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INTRODUCTION.

- When considering ADS-B for a surveillance service, the following list of Annexes and Documents quoted, are used as references, to help build up the knowledge required to make informed decisions.

- Many, if not all, of these documents, are referenced in the RFP process, with the implication on the vendor to ensure their systems comply with the documents. The same implication should apply to the owner(s) of the RFP.

- This presentation will look to highlight sections of each document which are applicable to the introduction of ADS-B only, and where necessary, provide an explanation of their impact.

- This is not a comprehensive list of all the documents available.

- The documents and references in this presentation are looked at from an Air Traffic Control background, and not those of a Surveillance Engineer. Therefore, my interpretation of their importance or non-importance, may differ from those of you with a technical background.

- This presentation will concentrate on DOC 4444 and CIR 326.

- The following are for reference and may be discussed if time permits:
  - ICAO Annex 10 Vol I – Radio Navigation Aids.
  - ICAO Annex 10 Vol III – Aeronautical Telecommunications.
  - ICAO annex 10 Vol IV – Surveillance and Collision Avoidance Systems.
  - ICAO Annex 11 – Air Traffic Services.
  - ICAO DOC 9871 – Technical Provisions for MODE S Services and Extended Squitter.
  - ICAO DOC 9924 – Aeronautical Manual.
  - ICAO DOC 9994 – Manual of Airborne Surveillance.

ANNEX

1 ANNEX 10 VOL I

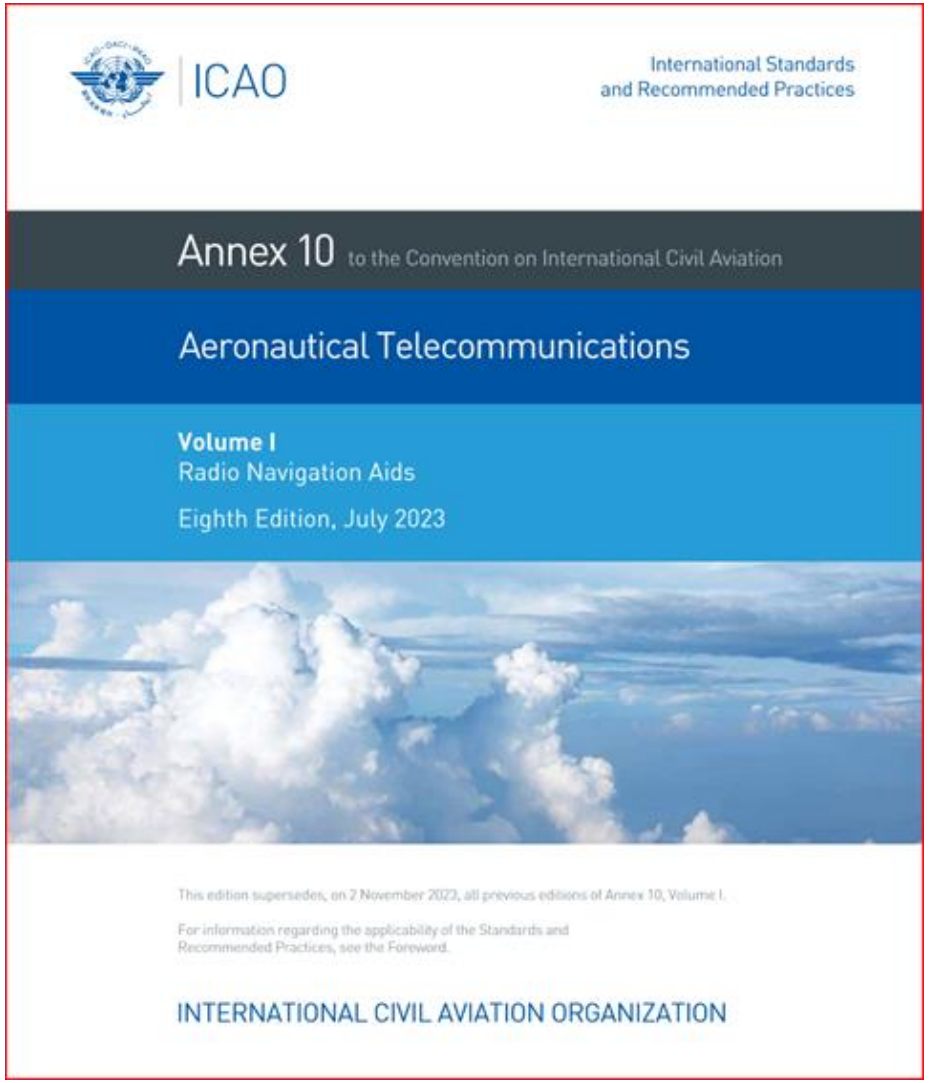
2 ANNEX 10 VOL III

3 ANNEX 10 VOL IV

4 ANNEX 11 – AIR TRAFFIC SERVICES

Annex 10 VOL 1

8th Edition – July 2013



ANNEX 10 – Volume 1 (Radio Navigation Aids).

8th Edition – July 2023.

Chapter 2: – General Provisions for Radio Navigation Aids.

- 2.1.4 – GNSS-specific provisions.
- 2.1.4.2 - Recommendation - a State that approves GNSS-based operations should ensure that GNSS data relevant to those operations are recorded .

- 2.2 - Ground and Flight Testing.
- 2.2.1 – Radio navigation aids of types covered in Chapter 3 and available for use by aircraft “shall be subject to periodic ground and flight tests”.

See DOC 8071 Manual on Testing of Radio Navigation Aids.

(Background Info GNSS).

- 3.7 – Requirements for the Global Navigation Satellite System (GNSS) – include the following:
  - GNSS - BeiDou, Galileo, GLONass and GPS.
  - Aircraft-based augmentation system (ABAS) – an augmentation system that augments and/or integrates the information obtained from other GNSS elements with information available on board the aircraft – defined in 3.7.3.3
  - Satellite-based augmentation system (SBAS) – a wide coverage augmentation system in which the user receives augmentation information from a satellite-based transmitter – defined in 3.7.3.4
  - Ground-based augmentation system (GBAS) – an augmentation system in which the user receives augmentation information directly from a ground-based transmitter. – defined in 3.7.3.5

Appendices.

- Appendix B – GNSS technical specifications.
- Appendix D – Information and guidelines for the implementation of GNSS standards and recommended practices.

See also CIR 267 – Guidelines for the Introduction and Operational use of the GNSS.

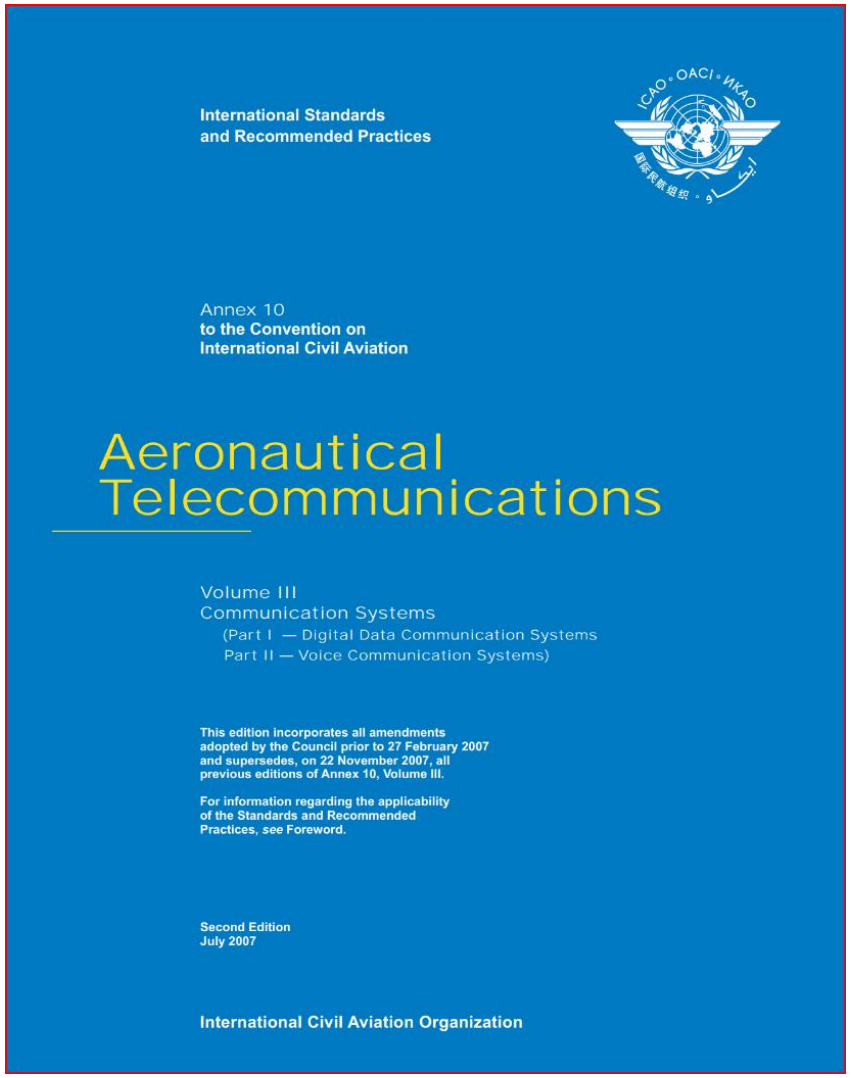
02

Annex 10 VOL III

2nd Edition – July 2007

Amendment 91

22/3/21



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ANNEX 10 – Volume III (Aeronautical Telecommunication Systems).

