date:
Affected System(s)	System Criticality	Change Consequence Level
Brief Description of Change:		

Commissioning Readiness Endorsement		
The endorsement of this form by the appropriate authorities as specified in the System Management Manual certifies that the requirements detailed in this form (with the exception of the non-critical deficiencies ¹ listed herein) have been completed prior to the commissioning of the system change or new system.		
Chief Engineer or Technical or Maintenance Authority		
Name:	Signature:	Date:
Designation:		
Name:	Signature:	Date:
Designation:		
Chief Operating/User Authority or Operating/User Authority		
Name:	Signature:	Date:
Designation:		

Records Management Instructions
Place the completed Commissioning Readiness Form, together with any support documents on the Project file
Provide a copy of the completed Commissioning Readiness Form to P&E, Asset Lifecycle Manager, Planning and Integration

Note 1: Non-critical deficiencies (NCD) are those outstanding technical and operational issues that do not prevent the safe and effective use or maintenance of the facility, but will be addressed in a specified and agreed time. NCDs shall be listed on the Commissioning Certificate (C-FORMS0300) and recorded in the relevant system (ASID / HEAT / SAIR). It is preferable for each NCD to be recorded as a separate Issue.

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Item No:	Requirement:	Requirement Reference: (Procedure/Instruction used to specified required input)	Completed or N/A	Evidence of Compliance (If a requirement is N/A, a reason why it is N/A is required to be entered)
1	OPERATIONAL SAFETY			
1.1	Provide a link to the completed SCARD SCARD Template (AA-TEMP-SAF-0042) Note: For unregulated systems the SCARD shall be used to assess the impact of the change and perform a preliminary hazard analysis	Safety Change Management Requirements AA-NOS-SAF-0104	Completed ☐ N/A ☐	Link to SCARD
1.2	The outcome of the SCARD will be the requirement for one of the following for commissioning: Safety Statement – included in SCARD or standalone Safety Statement which must provide Airservices Australia management with sufficient information to demonstrate that safety has been considered and the change presents minimal or no safety issues. Safety Plan & Safety Assessment Report, or Safety Plan & Safety Case Safety Plans, Safety Assessment Reports and Safety Cases are required to be available in the Document Search Database	Safety Change Management Requirements AA-NOS-SAF-0104 Document Search Database	Completed ☐ N/A ☐	Link to Safety statement or Link to Safety Plan & Safety Assessment Report or Link to Safety Plan & Safety Case
1.3	Safety risk management process completed and includes - any new hazards / impact to existing hazards identified? - controls identified and in place? and - residual risk justified and accepted.	Safety Risk Management Procedures AA-PROC-SAF-0105	Completed ☐ N/A ☐	
1.4	Impacts on the Operational Risk Assessments from residual risks have been assessed and implemented using Operational Risk Assessment Change Request and Acceptance Record – AA-FORM-SAF-0032	Operational Risk Assessment AA-NOS-SAF-0006 Safety Risk Management Procedures AA-PROC-SAF-0105	Completed ☐ N/A ☐	Link to Operational Risk Assessment Change Request and Acceptance Record:
1.5	Arrangements for monitoring and review of risks are in place including arrangements for safety performance monitoring following the transition.	Safety Risk Management Procedures AA-PROC-SAF-0105	Completed ☐ N/A ☐	
1.6	CASA have approved / accepted or been advised of the change, as applicable	Safety Change Management Requirements AA-NOS-SAF-0104	Completed ☐ N/A ☐	

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Item No:	Requirement:	Requirement Reference: (Procedure/Instruction used to specified required input)	Completed or N/A	Evidence of Compliance (If a requirement is N/A, a reason why it is N/A is required to be entered)
2 WORKPLACE HEALTH & SAFETY				
2.1	Initial WHS Hazard Identification must be completed as per the template AA-TEMP-SAF-0020	Safety Risk Management Procedures AA-PROC-SAF-0105 Initial WHS Hazard Identification AA-TEMP-SAF-0020 Workplace Health and Safety Risk Management Summary AA-TEMP-SAF-0016	Completed ☐ N/A ☐	Link to completed Workplace Health and Safety Management Summary AA-TEMP-SAF-0016
2.2	Ensure employees and stakeholders are consulted when significant changes to work arrangements are being considered.	Working Together Workplace Consultation AA-PROC-SAF-0009	Completed ☐ N/A ☐	
2.3	Tower Access / Classification assessed? Working at Heights Safety Checklist & Daily Toolbox Meeting (F098) Fall arrest facility / equipment available	Working at Heights PROC-157 Working at Heights Safety Checklist & Daily Toolbox Meeting F098	Completed ☐ N/A ☐	
2.4	WHS hazard controls are in place - Safe Work Method Statement completed - Plant risks managed - Radhaz survey completed, published on the Avnet and general public & occupational exposure boundaries identified	Safe Work Method Statement AA-TEMP-SAF-0017 Managing WHS Risk for Contractors and Projects AA-PROC-SAF-0012 Plant Risk Management PROC-134 RF Radiation, Surveys & Health & Safety Mgmt PROC-121	Completed ☐ N/A ☐	Link to completed Safe Work Method Statement AA-TEMP-SAF-0017 Link to completed F131 Plant Risk Management Checklist
2.5	At the completion of works ensure WHS Inspections are completed and hazard controls are in place. Building condition; clean, undamaged, all work completed.	Conducting Workplace Safety Inspections AA-PROC-SAF-0008	Completed ☐ N/A ☐	

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Item No:	Requirement:	Requirement Reference: (Procedure/Instruction used to specified required input)	Completed or N/A	Evidence of Compliance (If a requirement is N/A, a reason why it is N/A is required to be entered)
3	ENVIRONMENT			
3.1	Environmental Impact must be assessed using the Environmental Impact Screening & Assessment Criteria for Changes to On-ground Activities Assistance in assessing the Environmental Impact can be obtained from Environment and Climate Change Unit in Environment Group.	Environmental Screening & Assessment Criteria for Changes to On-ground Activities AA-REF-ENV-0010 Environmental Assessment of Changes to On-ground Activities AA-NOS-ENV-2.200	Completed ☐ N/A ☐	Link to completed Environmental Impact Screening and Assessment Form If a stage 2 assessment is required provide ARMS reference and links to any Permits, Master Development Plans and relevant correspondence as required.
3.2	Environmental Clearance obtained for ATM changes as per AA-NOS-ENV-2.100 Assistance in assessing the Environmental Impact can be obtained from Environment and Climate Change Unit in Environment Group.	Environment Assessment Process for ATM Changes AA-NOS-ENV-2.100	Completed ☐ N/A ☐	Provide ARMS reference and NRFC reference if ATM change required
4	PEOPLE- SUPPORT			
	ATC TRAINING			
4.1	ATC Training Needs Analysis completed and Training Plan developed?		Completed ☐ N/A ☐	Link to Training Needs Analysis and Training Plan
4.2	Sufficient number of trained, rated and endorsed ATC staff available.		Completed ☐ N/A ☐	Number Trained:
4.3	ATC staff individual training records in SAP database have been updated		Completed ☐ N/A ☐	
4.4	Plans are in place to complete any outstanding training, rating, and endorsement of remaining ATC staff (Normally an identified hazard)		Completed ☐ N/A ☐	HAZLOG Register No:

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TECHNICAL TRAINING				
4.5	Training Needs Analysis completed and Training Plan developed for system support staff and field maintenance staff?		Completed ☐ N/A ☐	Link to Training Needs Analysis and Training Plan
4.6	TechCert codes have been created, assessment criteria developed or existing assessment criteria has been amended	TechCert codes TechCert Guides and Forms	Completed ☐ N/A ☐	Link to TechCert Guides and Forms
4.7	Sufficient system support staff and field maintenance staff appropriately trained?		Completed ☐ N/A ☐	
4.8	Are plans in place to complete any outstanding training and certification of system support staff and remaining field maintenance staff?		Completed ☐ N/A ☐	
4.9	Field maintenance staff hold the relevant TechCert to perform duties.	Technical Certification PROC-141	Completed ☐ N/A ☐	
4.10	Statutory / special licensing obtained by field maintenance staff including high risk work competencies and licensing requirements?		Completed ☐ N/A ☐	
4.11	ABS and FMS staff training details sent to Technical Training Coordinator and training records updated as required?	Training PROC-119	Completed ☐ N/A ☐	
4.12	TechCert details sent to FMS System Support to update the Qualifications (TechCert) Database	Technical Certification PROC-141	Completed ☐ N/A ☐	
LOGISTICAL SUPPORT				
4.13	CMRD have been consulted regarding special test equipment, test beds, etc		Completed ☐ N/A ☐	

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4.14	CMRD / NDC have been consulted regarding spares holdings and repair of LRUs from this equipment or in-house support of Depot Level Support Contract / repair contract		Completed ☐ N/A ☐	
4.15	TEMACC advised of any specialised test equipment requirements.	Test Equipment Management PROC-150	Completed ☐ N/A ☐	
4.16	Maintenance support contracts in place (external and/or internal)? — Appropriate vendor and/or internal support? — Appropriate Level 3 maintenance arrangements		Completed ☐ N/A ☐	
4.17	Test equipment provided to maintenance base. Note: Test equipment purchasing and calibration requirements detailed in Engineering Execution Readiness form.		Completed ☐ N/A ☐	
4.18	Specialised hardware or software system support and field maintenance tools, test / patch leads, adaptors, isolators, electronic discharge protection (mats, straps), etc supplied?		Completed ☐ N/A ☐	
4.19	System Business Continuity/ Disaster Recovery provisions supplied/updated?		Completed ☐ N/A ☐	
4.20	Spares – Supplied, storage correct, transport cases supplied?	Management of Goods & Supplies PROC-118	Completed ☐ N/A ☐	
4.21	Spares – Software / firmware loaded, tested & configured?		Completed ☐ N/A ☐	
4.22	Service Restoration Times (SRT) established?	Airways Service Data PROC-207	Completed ☐ N/A ☐	

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4.23	Conduct Hardware physical configuration audit and ensure SAP Plant Maintenance has updated information of all installed and/or demolished equipment (including monitoring circuits) and sent to System Operations SAP PM DATA CHANGES	Equipment Installed/Demolished Advice SAP Data Input Form F104	Completed ☐ N/A ☐	Link to Email from SAP PM Support confirming update/s
5 PROCEDURES				
ATC DOCUMENTATION				
5.1	System Requirements documentation including Operating Concept or Business Process Rules - produced/updated and approved?		Completed ☐ N/A ☐	Link to documentation
5.2	Manual of Air Traffic Services (MATS) reviewed / updated. Aeronautical information publications (AIP Book, AIP SUPP, AIC, DAP, ERSA, Charts, etc) reviewed / updated. Amendment times are determined by the AIS Distribution Schedule	AA Publications AIS Distribution Schedule	Completed ☐ N/A ☐	NRFC No.
5.3	National ATC Procedures Manual (NAPM) and any other relevant ATC procedures reviewed / updated.		Completed ☐ N/A ☐	NRFC No.
5.4	ATC contingency / continuity plans reviewed / updated.	ATS Contingency Plans Business Continuity Plans C-BCP	Completed ☐ N/A ☐	ATS-CP No: C-BCP No:
5.5	NOTAM and/or AIP SUP issued / amended / cancelled	Works Planning PROC-213 Refer also LOA3024	Completed ☐ N/A ☐	NOTAM No:
5.6	ATC Temporary Local Instruction (TLI) issued notifying Operational staff of change?	Temporary Local Instructions & Database	Completed ☐ N/A ☐	NRFC No.

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USER DOCUMENTATION				
5.7	User/operator manuals updated		Completed ☐ N/A ☐	
5.8	User/operator procedures provided/updated as applicable		Completed ☐ N/A ☐	
5.9	On-line user/operator documentation completed and published		Completed ☐ N/A ☐	
5.10	ARFF instructions updated		Completed ☐ N/A ☐	
5.11	Other Business Groups instructions updated?		Completed ☐ N/A ☐	
TECHNICAL DOCUMENTATION				
5.12	Software design documents updated, adequate and supplied to system support?		Completed ☐ N/A ☐	
5.13	Software and/or dataset Version or Release Description Documentation supplied and adequate?		Completed ☐ N/A ☐	Link to Version Description Document or Release Description Document
5.14	Software installation procedure and instructions supplied/updated and adequate?		Completed ☐ N/A ☐	Link to Installation Procedure

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5.15	SMP: System Management Plan created / updated and adequate?	SMP Template	Completed ☐ N/A ☐	SMP No:
5.16	SCP: System Contingency / continuity plans supplied/updated and adequate?	SCP Template	Completed ☐ N/A ☐	SCP No:
5.17	Technical drawings updated and listed in Data Viewer and list supplied to system supporters and field maintenance staff.	Technical Drawing Management PROC-178	Completed ☐ N/A ☐	
5.18	Technical handbooks/manuals supplied to ABS or FMS Engineering/IT support and field maintenance staff (base and site copy).	Document Management PROC-103	Completed ☐ N/A ☐	
5.19	On-line system support and field maintenance documentation completed and published		Completed ☐ N/A ☐	
5.20	Technical documentation registered and placed under documentation control	Document Management PROC-103	Completed ☐ N/A ☐	
5.21	Appropriate engineering performance requirements specified and issued for ongoing use? System Specification documentation supplied/updated and adequate?	System Performance Requirements & Reporting Specification ASYS-106	Completed ☐ N/A ☐	
5.22	Configuration & Modification AEI: Equipment and System Modifications and Configuration (for hardware and software), and Software Release Authorisations are documented in a Part 2 AEI (or other approved documentation)	Development of Maintenance Instructions for Equipment PROC-151	Completed ☐ N/A ☐	AEI No/s: Link to documentation detailing configuration and modification
5.23	Maintenance AEI: Maintenance requirements, including Performance Inspection tolerances, have been defined and documented in AEIs (or other approved documentation). (AEI Part 3.4.7)	Development of Maintenance Instructions for Equipment PROC-151	Completed ☐ N/A ☐	AEI No/s:

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5.24	AEI: New maintenance AEIs trialled by maintenance staff	Development of Maintenance Instructions for Equipment PROC-151	Completed ☐ N/A ☐	
5.25	TTD: Temporary Technical Dispensation raised and published on the Document Search database.	Temporary Technical Dispensations PROC-153	Completed ☐ N/A ☐	TTD No:
5.26	Site Manifest updated	Site Manifests FMS-304	Completed ☐ N/A ☐	
6	SYSTEM			
DESIGN REQUIREMENTS				
6.1	System Requirements documentation including Operating Concept or Business Process Rules - supplied/updated and approved?	Design Control PROC-146	Completed ☐ N/A ☐	Links to documentation
6.2	Standards – Installation and equipment comply with all relevant Australian Standards? Building Codes - Structures comply with the relevant Building Codes? The relevant Australian Standards and Building Codes are to be determined by the Chief Engineer, Technical Authority or Maintenance Authority	Australian Standards Design Control PROC-146	Completed ☐ N/A ☐	
6.3	Other applicable Federal and/or State licensing requirements met? The relevant licensing requirements are to be determined by the Chief Engineer, Technical Authority or Maintenance Authority	Design Control PROC-146	Completed ☐ N/A ☐	

Item No:	Requirement:	Requirement Reference: (Procedure/Instruction used to specified required input)	Completed or N/A	Evidence of Compliance (If a requirement is N/A, a reason why it is N/A is required to be entered)
6.4	Electrical Mechanical, Structure and Building impacts have been assessed as adequate or modifications organised and completed through consultation with Engineering Branch, P&E? (Power supply capability / airconditioning capacity / mast loadings)	Design Control PROC-146	Completed ☐ N/A ☐	
6.5	Earthing and Lightning Protection meets Aircservices requirements?	Earthing and Lightning Protection Systems for Operational Facilities AEI 3.1504 Site Earthing and Lightning Protection Systems for Existing Installations AEI 2.3011	Completed ☐ N/A ☐	
6.6	Battery Procurement as per Aircservices requirements?	Lead Acid Batteries (Stationary) Procurement and Acceptance Testing AEI-3.7050 Panel Contract Arrangement C-PROC0140	Completed ☐ N/A ☐	
6.7	Assessing the impact of information systems against corporate objectives (7 Ticks process).	Information Technology Application Certification – 7 Ticks MI-0804 and PROC-190	Completed ☐ N/A ☐	Link to completed 7 Ticks Interim Certificate or Final Certificate
6.8	IT Security measures appropriate and in place (ie. to ensure effective security and control practices to minimise the risks of unauthorised access, inappropriate use, modification, destruction or disclosure of electronically held data).	IT Security Roles and Responsibilities Statement MS-0013 Information Security MI-0808 ICT Resources – Conditions of Use MI-0829	Completed ☐ N/A ☐	

Item No:	Requirement:	Requirement Reference: (Procedure/Instruction used to specified required input)	Completed or N/A	Evidence of Compliance (If a requirement is N/A, a reason why it is N/A is required to be entered)
6.9	Information Security	Information Security C-PROC0184	Completed ☐ N/A ☐	Link to completed security risk management plan
INSTALLATION REQUIREMENTS				
6.10	Has met the regulation and safety requirements for Telecommunications Installations. Cable Markers installed (external)? Equipment complies with ACMA statutory requirement Telecommunication Labelling (Customer Equipment and Customer Cabling) Notice 2001 as amended (i.e. 'A' ticked on the equipment compliance plate)	Implementing Regulation and Safety Requirements for Telecommunications Installations PROC-138 Installation of Optical Fibre Cable - Underground AEI 4.5001 Underground Cable Marking AEI 4.3001	Completed ☐ N/A ☐	Link to Telecommunications Cabling Advice
6.11	MDF/IDF Records created / updated? Labelling/Colour Coding – Rack, Cable, Chassis, etc. ?	Colour Coding of RJ45 Patch Leads for Voice and Data Installations AEI 7.3241	Completed ☐ N/A ☐	
6.12	Transmitters licence label affixed	Radio Communication Transmitter Labelling AEI 7.4238	Completed ☐ N/A ☐	
6.13	Electrical Certificate of Testing and Safety or Testing and Compliance on connection to a source of electricity (i.e. installation conforms to AS3000) are required to be supplied as soon as possible after connection or testing of any electrical installation or change. Labelling – Switch Boards, etc Meets Airservices Electrical Cable Colour Coding requirements?	Electrical Safety Regulation 2002 Sections 15 and 159 AS 3000 – Aust Standard Electrical Cable Colour Coding AEI 3.1502	Completed ☐ N/A ☐	Links to Electrical Certificates

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6.14	All modifications complete and scratch plate labels affixed to equipments	Identification of Airways Systems Equipment Hardware Modifications PROC-154	Completed ☐ N/A ☐	
6.15	Integration with National Technical Monitoring has been organised and completed through Engineering Branch, P&E?		Completed ☐ N/A ☐	
6.16	Alarm monitoring installed and tested at TOC for local and remote site?		Completed ☐ N/A ☐	
6.17	Source media – supplied/backed up, stored, registered with system support?	Software Media Archival and Storage PROC-147	Completed ☐ N/A ☐	
6.18	Site installable media – supplied/backed up, appropriately stored and registered by field maintainers?	Software Media Archival and Storage PROC-147	Completed ☐ N/A ☐	
6.19	Software licences provided, registered and appropriately stored? (Including details of any third party licensing)		Completed ☐ N/A ☐	
6.20	Update HEAT and/or ASID database to incorporate new system/version number and assign issue management roles?		Completed ☐ N/A ☐	

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DESIGN CONFIRMATION				
6.21	Airservices Physical Security requirements met. The minimum security requirements are specified in C-GUIDE0157. Physical Security advise can be obtained from the relevant Security Advisor in Security and Crisis Planning, Safety & Environment Physical Access requirements are determined and established Siting and accommodation impact has been assessed as being satisfactory or modifications organised through National Property?	Physical Security – Critical Operational Facilities C-GUIDE0157 Site Management PROC-170	Completed ☐ N/A ☐	
6.22	Network data load impact has been assessed as being satisfactory or modifications organised and completed through Engineering Branch, P&E?		Completed ☐ N/A ☐	
6.23	Spectrum licences (either cancelled if no longer required or for new licenses including if antenna moves by more than 10 metres)	Frequency Management: Obtaining a Frequency Assignment and Licence AEI 7.4202	Completed ☐ N/A ☐	
6.24	New system or system change acceptance tests (software and/or hardware) satisfactorily completed against the approved system requirements? — Test Plans provided? — FAT, SAT, UAT test results complete, passed to the required level and provided? — Test identified defect listings and re-test information provided?	System Management Manual SMM Design Control PROC-146	Completed ☐ N/A ☐	
6.25	Battery Acceptance Tests as per Airservices requirements?	Lead Acid Batteries (Stationary) Procurement and Acceptance Testing AEI-3.7050	Completed ☐ N/A ☐	Link to Battery Acceptance Test Results

Item No:	Requirement:	Requirement Reference: (Procedure/Instruction used to specified required input)	Completed or N/A	Evidence of Compliance (If a requirement is N/A, a reason why it is N/A is required to be entered)
6.26	Standard Operating Conditions (SOCs) / Site Configuration Data (SCD) established / approved	Standard Operating Conditions & Site Configuration Data Management PROC-143	Completed ☐ N/A ☐	
6.27	Flight Test results supplied and satisfactory	Certification of Radio Navigation Aid Facilities AEI 7.4003	Completed ☐ N/A ☐	
6.28	Equipment operation is as per AEI specifications and any additionally specified requirements? Relevant requirements and performance specifications to be determined by the Chief Engineer, Technical Authority or Maintenance Authority		Completed ☐ N/A ☐	
7 TRANSITION				
PLANNING				
7.1	Does the system meet all critical user and technical requirements?		Completed ☐ N/A ☐	
7.2	If non-critical deficiencies are proposed to be accepted into operation, are they managed and tracked via ASID, HEAT or SAIR, including responsibilities and timings and attached to the Commissioning Certificate?		Completed ☐ N/A ☐	
7.3	Cutover Plan prepared and authorised by: – Appropriate level of engineering authority? – Appropriate level of User Authority?	Cutover Plan C-TEMP0045	Completed ☐ N/A ☐	Link to Cutover Plan
7.4	Works plan created at least 7 days before deployment	Works Planning PROC-213	Completed ☐ N/A ☐	Works Plan No.

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NOTIFICATION				
7.5	Industry education / notification been completed?		Completed ☐ N/A ☐	
7.6	Relevant Business Managers advised of impending change?		Completed ☐ N/A ☐	
7.7	Change requester and/or sponsor notified?		Completed ☐ N/A ☐	
7.8	System Operations' TOC and Service Desk notified and accepted operating responsibility for the change.		Completed ☐ N/A ☐	
7.9	ABS/FMS Manager has accepted maintenance responsibility		Completed ☐ N/A ☐	
7.10	Notify the following (as appropriate) that the system is at "OPERATIONAL READINESS" and provide details of commissioning and any system changes: ATC System Supervisor, Melbourne (ATC) System Supervisor, Brisbane (ATC) National ATC Systems Manager Operating Authority (relevant)	Sys to Svc List	Completed ☐ N/A ☐	

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7.11	Notify the following (as appropriate) that the system is at “ENGINEERING READINESS” and provide details of commissioning and any system changes: P&E Technical Authority (relevant) Technical Operations Centre – Director Service Desk -Airways SAP PM Support	Sys to Svc List	☐ Completed ☐ N/A	

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COMMISSIONING CERTIFICATE

The requirement for this form is specified in the System Management Manual (Section 11.2 of V4), C-MAN0107

Project/Task Name	SAP Project/Task ID:	Sites or Locations affected:
Documentation prepared by:	Date:	Commissioning Date:
Affected System(s)	System Criticality	Change Consequence Level
Brief Description of Change:		

Commissioning Approval

The approval of this document by the appropriate authorities as specified in the System Management Manual certifies that the new system or system change is satisfactory to meet the specified service and performance requirements; that system operating and support requirements are in place; that required user and technical training is adequately provisioned; as detailed in the Commissioning Readiness Form and consequently the new system or system change is declared fit-for-purpose and can be deployed and operated until formally decommissioned or otherwise revoked.

This approval is provided subject to the non-critical deficiencies¹ listed herein.

Chief Engineer, Technical or Maintenance Authority

Name	Signature:	Date
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Designation:

Name:	Signature:	Date:
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Designation:

Chief Operating/User Authority or Operating/User Authority

Name:	Signature:	Date:
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Designation:

Records Management Instructions

Place the completed Commissioning Certificate, together with the completed Commissioning Readiness form on the Project file

Provide a copy of the completed Commissioning Certificate, and the completed Commissioning Readiness Form to P&E, Asset Lifecycle Manager, Planning and Integration

Note 1: Non-critical deficiencies are those outstanding technical and operational issues that do not prevent the safe and effective use of the facility by users or prevent effective technical maintenance, but will be addressed in a specified and agreed time.

[illegible]

Guidance Materials on Monitoring and Analysis of ADS-B Avionics Performance

1 Introduction

- 1.1 The APANPIRG has endorsed the following Conclusion during its 24th Meeting to encourage States/Administration to exchange their ADS-B performance monitoring results and experience gained from the process :

Conclusion 24/45 - Exchange ADS-B Performance Monitoring Result

“That, States be encouraged to exchange findings/result of their ADS-B performance monitoring including experience gained in conducting the required performance monitoring.”

- 1.2 Since the ADS-B mandate for some airspace in the Region became effective in December 2013, monitoring and analysis on avionics performance of ADS-B equipped aircraft has become an increasingly important task for concerned States. The fully functional ADS-B Avionics Problem Reporting Database (APRD) was launched on the 21 July 2017. The database is placed at ICAO APAC website in the restricted area with name: APAC ADS-B Avionics Problem Reporting Database accessible via <https://applications.icao.int/ADSB-APRD/login.aspx>. States are encouraged to make full use of the APRD for reporting ADS-B avionics problems and sharing experience as well as follow-up actions through the APRD web-page.
- 1.3 This document serves to provide guidance materials on monitoring and analysis of avionics performance of ADS-B equipped aircraft, which is based on the experience gained by States.

2 Problem Reporting and Feedback

- 2.1 For ADS-B avionics problems, it is critical that an appropriate reporting and feedback mechanism be established. It is highly desirable that those discovering the problems should report them to the appropriate parties to take action, such as study and analyse the problems, identify the root causes, and rectify them. Those action parties include :-
- (a) Air Navigation Service Providers (ANSPs) – upon detection of any unacceptable ADS-B reports from an aircraft, report the observed problem to the performance monitoring agent(s), if any, and the Aircraft Operators for investigation. In addition, ANSPs should take all actions to avoid using the ADS-B reports from the aircraft until the problem is rectified (e.g. black listing the aircraft), if usage of such reports could compromise safety.
 - (b) Regulators – to initiate any appropriate regulatory action or enforcement.

- (c) Aircraft Operators – to allow avionics specialists to examine the causes and as customers of the avionics manufacturers ensure that corrective action will take place.
- (d) Avionics Manufacturers and Aircraft Manufacturers – to provide technical evidence and knowledge about the problem and problem rectification

2.2 Incentives should be received by those parties acting on the problems including :-

- (a) Regulations that require deficiencies to be rectified
- (b) Regulatory enforcement
- (c) Consequences if conduct of operations with problematic equipment (e.g. no access to the airspace requiring healthy equipment)

2.3 When an ADS-B avionics problem is reported, it should come along with adequate details about the problem nature to the action parties. In addition, the problem should be properly categorised, so that appropriate parties could diagnose and rectify them systematically.

3 Problem Categorisation

3.1 Regarding ADS-B avionics, their problems are quite diversified in the Region but can be categorized to ensure they will be examined and tackled systematically.

3.2 Based on the experience gained from States, the common ADS-B avionics problems in the Region are summarized under different categories in Attachment A. It is noted that only a relatively minor portion of the aircraft population exhibits these problems. It must be emphasized that aircraft transmitting incorrect positional data with NUC = 0 or NIC = 0 should not be considered a safety problem. The data transmitted have no integrity and shall not be used by ATC. This situation exists for many aircraft when their GNSS receivers are not connected to the transponders.

4 Managing the Problem

4.1 There are two major approaches to manage the problems :-

(a) Regulatory approach

Regulations which require non-approved avionics to disable ADS-B transmission (or transmit “no integrity”), and the concerned operators to file flight plans to indicate no ADS-B equipage. APANPIRG has endorsed this approach which is reflected in the Regional Supplementary Procedures (Doc 7030).

(b) Blacklist approach

Filtering out (“black listing”) any airframes that do not comply with the regulations or transmitting bad data, and advising the regulator of the non-compliance. This approach is temporary which allows the ANSP to protect the system whilst regulatory action is underway.

While deciding on whether an aircraft transmitting erroneous ADS-B data should be added into the blacklist, the following factors will be critically assessed:

- i. Impact and risk to ATC operational safety
Use of erroneous ADS-B data to maintain separation may potentially contribute to loss of separation or ATC coordination error.
- ii. Frequency of erroneous position
Whether it is occasional or frequently broadcast of erroneous position.
- iii. Amount of deviation
This can be a track jumping problem which is of significant safety impact to ATC or just an occasional small position jump which is not detectable in ATC with insignificant impact.
- iv. Others
Such as the ICAO aircraft address received from ADS-B being inconsistent with the aircraft registration, Flight ID entered via cockpit interface mismatched with aircraft callsign in the Flight Plan, etc.

After deciding to put an aircraft into the blacklist list, the following procedures will be carried out:

- i. Informing the concerned aircraft operator/regulatory authority
The concerned aircraft operator/regularity authority will be notified of the decision and the rationale before putting the aircraft into the exclusion list.
- ii. Pre-processing of flight plan concerned
As the blacklist mechanism involves filtering out the ADS-B data of the subject aircraft, from operational perspective, air traffic controllers need to be aware in advance that the concerned aircraft plans to operate in their FIR. A flight plan pre-processing system may locate the flight plan by checking against the 24-bit address or aircraft registration in the blacklist, and issue an alert to the air traffic controllers if appropriate, such as automatically insert a remark in the Item 18 of the concerned flight plan before feeding the flight plan into the ATC Automation System, and the ATC Automation System may issue an alert to the air traffic controllers with a specific label annotated in the corresponding electronic flight strips.
- iii. Coordinate with adjacent Area Control Centre (ACC)
Upon posting of pending inbound flights with corresponding electronic flight strips indicating non-ADS-B equipage or in the blacklist, the air traffic controllers shall inform the upstream ACC that transfer of that particular flight will not be accepted at the ADS-B exclusive airspace. It is important to carry out this coordination action as early as possible as the upstream sector may have difficulty to adjust the flight route at the transfer stage.
- iv. Handling of an aircraft for removal from the blacklist once rectification action had taken place
Once notification from the aircraft operators/regulatory authorities is received that the problem has been rectified, performance of the aircraft will be closely

monitored when it flies to the concerned FIR. If the aircraft shows the observed problem has been resolved, the aircraft will be removed from the blacklist. The aircraft operator/regulatory authority will also be notified accordingly.

5 Systematic Monitoring and Analysis of the Problem

States using ADS-B should have in place systematic ways to identify and manage ADS-B deficiencies similar to that described below :-

5.1 Reporting Deficiencies

States using ADS-B should have in place systematic ways to identify ADS-B deficiencies including :-

- (a) Systematic capture of ATC reported events and engineering detected events into a database; and
- (b) Manual or automatic detection of anomalous avionics behavior independent from controller reports

5.1.1 ATC Reported Deficiencies

ATC procedures should exist that allow services to continue to be provided safely, as well as to capture relevant information for later analysis. This should include :-

- (a) ATC request for the pilot to select the alternate transponder; and
- (b) ATC to adequately record the circumstances including Flight ID, ICAO Aircraft Address (if readily available) accurate time, Flight plan, and pilot provided information.

5.1.2 Non ATC reported deficiencies

5.1.2.1 Where capability is available, States should also identify non ATC reported deficiencies.

5.1.2.2 Without overlapping radar coverage: ADS-B data may be examined for the following :-

- (a) NUCp of each ADS-B reported position is smaller than required for service delivery for more than 5% of total number of ADS-B updates;
- (b) NIC, NACp, SIL are smaller than required for service delivery for more than 5% of total number of ADS-B updates;
- (c) ICAO Aircraft Address (i.e. I021/080) is inconsistent with the flight planned registration (REG) based on each state's ICAO Aircraft Address allocation methodology;

- (d) Flight ID entered via cockpit interface and downlinked in ADS-B data (i.e. I021/170 in Asterix CAT 21) is a mismatch¹ with aircraft callsign in the ATS Flight Plan;
- (e) Inconsistent vertical rate compared to flight level change; and
- (f) Inconsistency of position reports and presence of "jumps".

5.1.2.3 Overlapping radar coverage: For States that have overlapping radar coverage, a systematic means to monitor and analyze ADS-B could be considered in addition to relying on ATC to report the problem, or utilising the evaluation criteria in 5.1.2.2 above.

This can be achieved by comparing radar information with ADS-B reported position, velocity, flight level and vertical rate change data as well as examining the ADS-B quality indicators and Flight Identification (FLTID) contained in the ADS-B reports.

For each ADS-B flight, its ADS-B data could be compared with its corresponding radar information. For example, this would allow analysis to determine if the following pre-defined criteria are met :-

- (a) Deviation between ADS-B reported position and independent referenced radar position is greater than 1NM², with the indication of good positional quality in the quality indicators for more than 5% of total number ADS-B updates. A sample screen shot of a system performing the analysis automatically is given at Attachment B for reference.

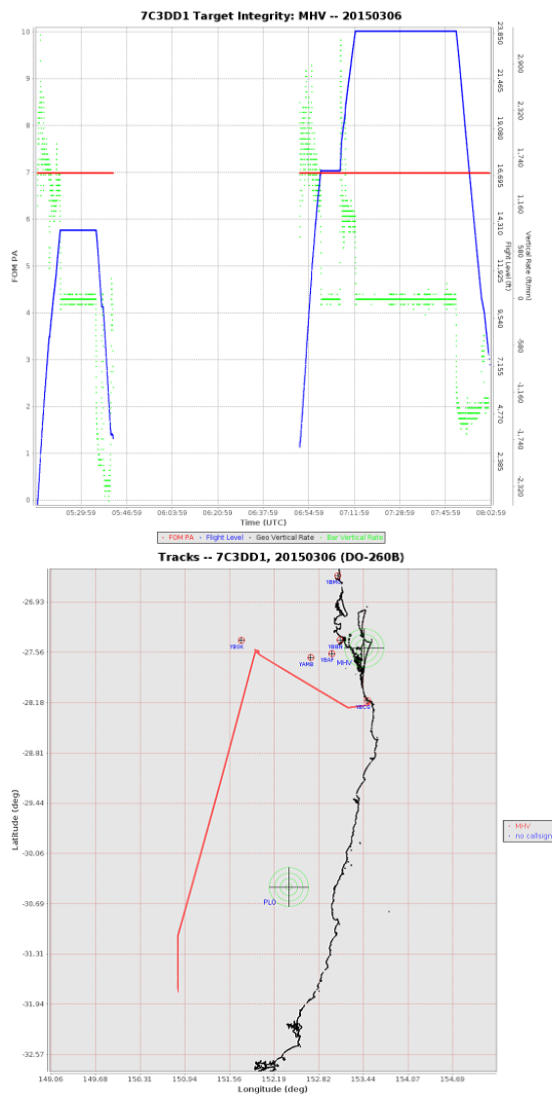
5.2 Managing and Processing Deficiencies

Whether detected by ATC or not, all deficiencies should trigger:

- (a) Systematic recording of the details of each occurrence such as date/time of occurrence, ICAO aircraft address and flight plan information should be obtained. Graphical representations such as screen capture of radar and ADS-B history tracks, graphs of NUCp/NIC value changes versus time and deviation between radar and ADS-B tracks along the flight journey would be desirable. Examples of typical graphical representations are shown below :-

¹ A missing Flight ID, or a Flight ID with only "spaces" should not be considered a mismatch.

² For example, the deviation between ADS-B and radar tracks could be set to 1NM in accordance with ICAO Circular 326 defining position integrity ($0.5\text{NM} < \text{HPL} < 1\text{NM}$) for 3NM aircraft separation use, on assumption that radar targets are close to actual aircraft position. The values of ADS-B quality indicators (NUCp, NACp, SIL, NIC) could be chosen based on the definition in ICAO Circular 326 on Position Accuracy and Position Integrity for 3NM aircraft separation minimum. A threshold of 5% is initially set to exclude aircraft only exhibiting occasional problems during their flight journey. The above criteria should be made configurable to allow fine-tuning in future. Evaluation of ADS-B vs radar may alternatively expose radar calibration issues requiring further investigation.



- (b) Systematic technical analysis of each detected issue using ADS-B recorded data, to ensure that all detected issues are examined and addressed. Typically this will need:
- systems to record ADS-B data, replay ADS-B data and analyze ADS-B data
 - staff and procedures to analyze each report
 - A database system to manage the status of each event and to store the results of each analysis
- (c) Procedures to support engagement with operators (domestic & foreign), regulators, other ANSPs, Airframe OEMs and avionics vendors to ensure that each issue is investigated adequately and maximize the probability that the root cause of the event is determined. The procedures could include :-
- Data collection procedures;
 - Telephone & email contact details; and
 - Mechanisms for reporting, as appropriate, to the Asia Pacific ADS-B Avionics Problem Reporting Database (APRD)

* * * * *

Attachment A – List of known ADS-B avionics problems

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
1.	Track Jumping problem with Rockwell Collins TPR901 (See Figure1)	Software issue with TPR901 transponder initially only affecting Boeing aircraft. Does not occur in all aircraft with this transponder. Subsequent investigation by Rockwell Collins has found that the particular transponder, common to all of the aircraft where the position jumps had been observed, had an issue when crossing ± 180 degrees longitude. On some crossings (10% probability), errors are introduced into the position longitude before encoding. These errors are not self-correcting and can only be removed by a power reset of the transponder. The problem, once triggered can last days, since many transponders are not routinely powered down.	Yes. Will present as a few wild/large positional jumps. Nearly all reports are tagged as low quality (NUC=0) and are discarded, however, some occasional non zero reports get through. Problem is very “obvious”. Could result in incorrect longitudinal position of Flight Data Record track. Can trigger RAM alerts.	Rockwell Collins has successfully introduced a Service Bulletin that solves the problem in Boeing aircraft. The problem is known to exist on Airbus aircraft. Rockwell has advised that a solution is available in their DO260B upgrade. Rockwell Collins may not have a fix for some time. Workaround solutions are being examined by Airbus, Operators and Airservices Australia. The only workaround identified at this time is to power down the transponders before flight to states using ADS-B – after crossing longitude 180. It can be noted that in Airbus aircraft it is not possible to safely power down the transponder in flight. Airbus have prepared a procedure to support power down before flight. Airservices Australia have negotiated with 2 airlines to enact this procedure prior to flights to Australia. An additional partial workaround is :

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
				to ensure that procedures exist for ATC to ask the pilot to changeover transponders if the problem is observed. Since there is a 10% chance of the problem occurring on each crossing of ± 180 degrees longitude, the chance that both transponders being affected is 1%. There is no complete workaround available for flights that operate across 180 degrees longitude directly to destination without replacing the transponder. Airbus advised that a new TPR901 transponder compliant with DO260B is available from December 2015. This new transponder does not have such problem.
2.	Rockwell Collins TDR94 Old version. The pattern of erroneous positional data is very distinctive of the problem. (See Figure 2)	Old software typically before version -108. The design was completed before the ADS-B standards were established and the message definitions are different to the current DO260. Rockwell has recommended that ADS-B be disabled on these models.	Yes. Will present as a few wild positional jumps. Nearly all reports are tagged as low quality (NUC=0) and are discarded, however, some occasional non zero reports get through. Also causes incorrect altitude reports. Problem is very “obvious”.	Problem well known. Particularly affects Gulfstream aircraft which unfortunately leave the factory with ADS-B enabled from this transponder model. Rockwell has issued a service bulletin recommending that ADS-B be disabled for aircraft with this transponder software. See Service Information Letter 1-05 July 19, 2005. It is easy to disable the transmission.

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
				If a new case is discovered, an entry needs to be made to the black list until rectification has been effected.
3.	Litton GPS with proper RAIM processing	Litton GNSSU (GPS) Mark 1 design problem. (Does not apply to Litton Mark II). GPS does not output correct messages to transponder.	No. Perceived GPS integrity changes seemingly randomly. With the GPS satellite constellation working properly, the position data is good. However the reported integrity is inconsistent and hence the data is sometimes/often discarded by the ATC system. The effected is perceived extremely poor “coverage”. The data is not properly “protected” against erroneous satellite ranging signals – although this cannot be “seen” by ATC unless there is a rare satellite problem.	This GPS is installed in some older, typically Airbus, fleets. Data appears “Correct” but integrity value can vary. Performance under “bad” satellite conditions is a problem. Correction involves replacing the GNSSU (GPS) which is expensive. If a new case is discovered, an entry needs to be made to the black list until rectification has been effected.
4.	SIL programming error for DO260A avionics	Installers of ADS-B avionics using the newer DO260A standard mis program “SIL”. a) This problem appears for DO260A transponders, with SIL incorrectly set to 0 or 1 (instead of 2 or 3) b) As the aircraft enters	No. First report of detection appears good (and is good), all subsequent reports not displayed because the data quality is perceived as “bad” by the ATC system. Operational effect is effectively no ADS-B data. Hence no risk.	Would NOT be included in a “black list”. Aircraft with “Dynon avionics” exhibit this behavior. They do not have a certified GPS and hence always set SIL = 0. This is actually correct but hence they do not get treated as ADS-B equipped.