2nd Edition – July 2007.

– Amendment 91 22nd March 2021.

Part I: Digital data communication Systems.

Chapter 9: Aircraft addressing system.

- 9.1 – twenty-four-bit aircraft address allocated by ICAO to the State of Registry.
- 9.2 – transponders installed on surface vehicles, obstacles or fixed MODE S target detection devices for surveillance and/or radar monitory shall be assigned a 24-bit code.
    - Appendix to Chapter 9 – A worldwide scheme for the allocation, assignment and application of aircraft addresses.
    - Administered by ICAO.

Note DOC 4444, Section 4.11.6 – Data format of ADS-B Messages references back to Part 1 of this ANNEX.

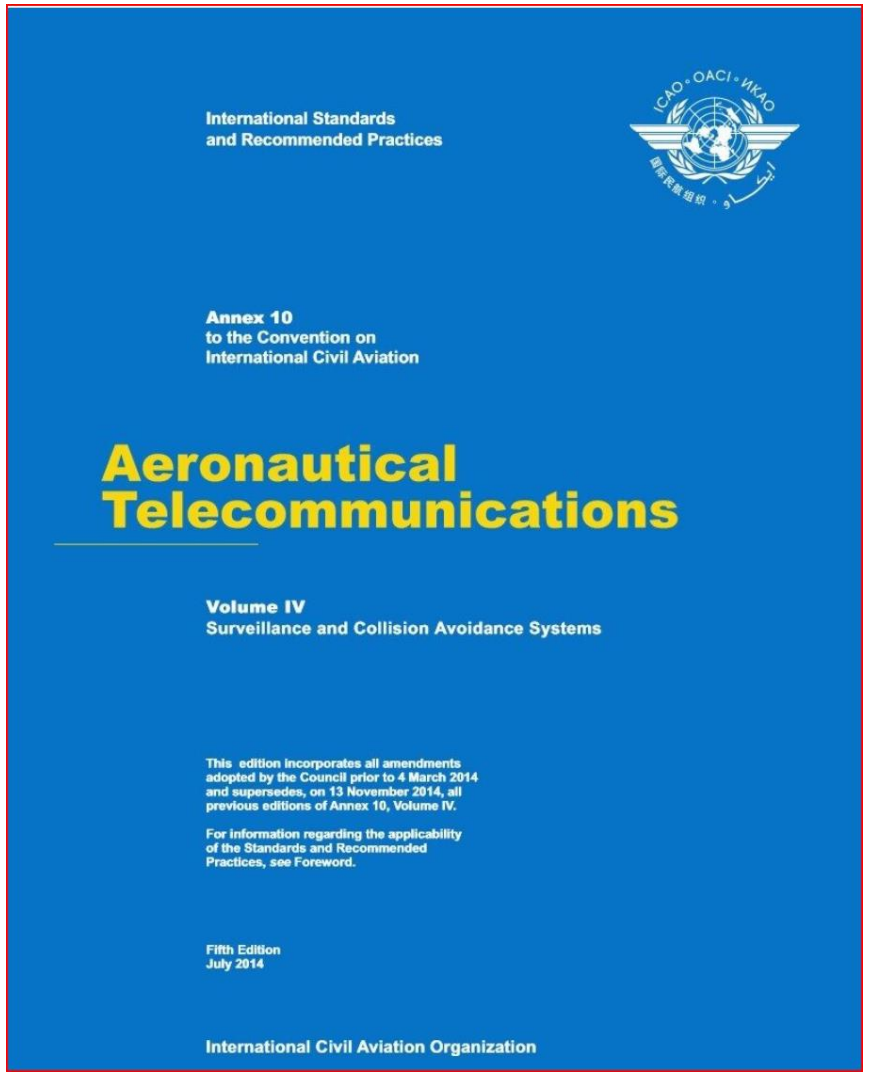
03

Annex 10 VOL IV

5th Edition – July 2014

Amendment 91

3/11/2022



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ANNEX 10 – Volume IV (Surveillance and Collision Avoidance Systems).

5th Edition – July 2014.

– Amendment 91 3rd November 2022.

Chapter 2 – General.

- 2.1 Secondary Surveillance Radar (SSR) – provides a basic outline of SSR operations.

Chapter 3 – Surveillance System.

- 3.1 - Secondary surveillance radar (SSR) system characteristics.
- 3.1.2 – Prescribes the characteristic of a MODE S SSR system.
  - Where available, a MODE S SSR is used as the reference radar for CIR 326.
- 3.1.2.8.6 – Extended Squitter, Downlink format 17 (DF17).
  - Supports the broadcast of aircraft-derived position for surveillance purposes. A form of automatic dependent surveillance known as ADS-B.
- 3.1.2.8.7 – Extended Squitter/Supplementary, Downlink Format 18 .

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Chapter 5 – MODE S Extended Squitter.

- 5.1 - MODE S extended squitter transmitting system characteristics.
- 5.1.1 - ADS-B Requirements.
- 5.1.1.1.2 – Recommendation. Extended squitter transmitting equipment should use formats and protocols of the latest version available.

  # Some states/regions mandate extended squitter version 2 or better.
- 5.1.1.4 - Control of ADS-B Out operation.
- 5.1.1.4.1 – Recommendation. Protection against reception of corrupted data from the source providing the position should be satisfied by error detection on the data input and appropriate maintenance of the installation.

- 5.1.3 - ADS-B Out requirements for surface vehicles.
- 5.1.3.2 - Guidance material contained in DOC 9871.

- 5.2 - MODE S extended squitter receiving characteristics (ADS-B IN and TIS-B in).
- 5.2.1.1 – MODE S extended squitter receiving systems shall perform the message exchange function (receive) and the report assembler function.

Chapter 6 – Multilateration Systems.

Reference only – Detailed technical guidance for MLAT and WAM can be found in:

- The Aeronautical Surveillance Manual, Appendix L -DOC 9924, and
- Technical Specification for Wide Area Multilateration System (WAM) - EUROCAE ED-117a.

Note DOC 4444, Section 4.11.6 – Data format of ADS-B Messages references back to Annex 10 Volume IV.

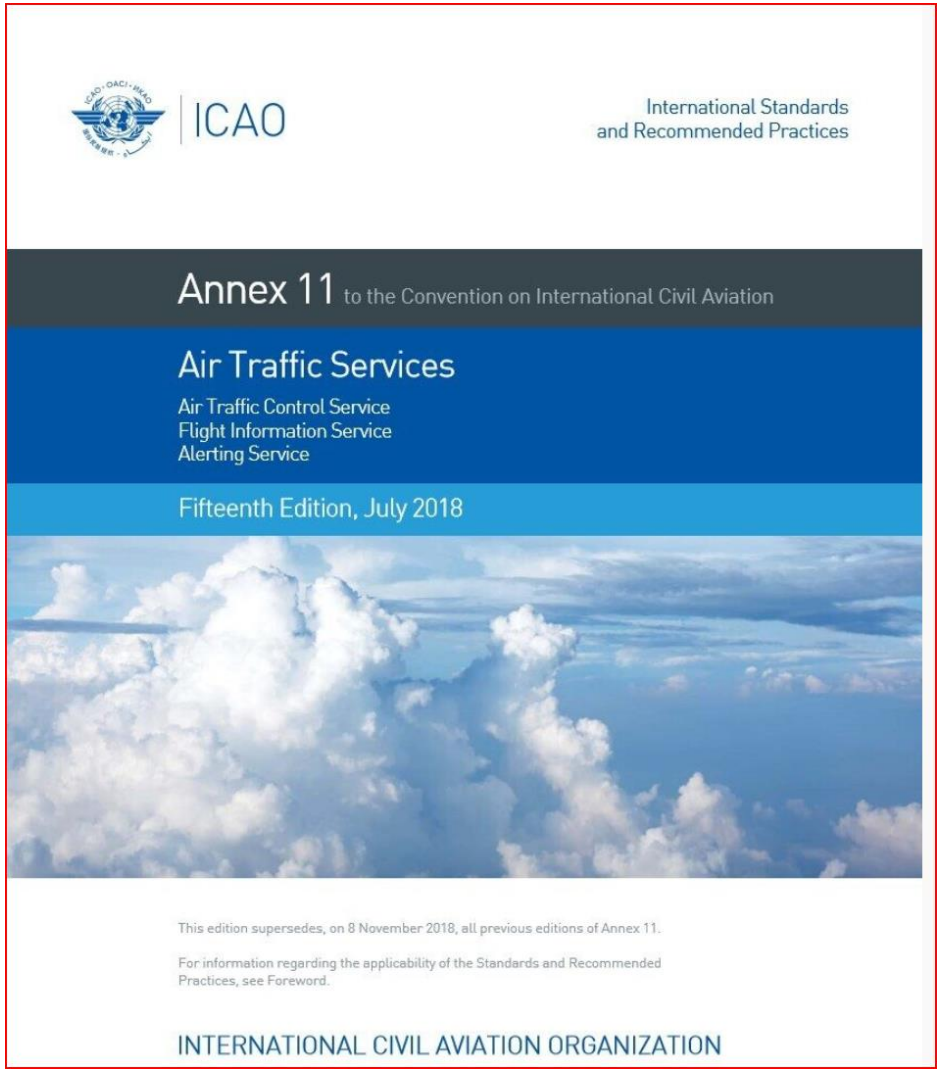
04

Annex 11

15th Edition – July 2018

Amendment 52

3/11/2022



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ANNEX 11 – Air Traffic Services.