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
		coverage, the ADS-B ground station correctly assumes DO260 until it receives the version number. c) The transmitted NIC (DO260A) is interpreted as a good NUC (DO260) value, because no SIL message has yet been received. The data is presented to ATC.		
5.	Garmin “N” Flight ID problem (See Figure 3)	Installers of Garmin transponder incorrectly set “Callsign”/Flight ID. This is caused by poor human factors and design that assumes that GA aircraft are US registered.	Yes. Flight ID appears as “N”. Inhibits proper coupling.	Can be corrected by installer manipulation of front panel. Does not warrant “black list” activity.
6.	Flight ID corruption issue 1 – trailing “U” Flight ID’s received : GT615, T615U ,NEB033, NEB033U, QF7550, QF7550U, QF7583, QF7583U, QF7585, QF7585, QF7585U, QF7594, QFA7521, QFA7531, QFA7531, QFA7531U, QFA7532, QFA7532U, QFA7532W, QFA7550, QFA7552,	TPR901 software problem interfacing with Flight ID source. Results in constantly changing Flight ID with some reports having an extra “U” character.	Yes. Flight ID changes during flight inhibits proper coupling or causes decoupling.	Affects mainly B747 aircraft. Boeing SB is available for Rockwell transponders and B744 aircraft. Rockwell Collins have SB 503 which upgrades faulty -003 transponder to -005 standard. If a new case is discovered, an entry needs to be made to the black list until rectification has been effected.

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
	QFA7581			
7.	Flight ID corruption issue 2	ACSS software problem results in constantly changing Flight ID. Applies to ACSS XS950 transponder Pn 7517800-110006 and Honeywell FMC (pn 4052508 952). ACSS fix was available in Sept 2007.	Yes. Flight ID changes during flight inhibits proper coupling or causes decoupling.	Software upgrade available. If a new case is discovered, an entry needs to be made to the black list until rectification has been effected.
8.	No Flight ID transmitted	Various causes	No. Flight ID not available. Inhibits proper coupling.	Aircraft could “fail to couple with Flight Data Record”. Not strictly misleading – but could cause controller distraction.
9.	ACSS Transponder 10005/6 without Mod A reports NUC based on HFOM.		Yes. Appears good in all respects until there is a satellite constellation problem (not normally detectable by ground systems).	Not approved and hence not compliant with CASA regulations. If known could be added to black list. Configuration is not permitted by regulation.
10.	Occasional small position jump backwards (See Figure 4)	For some older Airbus aircraft, an occasional report may exhibit a small “jump back” of less than 0.1 nm Root cause not known	No. Not detectable in ATC due to extrapolation, use of latest data and screen ranges used.	ATC ground system processing can eliminate these.
11.	Older ACSS transponders report integrity too conservatively	Design error reports integrity one value worse than reality	No. In poor GPS geometry cases the	Can be treated in the same manner as a loss of transponder capability.

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
			ATC system could discard the data when the data is in fact useable. Will be perceived as loss of ADS-B data.	
12.	Intermittent wiring GPS transponder	ADS-B transmissions switch intermittently between INS position and GPS position.	Yes. Normally the integrity data goes to zero when INS is broadcast, but sometimes during transition between INS and GPS, an INS position or two can be broadcast with “good” NUC value. Disturbing small positional jump.	If a new case is discovered, an entry needs to be made to the black list until rectification has been effected.
13.	Wrong ICAO Aircraft Address	Installation error	No. No direct ATC impact unless a rare duplicate is detected.	This is not a direct ADS-B problem, but relates to a Mode S transponder issue that can put TCAS at risk. Cannot be fixed by black list entry. Needs to be passed to regulator for resolution.
14.	Toggling between high and low NUC (See Figure 5)	Faulty GPS receiver/ADS-B transponder	No. ATC will see tracks appear and disappear discretely. No safety implications to ATC.	While it is normal for NUC value to switch between a high and low figure based on the geometry of GPS satellites available, it is of the view that more should be done to examine this phenomenon. It is observed that such switching between high and low NUC occurs on certain airframe and

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
				not on others. The issue was raised to the airlines so as to get a better understanding. On one occasion, the airline replied that a module on their GPS receiver was faulty. On another occasion, the airline replied that one of the ADS-B transponder was faulty. Good NUC was transmitted when the working transponder was in use and poor NUC was transmitted when the faulty ADS-B transponder was in use.
15.	Consistent Low NUC (See Figure 6)	GNSS receivers are not connected to the ADS-B transponders.	No. Data shall be filtered out by the system and not detectable in ATC	Not considered a safety problem but a common phenomenon in the Region – the concerned aircraft will be treated equivalent to “aircraft not equipped with ADS-B”. While it is normal for aircraft to transmit low NUC, it is of the view that “consistent low NUC” could be due to the avionics problem (e.g. GNSS receiver is not connected to the ADS-B transponder). It is recognised that operators may not be aware that their aircraft are transmitting unexpected low NUC / NIC values, due to equipment malfunction. Hence, it is desirable for States to inform the operators when unexpected low NUC

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
				values are transmitted, where practicable. Concerned airline operators are required to take early remedial actions. Otherwise, their aircraft will be treated as if non-ADS-B equipped which will be requested to fly outside the ADS-B airspace after the ADS-B mandate becomes effective.
16.	ADS-B position report with good integrity (i.e. NUC $\geq$ "4") but ADS-B position data are actually bad as compared with radar (met criteria 5.2(a))	Faulty ADS-B avionics	Yes. As the ground system could not "automatically" discard ADS-B data with good integrity (i.e. NUC value $\geq$ 4), there could be safety implications to ATC.	The problem should be immediately reported to the concerned CAA/operators for problem diagnosis including digging out the root causes, avionics/GPS types etc., and ensure problem rectification before the ADS-B data could be used by ATC. Consider to "blacklist" the aircraft before the problem is rectified.
17.	FLTID transmitted by ADS-B aircraft does not match with callsign in flight plan (see Figures 7a – 7d)	Human errors	Yes. Could lead to screen clutter - two target labels with different IDs (one for radar and another for ADS-B) being displayed, causing potential confusion and safety implications to ATC.	Issue regulations/letters to concerned operators urging them to set FLTID exactly match with callsign in flight plan.

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
18	B787 position error with good NIC	<u>Issue 1:</u> Software issue - surveillance system inappropriately “coasts” the position when data received by the transponder is split across multiple messages. System seems to self correct after some time. Can be corrected by surveillance system power off. <u>Issue 2:</u> Data packets were not being distributed to the transponder when the internal timing between different elements of the Integrated Surveillance System became synchronized.	Yes. Misleading position presentation which is typically detected by ATC observing aircraft “off track” when in fact it is “on-track”.	Boeing performed a change to the B787 Type Certificate for incorporation of the upgraded ISS software in March of 2017. All B787 aircraft delivered after Line number 541 have the upgraded ISS software which corrects this issue. Boeing released Service Bulletin B787-81205-SB340036-00 on 30 June 2017. Note that this Service Bulletin is available at no cost to the operator, and includes the concurrent requirement to implement Boeing Service Bulletin B787-81205-SB340005-00. On 5 Nov 2018, FAA issued Airworthiness Directive 2017-NM-118-AD, effective 10 Dec 2018, which requires application of Boeing SB B787-81205-SB340036-00 by 10 Dec 2019. EASA has invoked this AD for States under its jurisdiction. States and Operators are urged to implement the service bulletin immediately and report to FAA or ICAO APAC Office. As of 9 Sep 2020, 32 B787 aircraft were on the NSAL; 18 of these aircraft have been detected within

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
				U.S. ADS-B coverage during 2020. The FAA is coordinating with State Regulators who have operators with B787 aircraft on the NSAL.
19	A number of airlines have reported or experienced ADS-B outages for complete flight sectors in A330 aircraft. Appears as low reliability ADS-B and has afflicted both A & B side at same time.	Being actively investigated. One airline has implemented on-board recording which confirms that the MMRs are not providing HIL/HPL to the transponder whilst continuing to provide HFOM, GPS alt etc	No. Equivalent to a failed transponder.	Aircraft must be managed procedurally if outside radar coverage.
20	A380 flight ID lost after landing	For the A380 fleet, it has been confirmed that for some seconds after landing, the flight ID is set as invalid by FMS to AESS. Consequently, the current AESS design uses, as per design, the Aircraft Registration Number as a back-up source for A/C flight identification field in ADS-B broadcast messages.	No.	The correction to this logic is planned for next AESS standard release; planned for 2017.” Only a problem for arriving aircraft on surface surveillance systems.
21	A350 ADS-B On-ground Performance	On departure, A350 aircraft will initially use INS derived position for ADS-B reports when taxiing and only use GNSS when entering the runway. INS positions can drift leading to inaccurate	Yes. where ADS-B is used for surface movement display	Airbus is in discussion with FAA and EUROCONTROL about this issue.

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
		position reports.		
22	Incorrect Ground Bit Setting (GBS) in both Mode S Interrogation Reply and ADS-B Downlink	Occasionally, some airborne aircraft will incorrectly set ground bit as “1” meaning they are on ground, while some landed aircraft incorrectly set ground bit as “0” meaning they are airborne. This could confuse the ATC system, by not showing the airborne targets as the system thought they are on ground, or forming tracks for landed targets triggering alarms against other taking-off aircraft.	Yes. Misleading information shown on ATC system. Aircraft not visible to TCAS and will not reply to all-call interrogations.	States/Administrations contact the concerned airline operators for remedial actions.
23	Rockwell TSS-4100 track extrapolation issue.	The TSS-4100 shares software with the Rockwell Collins ISS transponder in the B787, and the software defect in the B787 ISS reported at SURICG/2 also exists in the TSS-4100.	Yes. Misleading position presentation which is typically shown on ATC system.	FAA Airworthiness Directive (AD) 2017-22-14 was issued on 20 Dec 2017. The compliance date for this AD is 20 Dec 2018 (or 750 hours in service, whichever occurs first). FAA has not detected any aircraft with this issue since the AD compliance date and will not further report on it, as it is considered resolved.

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
24	Embraer 170 track jumping issue	Unknown as being a random, occasional issue with no clear fault diagnosis available from Honeywell. FAA has decided that when the next E170 aircraft is detected with this issue, it will be immediately placed on the FAA's No Services Aircraft List (NSAL). Simultaneously, FAA will notify Embraer and Honeywell of the affected aircraft and request that appropriate engineering personnel be sent to inspect and test the affected aircraft.	Yes. Misleading position presentation which is typically shown on ATC system.	In all of the cases of this issue to date, removing and replacing the transponders cleared whatever the issue was. This issue has never recurred on the same aircraft. Bench testing by Honeywell avionics engineering of the removed transponders has revealed no faults or anomalies. As such, States/Administrations to consider removing and replacing the transponders concerned if issue observed. The FAA has since learned from discussions with the OEM that most recent events detected by FAA generated an "ADS-B NOT AVAIL" Crew Alerting System (CAS) message. When flight crews report this message, airline maintenance replaces the transponder(s), which resolves the problem. To date, this has consistently occurred before FAA monitoring detected the problem and engaged with the airline. The root cause for this issue remains unknown.
25	Airbus Single Aisle production wiring issue	FAA has observed 17 Airbus Single Aisle aircraft from two airlines with missing Length-Width Codes (LWC	No.	Airbus released three Service Bulletins to correct this issue, which existed in 128 Airbus Single Aisle aircraft.

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
		is a message element in DO-260B/ED-102A that is required by both the US and European mandates). FAA believes that this was a production line wiring issue.		As of 1-Dec-2018, all of the aircraft which operate at US airports with ADS-B surface surveillance were corrected. The FAA will not further report on this issue.
26	Boeing 777-300ER production wiring issue	FAA has observed at least 10 Boeing B777-300ER aircraft with missing or improper NACv/SDA/eCat/LWC message elements (these are message elements in DO-260B/ED-102A that are required by both the US and European mandates (eCat is FAA shorthand for Emitter Category). After notification, Boeing reported to FAA that this was a production line parity pin wiring issue.	No.	On 7 July 2017, Boeing released Service Bulletin SB 777-34-0281 to correct this issue. Boeing has informed FAA that all affected B777 operators have been notified. The FAA will not further report on this issue.
27	Rockwell TSS-4100 Geometric Altitude Reporting as Pressure Altitude	This issue exists in any TSS-4100 installed with TSSA-4100 software RCPN 810-0052-100, RCPN 810-0052-101, or RCPN 810-0052-102. All of the following must be true for the issue to occur: (1) TSS is the selected transponder; (2) TSS is receiving valid	Yes.	At present, the FAA regulator has determined that this issue occurs too rarely to warrant issuing an Airworthiness Directive or a Special Airworthiness Information Bulletin (SAIB). Rockwell Collins has released updated software, RCPN 810-0052-110, to address this issue. Refer to SIL TSSA-4100-10-1 titled, "TSSA-

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
		pressure altitude; (3) TSS is receiving valid GPS data with an integrity of NIC 9 or better; and (4) The mode of operation for the transponder must be "ALT OFF". Note that in an SBAS service area, only condition (4) would be considered uncommon. When the issue exists, the TSS will insert geometric altitude information into the ADS-B Airborne Position Squitter, but this altitude will be encoded as if it were pressure altitude. The net effect is that, when this issue occurs, the TSS-4100 reports geometric altitude information as if it were pressure altitude. In many cases, this will be incorrect altitude information.		4100 Field Loadable Software", RCPN 523-0818785.
28	NACv reporting greater than 2	The FAA has detected a number of aircraft which	No.	While there is no known urgent issue with these findings, as no known

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
		consistently report NACv = 3 and NACv = 4. Per FAA AC 20-165B section 3.3.3.7.3, “A NACv = 3 or NACv = 4 should not be set based on GNSS velocity accuracy unless you can demonstrate to the FAA that the velocity accuracy actually meets the requirement.” EASA CS-ACNS states that “There is currently no established guidance on establishing a NACv performance of ‘three’ or better.” Therefore, it appears that there are improperly configured ADS-B installations operating in the U.S.		ATC or airborne application requires NACv values exceeding two, FAA does have long-term intentions of deploying surveillance tracking and alerting prediction algorithms in ATC automation which will use real-time NACv values. ICAO States planning to make similar improvements should be aware of this situation.
29	B787 NACv = 0 Issue	FAA noted certain B787s exhibiting a relatively high percentage of NACv =0 reports. Starting with line number 442 (June 2016), Honeywell Integrated Navigation Receiver (INR) P/N 940-2001-008 was introduced,	No.	The erroneous NACv=0 condition clears at the next power up of the ISSPU. Boeing has issued guidance urging B787 operators to not intermix INR P/N 940-2001-002 or -004 (which do not output HFOMv) with INR P/N 940-2001-008 (which does output HFOMv) until the ISSPU software

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
		which has an HFOMv output. Boeing investigations revealed a software flaw in the ISSPU that causes an erroneous NACv=0 reporting condition on B787s equipped with a mixed set of Honeywell INR part numbers. This condition occurs when the ISSPU switches between an INR with an HFOMv output and an INR without an HFOMv output.		has been updated per an available Boeing Service Bulletin. This guidance was provided in Boeing Fleet Team Digest 787-FTD-34-19005 (dated 21 Dec 2019). As of 9-Aug-2020, FAA has observed no significant occurrences of this issue within U.S. ADS-B coverage during the prior two months.
30	Honeywell Primus II RCZ issue	FAA observed that a number of operators equipped with the Honeywell Primus II integrated system were filing flight plans as ADS-B equipped, but not transmitting ADS-B. Honeywell had identified an issue where the ADS-B Out capable RCZ transponder and Radio Management Unit (RMU) components of the Primus II system will not broadcast ADS-B data if powered on under specific conditions. Also, the Radio Management Unit (RMU)	No	In October 2015, Honeywell released a Service Information Letter (Publication Number D201507000061) to notify customers of these power up conditions, the effect it would have on the Primus II equipment, and a potential work around to address the problem. In December 2019, Honeywell released Service Bulletin (SB) (Publication Number A21-2254-148) providing required modifications for the RMU to correct the ON/OFF logic for the ADS-B Out functionality. The FAA has been working in

Ref.	Problem	Cause	Safety Implications to ATC (Yes / No)	Recommendations
		will fail to notify the flight crew that ADS-B Out functionality is disabled.		collaboration with Honeywell to update the existing Service Information Letter to emphasize the importance of updating the RMU with the latest SB, to include implementing the option of configuring the ADS-B Out installation through a strap setting to provide indication of the ON/OFF control of ADS-B to the flight crew. The latest revision of the Service Information Letter will be referenced as part of the FAA issued Special Airworthiness Information Bulletin (SAIB) expected to be released before the end of December 2021.



Figure 1 - Track Jumping problem with TPR901



Figure 3 - Garmin "N" Flight ID problem

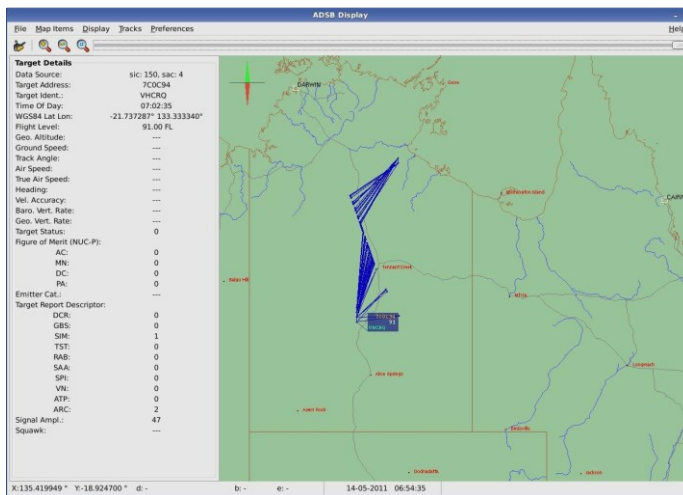


Figure 2 - Rockwell Collins TDR94 Old version. The pattern of

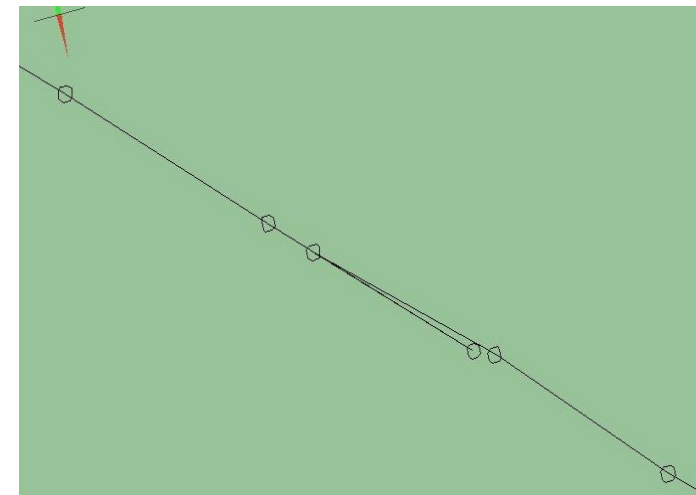


Figure 4 - Occasional small position jump backwards

erroneous positional data is very distinctive of the problem

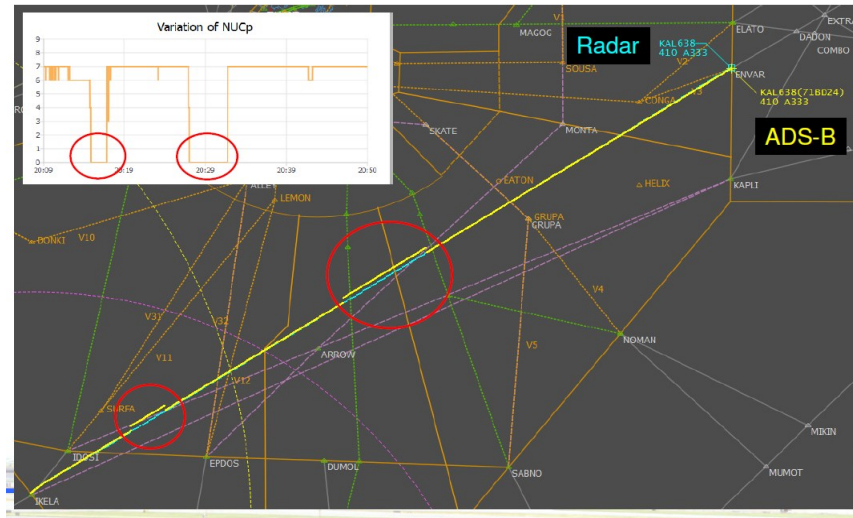


Figure 5 - NUC value toggling

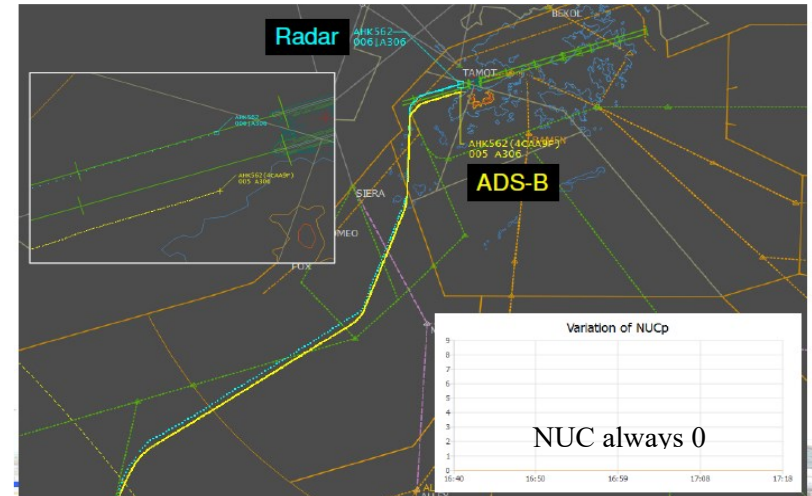


Figure 6 – Consistent low NUC

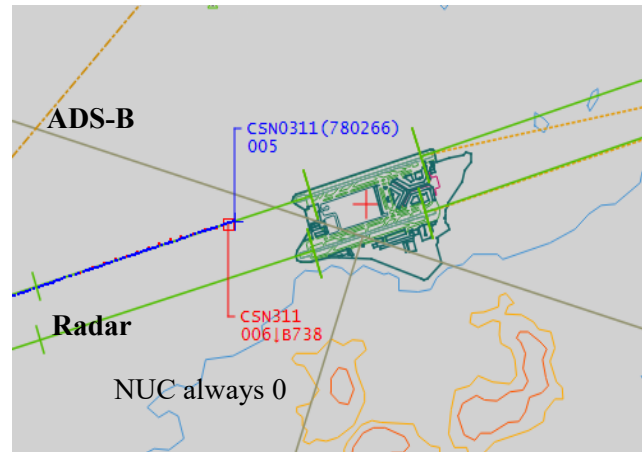


Figure 7a - Additional zero inserted

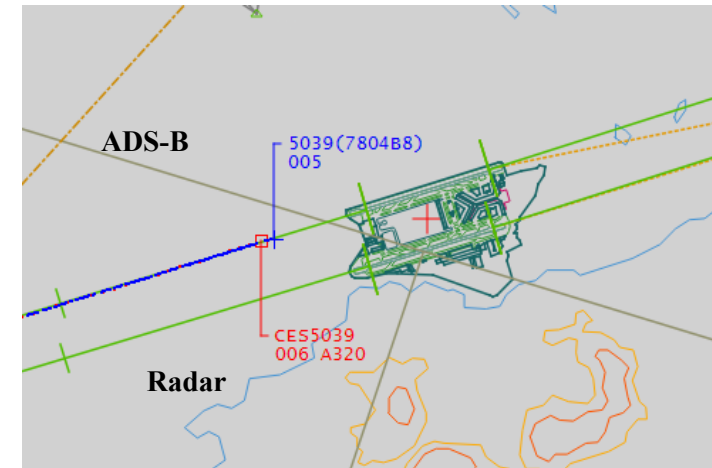


Figure 7b - ICAO Airline Designator Code dropped

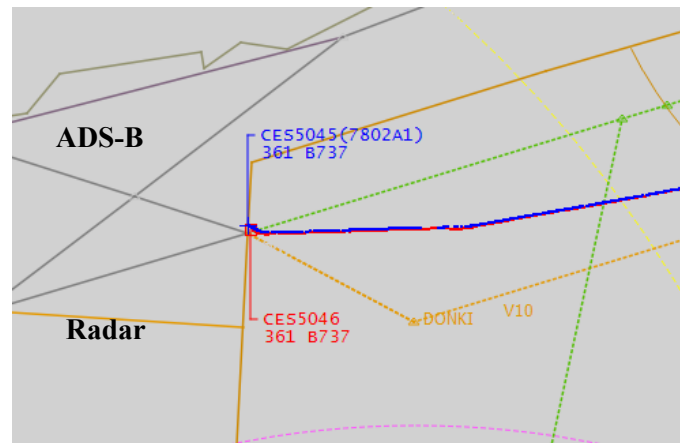


Figure 7c - Wrong numerical codes entered

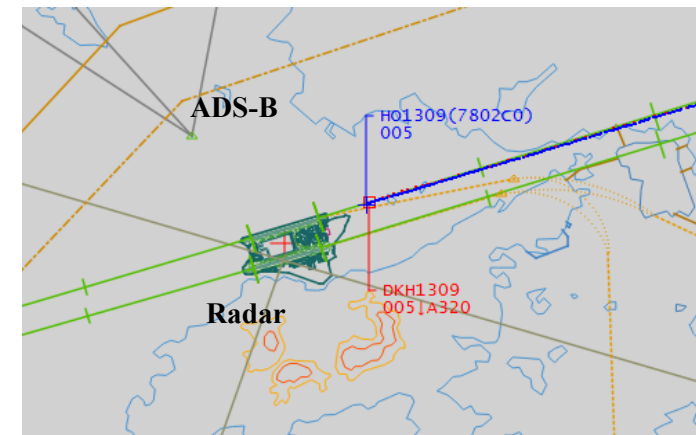
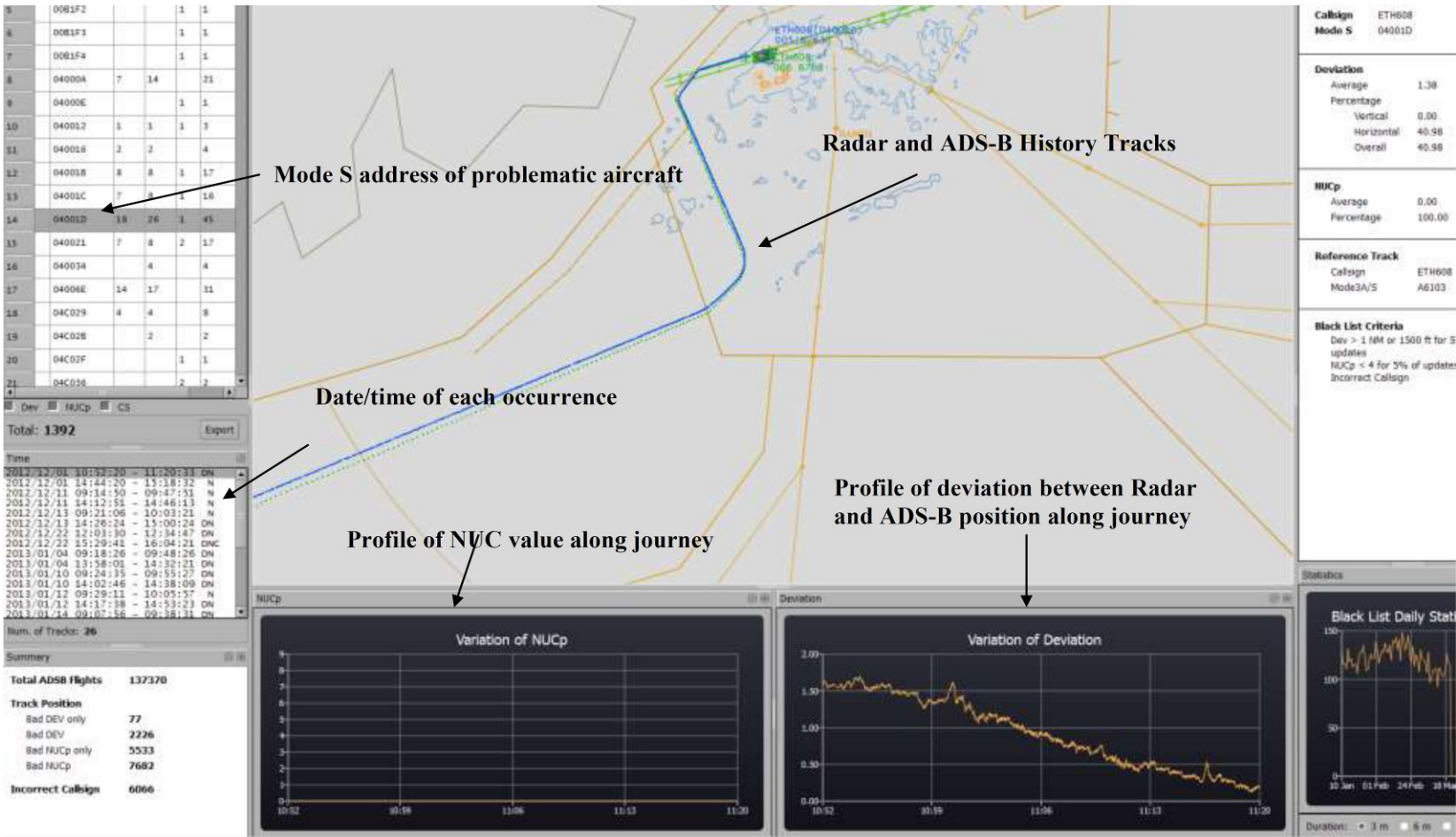


Figure 7d - IATA Airline Designator Code used

Attachment B - Sample screen shot of a system to monitor and analyse performance of ADS-B avionics



A Template for ADS-B Mandate/Regulations for Aircraft Avionics

- (1) On and after dd/mm/yyyy, if an aircraft carries 1090MHz extended squitter (1090ES) ADS-B transmitting equipment for operational use in xxxxxxxx territory, the equipment must have been certificated as meeting :¹
 - (a) European Aviation Safety Agency - Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHz Extended Squitter (AMC 20-24), or
 - (b) European Aviation Safety Agency - Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance Subpart D — Surveillance (SUR) (CS-ACNS.D.ADS-B), or
 - (c) Federal Aviation Administration – Advisory Circular No: 20-165A (or later versions) Airworthiness Approval of Automatic Dependent Surveillance – Broadcast (ADS-B) Out Systems, or
 - (d) the equipment configuration standards in Appendix XI of Civil Aviation Order 20.18 of the Civil Aviation Safety Authority of Australia.
- (2) On and after dd/mm/yyyy, if an aircraft operates on airways (insert routes).....at or above FLXXX.....(or in defined airspace boundaries at or above FLXXX):²

The aircraft must carry serviceable 1090MHz extended squitter (1090ES) ADS-B transmitting equipment that has been certificated as meeting :-

- (a) European Aviation Safety Agency - Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHz Extended Squitter (AMC 20-24), or
 - (b) European Aviation Safety Agency - Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance Subpart D — Surveillance (SUR) (CS-ACNS.D.ADS-B), or
 - (c) Federal Aviation Administration – Advisory Circular No: 20-165A (or later versions) Airworthiness Approval of Automatic Dependent Surveillance – Broadcast (ADS-B) Out Systems, or
 - (d) the equipment configuration standards in Appendix XI of Civil Aviation Order 20.18 of the Civil Aviation Safety Authority of Australia.
- (3) An aircraft carrying 1 090 MHz extended squitter (1090ES) ADS-B equipment shall disable ADS-B transmission unless:
 - (a) the aircraft emits position information of an accuracy and integrity consistent with the transmitted value of the position quality indicator; or
 - (b) the aircraft always transmits a value of 0 (zero) for one or more of the position quality indicators (NUCp, NIC, NACp or SIL); or

¹ This paragraph ensures all aircraft operating in the airspace, if equipped with ADS-B, are compliant to standards.

² This paragraph provides mandate requirements within certain parts of the airspace

- (c) the operator has received an exemption granted by the appropriate ATS authority.

Note: States are urged to include at least the standards stated in the template. States may include other standards allowed by the State's regulations.

**An Example of Advice to Operators Concerning Inconsistency Between ADS-B
Flight Planning and Surveillance Capability**

1 Background

Newer technologies for aircraft surveillance are now available – such as Mode S and ADS-B – which in many aircraft are installed as replacements for older Mode A/C transponders.

Air Traffic Control makes use of these new capabilities, and uses the Flight Plan information as a decision support tool – to allow the Air Traffic Controller to predict the surveillance capability of a particular aircraft before it enters radar or ADS-B coverage.

Requirements for ADS-B and Mode S (**insert local reference document if applicable**) may mean that if flight planning does not accurately reflect the aircraft capability, services may be withheld (for example if ADS-B is mandatory, but not indicated on the flight plan – **this section to be modified for local requirements**).

2 Flight Planning Requirements for Transponder and ADS-B

The flight planning requirements for aircraft are described in (**local document reference or ICAO DOC 4444 Appendix 2**) and repeated below.

Surveillance Equipment

N if no surveillance equipment for the route to be flown is carried, or the equipment is unserviceable

OR

INSERT one or more of the following descriptors, to a maximum of 20 characters, to describe the serviceable surveillance equipment and/or capabilities on board:

SSR Modes A and C

A Transponder — Mode A (4 digits — 4 096 codes)

C Transponder — Mode A (4 digits — 4 096 codes) and Mode C

SSR Mode S

E Transponder — Mode S, including aircraft identification, pressure-altitude and extended squitter (ADS-B) capability

H Transponder — Mode S, including aircraft identification, pressure-altitude and enhanced surveillance capability

I Transponder — Mode S, including aircraft identification, but no pressure-altitude capability

L Transponder — Mode S, including aircraft identification, pressure-altitude, extended squitter (ADS-B) and enhanced surveillance capability

P Transponder — Mode S, including pressure-altitude, but no aircraft identification capability

S Transponder — Mode S, including both pressure altitude and aircraft identification capability

X Transponder — Mode S with neither aircraft identification nor pressure-altitude capability

Note : Enhanced surveillance capability is the ability of the aircraft to down-link aircraft derived data via a Mode S transponder.

ADS-B

B1 ADS-B with dedicated 1 090 MHz ADS-B “out” capability¹

B2 ADS-B with dedicated 1 090 MHz ADS-B “out” and “in” capability¹

U1 ADS-B “out” capability using UAT

U2 ADS-B “out” and “in” capability using UAT

V1 ADS-B “out” capability using VDL Mode 4

V2 ADS-B “out” and “in” capability using VDL Mode 4

3 Additional information

The capability of your aircraft transponder, and ADS-B capability, will typically be available in the transponder manual, or in the aircraft flight manual for the aircraft. For General Aviation aircraft, the most common configurations for filing in the flight plan item10b will be (listed in order of capability).

EB1 – An ADS-B equipped aircraft would typically file this to indicate the Mode S transponder capability with ADS-B out.

S – The majority of Mode S transponders (without ADS-B) will support pressure altitude information and Flight ID transmission.

C – For aircraft with an older Mode A/C transponder – most of which provide pressure altitude capability.

Less common configurations in General Aviation will include:

¹ Based on current version of ICAO Doc 4444

H, LB1 or LB2 – Enhanced surveillance capability is more usually associated with higher end aircraft. ADS-B IN (B2) is relatively rare at this time, but may be available for some aircraft.

I, P or X – Most Mode S transponders will support Flight ID and pressure altitude, so these configurations are not common.

A – some low end GA aircraft may not provide pressure altitude information.

U1 or U2 – these ADS-B technologies are only authorized in a limited number of countries in the Asia Pacific Region.

Planning designations not to be used in Asia Pacific:

V1 or V2 – these ADS-B technologies are not authorised for use in Asia Pacific Region.

Remember:

Always flight plan the correct surveillance capability for your aircraft. If in doubt, consult the transponder manual, aircraft flight manual, or your Licenced Aircraft Maintenance Engineer.

Checklist of Common Items or Parameters for the Monitoring of ADS-B System

1 ADS-B Ground Station

Site Monitoring

- Receiver Sensitivity
- Antenna Cable
- GPS Health
- Coverage Check
- Probability of Detection
- Station Service Availability
- Receiver Status

Remote Control & Monitoring (RCMS)

- CPU Process Operation
- Temperature
- ASTERIX Output Load and Link Status
- Time Synchronization
- GPS Status
- Power Status
- Site Monitor Status
- Memory Usage
- Software Version (Operating System and RCMS Application)

Logistic Support Monitoring

- Record all failures, service outage and repair/return to service times

2 ADS-B Equipage Monitoring

- Update and maintain list of ADS-B equipped airframe details database
- Identify aircraft non-compliant to regional mandate

3 ADS-B Avionics Monitoring

- Track Consistency
- Valid Flight ID
- Presence of NACp/NIC/NUC Values
- Presence of Geometric Altitude
- Correctness of ICAO Aircraft Address

- Avionics Configuration and Connections
- Update and maintain list of aircraft with faulty avionics

4 ADS-B Performance Monitoring

- Percentage of aircraft with good integrity reports
- Accuracy of ADS-B Horizontal Position (Based on a reference sensor)
- Deviation between Geometric and Barometric Height
- Monitor the number of position jumps
- Message interval rate

5 ADS-B Display on ATC Display

- Split Track – ADS-B reported position might be off
- Coupling Failure – Wrong aircraft ID
- Duplicated ICAO Aircraft Address
- Display of data block

BASELINE ADS-B SERVICE PERFORMANCE PARAMETERS

The following table provides guidelines for various performance requirements of ADS-B Category (Tier) 1, 2 or 3 services that States may consider when acquisition of an ADS-B managed service agreement with a service provider:

Service Parameter	Guidance	Category 1 (Tier 1) 5Nm separation capable commensurate with Radars (separation/vectoring/high performance with reliability, integrity & latency)	Category 2 (Tier 2) Situational awareness similar to ADS-C (safety-net alerts, SAR, supports procedural separation without voice, not 5nm separation)	Category 3 (Tier 3) Position Reporting with Enhanced Flight Operation
Aircraft Updates	Recommended	0.5 second < Interval < 5 seconds as Operationally required	0.5 second < Interval < 20 seconds as Operationally required	0.5 second < Interval < 60 seconds as Operationally required
	Maximum	0.5 second < Interval < 10 seconds as Operationally required		
Network Latency	Recommended	95%: < 2 seconds of receiver-station output	95%: < 15 seconds of receiver-station output	95%: < 60 seconds of receiver-station output
Reliability 1	Recommended	2 autonomous receiver-stations including antenna, each providing data, no common point of failure	1 unduplicated receiver-station including antenna	1 unduplicated receiver-station including antenna
Reliability 2 - MTBF	Recommended	Each receiver-station including antenna to have MTBF >10,000 hrs	Each receiver-station including antenna to have MTBF >10,000 hrs	Each receiver-station including antenna to have MTBF >10,000 hrs
Reliability – Communications Infrastructure	Recommended	Completely duplicated, no common point of failure	Unduplicated, MTBF > 400 hrs	Unduplicated, MTBF> 200 hrs
Reliability – Total ADS-B Service	Recommended	Total Service MTBF >50,000 hrs	Total Service MTBF > 400hrs	Total Service MTBF> 200 hrs
Availability – Total ADS-B Service	Recommended	Total Service Availability > .999	Total Service Availability >.95	Total Service Availability >.90

Service Parameter	Guidance	Category 1 (Tier 1) 5Nm separation capable commensurate with Radars (separation/vectoring/high performance with reliability, integrity & latency)	Category 2 (Tier 2) Situational awareness similar to ADS-C (safety-net alerts, SAR, supports procedural separation without voice, not 5nm separation)	Category 3 (Tier 3) Position Reporting with Enhanced Flight Operation
Integrity – Ground Station	Recommended	Site monitor System Monitoring	Site monitor System Monitoring	System Monitoring
	Minimum	System Monitoring	Not required	Not required
Integrity – Data Communications & Processing	Recommended	All systems up to ATM system, errors < 1 x 10E-6	All systems up to ATM system, errors < 1 x 10E-6	All systems up to ATM system, errors < 1 x 10E-6

The choice of category (tier) could be based upon a number of factors including the following,

- a) The desired service
- b) The available budget
- c) The available ATC automation system & its capabilities and/or interim display systems
- d) ATC training and ratings
- e) Availability of appropriately tailored ATC procedures

States could initially choose one level and transition to another at a later time. For example, Category (Tier) 2 could be used to add additional safety nets/situational awareness and gain operational experience during the initial stage, moving later to a full separation service using Category (Tier) 1.

Note: The Performance Based Surveillance Sub Group of the ICAO Surveillance Panel is reviewing performance standards for surveillance systems generally. A future update to the requirements in the above table may be based on the outcomes of that panel.

**GUIDANCE MATERIAL ON
GENERATION, PROCESSING & SHARING of ASTERIX
CATEGORY 21 ADS-B MESSAGES
(Including Attachments A, B, C & D)**

1. INTRODUCTION

1.1 The “All Purpose Structured Eurocontrol Surveillance Information Exchange” (ASTERIX) Category 21 is a data format standard globally accepted by the Air Traffic Management (ATM) system manufacturing industry for sharing of ADS-B data with ATM automation system.⁸ Asterix Category 21 data is used to convey ADS-B data from ADS-B receiver stations to ATC processing and display system. This guidance material discusses various aspects of this process. Since the ASTERIX Category 21 edition 0.23 was issued in November 2003, it has undergone continuous revisions with some 19 subsequent editions. The focus of this guidance material is to concentrate on 1090ES ADS-B data using:

- a) RTCA DO-260 (Version 0);
- b) RTCA DO-260A (Version 1); and
- c) RTCA DO-260B (Version 2)

1.2 The ASTERIX Category 21 edition 1.0 issued in August 2008 fully incorporated the DO260A standard while edition 2.1 issued in May 2011 fully incorporated the latest DO260B standard. The latest edition (as at April 2018) is edition 2.4.