15th Edition – July 2018.

– Amendment 52 5th November 2020.

Chapter 3 – Air Traffic Control Service.

- 3.4 - Separation Minima – details of current separation minima prescribed by ICAO are contained in PANS-ATM (Doc 4444) and Regional Supplementary Procedures (DOC 7030)).

- 3.9 - Provision of Radar and ADSB – Recommendation – Radar and ADS-B ground systems should provide for the display of safety-related alerts and warnings including;
  - Conflict alert.
  - Minimum safe altitude warning.
  - Unintentionally duplicated SSR codes.
  - Conflict prediction.

DOCUMENTS

DOC 4444 – Procedures for Air Navigation Services

DOC 9871 – TECHNICAL PROVISIONS FOR MODE S SERVICES AND EXTENDED SQUITTER

DOC 9924 – Aeronautical Surveillance Manual

DOC 9994 – Manual on airborne surveillance applications

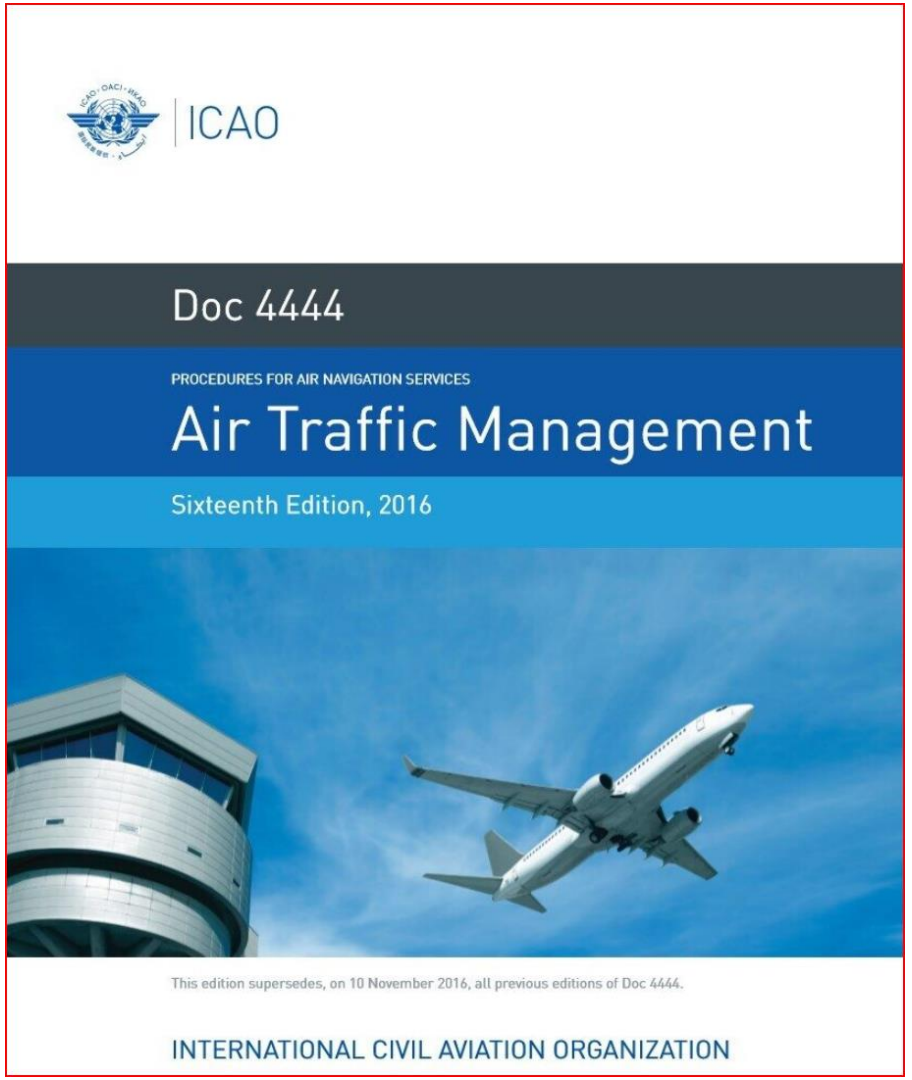
CIR 326/AN188 – Assessment of ADSB and Multilateration to Support ATS and guidelines for implementation

DOC 4444

16th Edition – Nov 2016

Amendment 11

3/11/2022



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DOC 4444 – Procedures for Air Navigation Services - Air Traffic Management (PANS – ATM).

16th Edition – Nov 2016.

– Amendment 11, 3rd November 2022.

Edition 16 provides a comprehensive update of the procedures and a major reorganisation of the contents. The new title reflects that provisions and procedures relating to safety management of air traffic services and to air traffic flow management are included.

2 - Scope and Purpose.

- 2.1 - DOC 4444: Is complementary to Standard and Recommended Practices in Annex 2, Rules of the Air in Annex 11 and are supplemented by regional procedures, when necessary, as explained in DOC 7030.

Chapter 2 – ATS Safety Management.

- 2.2 – Objectives.

The objectives of ATS safety management are to ensure that:

- The established level of safety applicable to the provision of ATS within an airspace or aerodrome is met, and
- Safety-related enhancements are implemented whenever necessary.

- 2.3 - ATS Safety Management Activities.
- 2.3.1 - An ATS SMS should include:
  - c) safety risk assessment for the introduction of new equipment systems (e.g., ADS-B).

- 2.5 – Safety Reviews.
- 2.5.2 - Scope – includes both Regulatory and Operations Issues.

  Operations and technical issues should ensure that:

  d) Communications, navigation, surveillance and other safety significant systems and equipment.

  1. Tested for normal operations on a routine basis.
  2. Meet the required level of reliability, and availability as defined by the appropriate authority.
  3. Provide for the timely and appropriate detection and warning of system failures and degradations.
  4. Include documentation on the consequences of system, subsystem and equipment failure and degradations.
  5. Include measures to control the probability of failures and degradations, and
  6. Include adequate backup facilities and/or procedures in the event of a system failure or degradation.

- Terms:
  Reliability – the probability that a device or system will function without failure over a specified period or amount of usage.
- Availability – The ratio of percentage of the time that a system is operating correctly to the total time in that period.

- 2.6 - Safety Risk Assessment.
- 2.6.1.1 – A safety risk assessment shall be carried out including:
  - f) implementation of new communications, surveillance or other safety-signification systems, including those providing new functionality and/or capabilities.

- 2.6.2 - Safety-significant Factors.

  The safety risk assessment shall consider all factors to be safety-significant, including:
  - f) Type and capabilities of surveillance system and the availability of systems providing controller support and or alert functions. Where ADS-B implementation envisages reliance upon a common source for surveillance and/or navigation, the safety risk shall take account of adequate contingency measures to mitigate the risk of either degradation or loss of the common source (e.g., GPS).

- 2.7 - Safety-Enhancing measures.
- 2.7.2 – Except where risk is acceptable, the ATS authority SHALL implement appropriate measures to eliminate or reduce the risk to a level that is acceptable - including through the introduction of surveillance such as ADS-B relying on highly accurate GPS.

Chapter 3 – ATS System and Capacity and Air Traffic Flow Management.

3.1 - Capacity Management .

3.1.2 - Capacity Assessment should include:

- d) The types of surveillance systems in use, their technical reliability/availability as well as backup availability.

3.1.4 - Enhancement of ATC capacity including:

- d) Develop plans to increase capacity when/where required.

3.2.2 - Flow Management procedures – Not considered here.

Chapter 4 – Divisions of Responsibility for Control Between Air Traffic Control Units.

- 4.11.6 - Data format of ADS-B messages – see ANNEX 10 VOL III Part 1 and VOL IV.

Chapter 5 – Separation and Minima.

- 5.2.2 - Degraded aircraft performance – any degradation of performance below the level required for the airspace in which it is operating Shall be communicated by the pilot to ATC – When the degradation affects separation minimum, the controller shall take action to establish another appropriate type of separation or separation minimum.
  - NOTE – For a radar service, as part of the introduction of ADS-B a Controller may notice through alerts on the screen that ADS-B performance has degraded before or even if the pilot is aware. Controllers have a responsibility to inform the pilot and apply the appropriate separation.
  - NOTE – It is up to an ANSP to decide if they wish to display degraded data to controllers.

- 5.4.2.3 - Longitudinal Separation Based on Distance Using Distance Measuring Equipment (DME) and/or GNSS.
  - NOTE - Use of GNSS may be new to controllers.

- 5.4.2.4 - Longitudinal Separation Minima with Mach Number Technique based on Time.
  - NOTE - ADS-B does not provide IAS or MACH for Versions 0, 1 or 2.

- 5.4.2.7 - Longitudinal Separation Minima Based on Distance using ADS-B IN-Trail Procedure (ITP).
  - See CIR 325.

Chapter 6 – Separation in the Vicinity of Aerodromes.

- 6.7.3.2 - Requirements and Procedures for Independent Parallel Approaches.
    - Table 6-1 ATS surveillance system criteria for different runway spacings.

Note 1 and Note 2.

Note 1 references CIR 326 re ADS-B performance criteria.

Note 2 refers to Chapter 2, Section 2.6.2 f) on ADS-B implementation that envisages reliance upon a common source for surveillance and/or navigation – i.e., GPS.