2. ASTERIX CAT 21 IN ASIA AND PACIFIC REGIONS

2.1 To ensure interoperability of ADS-B receiver stations in the Asia Pacific (ASIA/PAC) Regions, during the 16th APANPIRG Meeting held in August 2005, the ASTERIX Category 21 edition 0.23 which had incorporated DO260 standard was adopted as the baselined ADS-B data format for deployment of ADS-B receiver stations and sharing of ADS-B data in the ASIA/PAC Regions. At that time DO260A and DO260B standards were not defined.

3. CHOICE OF ASTERIX VERSION NUMBER

3.1 The Asterix standard has been developed over many years. Stability in the standard is desirable so that ADS-B receiver station designers and ATM automation designers and manufacturers can build interoperable systems with confidence. Because ADS-B technology has been evolving over the years, and will continue to do so, it is not surprising that the Asterix standard has also developed along with the ADS-B link technology standards to grasp the best benefits of its intended design.

3.2 During 2005, Asia Pacific decided to use Ed0.23 as the edition for sharing ADS-B data between states. This version provides adequate information so that useful ATC operational services can be provided including ATC 3 nautical mile and 5 nautical mile separation services. Ed0.23 can be used with DO260, DO260A and DO260B ADS-B avionics/receiver stations to provide basic ATC operational

⁸ FAA utilise Asterix Cat 33 for ADS-B message distribution.

services. However, Ed0.23 cannot fully support all the capabilities offered by DO260A and DO260B.

3.3 Nearly all Ed0.23 data items can be “re-constructed” from a received Ed2.1 data stream. However, most of the special DO260A/B data items cannot be “re-constructed” from an Ed0.23 data stream. In terms of domestic use and data sharing with other ANSPs concerning ADS-B data, several options exist for ANSPs as follows:

Option	Domestic use	Data sharing
1	Ed0.23	Ed0.23. This is the default and basic standard.
2	Ed2.1	Ed0.23. This will require some conversions to occur, probably through an ADS-B format conversion and filter system (see Paragraph 11), between a domestic system and a foreign system. Difficulties may exist if the domestic ATM system requires special DO260A/B data items, since they cannot all be re-constructed from the external foreign Ed0.23 data stream.
3	Ed2.1	Ed2.1. Must negotiate bilaterally with data sharing partner regarding exact version to be used to achieve the intended functions.

Note: In this table, Ed2.1, a later DO260B compliant Asterix Cat 21 edition, is chosen as a representation of an Asterix Cat 21 edition after Ed0.23. There exists other Asterix CAT 21 editions (e.g. 0.26, 1.3, 2.4 etc.) after Ed0.23 that could be used by ANSPs for domestic and data sharing use.

4. SPECIFICATION OF ASTERIX MESSAGE PROCESSING

4.1 Care is needed to understand the difference in specifications :

4.2 **Asterix Cat 21:** Defines the characteristics of the data ON the interface including fields that are mandatory on the interface.

4.3 **ADS-B receiver station specifications:** To define the Asterix standard, the ANSP must also define which optional Asterix data items are required to be delivered on the Asterix interface, when the appropriate data is received from the aircraft. It is desirable that suppliers be required to:

- a) indicate how the receiver station processes and outputs every received DO260, DO260A and DO260B data element into an Asterix data element/field; and
- b) indicate which and how each Asterix data element and field presented at the output are populated.

4.4 **ATM automation system specifications:** Defines which received Asterix data element and fields are processed and how they are processed. Also defines which Asterix optional data fields are required by the ATM automation systems (if any). ANSPs that specify ADS-B receiver stations and ATM automation systems need to consider carefully and clearly about what they desire to achieve. Specifications which simply require compliance with a particular Asterix edition will be inadequate in most circumstances. In particular ANSPs, together with their suppliers should :

- a) Specify the Asterix standard edition to be used. This defines the message formats that are placed on the link between ADS-B receiver station and downstream systems like ATM automation, recording & analysis systems, bypass ATC systems and foreign ANSPs. The edition will define which messages elements are mandatory in each message (very few fields) and a large number of optional fields. The optional fields can only be filled if relevant data is received from the aircraft. The optional fields will only be filled if the receiver station specification requires them to be filled.
- b) Specify the ADS-B receiver station behaviour so that when data is received from the aircraft, the receiver station is required to fill appropriate optional Asterix data fields.
- c) Specify the ATM automation system behaviour including appropriate semantic and syntax checks applied to the Asterix data, including any triggers for the system to discard data. The processing applied to each received Asterix data field should be specified. The ATC system should discard any messages with unexpected Asterix categories without discarding messages with known and defined Asterix categories.

5. MANDATORY FIELDS : ASTERIX AND 1090ES ADS-B

5.1 Asterix Cat 21 has been designed to support multiple datalinks. It has been defined to support data fields which are not available in the 1090ES standards. Therefore some data items and fields are not relevant when 1090ES is used.

5.2 The standard itself defines various items as optional or mandatory. This is defining what is ON the interface. It does NOT specify the behaviour of the transmitting receiver station nor the behaviour of the receiving ATM automation system.

5.3 When a single link technology has been chosen it may be sensible to diverge from the formal Ed0.23 standard to reduce the required Asterix datalink bandwidth. E.g.: in an environment with only 1090ES, it is unnecessary to transmit “Link Technology Indicator”. Asterix Cat 21 Ed 2.1 allows this selection.

Data Items	Description	Mandatory (M) or Optional (O) items as per ASTERIX Category 21	
		Version 0.23 Specification	Version 2.1 Specification
I021/010	Data Source Identification	M	M
I021/030	Time of Day	M	N/A
I021/071 or I021/073	Time of Applicability of Position or Time of Message reception for position	N/A	One of these is must be transmitted
I021/040	Target Report Descriptor	M	M
I021/080	Target Address	M	M
I021/210	Link Technology Indicator/MOPS version	M	O

6. GENERATION OF ASTERIX AT AN ADS-B RECEIVER STATION

6.1 The following general principles should be adopted:

6.2 Commensurate with link bandwidth availability, transmit all mandatory Asterix data items and also transmit those Asterix data items that are operationally desirable. That is, when the appropriate aircraft transmission is received by the ADS-B receiver station, the data should be transmitted to the ATC system for operational use or for technical recording and analysis use. If no aircraft transmission data is received to fill an Asterix data item during any update cycle, the data item should not be included in the Asterix data stream to reduce bandwidth requirements.

6.3 **Group 1 (Mandatory Data Items):** An Asterix Cat21 message should not be transmitted unless the mandatory data items defined in Appendix A are all present.

6.4 **Group 2 (Desirable Data Items) :** The data items defined in Appendix B are operationally desirable which should always be transmitted in the Asterix Cat 21 messages whenever the data are received by the 1090ES receiver station from aircraft (if allowed by the relevant Asterix standard chosen).

6.5 **Group 3 (Optional Data Items) :** The data items defined in Appendix C are considered optional and may or may not need to be transmitted depending on availability of such data from aircraft and/or other specific operational needs.

6.6. **Group 4 (Future Data Items):** The following data are defined in the DO260A and DO260B standards but are not yet defined in the Asterix standard. This group is provided for information only. It illustrates the need for system designers to provide for future adaptability when possible and when cost effective to do so. Not only will the Asterix standard continue to evolve, but changes to DO260 can also be anticipated within the decade.

- a) Target heading: Information from DO260A/B Target state and status messages (On condition messages). These could be used for detection of pilot

errors in selection of heading/altitude; and

- b) GPS Offset: Could be used to more accurately display aircraft position on an airport surface, or better detect that an aircraft has passed an airport hold point.

6.7 When developing a specification for an ADS-B receiver station, it is considered necessary that the specification requires the transmission of all data items that are operationally desirable (Group 2), when such data are received from the aircraft, in addition to the data items that are mandatory (Group 1) in Asterix messages. Whether Group 3 optional data items will need to be transmitted or not should be configurable on item-by-item basis within the ADS-B receiver station depending on specific operational needs.

7. PROCESSING OF ASTERIX ADS-B DATA AT THE ATC SYSTEM

7.1 An Asterix Cat21 message should not be accepted by the ATC system for processing unless it includes at least all the Group 1 data items.

7.2 The ATC system should process all received Asterix Cat21 message data items that bring operational benefits (i.e. Group 2 data items). An ATM automation specification should require that the system appropriately process those Group 2 data items depending on specific operational need. Whether the ATC system will process Group 3 optional data items will depend on specific operational needs.

8. DATA SHARING OF ASTERIX ADS-B DATA

8.1 In principle, all data receiving from the shared ADS-B receiver station should be delivered to the receiving party as far as practicable without filtering, unless owing to technical reasons such as the need to convert the data from one ASTERIX format to another, or it is requested by the receiving party of the data.

8.2 It is considered necessary that all data items that are mandatory in Asterix messages (i.e. Group 1 data items) and operationally desirable (i.e. Group 2 data items) when such data are received from aircraft, should be included in data sharing. In the event that the data have to be filtered, the list of optional data items (i.e. Group 3 data items) needs to be shared will be subject to mutual agreement between the two data sharing parties concerned.

9. ISSUE RELATED TO DO260A

9.1 Support of DO260A using Asterix Cat 21 Ed0.23

- a) DO260A was developed after Ed0.23 of Asterix was defined. Therefore, Ed0.23 does not directly support DO260A. However, receiver station software can generate useful Ed0.23 Asterix data from DO260A reports through use of the following techniques;

- b) A useful I021/090 Figure of Merit can be generated from DO260A messages. Some implementations have a table, which defines the FOM/PA to be generated for each combination of SIL, NIC and NAC. The contents of the table can be offline defined to generate the appropriate FOM/PA values. The downstream ATC system can then process DO260A reports as if they were DO260 reports; and
- c) If there is a particular need for the ATC system to have access to the NIC/NAC or SIL or other data item that exist in DO260A (but not in DO260), then users may need to consider a more recent version of Cat 21.

9.2 Support of DO260A using Asterix Cat 21 Ed 1.0 or Ed2.1 (or later versions)

- a) When DO260A is used, then the ANSP could decide to use Asterix Cat 21 Ed1.0 (or later versions) or Ed2.1 (or later versions); and
- b) Readers are invited to carefully examine the DO260A fields (see Appendix D) to determine if the benefits of additional DO260A fields are large enough to warrant adoption of Asterix Cat 21 Ed1.0 (or later versions) or Ed2.1 (or later versions).

10. ISSUE RELATED TO DO260B

10.1 Support of DO260B using Asterix Cat 21 Ed0.23

- a) DO260B was developed some years after DO260A. Therefore, Asterix Cat 21, Ed0.23 does not directly support DO260B;
- b) The same techniques used for processing DO260A can be used for processing DO260B, however, the table used must account for NIC supplement B & NIC supplement C, and may also wish to account for SDA; and
- c) If there is a particular need for the ATC system to have access to the new data items offered by DO260B, then users may need to consider a more recent version of Cat 21 (e.g. Ed2.1 or later versions).

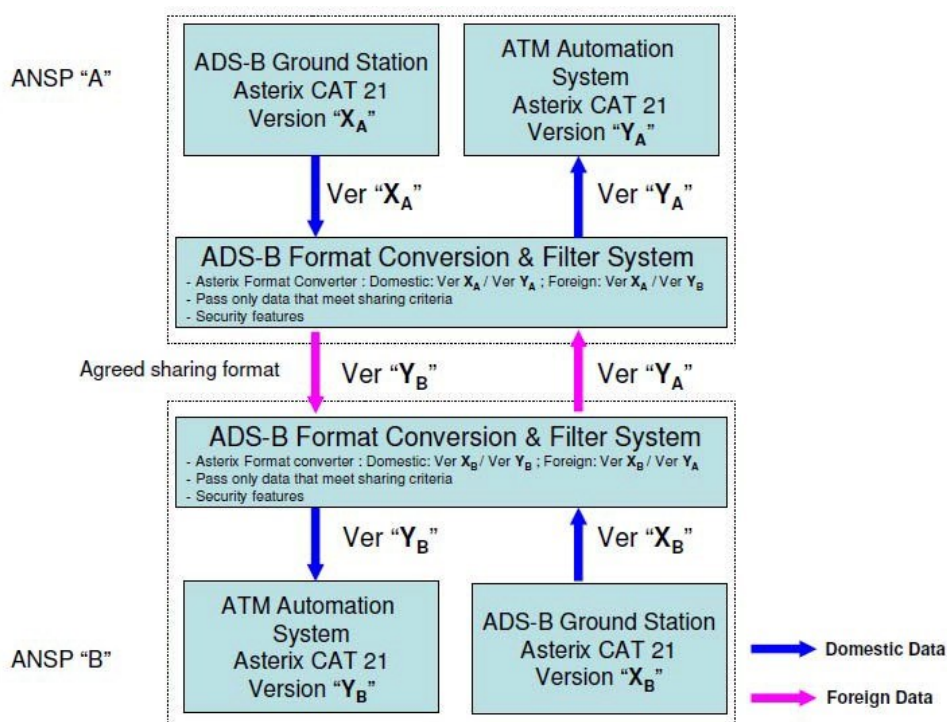
10.2 Support of DO260B using Asterix Cat 21 Ed2.1 or later versions

- a) If DO260B is used, then the ANSP could decide to use Asterix Cat 21 Ed2.1 or later; and
- b) Readers are invited to carefully examine the DO260B data items (see Appendix D) to determine if the benefits of additional DO260B data items are large enough to warrant adoption of Asterix Cat 21 Version 2.1 or later.

11. ADS-B FORMAT CONVERSION AND FILTER SYSTEM

11.1 It is clear that the evolution of 1090ES ADS-B transmission will continue. Avionics software will be upgraded to provide additional or changed functionality. As a result Asterix standards will also continue to evolve, and ATC systems will need to be adaptable to be able to cope with new functionality requirements and new message standards.

11.2 The use of an ADS-B format conversion & filter (ADS-B FC&F) system between domestic ADS-B systems and data shared with other states is a cost-effective way to provide the necessary protection and flexibility in this evolution. Such a system provides ADS-B format conversion between domestic and foreign ADS-B systems. While decoupling one ADS-B Asterix environment from another, the system allows information that meets specific sharing criteria to be passed through for data sharing. By doing so, loading on the ATM automation systems to process ADS-B data and bandwidth requires to transmit the ADS-B data could then be reduced. The system also allows independent domestic format changes without disruption to the foreign environment. A typical structure could be as shown below:



7 Attachment A - Group 1 (Mandatory Data Items)

Data Items	Description	Ed 0.23	Ed 2.1	Remarks
I021/010	Data Source Identification	X	X	Identifies source of data. Important if validity checks are performed as an anti spoofing capability. Validation that the data is received from an approved ADS-B receiver station. Data received from a receiver station should not be processed if the position of the reported aircraft is an unreasonable distance away from the known location of the ADS-B receiver station. Where space based ADS-B is used and a nominal station location is defined, such range processing limits will need to account for the coverage supplied.
I021/030	Time of Day	X		Necessary to extrapolate the ADS-B data to time of display. Data received with a Time of Day too far in the past should be discarded. This data is too old.
I021/071 or I021/073	Time of Applicability of Position or Time of Message reception for position		X	Necessary to extrapolate the ADS-B data to time of display. Data received with a Time of Day too far in the past should be discarded. This data is too old.
I021/040	Target Report Descriptor	X	X	Indicates if report is a duplicate, on the receiver, is a simulated target, is a test target. This needs to be checked by ATC system prior to processing. If the data indicates that the report is a test target or a simulated target, it is normally processed differently to "real" targets.
I021/080	Target Address	X	X	Included in all 1090ES downlink messages, so always available. Used for report/report linkage in ATC tracking.
I021/090	Figure of Merit/Quality Indicators	X	X	Position cannot be used without quality indicator. If the quality of the positional data does not meet the requirements the data should be discarded.
I021/130	Position in WGS-84 co-ordinates	X	X	Report cannot be used without position

Attachment B - Group 2 (Desirable Data Items)

Data Items	Description	Ed 0.23	Ed 2.1	Remarks
I021/008	Aircraft operational status		X	TCAS capability, Target state reporting capability, CDTI capability, Single/dual aircraft antenna. It is desirable to have immediate knowledge of RA event.
I021/020	Emitter Category	X	X	Aircraft or vehicle type
I021/140	Geometric Altitude/Height	X	X	Useful for RVSM monitoring. Not normally used for ATC application. Could perhaps be used as an indicator of correct QNH setting in aircraft.
I021/145	Flight Level	X	X	Flight level is an important information to ATC
I021/155	Barometric Vertical Rate	X	X	Used for predictive tools and safety nets. Either Barometric vertical rate or Geometric vertical rate is provided by the aircraft – not both. However, the ATC system can calculate vertical rate from multiple flight level reports if these data items are not available.
I021/157	Geometric Vertical Rate	X	X	
I021/160	Ground Vector	X	X	Provides excellent vector to support extrapolation of positional data to time of display. However, the ATC system can calculate the velocity vector (ground vector) from multiple position reports. I021/160 however, is normally far superior than ATC system calculation.
I021/170	Target Identification	X	X	This is the callsign/Flight ID is extremely useful for ATC and matching to the flight plan (if any). Target identification is only sent once per 5 seconds. Some receiver stations designs attach the target identification (if known from previous recent downlinks) even if not received in the last 5 seconds. The field can be missing at the edge of ADS-B coverage – for flights inbound to coverage.

I021/200	Target Status	X	X	This is the emergency type and is highly desirable.
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Attachment C - Group 3 (Optional Data Items)

Data Items	Description	Ed 0.23	Ed 2.1	Remarks
I021/077	Time of report transmission		X	Time of applicability is relevant for ATC system processing. Time of transmission is less relevant.
I021/032	Time of Day Accuracy	X		Maximum error in Time of day. Normally the maximum value is known by the ANSP because of station design.
I021/095	Velocity Accuracy	X		If using GPS, velocity accuracy will be adequate if the Position quality is accurate.
I021/072	Time of applicability of velocity		X	Can be managed by a velocity data time out in receiver station.
I021/075	Time of message reception of velocity		X	Normally velocity is in the same Asterix message as position. Velocity data time out in receiver station.
I021/161	Track number		X	Tracking can be performed by ATC system. Also the 24 bit code (aircraft address) could be used as a pseudo track number.
I021/110	Trajectory Intent	X	X	Defined in DO260 but not transmitted by any known product. Not defined in DO260A or DO260B
I021/146	(Intermediate) Selected Altitude	X	X	Target altitude : Information from DO260A/B Target state and status messages (On condition messages). These could be used for detection of pilot errors in selection of heading/altitude.
I021/148	Final State Selected Altitude	X	X	
I021/015	Service identification		X	Type of Service (VDL4, Ext Squitter, UAT, TIS-B VDL4, TIS-B Ext Squitter, TIS-B UAT, FIS-B VDL4, GRAS VDL4, MLT). Not useful to most ATC systems.
I021/016	Service management		X	Update rate or whether data driven output from GS. Normally known by receiver.