Chapter 7 – Procedures for Aerodrome Control Service.

Note – Provisions for the use of Surveillance in the aerodrome control service are contained in Chapter 8, 8.10.

Chapter 8 – ATS Surveillance Services.

- 8.1 - ATS Surveillance Systems Capabilities.
- 8.1.1 – Surveillance systems shall have a very high level of reliability, availability and integrity. System failures or significant degradations which may cause complete or partial interruptions shall be very remote. Backup facilities shall be provided.

Note 3 – Guidance material pertaining to the use of ADS-B and MLAT systems and their system performance is contained in Cir 326.

- 8.1.5 – States should, where possible, facilitate the sharing of information derived from ATS surveillance systems to extend and improve surveillance in adjacent control areas.
- 8.1.7 – ATS surveillance systems may be used either alone or in combination to provide air traffic services including separation between aircraft provide:

  c) in the case of ADS-B the availability of data from participating aircraft is adequate.

- 8.1.10 ADS-B shall only be used for the provision of air traffic control services provided the quality of the information contained in the ADS-B message exceeds the values specified by the appropriate ATS authority.

- 8.1.11 - ADS-B may be used alone, including in the provision of separation between aircraft, provided:
  - a) Identification is established and maintained.
  - b) Data integrity measure is adequate to support the separation minima.
  - c) There is no requirement for detection of aircraft not transmitting ADS-B.
  - d) There is no requirement for determining the aircrafts position independent of the position-determining elements of the aircraft navigation system.

- 8.2 - Situation Display.
- 8.2.3 - Position indications may be displayed as: a) individual position symbols (e.g., PSR, SSR, ADSB or MLAT) or as combined symbols.

- 8.4 - Provision of ATS Surveillance Services.
- 8.4.1 – Information from ATS surveillance systems ……. should be used where possible in the provision of and ATC service to improve capacity, efficiency and to enhance safety.

- 8.5 - Use of SSR Transponders and ADS-B Transmitters.
- #Note - Transponder operating procedures are contained in PANS-OPS DOC8168 VOL 1, Part III Section 3.

- 8.5.1 - General – pilots and controllers shall strictly adhere to published operating procedures and standard radiotelephone phraseology. The correct setting of transponder codes, and/or aircraft identification shall be ensured, at all times.

- 8.5.4 - Operation of ADS-B transmitters.

  # Note 1 – To notify state of emergency or other urgent information ADS-B Ver 2 is the same as a MODE A/C/S transponder. Ver 1 has issues around the transmission of the MODE 3A code and Ver 0 does not transmit a MODE 3A code so only transmits a general EMG code regardless of what the pilot selects.

- 8.5.5.1 Verification of level information.

  #Note – you cannot use GEOMETRIC height output from an aircraft within the ATMS for surveillance separation.

- 8.6 - General Procedures.
- 8.6.2 - Identification of Aircraft .

  # Note the difference between 8.6.2.2 ADS-B identification procedures and 8.6.2.3 SSR and/or MLAT identification procedures. Why?

- 8.7 - Use of ATS Surveillance in the Air Traffic Control Service.
- 8.7.3 - Separation minima based on ATS surveillance systems – 5 NM minimum unless reduced by appropriate ATS authority.
- 8.7.6 - Speed control – procedures for speed control are contained in Chap 4 Section 4.6.

- 8.8 - Emergencies, Hazards and Equipment Failures.

  #Note 1 – Aircraft equipped with Ver 0 ADS-B have the capability to only transmit a general EMG, regardless of the Mode 3A code set on the transponder.

- 8.8.5 - Degradation of aircraft position sources – ATS authority shall establish contingency procedures in the event of ADS-B data degradation.

- 8.9 - Use of ATS surveillance system in the Approach control service.

- 8.10 - Use of ATS surveillance systems in the aerodrome control service.
  - NOTE - 8.9 and 8.10 cover surveillance use in approach and tower control. Areas where a reduction of minimum separation to 3 and 2.5 NM can be approved by the ATS authority.

- 8.10.2 - Use of ATS surveillance for surface movement control.
  - See also ED-163.

Chapter 9 – Flight information and Alerting Service.

Chapter 10 – Coordination.

Chapter 11 – Air Traffic Service Messages.

Chapter 12 – PHRASEOLOGIES.

- 12.3 - ATC Phraseologies.
  - 12.3.1.14 GNSS service status.
  - NOTE - To be used if unavailable or unreliable.

- 12.4 - ATS Surveillance Service Phraseologies.
- 12.4.3 - Secondary Surveillance radar (SSR) and ADS-B phraseologies.
  - NOTE – Can be confusing to aircrew who see no difference in the cockpit to a MODE S transponder of a transponder which also squits ADSB data.

Chapter 13 – ADS-C.

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Chapter 14 – CPDLC.

Chapter 15 – PROCEDURES RELATED TO EMERGENCIES, COMMUNICATION FAILURE AND CONTINGENCIES.

- 15.1 - Emergency Procedures.
  - 15.1.3.2 and 15.1.4.2 – use of 7500 and 7700,
- 15.3 - Air Ground Communications Failure – use of 7600.

Note a Ver 0 (DO260) ADS-B transponder does not transmit these codes, only on a GEN EMG alert.

- 15.7 - Other ATC Contingency Procedures – includes ACAS, STCA, and MSAW alerts.

Chapter 16 – Miscellaneous Procedures .

Appendices.

Appendix 1 – Instructions for air-reporting by voice communications.

APPENDIX 2 – FLIGHT PLAN.

- Correct filing of Flight Plan data – including:
  - Field 7 – Aircraft Identification – ACID in use (not necessarily the aircraft registration).
  - Field 10 – Equipment including surveillance capabilities (e.g., B1 or B2).
  - Field 18 – Other information including MODE S address (e.g., CODE/C81818).

Appendix 3 – Air Traffic Service Messages.

Appendix 4 – Air Traffic Incident Report.

Appendix 5 – CPDLC message set.

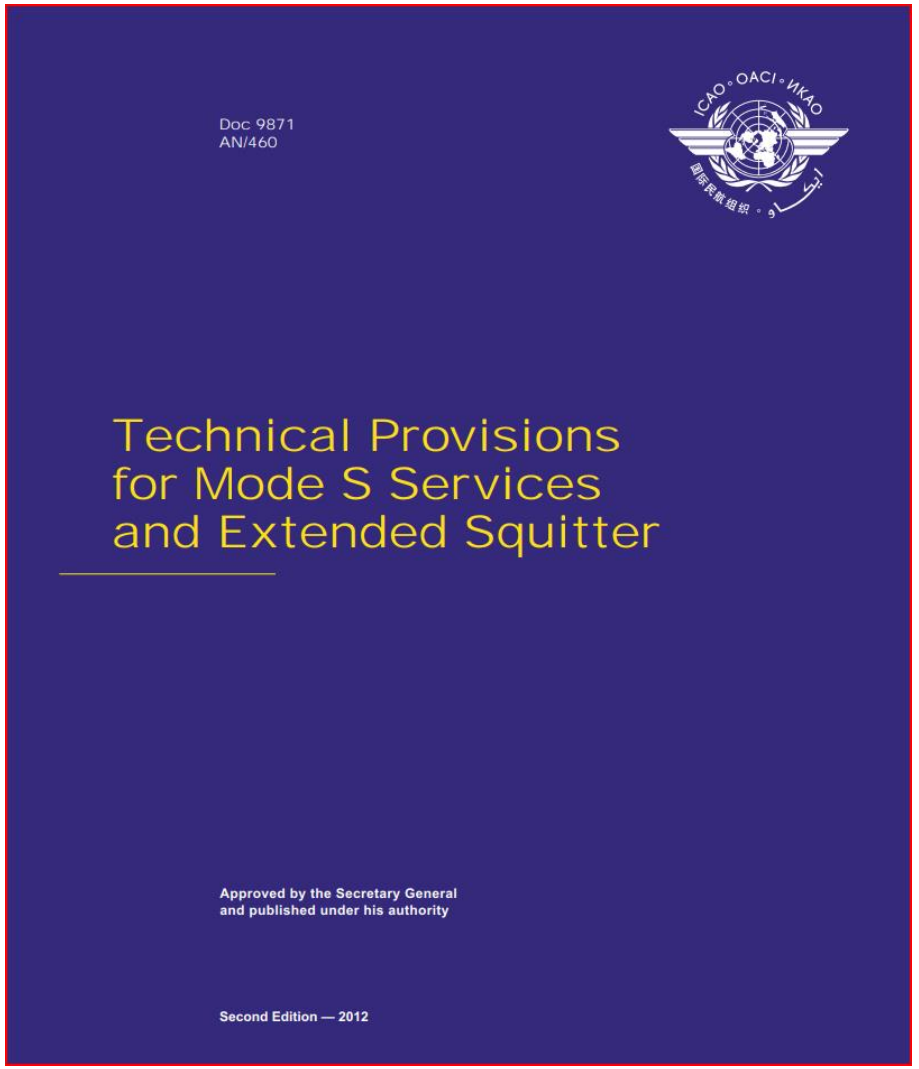
Appendix 6 – AIDC messages.

02

DOC 9871

2ND Edition – 2012

Amendment 2
03/04/2023



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DOC 9871 – TECHNICAL PROVISIONS FOR MODE S SERVICES AND EXTENDED SQUITTER.

2nd Edition 2012.

– Amendment 2 03/4/2023.

Forward: This second edition includes additional parameters to support the identified ADS-B operational requirements not in the original version.

Chapter 2 – Overview of MODE S and extended squitter (ADS-B) version ZERO.

- 2.3.1 - Using the 1090 ES message formats, ADS-B surveillance quality is reported by Navigation Uncertainty Category (NUC), which can be an indication of either accuracy or integrity of the navigation data – DO260.

Chapter 3 – Overview of Extended Squitter Version 1.

- 3.1.1 – Formats for version 1 revised to overcome limitation of reporting the surveillance quality using navigation uncertainty category (NUC). Revised formats are:
    - Navigation accuracy category (NAC).
    - Navigation integrity category (NIC), and
    - Surveillance integrity level (SIL).

Note – Version 1 formats are fully backward compatible with Version 0.

Chapter 4 – Overview of Extended Squitter Version 2.

- 4.1.1 – Update of formats and protocols to reflect experience gained with ADSB leading to the introduction of DO260B. Some of the changes include:
    - Separated reporting of source and system integrity.
    - Additional levels of NIC to support airborne and surface applications.
    - Update to the processing of MODE 3A.
    - Eliminated the vertical component of NIC and NAC.

- ES formats now include the transmission of selected altitude, selected heading, and barometric pressure, as well as MODE A codes in standard format.
- Table 4-1 ADS-B Version 2 Backward Compatibility Summary.
  - Comprehensive list of changes to Version 2.

Appendix A – Provisions for Extended squitter Ver 0.

Appendix B – Provisions for Extended squitter Ver 1.

Appendix C – Provisions for Extended squitter Ver 2.

Appendix D – Implementation guidelines.

- Provides guidelines on the data formats contained in APPX A, B and C, and is used by the avionics industry and developers of Air Traffic Services (ATS) applications.

03

DOC 9924

3rd Edition – 2020

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DOC 9924 – AERONAUTICAL SURVEILLANCE MANUAL.

3rd Edition 2020.

Chapter 1 – Introduction.

- 1.1.2 – This manual has been produced as a reference document on aeronautical surveillance for ATM purposes. The chapters should leave the reader with a good understanding of how aeronautical surveillance in applied in the ATM process. Specifically:
  - c) guidance on performance of a surveillance system.
- 1.2 – The need for Aeronautical Surveillance.

Chapter 2 – Surveillance System Definition.

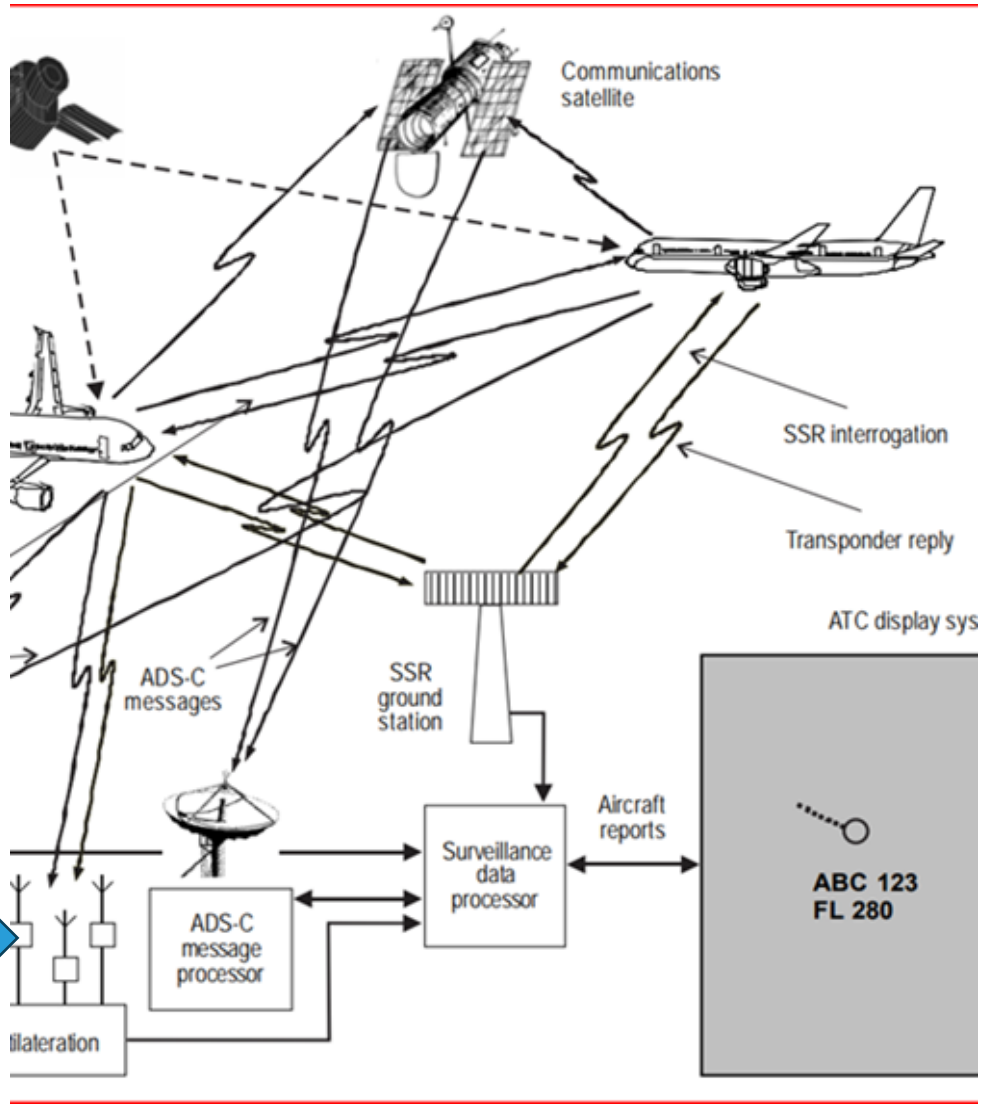
- 2.1.2 – Requirements for ATS surveillance are contained in DOC 4444.
- 2.2 - Surveillance Categories – provides an outline of the various surveillance systems.

Chapter 3 Applications of Air Traffic Surveillance.

- 3.1.1 - Aeronautical Surveillance Systems.

- 3.1.1.2 - This section presents general ideas, rather than prescribing firm surveillance requirements for each control service (APP, AREA etc). Care must be taken to match the surveillance system to the environment and operational needs as well as aircraft equipage.

Example of an Area Control Surveillance Architecture



- 3.3 - Operational use of Surveillance Data.
- 3.3.1 – In addition to technical considerations, operational requirements need to be fulfilled, to allow air traffic controllers to provide services based on information from the surveillance system. – see DOC 8168.
- 3.3.2 – References anti-spoofing, and anti-jamming.
    - SSR, and ADS-B are vulnerable to anti-spoofing, while most surveillance system are vulnerable to anti-jamming.

Chapter 4 – Technical Performance Requirements for Surveillance Systems.

- 4.1.3 – It SHALL be noted that technical performance requirements for surveillance systems are insufficient to authorize a given operational separation. Other factors include Human Factors, procedures, airspace and traffic density.
- 4.2 - Definition of Parameters Contributing to Quality of Services – includes Data item, accuracy, data integrity, availability, continuity, reliability, update rate, integrity (system), integrity (data) and coverage.

- 4.3 – Other performance-related issues.
- 4.3.3 – Verification that a surveillance system meets the requirements prior to being put into operational service. – Carry out periodic testing.

Chapter 5 – Air-Ground Surveillance Systems.

- 5.1 – Components include:
  - Remote surveillance subsystem (on aircraft),
  - Sensor system (e.g., SSR or ADSB antennae),
  - Communications system (between sensor and SDP),
  - Surveillance Data Processor (SDP) (combines, integrates with other data, and provides/distributes to users).
- 5.4 – Dependent Cooperative Systems – ADS-C , ADS-B, UAT, VDL Mode 4.
- 5.5 - SDP Systems – including Mosaic tracking, and track fusion.

- 5.6 – Surveillance Data Distribution by Asterix:
  - Describes formats for the exchange of data between the surveillance sensors and the data processing systems, and for the exchange of data between exchange of surveillance data between systems.
  - Contains the system area code (SAC) and the system identification code (SIC) – see appendix N for further details on Asterix.

Chapter 6 – Airborne Surveillance.

- Includes ADS-B IN for newer separations such as “In-Trail-Procedure” in Oceanics airspace.

Chapter 7 – Surveillance System Deployment Considerations.

- 7.1 - Best Practices Checklist – includes:
  - Define the operational requirements,
  - Analyse design options,
  - Define local environment (current and future),
  - Implementation.

- 7.2 - Transition to Dependent Surveillance Systems.
- 7.2.1 – Any new surveillance system must provide at least the same level of performance.
- 7.2.2 – In addition to accuracy, availability, reliability, integrity and update rate the following (a-g) should be considered:
  - a) Protection against common mode failures.
  - b) fallback surveillance or operational procedures in case of GNSS failure in an individual aircraft.
  - c) Loss of GNSS over an extended area.
  - d) Validation of the reported ADS-B position.

- 7.3 Other Issues – to be considered when designing a surveillance system (a-h).
  - c) The impact of the loss of surveillance of individual aircraft.
  - d) The impact of the loss of surveillance over a wide area.
  - f) The ability to operate to specification with the expected traffic density.

Appendices – (A to S).

Appendix A – Technical Performance Requirements.