Data Items	Description	Ed 0.23	Ed 2.1	Remarks
I021/074	Time of message reception of position – high resolution		X	High resolution is designed to support MLAT system processing by receiver. Not required for pure ADS-B.
I021/076	Time of message reception of velocity – high resolution		X	High resolution is designed to support MLAT system processing by receiver. Not required for pure ADS-B.
I021/210	MOPS version/ Link Technology Indicator	X	X	Maybe useful for statistics about equipage. Not operationally relevant
I021/070	Mode 3/A code		X	Could be used for legacy ATC system that do not use Flight ID
I021/165	Rate of Turn/Track Angle rate	X	X	Not transmitted in DO260, DO260A or DO260B messages
I021/271	Surface capabilities and characteristics		X	
I021/132	Message amplitude		X	Useful for technical analysis. Not operationally relevant
I021/250	Mode S MB data		X	
I021/260	ACAS resolution advisory report		X	
I021/400	Receiver ID		X	
I021/295	Data ages		X	
I021/150	Air Speed	X	X	Defined in standards but only sent in absence Ground vector information. Can't be used for extrapolation unless wind speed known.
I021/151	True Air Speed	X	X	
I021/152	Magnetic Heading	X	X	Defined in standards but only sent in absence Ground vector information.
I021/220	Met Report	X	X	Not transmitted in DO260, DO260A or DO260B messages
I021/230	Roll Angle	X	X	Not transmitted in DO260, DO260A or DO260B messages
I021/131	Position in WGS-84 coordinates, high resolution		X	

Attachment D - Differences among DO260, DO260A, DO260B

	DO-260	DO-260A	DO-260B	Availability of data in Asterix CAT 21	Potential uses of additional information
Introduction of Navigation Integrity Category (NIC) to replace Navigation Uncertainty Category (NUC _P)	NUC _P is used.	NIC is used to replace NUC _P .	More levels of NIC available. Vertical component removed.	NIC is shown in Ed1.0 and above. More levels of NIC (shown as PIC) are available in v2.1.	The additional quantum levels of NIC would allow the ANSP more flexibility in deciding whether the NIC is considered as 'good' (if required) However, for 3 NM & 5 NM separation with HPL 1Nm and 2 Nm respectively, this additional quantum is not useful.
Quality Indicator for Velocity (NUC _R and NAC _V)	NUC _R is used.	Replaced with NAC _V . Definition remains the same.	Vertical component removed.	Available in Ed0.23 and above.	Vertical component is not available for DO260B.
Surveillance Integrity Level and Source Integrity Level (SIL)	Not available.	Surveillance Integrity Level is used.	Renamed as Source Integrity Level. Definition is changed to exclude avionics fault.	Available in Ed1.0 and above.	The SIL will allow the user to further assess the integrity of the reported position (if required). NB: An implied SIL exists for DO260 aircraft if they always use GPS. However DO260 aircraft do not provide SIL.
System Design Assurance (SDA)	Not available.	Not available.	To address probability of avionics fault.	Available in Ed2.1.	The SDA will indicate the robustness of the system. ANSPs may decide on a minimum SDA for ADS-B services. If this action is taken then DO260 and DO260A aircraft will be unable to meet the criteria.

	DO-260	DO-260A	DO-260B	Availability of data in Asterix CAT 21	Potential uses of additional information
Navigation Accuracy Category (NAC _P)	Not available.	Derived from HFOM and VFOM.	Relies only on HFOM.	Available in Ed1.0 and above.	A reported accuracy is not provided by DO260. However, an estimated accuracy can be derived from NUC – assuming that NUC is HPL based.
Geometric Vertical Accuracy (GVA)	Not available.	Not available.	Derived from VFOM.	Available in Ed2.1.	Geometric altitude accuracy is not normally required for operational purposes.
Barometric Altitude Integrity Code (NIC _{BARO})	Not available.	To indicate integrity of barometric altitude.	Same as DO-260A	Available in Ed1.0 and above.	The NIC _{BARO} indicates the integrity of the barometric height. ANSPs could indicate to the controller that Barometric data has not been verified, however, aircraft without dual barometric systems/air data computers may be unable to provide a non zero NIC _{BARO} as data could be unnecessarily discarded.
Length / Width of Aircraft	Not available.	Provide an indication of aircraft size.	Same as DO-260A	Available in Ed1.0 and above.	The width / length indicate the size of the aircraft. This information may be used as an input for generating alerts on airport surface movement control.

	DO-260	DO-260A	DO-260B	Availability of data in Asterix CAT 21	Potential uses of additional information
Indication of capabilities	Only show status of TCAS and CDTI.	More information available including capability to send Air Reference Velocity, Target State and Trajectory Change reports. Status of Identity Switch.	Additional information on type of ADS-B in (i.e. 1090ES in or UAT in).	Available in Ed1.0 and above, except availability of 1090ES/UAT in and information on GPS antenna offset.	Indication on the availability of 1090ES in / UAT in may allow the controller to anticipate a potential request for in-trail procedure clearance. NB: ITP requires decision support aids which are more complex than ADS-B IN alone.
Status of Resolution Advisory	Not available.	Information on whether Resolution Advisory is active.	Same as DO-260A	Available in Ed1.0 and above,	Indication of the resolution advisory status allows the controller to know whether the pilots were alerted about the potential conflict.
GPS offset	Not available.	Indication on whether GPS offset is applied.	Information on GPS antenna offset is provided.	GPS offset status is available in Ed1.0 and above. Information on GPS offset is not available in ASTERIX	Indication on GPS offset may be one of the inputs for generating alerts on airport surface movement control.
Intention	Not available.	Able to indicate intended altitude and heading.	Same as DO-260A	Intended altitude is available in Ed0.23. Intended heading is not available in ASTERIX.	The intended heading and flight level can be used as an input to the trajectory prediction algorithm in the Short-Term Conflict Alert.

	DO-260	DO-260A	DO-260B	Availability of data in Asterix CAT 21	Potential uses of additional information
Target Status	Not available.	Not available.	Indication of Autopilot mode, Vertical Navigation mode, Altitude Hold mode, Approach Mode and LNAV Mode.	Vertical Navigation mode, Altitude Hold mode and Approach Mode are available in Ed 0.23 and above LNAV Mode is available in Ed2.1	The target status allows the controller to know the mode that the aircraft is in. i.e.: It could be presented to ATC.
Resolution Advisory	Not available.	Not available.	Availability of Active Resolution Advisories; Resolution Advisory complement record, Resolution Terminated; Multiple Threat encounter; Threat Type indicator; and Threat Identity data.	Available in Ed1.0 and above.	The Resolution Advisory will help the controller know the advisories that are provided to the pilots by the ACAS. This helps prevent the controller from giving instructions that are in conflict with the ACAS.

	DO-260	DO-260A	DO-260B	Availability of data in Asterix CAT 21	Potential uses of additional information
Mode A	DO260 change 1, allows this using test message in USA only. This was not implemented in actual products.	Broadcasted using test message in USA only.	Broadcasted worldwide as a regular message.	Available in Ed0.26 and above.	The Mode A allows flight plans to be coupled with the ADS-B tracks (supports legacy ATM automation system).

Appendix 8

ATTACHMENT to State letter SP 44/2-19/77

GUIDANCE ON 1 090 MHZ SPECTRUM ISSUES AND PROPER MANAGEMENT OF 24-BIT AIRCRAFT ADDRESSES ASSOCIATED WITH UNMANNED AIRCRAFT (UA)

Note. — This document is an unedited advance version of an ICAO publication as approved in principle, by the Secretary General, which is made available for convenience. The final edited version will be included in the next amendment to the Aeronautical Surveillance Manual (Doc 9924), which will be published in due course.

1. Background

1.1 The frequencies 1 030 and 1 090 MHz, acting as a frequency pair, support several aeronautical surveillance systems including secondary surveillance radar (SSR), multilateration (MLAT), airborne collision avoidance systems (ACAS) and automatic dependent surveillance-broadcast (ADS-B). Aircraft are interrogated by ground SSR/MLAT (or other aircraft, in the case of ACAS) on 1 030 MHz and reply (or broadcast) on 1 090 MHz with information such as their position, altitude and velocity vector.

1.2 The increasing density of ground-based and on-board surveillance systems using the 1 030/1 090 MHz frequencies is currently raising concerns, especially in dense airspaces. Ultimately it may result in a reduction to the overall performance of ACAS as well as the SSR/MLAT and ADS-B systems. In addition, the increased usage of ADS-B OUT applications for safety of life services and potential future evolution of those applications, such as space-based ADS-B, have raised serious concerns of potential congestion at 1 090 MHz. To ensure continued safe operation for all aircraft, proper and efficient utilization of available bandwidth at 1 090 MHz is required. This may include, when necessary, limiting access to 1 090 MHz by certain users.

1.3 Furthermore, it is important to note that those aeronautical surveillance systems rely on a limited capacity 24-bit aircraft address scheme. The allocation of a 24-bit aircraft address and its correct configuration in aircraft is a key element for safe operation of aircraft and associated protocols used to support communication and surveillance systems.

1.4 As defined in Annex 10 — *Aeronautical Telecommunications*, Volume III — *Communication Systems*, aircraft addresses are allocated in blocks by ICAO to the State of Registry or to the common mark registering authority. Using its allocated block of addresses, the State of Registry or the common mark registering authority assigns an individual aircraft address to each suitably equipped aircraft entered on a national or international register.

1.5 It is essential for States to recognize that their allocated block of 24-bit aircraft addresses is a finite and valuable asset. There are only 16 777 214 aircraft addresses in total and many of those have already been allocated to States of Registry or common mark registering authorities. Aircraft traffic growth has been forecast to double in the next 15 years and to manage these addresses in a sustainable manner, States need to validate whether new aircraft address allocation requests by aircraft operators fit the conditions defined in Annex 10, Volume III.

2. Issues identified in relation to operation of unmanned aircraft

2.1 As described above, concerns are being raised about congestion of the 1 090 MHz frequency and shortage of 24-bit aircraft addresses. The rapid growth in the number of UA is making those concerns more severe.

2.2 Exponential increase of the safety risk due to 1 090 MHz congestion

2.2.1 A recent study indicates that large numbers of UA (one UA per 2 square kilometres) operating at low level (less than 500 feet above ground level) in a typical high-density terminal airspace (760 ADS B-equipped aircraft operating within a 200 NM radius and from ground level to FL180) can

interfere with ADS-B ground station reception of ADS-B reports when the transmit power of each UA is 1 watt or higher.

Note. — Some other studies indicate that even a low power (0.1W) transmission from large numbers of UA can reduce the coverage range of ADS-B.

2.2.2 All studies reviewed conclude that the operation of ADS-B OUT by a large number of UA raises a serious concern for the safety of other aircraft in the same airspace.

2.3 Future depletion of 24-bit aircraft addresses

2.3.1 The 24-bit aircraft address scheme was not designed for a very large number of aircraft. Some studies predict that based on the present growth of UA, there will be over a million such vehicles by 2025. Based on these current projections, it will be impossible to accommodate all UA in the current scheme.

2.3.2 In some situations UA may require a 24-bit aircraft address, for instance if the UA fly in controlled airspace or in proximity to traditional manned aircraft. States will need to evaluate such situations on a case-by-case basis when receiving a new aircraft address application from the UA community.

Note. — As described in the Manual on Remotely Piloted Aircraft Systems (RPAS) (Doc 10019), an aircraft which is intended to be operated with no pilot on board is classified as unmanned and an unmanned aircraft which is piloted from a remote pilot station is a remotely piloted aircraft (RPA) (refer to the following figure).

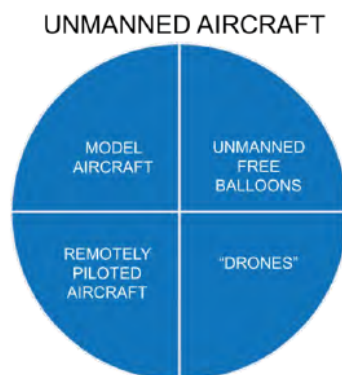


Figure 1-1 Unmanned aircraft

3. Procedure to ensure proper utilization of 1 090 MHz and for non-allocation of (24-bit) aircraft address for UA

3.1 There is increasing pressure to use 1 090 MHz Mode S or ADS-B OUT applications by UA. Given the large forecasted increase of UA and the fact that transmissions from their transponders or ADS-B OUT devices will impact the already congested use of 1 090 MHz by existing aeronautical surveillance and collision avoidance systems, States are urged to:

- 1) perform radio frequency spectrum analysis to analyse the degree of congestion of 1 090 MHz and, based on the outcome of this analysis, consider how 1 090 MHz ADS-B UA operations might impact the performance of the air navigation service provider (ANSP)-operated surveillance

systems in airspace of interest as well as the automatic collision avoidance systems on board aircraft operating in that airspace;

- 2) formulate the circumstances and define procedures to determine the potential requirement for 1 090 MHz ADS-B OUT equipage on UA in order to allow or prohibit such equipage as appropriate. During this process, States should consider:
 - the degree to which individual UA may or may not require air traffic services. For example, a UA operating in uncontrolled airspace may not be required to use ICAO-compliant aeronautical surveillance systems; and
 - the degree to which the operation of individual UA may or may not interoperate in the airspace with traditional manned aircraft. For example, if UA are not operating in proximity to traditional manned aircraft, then the use of ICAO-compliant aeronautical surveillance equipment by UA may not be justified.
- 3) in cases where UA are not required to equip with ICAO-compliant aeronautical surveillance equipment, States should not allocate 24-bit aircraft addresses.

Note. — 24-bit aircraft address allocation should be a part of the UA registration or operator approval process. For guidance material on reliable usage of 24-bit aircraft addresses, refer to Annex 10, Volume III and Doc 9924.

INTERNATIONAL CIVIL AVIATION ORGANIZATION

ASIA AND PACIFIC (APAC) OFFICE

Surveillance Study Group (SURSG)



STUDY REPORT

Surveillance Data Sharing - Feasibility Study Stage

- Implementation Model
- Infrastructure Model
- Business Model
- Participation Model
- Implementation Roadmap

China

Hong Kong, China

Republic of Korea

Singapore

Thailand

Viet Nam

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DRAFT

ACRONYMS AND ABBREVIATIONS

A-CDM	Airport Collaborative Decision Making
ADS-B	Automatic Dependent Surveillance - Broadcast
AIXM	Aeronautical Information Exchange Model
ANSP	Air Navigation Service Provider
APANPIRG	Asia/Pacific Air Navigation Planning and Implementation Regional Group
ASEAN	Association of Southeast Asian Nations
ASBU	Aviation System Block Upgrades
ASTERIX	All Purpose Structured Euro control Surveillance Information Exchange
ATFM	Air Traffic Flow Management
CONOPS	Concept of Operations
CRV	Common aeRonautical Virtual Private Network
CRV OG	CRV Operations Group
CTOT	Calculated Take Off Time
EMS	Enterprise Messaging Service
FIXM	Flight Information Exchange Model
GANP	Global Air Navigation Plan
IWXXM	ICAO Meteorological Information Exchange Model
MET	Meteorological
MLAT	Multilateration
MQ	Message Queue
NUC/NIC	Navigation Uncertainty Category/Navigation Integrity Category
POC	Proof of Concept
SAC	System Area Code

SCDP	Surveillance Central Data Processor
SDDS-NG	Surveillance Data Distribution Solution Networking Group
SIC	System Identification Code
SLA	Service Level Agreement
SURICG	Surveillance Implementation Coordination Group
SURSG	Surveillance Study Group
SWIM	System Wide Information Management
SWIM TF	SWIM Task Force

Chapter 1: IMPLEMENTATION MODEL (TASK 2-2)

1.1 Introduction

- 1.1.1 SWIM could be the key driver to the implementation of surveillance data sharing as the SWIM platform can be adapted to realize data sharing across different States, in addition to the exchange of expected SWIM data traffic such as FIXM, AIXM, and IWXXM messages. Working papers in relation to collaboration in sharing of surveillance data in SWIM presented to SWIM TF/4 (WP/13) and CNS SG/24 (WP/22) are highly relevant to this chapter.

This chapter focuses on the implementation approach and practical implementation models with particular air traffic control operation identified and infrastructure services required to realize surveillance data sharing. This chapter also considers the system design and collaboration model expected for implementation of surveillance data sharing.

1.2 Implementation Philosophy

- 1.2.1 “Bottom up” and “Starting small and simple” – ADS-B data to be shared

- a) To align with the philosophy and roadmap for implementation of SWIM in APAC, the same incremental approach (i.e. starting small and simple) will be leveraged for surveillance data sharing in SWIM. With focus on one operation selected to benefit from surveillance data sharing, the infrastructure and associated information service would be identified and implemented to efficiently support the operation. Where the first implementation of surveillance data sharing of ADS-B data proves feasible and beneficial, sharing of other types of surveillance data may take reference from and be leveraged on the mechanism and infrastructure established for the previous case.
- b) Given data ownership, concerns and considerations of potential contributors of other surveillance data types, a one-size-fits-all model capable of catering to multiple surveillance data types would be too complex and with too many considerations to render this Study Report easily readable and its proposed sharing model implementable since an all-encompassing model would imply elaborate and extensive ground works, infrastructure, papers, documentation and agreements to be sorted out first. Unless most other surveillance data types, ADS-B data is self-initiated and broadcast to all by aircraft and is easier to be shared with well-established data format standard. Therefore the scope of this study is devoted to the sharing of ADS-B data.
- c) Currently, ADS-B CAT 21 Version 2.1 format has been the common standard in the aviation community since its publishing in 2011. While for the sake of compatibility it may be tempting to specify the upcoming or a list of legacy versions in this Study Report, such a comprehensive approach would be discouraging to potential data contributors and could complicate matters with extra version conversion efforts, which would add to data latency and lead to potential query of data integrity due to extra processing and conversion. It is best to aim for one standard version of ADS-B data in the implementation. Where a data contributor's data is of a different version, such data should not be rejected however, since in the publish-n-subscribe mechanism of SWIM and its service registry, a data recipient should be fully aware of the data version although it is desirable that a single standard prevails in the surveillance data sharing scheme without an intervening version conversion service to be provided by a the data contributor or a 3rd party.

- 1.2.2 Start with Particular Operational Application - ATFM

Air Traffic Flow Management (ATFM) is an application that could benefit from surveillance data sharing to facilitate air traffic planning, particularly as its demand on target update rate is much relaxed (as far apart as in minutes) than, say, ATC (normally within 8 seconds), which otherwise could have called for strong commitments from data contributors on data reliability and timeliness, which could dissuade a potential data contributor from participating. Even if it is not expected that at start of the surveillance data sharing initiative with contiguous coverage from departure to destination across FIRs, surveillance data showing nearly real-time take-off time would be of strong interest to the ANSPs of the concerned arrival/en-route flights.

1.3 Required Infrastructure and Information Service – SWIM over CRV

1.3.1 ToR of SURSG – a part of the ToR is the study on the “Sharing of Surveillance Data in SWIM”, for which CRV has been endorsed as the carrier of SWIM data at CRV OG/5 and SWIM TF/3 meeting, it is therefore assumed that SWIM over CRV is the platform on which this Study is based considering that the CRV is a flexible, trusted, secure, well-governed (by CRV OG) and well-maintained network infrastructure, which is **already existent** with a user base of 16 subscribers (as at 23 December 2021) and growing.

1.3.2 Assumptions:

- a) No assumption is made that CRV is the sole network capable of supporting the sharing of surveillance data but a practical assumption is made that the establishment of a separate, trusted and secure network for surveillance data sharing, even if built upon the Internet, would still require heavy commitments (costs and resources), involvement by active participants and guidance from ICAO APAC to ensure a reliable, well governed and well maintained network system and adequate bandwidth, which are already available under CRV.
- b) While SWIM information services such as service discovery, governance, Certificate Authority (CA) services and applications are yet to be realized, a reasonable assumption is made that a somewhat rudimentary implementation of surveillance data sharing is possible at start without SWIM and the implementation could be assimilated into the SWIM environment as the SWIM services and applications become available over time.
- c) An assumption is also made that the sharing of surveillance data (not just ADS-B data) in SWIM over CRV would secure the endorsement at a suitable time. It is envisaged that SWIM over the readily accessible CRV be the means to share the surveillance data such that States could benefit from SWIM initiatives without high initial investment cost for a new platform and development expense of traditional systems.
- d) The readiness of the infrastructure and information service for implementation of surveillance data sharing is highly dependent on the implementation of SWIM. Insofar as this Study Report covers the various facets of sharing of ADS-B data in SWIM over CRV, no assumption is made that ADS-B data sharing could only commence when the supporting infrastructure and services are mostly available given the developing status of SWIM in APAC. It is also possible that sharing of ADS-B data could be migrated to SWIM as SWIM takes onto a substantial status of development.

1.4 Consideration of System Design – Hybrid SWIM Model

1.4.1 The SWIM infrastructure for surveillance data sharing could be implemented in either Distributed Model, Centralized Model and/or Hybrid Model (details in Chapter 2). By taking into account the efficiency and effectiveness of the implementation (again “starting small and simple” philosophy), Hybrid Model, representing the coexistence of ANSPs operating their own EMSes (Distributed Model) and ANSPs accessing centralized SWIM services provided by

government or commercial concerns (Centralized Model) is considered a suitable model. In gist, the Hybrid Model:

- a) can cater to States with different levels of commitment to SWIM from operating their own EMSes (Distributed Model) to accessing SWIM services via centralized services provided by a 3rd party (Centralized Model); and
- b) more importantly, allows for potential participation from commercial party(ies), which are expected to accelerate SWIM implementation and therefore sharing of surveillance data.

1.4.2 While States may subscribe to CRV if they choose to, the Hybrid Model could serve as the gateway for interested parties who are not subscribers of CRV to be able to share/receive surveillance data through connecting to a 3rd party(ies) that hosts the EMS and centralized services, subject of course to the endorsement from CRV OG. SWIM TF, CNS SG in future in accepting such a scheme.