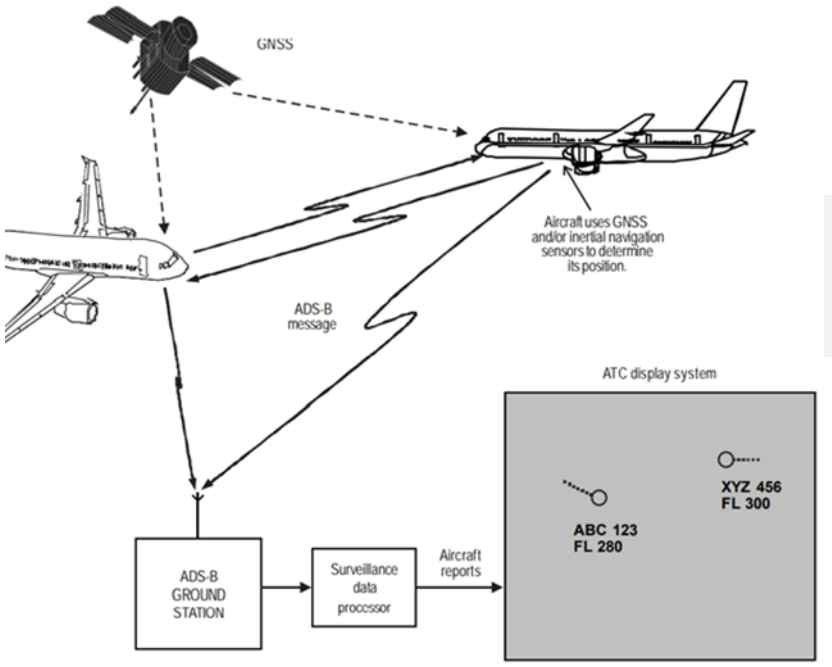
Appendix K – 1090 MHz ES.

Appendix N – Asterix interface specifications.

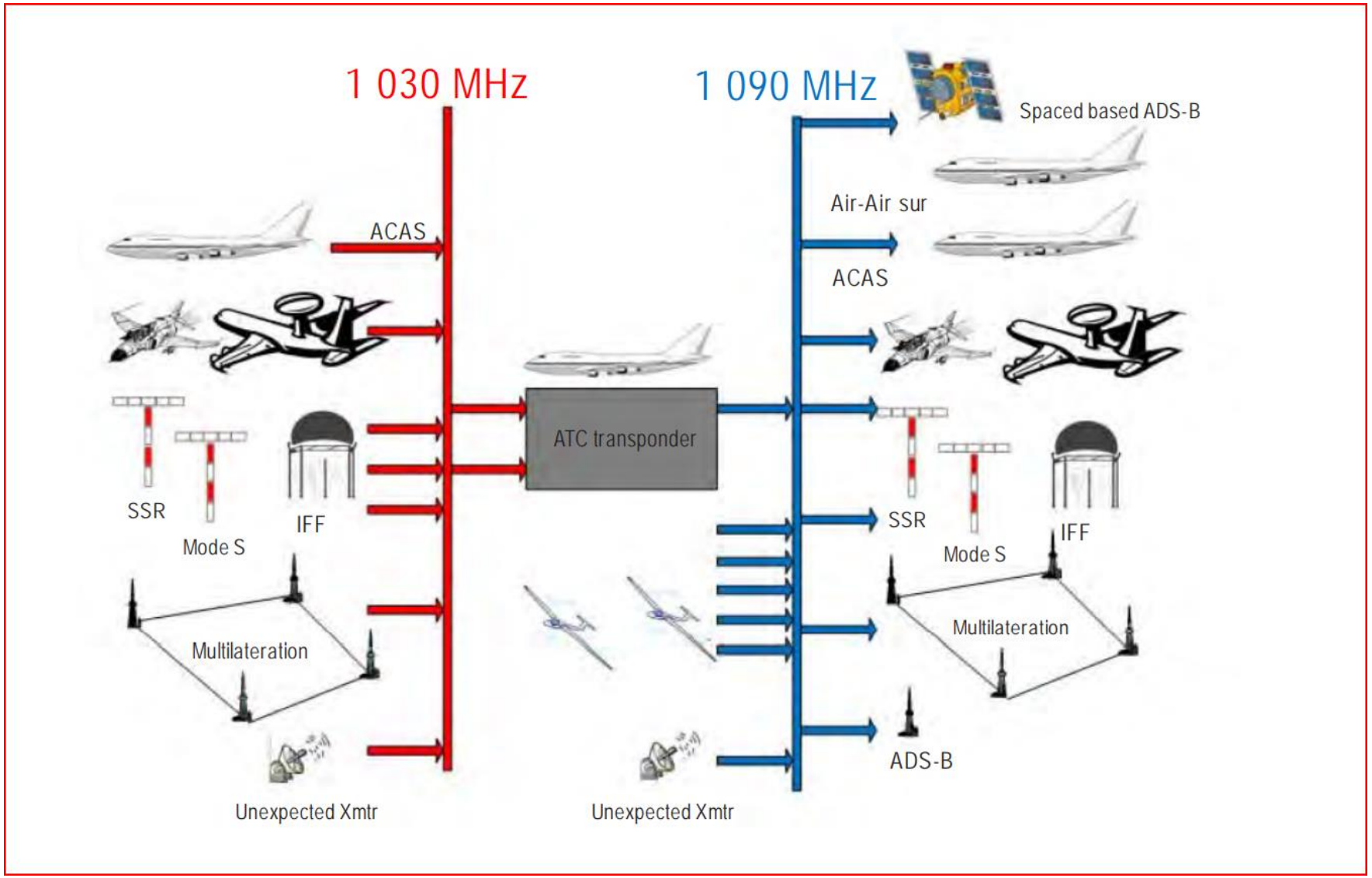
Appendix P – Guidance for ADS-B flight testing.

- Section 3 ADS-B Flight Test Performance Measurements.

Fig K-1 ES Concept



1030 and 1090 MHz Systems



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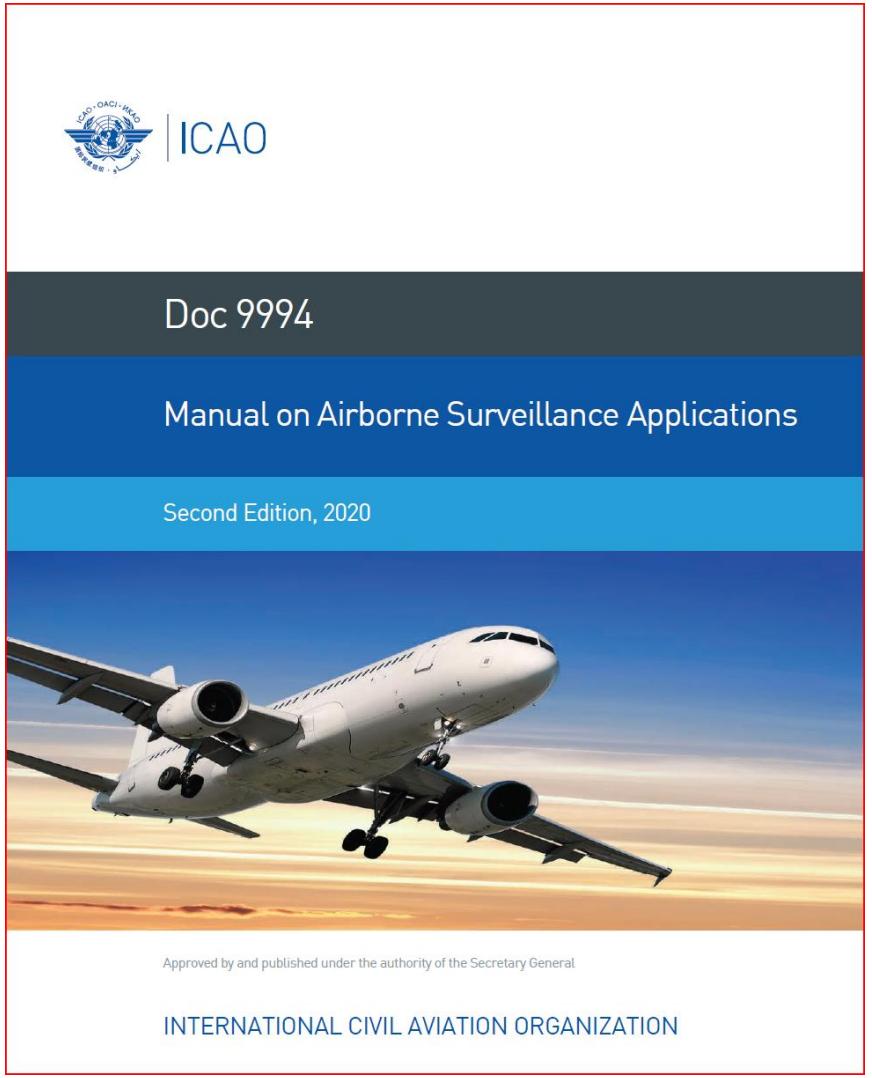
DOC 9994

2nd Edition, 2020



ICAO

DOC 9994 – Manual on Airborne Surveillance Applications

2nd Edition – 2020.

Chapter 1 – Automatic Dependent Surveillance-Broadcast (ADS-B).

- 1.1 Overview.
- 1.3 Limitations of ADS-B.

  1.3.1 - Requires the proper equipage of a large population of aircraft, an installed and certified data source supplying position/velocity and an indication of the quality of that information.