1.5 Collaboration Model

1.5.1 Data Contributor – Eligibility

1.5.1.1 On the eligibility to share, member states/administrations are most welcome to share their data.

1.5.2 Data Contributor - Service Level of Shared Surveillance Data

1.5.2.1 Reliability and availability of the shared surveillance data are determinative factors on the success of implementation and degree of participation. It is essential that the shared data service reaches certain performance levels. In Appendix 6 “*Baseline ADS-B Service Performance Parameters*” of ICAO’S *ADS-B Implementation and Operations Guidance Document Edition 13.0 – September 2020*, there are some major performance requirements of ADS-B which are relevant to surveillance data sharing from potential data contributors: [See Chapter 3]

Service Parameters	Tier-Level 1 ¹	Tier-Level 2 ²
System Availability	Total Service Availability > 99.9%	Total Service Availability > 90%
System Reliability	Total Service MTBF > 50,000 hours	Total Service MTBF > 200 hours
Aircraft Updates	0.5 second < Interval < 105 seconds	0.5 second < Interval < 60 seconds
Data Latency	95%: < 2 seconds	95%: < 60 seconds

1.5.2.2 It is justifiable to follow the above requirements for the sharing of surveillance data. Yet, practically, the requirements, particularly for [Tier-Level 1](#) service level, can present themselves as obstacles for a potential data contributor unless:

- a) the potential contributor is already providing such data via another channel with the required service performance level and the shared data represents simply data duplication into another channel for sharing;
- b) the service level is non-binding; and/or
- c) such service is provided “as is”.

¹ [Tier-Level 1](#) standards are for a high performance traffic separation service.

² [Tier-Level 2](#) standards are for a traffic situational awareness service with procedural separation.

1.5.2.3 There exists a dilemma where a potential data contributor may be discouraged because of demands of required service level performance imposed on the contributor whereas a use-at-your-own-risk approach with no service guarantee would lessen the appeal/trust of the shared data for operational use not that this would necessarily discourage interested parties from participating as such data might still serve "for reference" and considered "nice-to-have". Such consideration might argue for the case of a trial implementation by pioneering members to showcase the benefits of the surveillance data scheming. [See Chapter 3]

1.5.2.4 Para. 1.5.2.3 also echoes the Implementation Philosophy in para. 1.2 to start small and simple and to start with an application, i.e. ATFM, where the less stringent service parameters of [Tier Level 2](#) (compared to those of [Tier Level 1](#)) would still serve the purpose. At the same time, it also highlights an expected advantage of centralized services by a 3rd party to shoulder such service performance parameters (subject always to external factors beyond control). [See Chapter 3]

1.5.3 Data Consumer – Eligibility

1.5.3.1 On the eligibility to receive shared data, there are various options proposed in the CONOPS (SURICG/7-IP/17):

- a) Option 1: The data to be shared among all participating users, be they data contributors or pure consumers
- b) Option 2: A data contributor to decide which user(s) to receive the data and the volume of surveillance coverage
- c) Option 3: By default, only data contributors can be consumers

In order to support the ATFM operation identified in para. 1.2.2 above, Option 1 is highly recommended as it resonates with the spirit of surveillance data sharing. Non-targeting data sharing would help speed up the collaborative sharing of surveillance data with a faster growth of the community, given the benefits derived from shared surveillance data and active States wishing to contribute and play an active part in this initiative, perhaps as a reference model or implementation experience for exchange of aviation data in an increasingly connected aviation community.

Options 2 and 3 may be implemented as the data sharing scheme further develops over time. Both options likely would involve complex and extensive multi-lateral discussions and agreements to reach detailed arrangements of data sharing. Options 2 and 3, clearly with some implied exclusivity, does not align well with ICAO's ASBU initiatives – global connectivity and is not recommended to avoid the scheme ending up a few participants with localized interests sharing data among themselves. For practical consideration, it is therefore desirable consider lessening or shifting the "burden" on a data contributor to a 3rd party providing centralized services to promote participation in the sharing scheme. [See Chapter 3 and Chapter 4]

1.6 Implementation Sequence

1.6.1 Stage 1 – [Tier Level 2](#) ADS-B data sharing

The data services are classified into two ~~tiers~~ [levels](#) based on the nature of ATS applications:

- a) [Tier Level 1](#) Data Service
For supporting ATS applications which make use of shared surveillance data for aircraft separation.

b) [Tier-Level 2](#) Data Service

For supporting ATS applications which do not use the shared surveillance data for aircraft separation.

Given the idea of starting small and simple, it is recommended to start with [Tier-Level 2](#) data service considering the stringent service performance requirements for [Tier-Level 1](#) data service (for ATC) and the expected non-contiguous surveillance data coverage at start.

1.6.2 Stage 2– [Tier-Level 1](#) ADS-B data and other surveillance data sharing

Stage 2 would be at a much later stage, after lessons learned and experience gained from ADS-B data sharing in Stage 1. The implementation of stage 2 would be highly dependent on the success of Stage 1 implementation given the considerations stated in para. 1.2.1. It may be worth focusing efforts on technical implementation of data sharing by opting for a surveillance data to be shared and a sharing scheme with the least (but sometimes unavoidable) diversions to other non-technical aspects. If and when sharing of other surveillance data such as radar data is ready in future, a dedicated study group would be called for to work on the implementation details and arrangement of sharing of such and other surveillance data.

Chapter 2: INFRASTRUCTURE MODEL (TASK 2-3)

2.1 Introduction

- 2.1.1 The CRV is a common network infrastructure in the APAC initiated by the ICAO with a view to overcoming the existing limitations in the communications of legacy civil aviation technologies and to constructing a centralized IP-based private network infrastructure by adopting modern technology. One of its purposes is to support future high-speed aviation applications. During feasibility study stage, CRV was already identified as the SWIM-enabler under ASBU framework.
- 2.1.2 Since the commencement of CRV operations in 2018 for voice and AMHS applications, for its performance and reliability, it has been endorsed by States/Administrations at different meetings/forums (e.g. CRV OG and SWIM TF) that CRV as the underlying infrastructure to support SWIM. And throughout a series of studies and discussions, both CRV OG and SWIM TF agreed and concluded that CRV would be used to support SWIM.
- 2.1.3 The SWIM TF TOR was updated in SWIM TF/5 (2021) and endorsed by CNS SG/25 (2021) that the SWIM should be implemented **principally** over CRV.

2.2 SWIM Technical Infrastructure

- 2.2.1 The SWIM Infrastructure has been discussed at various ICAO meetings and conferences aiming to unify the design and implementation. In these discussions, three models of infrastructure have been identified, which are Distributed, Centralized and Hybrid.
- 2.2.2 A typical Distributed Model is made up of active APAC SWIM participants who host their EMS servers and services to form Global Enterprise Messaging Services (GEMS) on the CRV network while supporting local access by specific systems to publish or subscribe to SWIM data. Such a Distributed Model is illustrated in Figure 1 below. The local stakeholders, such as ANSPs, airports, airlines and MET offices will then be able to publish and subscribe SWIM data through its locally connected EMS to reach other States by the GEMS.

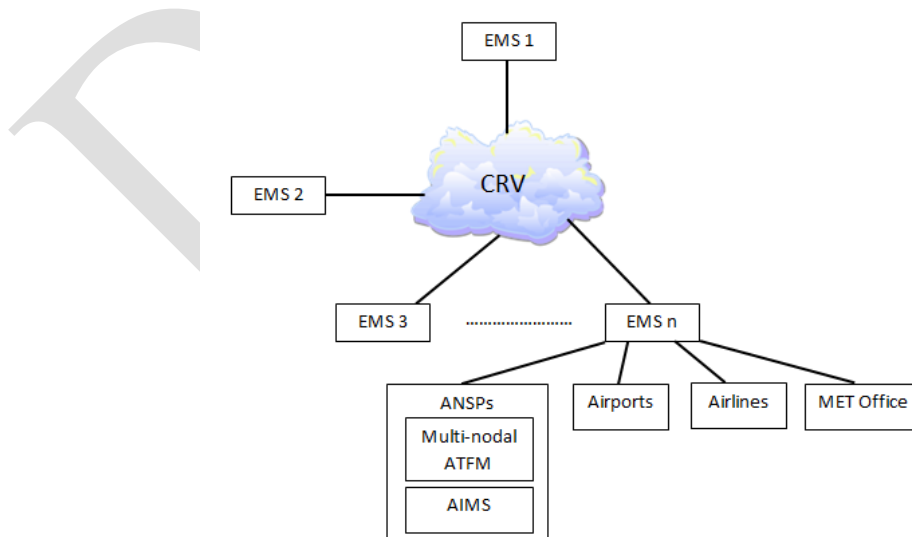


Figure 1 – “Distributed Model” of EMS services

- 2.2.3 In the Centralized Model, a third party may host EMS services in the CRV available to subscribers such that qualified States/Administrations/Stakeholders may subscribe or publish

SWIM data irrespective of their geographical locations but insofar as they can access to the CRV. Such a model is illustrated in Figure 2 below. Simplistically, the hosted EMS services are inside the CRV cloud.

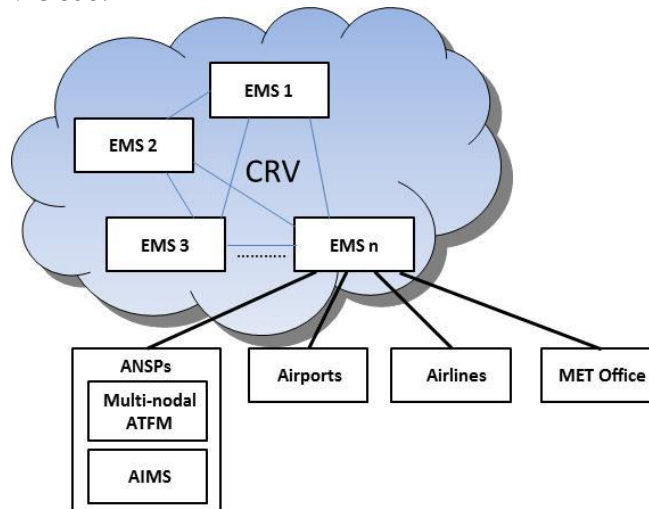


Figure 2 – “Centralized Model” of EMS services

- 2.2.4 In the Hybrid Model, the Distributed Model and the Centralized Model coexist, as illustrated in Figure 3 below. Simplistically, there are EMSes inside the CRV cloud (Centralized Model) and EMSes outside of the cloud (Distributed Model).

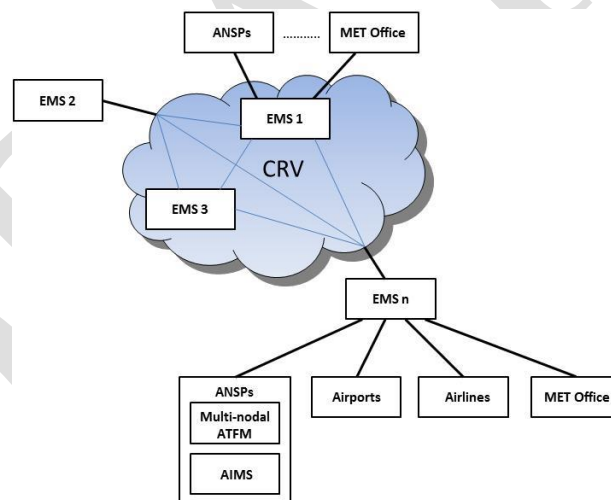


Figure 3 – “Hybrid Model”

2.3 Suggested Model for Surveillance Data Exchange

- 2.3.1 It is worth noting that the Hybrid Model was showcased in the ASEAN SWIM demonstration conducted in November in 2019 with successful outcome. In the demonstration, various operational information, including trajectory updates for situational awareness, aircraft turnaround for A-CDM and CTOT for ATFM Ground Delay Program was exchanged.
- 2.3.2 The table extracted from the report of the ASEAN SWIM Demonstration deliberating the pros and cons of different models is given as follows.

Pros	Cons
Option 1 Single EMS Architecture	
• Efficient implementation – Each participant only needs to connect once • Less metadata needed to ensure proper message routing • Faster to integrate	• Hard to get consensus on who to implement the EMS • If EMS is implemented by third party, no participant has control over how messages are routed
Option 2 Every Participant Implementing Interconnected EMS Architecture	
• Every participant is responsible for their own EMS implementation • Each participant has full control over how their EMS routes messages	• Every participant needs to establish EMS-EMS connection to every other participant, leading to point-to-point connection • Message routing is complex and less efficient, compared to Option 1
Option 3 Combined Public and Private EMS Architecture	
• Participants can decide how they wish to connect to regional SWIM, either through their own EMS or through the commercial EMS • The number of EMS being implemented is small	• Although all EMS are required to be interconnected, the complexity is still less than Option 2 • Message routing has to be agreed upon by the group that is implementing the EMSs

Note: Option 1 is considered as Centralized Model
Option 2 is considered as Distributed Model
Option 3 is considered as Hybrid Model

- 2.3.3 Considering that APAC members could opt for subscribing to the EMS services in CRV (if existent then) or hosting EMS servers of the own, having regard to factors such as cost, time and efforts of setup, role of data contributor/consumer, etc. as well as the successful outcome of the ASEAN SWIM Demonstration, it is suggested to also adopt the Hybrid Model in the surveillance data exchange in SWIM over CRV.

2.4 Other Elements in SWIM

- 2.4.1 The scope of this Study is on the sharing of surveillance data in SWIM. Implementation of information services (which includes shared surveillance data) and other elements in SWIM framework such as governance, service registry and security are under the purview of SWIM TF. Yet, the sharing of surveillance data over can be realized as a non-SWIM service and migrate to SWIM as more SWIM elements and services available as an assumption stated in para. 1.3.2.

2.5 CRV Requirements

- 2.5.1 The CRV service providers already provide different packages for the States/Administrations to access CRV. In particular, package D offers a flexibility for the States/Administrations to access CRV via the Internet (IP-SEC VPN), though its serviceability relies on the unpredictable reliability of the Internet connection. For both data contributors and consumers, network bandwidth should be evaluated based on their own requirements according to which [tier-level](#) of data planned to be carried.
- 2.5.2 On bandwidth requirements, the bandwidth required of a data contributor depends on the number of data consumers who are directly served the data from the contributor Vs the case of centralized service which would serve the surveillance data to the subscribed data consumers, thereby reducing the bandwidth requirements of the original data contributor. An implementation of centralized service tailored for surveillance data sharing (with data repository service, processing service, conversion service and other value-added services)

would be via a Surveillance Central Data Processor (SCDP) as further elaborated in para. 2.6. At a proof-of-concept event conducted in Hong Kong in October 2018 [WP/20 of SWIM TF/3], the capability of CRV to carry SWIM data was successfully demonstrated and it was concluded that bandwidth requirement was a matter of the CRV data package subscribed. At a recent proof-of-concept exercise conducted in Hong Kong in February 2022, to demonstrate and simulate the sharing of surveillance data in SWIM over CRV, some reference figures have been obtained and tabled at Appendix X to this study report. *[Note: Appendix X currently in WIP status, to be provided once available.]*

2.6 EMS and SCDP

- 2.6.1 A 3rd party wishing to provide centralized surveillance data sharing service may do so by way of an SCDP, which filters and collates surveillance data feeds from data contributors and outputs user-selectable data streams as a SWIM service.
- 2.6.2 Whereas a centralized registry for all SWIM services might not be available in the near future, this SCDP could host the service registry and exercise any governance rules if they exist.
- 2.6.3 From system perspective, the SCDP will be designed with redundancy and resilience in mind to achieve high availability. And the SCDP would also be served with high-bandwidth CRV links to be able to receive and serve surveillance data to other ANSPs.

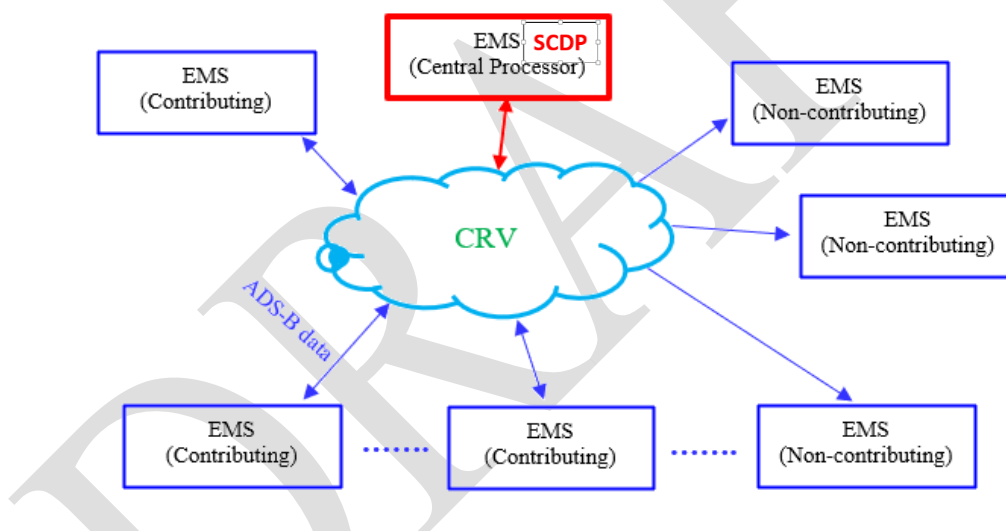


Figure 4 – Proposed Model of SCDP

- 2.6.4 The EMS and SCDP are to be tightly coupled regardless if they are provisioned by single service provider or not with expected advantages as follows:
- With expected low latency and throughput in the local connection between EMS and SCDP, potential bottlenecks in data flows and processing could be eliminated, which is important and necessary since a high volume surveillance data traffic would be exchanged between EMS and SCDP internally and between EMS and other EMSes externally.
 - A closely coupled EMS and SCDP would be more reliable and clearly cost-effective services with the need for remote connection, network equipment and link costs.

- c) An SCDP will also greatly alleviate the bandwidth requirements of individual data contributors who need to cater for a large number of data consumers by providing a single stream of surveillance data to the SCDP for its onward distribution to data subscribers.

DRAFT

Chapter 3: BUSINESS MODEL (TASK 2-4)

3.1 Responsibilities of Data Contributors

3.1.1 Service Availability & Reliability

To provide reliable data sharing service to participating users, data contributors should maintain a certain level of system availability and reliability in their surveillance data sharing service. In the initial stage, the implementation focuses on the sharing of ADS-B data. By referring to Appendix 6 “Baseline ADS-B Service Performance Parameters” of ICAO’S ADS-B Implementation and Operations Guidance Document Edition 13.0 – September 2020, (“Ref 1”), the following service parameters are recommended to be delivered by surveillance data sharing systems to support the corresponding operation mode of the data services.

Service Parameters	Tier-Level 1 Data Services [Equivalent to Category 1 (Tier 1) under “Ref 1” to support aircraft separation]	Tier-Level 2 Data Services [Equivalent to Category 3 (Tier 3) under “Ref 1” to support enhanced flight operation]
System Availability	Total Service Availability > 99.9%	Total Service Availability > 90%
System Reliability	Total Service MTBF > 50,000 hours	Total Service MTBF > 200 hours

3.1.2 Integrity of ADS-B Data

- a) The Data Contributors should not modify the content of the surveillance data except for the following purposes:
 - i. ASTERIX Edition upgrading or downgrading;
 - ii. Format conversion to meet the agreed data format for sharing;
 - iii. SAC/SIC amendment; and
 - iv. Fusion of data from multiple sensors such as removal of duplicated ADS-B position reports. Any extrapolation of position reports shall not be shared.
- b) Time stamp of the surveillance data report shall be based on a reliable time source without any modification by the data contributors.

3.1.3 Report Filtering

- a) Screening out special or non-civilian flights (e.g. State aircraft) is allowed with the filters being agreed upon prior to implementation. The filtering mechanism shall be detailed in the data services provided.
- b) For ADS-B data, the data contributors shall not perform any data filtering based on ADS-B quality indicators or blacklist. All the ADS-B data shall be shared with users as far as possible.

- c) Considering that States will be making the assessment of data usability, and that lower NUC/NIC can still support lower [Tier-Level](#) operations, all data should be sent without filtering based on NUC/NIC.

3.1.4 Update Intervals / Data Latency

- a) With the same reference to “Ref 1” in para. 3.1.1, the following service parameters are recommended on the timeliness and data latency of the surveillance data sharing systems.

Service Parameters	Tier-Level 1 Data Services [Equivalent to Category 1 (Tier 1) under “Ref 1” to support aircraft separation]	Tier-Level 2 Data Services [Equivalent to Category 3 (Tier 3) under “Ref 1” to support enhanced flight operation]
Aircraft Updates	0.5 second < Interval < 105 seconds	0.5 second < Interval < 60 seconds
Data Latency	95%: < 2 seconds	95%: < 60 seconds

3.1.5 Format of the data

- a) ASTERIX CAT 21 Edition 2.1 is recommended for the initial implementation, as most of the States are able to support without additional data conversion efforts.
- b) The SCDP would be able to provide data conversion services between different ASTERIX CAT 21 editions, to support legacy system if required.