  - 1.3.2.3 – Existence in parallel of different link versions (VER 0, 1 and 2) requires ground systems to mitigate for :
    - Differences in broadcast data (quality indicators) and,
    - Data not available (e.g., selected altitude, MODE 3A).
  - 1.3.3.3 – Factors which limit range of ADS-B information are:
    - Position of the transmitting and receiving antennas.
    - Power of the ADS-B transmitter.
    - Receiver sensitivity.
    - Extent of radio frequency interference, and
    - Local traffic density.

Chapter 2 – Initial airborne Surveillance Capabilities and In-Trail procedure (ITP).

- Info only.

Chapter 3 – Specific Implementations.

- Info only.

Chapter 4 – Interval Management.

- Info only.

Chapter 5 – Advanced applications.

- Info only.

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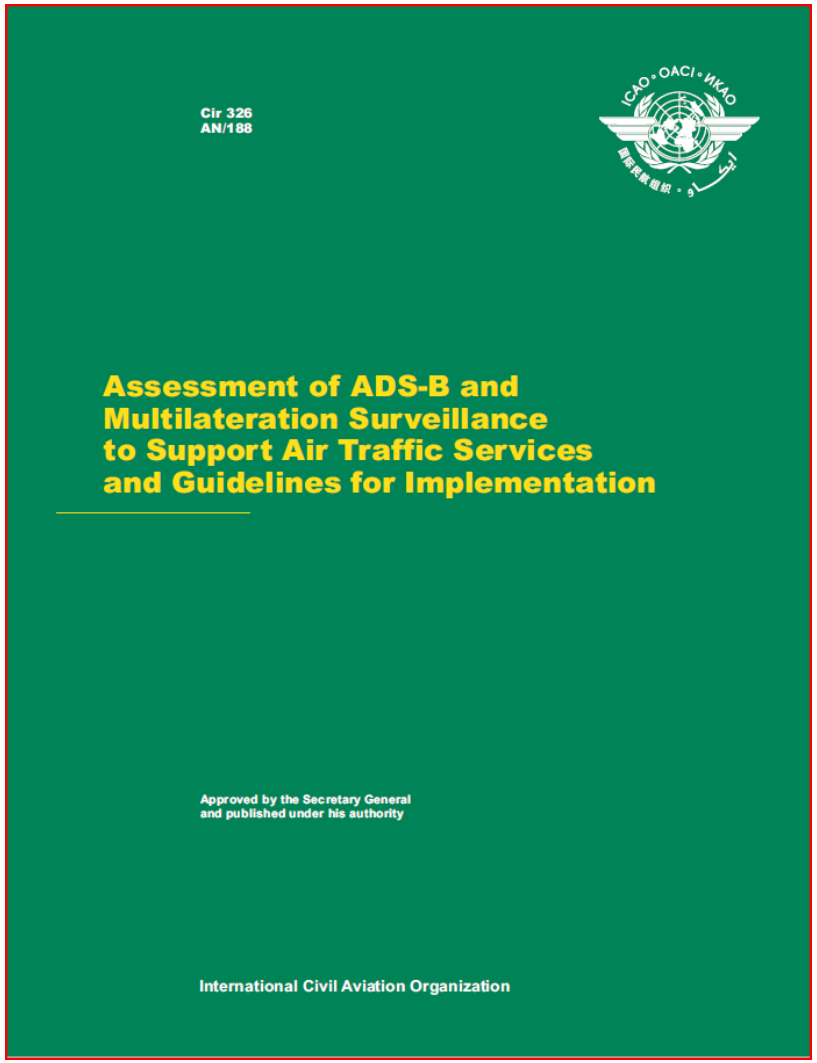
CIR 326
AN/188

Edition -
2012



CIR 326 – ANB/188 – Assessment of ADS-B and Multilateration Surveillance to Support Air Traffic Services and Guidelines for Implementation.

- 2012 EDITION.

CIR 326 provides details of a comparative assessment by the ICAO Separation and Airspace Safety Panel (SASP) that concludes ADS-B and MLAT can be used to provide ATS surveillance, including separation subject to certain conditions.

References used.

- Annexes - Annex 10 Vol III.
- Procedures for Air Navigation Services (PANS) – Air traffic Management (PANS ATM - DOC 4444).
- Manuals – DOC 9849, 9689, and 9859.
- Other Publications – EUROCAE (ED-117, ED-126, ED-146), Eurocontrol Comparative Assessment – SSR to MLAT.
- RTCA – DO-242A, DO-208, DO-260, DO260A, and DO-288.

Chapter 1 Introduction.

1.1 – Identification of performance requirements which must be met - see appendix C. SASP concluded ADS-B can be used as a means of separation in accordance with Chapter 8 of DOC 4444.

1.2 – CIR326 is a consolidated AND single-point of reference of the assessment undertaken by SASP and includes:

a) An overview of ATC surveillance - Chapter 2.

b) The rationale used by SASP in developing the methodology and arriving at the conclusion – found in Chapters 3 and 4 and Appendices A and B.

c) The performance requirements attached to the conclusions – see Chapter 3 and Appendices A, C and D.

d) Evidence of the ADS-B surveillance performance during several state trials – see Chapter 3 and Appendices E and F.

e) A compendium of hazards and mitigation measures identified during the development of a safety case to support trials and implementation - see Chapter 3 and Appendices G and H.

f) A state implementation roadmap - see Chapter 4.

1.5 – Within the context this SASP assessment, it is appropriate to draw attention to two of the benefits from using ADS-B:

- Extension of surveillance coverage, especially at low altitudes, leading to more efficient use of airspace and,
- Cost savings from use of ADS-B rather than costs associated with installing, maintaining, life-cycling and extending existing SSR based surveillance.

1.6 – SASP considered that ADS-B will improve safety and increase operational efficiency in areas where radar is not justified.

1.7 – While ADS-B and radar are similar, some aspects such as failure modes are not identical.

- ADS-B is characterised by dependence on the aircrafts on-board position determination and ATC surveillance – potential for common mode failure exists.(E.g., in an aircraft where GNSS is the sole means of ADS-B position AND navigation, GNSS becomes a common point of failure for both navigation and ATC surveillance).
- Such failure modes need to be identified and mitigated during the implementation of the safety assessment process.

APPENDIX C.

KEY ADS-B PERFORMANCE REQUIREMENTS TO SUPPORT THE CLAIM THAT ADS-B SURVEILLANCE IS "AS GOOD AS THE REFERENCE SSR."

Table C-1 identifies 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.

States should refer to Attachment A of the SASP comparative assessment document for the description of the reference SSR used in that assessment.

The list is not intended as an exhaustive list of performance requirements; but namely a list of characteristics requiring consideration when deploying ADS-B and assumes a sound background of "radar" knowledge, techniques and practice.

Table C-1: SASP comparative assessment

	Characteristic	Minimum Requirement 3 NM	Minimum Requirement 5 NM
1.	Position: Accuracy	A 95 percentile accuracy of 0.3 NM This can be represented by either: Chapter One navigation accuracy category (position) = 6 or better; or Chapter Two navigation uncertainty category = 5 (for GNSS derived positional data only)	A 95 percentile accuracy of 0.5 NM This can be represented by either: Chapter Three navigation accuracy category (position) = 5 or better; or Chapter Four navigation uncertainty category = 4 (for GNSS derived positional data only)
2.	Position: Integrity	A containment radius of <1 NM and the likelihood of the position error exceeding containment radius of 1e - 5 This can be represented by either: 1. navigation uncertainty category = 4 or better; or 2. navigation integrity category = 5 (or better) and surveillance integrity limit = 2 (or better)	A containment radius of <2 NM and the likelihood of the position error exceeding containment radius of 1e - 5 This can be represented by either: a) navigation uncertainty category = 3 or better; or b) navigation integrity category = 4 (or better) and surveillance integrity limit = 2 (or better)
3.	Position: Latency	4 seconds	4 seconds
4.	Position: Update Rate	5 seconds	12 seconds

Note.– For the provision of separation services to aircraft equipped with DO260 avionics, a State may select lower encoded values for NUC in relation to accuracy and integrity when it is demonstrated by safety assessment that the 95 percentile accuracy, and containment radius values, identified in Table C-1 will continue to be met.

Chapter 2 – ATS Surveillance.

ADS-B Surveillance – high-level overview of radar and its use by ATC.

2.1 to 2.12 are accepted as already known and understood.

- 2.13 – Fundamental data (aircraft identity, position and altitude) from ADS-B are the same as Radar.
- 2.14 – In many cases the data from the aircraft via ADS-B, is of higher quality and more-timely than radar data.
- 2.15 – ADS-B data may be used to support safety net functions in the same manner as radar surveillance data.

2.16 to 2.20 are MLAT only.

Key differences between Radar Surveillance and ADS-B Surveillance.

- 2.21 The major difference is the means of determining the aircraft position and state vector data.
  - Radar measures the aircraft position independent of aircraft system, estimating the aircraft speed, direction, turn rate etc.
  - ADS-B data-links to the ground, aircraft position and state vector determined by aircraft avionics (e.g., the aircraft navigation system or from a stand-alone GNSS receiver/navigator).
- 2.23 – In both Radar and ADS-B, aircraft data has their source in the air data computer or a barometric encoder. The flight management system (FMS) supplies the flight identity.

Situation Displays

- 2.25 - ADS-B data may be displayed on a situation display in a similar manner to radar.