3.2 Collaboration Model

3.2.1 Participating as Data contributors

- a) Due to the varying degrees of SWIM implementation status of States, data contributors should offer flexibility to allow surveillance data sharing to the data consumers either by direct interfacing or by centralized SCDP services provided by a 3rd party.
- b) Direct interfacing between data contributor and data consumer can be established regardless if there exists an SCDP. However, an SCDP is expected to greatly accelerate the implementation of surveillance data sharing and popularize its utilization in accordance with the “starting small and simple” philosophy. SWIM-enabled States can choose this collaboration model for an initial trial with a “local SCDP” and then populate the SCDP services through further collaboration in a later stage by expanding their capabilities or by way of 3rd-party SCDP centralized services.
- c) Surveillance data sharing services ([Tier-Level 1](#) and [Tier-Level 2](#)), if offered via SCDP, require the collaboration between States (as data contributors) and the SCDP service provider for the data provision mechanism, including data format, data update rate, etc., to ensure the SCDP can deliver the ultimate surveillance data sharing services, meeting the service parameters mentioned in para.3.1.4.
- d) Data charging scheme or incentives provided to States who are data contributors to the SCDP should be explored to encourage data contribution to the SCDP.
- e) With the presence of SCDP, States without SWIM infrastructure can also contribute their data by legacy means and in legacy data formats (if it is the case) to the SCDP, which will

then take care of data conversion and onward data surveillance sharing service for dissemination.

3.2.2 Participating as Data consumers

- a) States, based on their own SWIM implementation status, can choose between direct interfacing with the data contributor or use the surveillance data sharing service provided by SCDP.
- b) States with SWIM infrastructure may participate in the initial trial by direct interfacing between data contributors, in respect to para. 3.2.1(b).
- c) Data consumer without SWIM infrastructure can subscribe to the surveillance data sharing services from the SCDP to benefit from shared surveillance data.

3.2.3 Eligibility to be a data consumer

- a) In para. 1.5.3, three options of participating as data consumers were explored, repeated below:
 - i. Option 1 - data will be shared among all the participating users;
 - ii. Option 2 - data contributor gets to decide who can receive its shared data;
 - iii. Option 3 – only data contributors can be consumers.
- b) In para. 1.5.3, it was recommended that Option 1 be adopted in the spirit of sharing and benefitting the aviation community as a whole. Option 2 may be considered for some data contributors if there are specific circumstances. Option 2 nevertheless would not be conducive to quick implementation of data sharing due to a lack of across-the-board “free to use” approach which would necessitate multi-lateral agreements, more elaborate technical implementation and service governance and controls.
- c) Options 1 and 2 are not mutually exclusive however. Technically, there should be no issue in implementation either or both options in the SWIM environment. Option 3 is not preferred since by nature it would require an ensemble of interested parties, all of whom necessarily data contributors, to participate. This by itself becomes a hurdle to quick implementation of surveillance data sharing and, like Option 2, goes against the spirit of data sharing.

3.3 Data Coverage

3.3.1 Considering the benefits from shared surveillance data, some possible choices on the extent and geographical coverage of data to be shared are listed below:

- a) Choice 1: Data contributor to share data from all its ADS-B stations (maybe difficult for States with large FIRs);
- b) Choice 2: Data contributor to share data from at least one of its ADS-B stations (the data from the chosen station may not be useful to all other States);

- c) Choice 3: Data contributor to share data from all its international flights (useful for ATFM);
- d) Choice 4: Data contributor to share ADS-B data from stations that are near the FIR boundaries (useful to cover surveillance gaps);
- e) Choice 5: Data contributor to share data from ADS-B stations that are near airports for international flights (useful for ATFM).

3.3.2 Among the above five choices, choice 4 can support [Tier-Level 1](#) data service as a minimum while choice 5 can support [Tier-Level 2](#) service as a minimum. Therefore, it is recommended that combination of choices 4 and/or 5 be selected as a minimum for a data contributor.

3.3.3 As mentioned in para. 3.2.1(d), data contributor could be offered some incentives in using SCDP. States are thus encouraged to contribute data as much as they could, which can help build up a rich and more comprehensive set of data via the SCDP.

3.4 Operational Arrangement and Governance by an Operations Group

3.4.1 An Operations Group, such as CRV OG, might be necessary to administer and supervise the data exchange system, which would be subjected to extent of participation, commitment and 3rd party/commercial participation.

3.4.2 Preferably, the Operations Group can be established before implementation or a trial implementation to consider and manage the various issues arising.

3.4.3 The Operations Group should oversee the following:

- a) Membership;
- b) Administration of the agreement with 3rd party/commercial participations (if any);
- c) Maintenance of the technical specifications of the surveillance data sharing platform;
- d) Management of the performance of the surveillance data sharing platform, such as SLA management; and
- e) Facilitation of communications among member States for the deployment and implementation status update from the States.

3.4.4 To shorten the implementation time and minimize operating costs, a bottom-up, agile approach to exchange surveillance data by leveraging CRV and adopting ASTERIX surveillance data format via some centralized and dedicated EMS and SCDP services provided by business entities and/or pioneering participants running their own EMSes to provide dedicated surveillance data sharing services should be adopted. The comprehensive governance framework under SWIM is not a necessity in the beginning of the implementation or its trial.

3.5 Financial

3.5.1 As a default, data consumers should be responsible for the cost to connect to the main sharing platform (which could be the SWIM network or SCDP). Data contributors should keep track of the user base to ensure their CRV connections are provisioned with sufficient bandwidth for uploading the data for sharing through direct connections to data consumers and/or to the SCDP. Given the expected surveillance data of other airspaces in return of the contributed

surveillance data of own airspaces, they should be able to justify the additional bandwidth requirements on the CRV connections for both contributing own and receiving other surveillance data. The States can choose to setup its own EMS for data sharing and be responsible for the cost in the initial setup and the on-going maintenance and support. Alternatively, ANSP can choose to subscribe to the commercial centralized EMSes and be responsible for the service subscription fee instead.

3.5.2 In general, there are two approaches in setting up the surveillance data sharing platform, namely On-Premise Approach and Cloud Based Approach. A comparison, including financial implication, between the two approaches are given below for States' consideration.

	On-Premise Approach		Cloud Based Approach	
	Contributor	Consumer	Contributor	Consumer
Cost				
One Time Cost (System Setup)	High	-	Low	-
System Operation & Maintenance	High	-	Nil	-
Recurrent Cost - Service Subscription	Nil	depends on Contributor	OPEX	OPEX
Network Connection for data sharing	Need to upgrade	Need to upgrade	Handled by service provider	Handled by service provider
Network Resilience	Need to upgrade	Need to upgrade	Handled by service provider	Handled by service provider
Development Efforts (Service upgrade, Security etc.)	Handled by Contributor	-	Handled by service provider	-
Control	Handled by Contributor	-	Handled by service provider based on the instructions from Contributor	-
Compliance	Handled by Contributor	-	Handled by service provider	-
Delivery Lead Time	Long	-	Short	-
Flexibility	Low	-	High	-
24x7 Trouble Shooting	Handled by Contributor	-	Handled by service provider	-

Chapter 4: PARTICIPATION MODEL (TASK 2-5)

4.1 Introduction

- 4.1.1 As the availability of shared surveillance data is fundamental to the successful implementation of the surveillance data sharing, this part explores and identifies a participation model to encourage participation from States and non-ANSP stakeholders as well as to promote surveillance data sharing for the good of the aviation community.
- 4.1.2 This part is to define obligations/eligibility of the participating users and develop a set of requirements and guidelines for participation.

4.2 Rights of Data Consumers

4.2.1 Rights to receive shared data

There are various options of eligibility to receive shared data:

- a) Option 1 - data will be shared among all the participating users;
- b) Option 2 - data contributor gets to decide who can receive its shared data;
- c) Option 3 – only data contributors can be consumers.

Option 1 is the preferred approach as described in para. 3.2.3 and not repeated here.

4.3 Responsibility of Data Consumers

- 4.3.1 While data consumers benefit from the shared surveillance data, they should be encouraged to contribute surveillance data by relaying and/or providing their own as the case may be, increasing the appeal of the sharing scheme with a broader set of data and therefore greater geographical coverage. However, imposing such an obligation for sharing may not be practicable at the early stage due to the implementation complexity. It will also raise hurdles for and discourage participation initially. To be consistent with the agile approach for surveillance data sharing, it is suggested to allow more flexibility in enforcing the obligation at the early stage.
- 4.3.2 The obligation and eligibility should be limited to ANSPs who have data to be shared. Other members, who may not have data to share can be admitted through multilateral agreement(s) or other participation schemes with contribution in other forms, such as subscription or bearing cost of surveillance data sharing.

4.4 Safety Related Requirements

- 4.4.1 Despite reasonable steps taken by the data contributors to ensure the service availability and reliability, the data consumers, being the users of the shared data, shall be responsible for:
- a) assessing the surveillance data received to decide whether it is suitable for use; and
 - b) provision of contingency plan(s) in case of interruption of data sharing service.

4.5 Memberships

- 4.5.1 Members could comprise ANSPs of ICAO APAC States, airlines, airport operators and aviation service providers. It is beneficial to include as many members in the industry as possible to build up a user base for sharing, support and collaboration.
- 4.5.2 For members who may not be able to contribute surveillance data (such as airlines), they could either be provided with secure connections to their respective ANSPs' EMSes or directly subscribe to the services from SWIM surveillance data service providers for accessing the surveillance data shared. They could contribute by subscription or other forms.
- 4.5.3 Requirements/Guidelines for Qualification of Membership

To support the fundamental consideration of encouraging participation, it is recommended that membership be simple and straightforward. By default, all ICAO APAC States/Administrations qualify as members subject to signing a multilateral agreement to demonstrate and commit to:

- a) the compliance with the membership obligations; and
- b) adherence to the rules, standards and guidance.

For other stakeholders, membership is to be determined by the Operations Group. Regular review/renewal of membership is recommended to ensure the continuous compliance with the obligations and rules that might be adjusted over time.

Chapter 5: IMPLEMENTATION ROADMAP AND TIMEFRAME (TASK 2-6)

5.1 Introduction

- 5.1.1 This paper presents a proposed implementation roadmap and time frames for surveillance data sharing in SWIM over CRV, with consideration of approach, types of surveillance data and information exchange model.
- 5.1.2 This study report is to be delivered as a deliverable in the feasibility study stage for SURSG's consideration and facilitate the preparation in later recommendation stage.

5.2 Implementation Roadmap

5.2.1 Development of CONOPS

A proposed concept of operations (CONOPS) for surveillance data sharing in SWIM has been developed by Singapore, Hong Kong China, Thailand and Vietnam. A comprehensive discussion has been included, ranging from practical models for collaboration and operation to business models by taking into account available platform(s) and other technical considerations.

5.2.2 Development of different models

Based on the CONOPS, it is required to study, identify and recommend practical models for specific subject matters including implementation model, infrastructure model, business model and participation model. In order to facilitate the sharing of surveillance data, it is essential to have a certain level of details recommended in the developing models. The models covered in Chapter 1 – 4 foresee the potential issues/concerns to be encountered and suggest way forward.

5.2.3 Preparation of guidance material and multilateral agreement

- a) With reference to the models and recommendations advised in this Study Report to be adopted by SURSG/2 meeting, guidance material, specified system requirements, performance requirements, operation and maintenance practice and so forth, should be developed to facilitate and harmonize the implementation of surveillance data sharing. The guidance material should also provide guidance for design, testing and commissioning of the system for surveillance data sharing to ensure coherent system development.
- b) Multilateral agreement may involve a lengthy negotiation process, depending on size of participant group and agendas. Despite considerable time it may take, multilateral agreement is considered a more suitable option over bilateral agreement in order to attain non-discrimination data sharing with transparent, fair and equitable treatment.

5.2.4 Implementation of infrastructure – SWIM, CRV and EMS

SWIM over CRV is the default means to share surveillance data. Different SWIM infrastructure models may be adopted by different States and members, namely Distributed (with locally connected EMS), Centralized (with centralized EMS in CRV) and Hybrid. The Hybrid Model is considered the most suitable one with maximum efficiency and minimal geopolitical concerns. The members are suggested to evaluate and determine which infrastructure models to adopt based on their own context. The infrastructure should be implemented according to the requirements set out with considerations of latency, throughput, network security, system reliability and cost effectiveness.

5.2.5 Implementation of information service – software development, functional test and functional validation

It is envisaged that information service developed based on the functional and performance requirements, such as message format and data filtering, will be properly tested and validated locally or with the adjacent regions so as to ensure a reliable system for surveillance data sharing.

5.2.6 Operational test, validation user acceptance and operation deployment

Upon the completion of the implementation of infrastructure and information service, the overall functions of sharing of surveillance data could be verified through operational test and user acceptance test. Member's involvement in this stage is important to identify system deficiencies or interface issues, if any, for further investigation and improvement before putting into operation.

With the comprehensive testing and review over the system, it would be ready to deploy for operation. Regular meetings across the States should be held with an operations group to review the performance and examine issues found, if any. Collaborative review process and cooperative system fine-tune will be crucial for the continuous improvement and further development of surveillance data sharing.

5.3 Approach

5.3.1 As advised by SURSG/1 – WP05, the bottom-up, agile-like approach adopted for APAC SWIM implementation should be adopted for surveillance data sharing in SWIM to align the philosophy and roadmap for both. It is easier to deploy multiple and incremental approaches to build up capabilities to share the data.

5.3.2 The incremental approach is to start small and simple, identifying and selecting one particular operation for implementation of surveillance data sharing, followed by identification and implementation of information services and infrastructure services required to support the operation.

5.3.3 This bottom-up approach will help to justify the implementation of the infrastructure needed to efficiently support the operations. Once the advantages of the surveillance data service are revealed after the first operation, the same process can be applied to other operations considered suitable.

5.4 Type of Surveillance Data Shared

5.4.1 Considering the mature experience of States in sharing ADS-B data and little concern over data ownership, it is proposed that the sharing of ADS-B data should be focused in the initial implementation stage.

5.4.2 However, the sharing of surveillance data is not limited to ADS-B. With the experience obtained from ADS-B data sharing, adjustment/fine-tune could be made, where considered necessary, on various aspects including the implementation platform, exchange model, business model and so forth to accommodate the sharing of other types of surveillance data.

5.5 Information Exchange Model

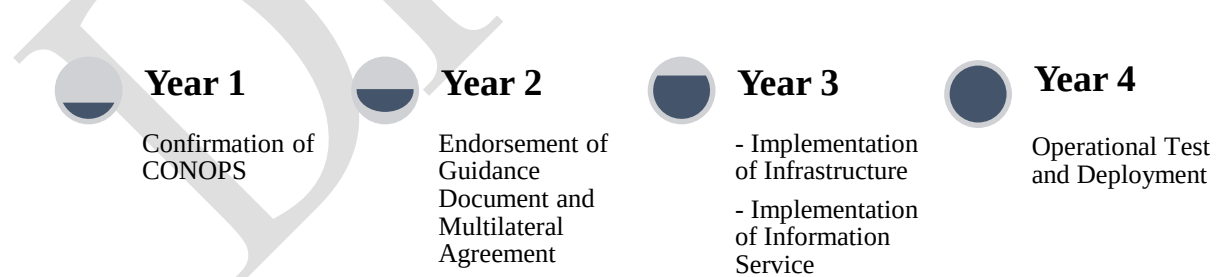
- 5.5.1 It is envisaged that the data will be used by the existing surveillance data processors. Unified data format ASTERIX CAT 21 edition 2.1 is recommended to facilitate the use of surveillance data shared.
- 5.5.2 While SWIM over CRV is the default means to share surveillance data, there are three SWIM infrastructure models recommended: Distributed Model, Centralized Model and Hybrid Model. To align with the principle, starting small and simple, Hybrid Model is considered the best suitable solution as it makes a good balance between maximum efficiency and geopolitical concerns.

5.6 Collaboration Agreement

- 5.6.1 Bilateral agreement is relatively easy to go into effect as only two countries are involved in the negotiation. Nevertheless, it may result in exclusive deals which are against the vision of surveillance data sharing. Some willing participating ANSPs with less data may be unfavorable compared to those possessing key surveillance data.
- 5.6.2 In contrast, despite the complex negotiation and significant effort required, multilateral agreement allows for an equal and transparent arrangement for surveillance data sharing, which definitely encourages active participation and promotes collaborative surveillance data sharing. The value of the sharing could be recognized with a certain extent of participation.
- 5.6.3 With the above considerations, multilateral agreement, rather than bilateral agreement, is recommended to standardize the terms and conditions among the participating States/parties and achieve an equal playing field.

5.7 Timeframe

- 5.7.1 The implementation timeline places the tasks identified in the implementation roadmap proposed in para. 5.1 in chronological order. The implementation timeline may differ to certain extent, depending on the actual deployment model and approach. The implementation of SWIM platform is definitely a key contributing factor to the timeline of surveillance data sharing.



5.8 Trial Implementation of Surveillance Data Sharing in SWIM

- 5.8.1 It is known that some states are already sharing surveillance data through direct peer-to-peer connections. There does not appear to be technical issues in the sharing surveillance data in the SWIM environment. It is also known that status of SWIM implementation among states/administrations varies. There could be mismatched resources where those with data to contribute or to receive might not have ready access to a SWIM platform to participate in the

trial. To quickly build up a sizable participant base with reasonable breadth of shared surveillance data, some participant(s) with EMSes would need to share their data to quite a number of data consumers, with cost implication of bandwidth and system management even if service performance levels need not apply in the trial as mentioned in para. 1.5.2.3.

- 5.8.2 Pioneering participant(s) with EMS(es) might not be willing to take up the efforts of establishing, shouldering responsibilities and costs of such a trial, whereas a 3rd party/commercial concern might be willing to and with SCDP and value-added services provided as well except that commercial considerations would be its paramount consideration. Yet 3rd party/commercial participation has the clear advantage in its ability to significantly accelerate the trial implementation.
- 5.8.3 It is therefore worth considering that the trial implementation of surveillance data sharing over SWIM a rudimentary one with the minimal SWIM services, regardless if there is 3rd party/commercial participation instead of a full-fledge implementation in line with the starting simple and small principle and to minimize participants' financial commitment.
- 5.8.4 By the two POCs in October 2018 and February 2022, there is not much doubt of the feasibility of surveillance data sharing in SWIM over CRV. The trial, if implemented, is not to demonstrate such feasibility in a one-off event, but to showcase, as an ongoing effort, the user benefits and to form the model on which continuous enhancements are to be applied as lessons are learned and experience gained. Whether a trial implementation would precede the implementation proper would be a subject of discussion at CRV OG and SWIM TF meetings.

Chapter 6: High-Level Summary of Recommendations

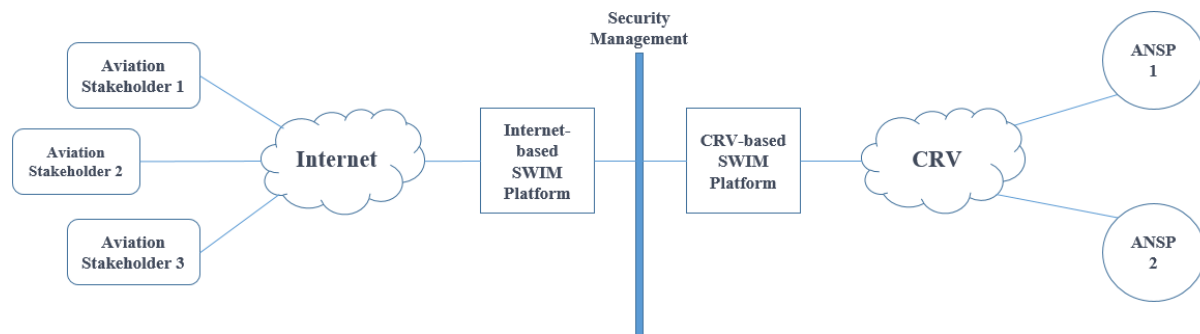


Figure 5 – Different Connectivity Options

- 6.1 A proposed and full implementation of surveillance data sharing using SWIM platform is depicted in Figure 5 showing one 3rd party/commercial interest providing the centralized services. The core network to be used will be riding on the CRV (right side of the diagram), which surveillance data exchange among ANSPs takes place under a secured and SLA guaranteed environment, to ensure necessary performance parameters can be achieved, to fulfil the required operational needs (i.e. [Tier-Level 1](#) Data Service).
- 6.2 Stakeholders that are currently not under the coverage of CRV can subscribe to the surveillance data sharing service (whether it is under the CRV network or not) through the internet-based platform (left side of the diagram), by various connection means. With proper security management, the internet-based platform will be able to communicate with the CRV network and allow surveillance data exchange between the two platforms. This type of connection will be feasible for applications that are not time critical (i.e. [Tier-Level 2](#) Data Service), as the SLA brought by the internet-based platform is not guaranteed.
- 6.3 With the analysis over different models in this Study Report, it has been repeatedly suggested that the principle of starting small and simple is the fundamental principle for the implementation of surveillance data sharing. For quick implementation of surveillance data sharing, it is highly recommend to have the following engagement as far as possible:
 - a) 3rd party/commercial participation to provide centralized SCDP services;
 - b) Start off the implementation with a trial; and
 - c) Early establishment of Operations Group.