- 2.26 – ADS-B may be integrated with radar data OR processed and displayed separately.

- 2.27 – Key data elements of ADS-B broadcast message are:
  - Aircraft identification (24-bit address).
  - Position data (and associated accuracy and integrity information).
  - Velocity vector (and accuracy).
  - Barometric altitude.
  - Status, emergency indicators and SPI.
    - # Note DO260 transmits a general Emergency alert and are unable to squawk ident while the EMG exists.
    - # Note DO260A provides for communications failure, unlawful interference and emergency, BUT may display the MODE 3A code incorrectly it the ATM decoding is not correct.

- 2.28 – Source of data elements in an airborne ADS-B installation.
  a) ADS-B emitter (DF18), SSR transponder or stand-alone ADS-B transmitter.
  b) Data source of aircraft's position and speed – FMS or GNSS receiver/navigator.
  c) Data source of barometric altitude (air data computer or stand-alone barometric pressure encoder.
  d) Data source of flight identity (entered by the pilot into the transponder control panel or FMS which passes the data to the transponder).

- 2.32 to 2.37 are Specific to MLAT systems.

ATC Surveillance Performance Characteristics.

- Table 2-1 Surveillance data elements and performance characteristics – e.g., the position of the aircraft needs to be known by the controller, the accuracy of the position and integrity of the position data are also important.

ATC Surveillance Performance Characteristics.

Table 2-1:

- The light grey shows where a data element is elaborated in the technical comparison.
- The dark grey is used for the specific case of velocity vector.
- X means the surveillance characteristics of the related data element could be affected at that level.
- * means that the performance parameter value is expected not to be degraded between origination and use.
- For radar, position integrity and accuracy are known therefore indicated as fixed. For ADS-B the values are dynamic.

Table 2-1. Surveillance data elements and performance characteristics

Data element	*Performance characteristics*	*SSR*		*ADS-B*		*MLAT*	
		Ground	*Airborne*	*Ground*	*Airborne*	*Ground*	*Airborne*
Position	Accuracy	X (fixed)		•	X NIC/NUC	X (dynamic)	
	Integrity	X (fixed)		•	X SIL/NUC	X (fixed)	
	Update rate	X		X	X	X	
	Latency	X		X	X	X	
	Reliability	X		X	X	X	
Position NIC or NUC	Latency			X	X		
	Update rate			X	X		
	Reliability			X	X		
Position SIL	Latency			X	X		
	Reliability			X	X		
Velocity vector	Accuracy	X		• (or X)	X	X (dynamic)	
	Integrity	X		• (or X)	X	X	
	Update rate	X		X	X	X	
	Latency	X		X	X	X	
	Reliability	X		X	X	X	
Altitude	Accuracy	•	X	•	X	•	X
	Integrity	•	X	•	X	•	X
	Update rate	X	X	X	X	X	X
	Latency	X	X	X	X	X	X
	Reliability	X	X	X	X	X	X
Identification/identity	Integrity	•	X	•	X	•	X
	Reliability	X	X	X	X	X	X
	Latency	X	X	X	X	X	X
	Update rate	X	X	X	X	X	X
Emergency/SPI	Reliability	X	X	X	X	X	X
	Update rate	X	X	X	X	X	X
	Latency	X	X	X	X	X	X

ATS Surveillance Performance and System Safety.

- 2.40 – A safety assessment shall demonstrate the system will not induce dangerous situations. In the CNS/ATM system elements will need to be qualified to ensure the system performs as expected and is safe.

- 2.42 – In order to ensure that ADS-B implementation is safe, airspace planners must undertake a safety assessment in parallel to a performance assessment.

Chapter 3 – Assessment of ADS-B and MLAT Surveillance.

- 3.1 to 3.18 – Describe the methodology used to provide the conclusions in 3.20 and 3.21 .

Note to assess the suitability of ADS-B for use by ATS, SASP sought to follow the guidance from the Manual on Airspace Planning Methodology for the Determination of Separation Minima (Doc 9689).

- 3.19 – Using 3.1 to 3.18, SASP undertook a sequence of steps as part of the site-specific ADS-B surveillance trials and implementation This is reflected in TABLE 3-1 ADS-B and MLAT surveillance trials and implementations.

Table 3-1.

Table 3-1. ADS-B and MLAT surveillance trials and implementations

Step 1: A reference radar was selected and its general performance described. This reference system is used to provide a 3 NM separation minima for both en-route and terminal area operations.	***Output 1:*** Preliminary benchmark set against which ADS-B and MLAT surveillance could be compared — see Appendix A.
Step 2: Identification of radar display data that influence controller working practices, e.g. HMI, conflict resolution.	***Output 2:*** Key characteristics specific to ADS-B and MLAT surveillance were identified and selected to allow comparison to the reference radar — see Appendix B.
Step 3: A technical comparison of the key characteristics was undertaken between the reference radar and ADS-B and MLAT surveillance — see Appendix B.	***Output 3:*** Minimum performance requirements ADS-B and MLAT surveillance identified — see Appendix C.
Step 4: Completion of several safety cases for site-specific ADS-B and MLAT implementation and/or trials.	***Output 4:*** A compendium of hazards and mitigation measures were extracted from safety cases, including character-istics specific to ADS-B and MLAT systems — see Appendices G and H.
Step 5: ADS-B and MLAT surveillance implemented operationally or on a trial basis at several specific locations.	***Output 5a:*** The compendium of hazards and mitigation measures were updated in the light of experience gained during the trial — see Appendices G and H. ***Output 5b:*** ADS-B and MLAT surveillance trials demonstrated that achieved performance is "better or at least no worse than" that of the reference radar — see Appendices E and F. ***Output 5c:*** Amendment to PANS-ATM definitions and Chapter 8 to enable ADS-B and MLAT 3 NM and 5 NM separation minima.

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Conclusions.

- **3.20 – "ADS-B and MLAT surveillance is BETTER or at least NO WORSE than the reference SSR and therefore NO LESS SAFE than radar."**

- **3.21 – "ADS-B or MLAT surveillance can be used to provide a 2.5 NM, 3 NM or 5 NM separation minima as prescribed in PANS-ATM whether ADS-B or MLAT is the sole means of ATC surveillance or used together with radar."**

Chapter 4 – State Implementation Road Map.

- 4.2 - The state implementation roadmap contained in this chapter is based upon the assumptions that a need for ADS-B surveillance has been identified and that necessary consultation has taken place with airspace users.

Implementation Considerations.

- 4.3 - Implementation Considerations.
  - a) Airborne equipage – equipage, number and adjacent states.
  - b) Avionic performance requirements – monitoring programme.
  - c) Safety requirements and assessment.
  - d) Controller licencing and training – Consider human factors.
  - e) Installation of the ADS-B ground stations – time and resources, Vendor or ANSP?
  - f) Creation of surveillance-based airspace – time consuming and complex.

- 4.5 - State implementation comprised of four processes:
  a) Process A - Definition of Airspace Concept.
  b) Process B - Identification of ADS-B Performance requirements.
  c) Process C - Safety Assessment Preparation for implementation.
  d) Process D - Preparation for Implementation.

  - These processes are covered in points 4.7 to 4.26.

  - # Note 4.18 – States can use your own reference radar to compare ADS-B against. However, if a States reference radars performance is equal to or less than the reference MSSR use by SASP, States are strongly advised to use the SASP reference MSSR as the reference MSSR for their purposes. Without considering safety requirements, this would suggest that the SASP ADS-B performance characteristics immediately apply.
  - # Note 4.19 – If the performance of the State MSSR is more demanding than the SASP reference MSSR, States should use their own reference MSSR as the benchmark against which the ADS-B performance requirements are determined.

- 4.22 – Doc 9589 describes the safety assessment process.

Appendix A – General description of the reference radar.

- Describes SSR characteristics and technical specification.
- Technical performance of the reference radar can be compared with baseline documented in Eurocae ED126 .

Appendix B – Technical comparison between MSSR, ADSB and MLAT.

Appendix C – Key ADS-B performance requirements to support claim that ADS-B Surveillance is “As Good As the Reference SSR.”

- Table C-1: SASP comparative assessment – previously looked at.

Appendix C.

Table C-1.

Table C-1: SASP comparative assessment

	Characteristic	Minimum Requirement 3 NM	Minimum Requirement 5 NM
1.	Position: Accuracy	A 95 percentile accuracy of 0.3 NM This can be represented by either: a) navigation accuracy category (position) = 6 or better; or b) navigation uncertainty category = 5 (for GNSS derived positional data only)	A 95 percentile accuracy of 0.5 NM This can be represented by either: a) navigation accuracy category (position) = 5 or better; or b) navigation uncertainty category = 4 (for GNSS derived positional data only)
2.	Position: Integrity	A containment radius of <1 NM and the likelihood of the position error exceeding containment radius of 1e - 5 This can be represented by either: a) navigation uncertainty category = 4 or better; or b) navigation integrity category = 5 (or better) and surveillance integrity limit = 2 (or better)	A containment radius of <2 NM and the likelihood of the position error exceeding containment radius of 1e - 5 This can be represented by either: a) navigation uncertainty category = 3 or better; or b) navigation integrity category = 4 (or better) and surveillance integrity limit = 2 (or better)
3.	Position: Latency	4 seconds	4 seconds
4.	Position: Update Rate	5 seconds	12 seconds

Note.– For the provision of separation services to aircraft equipped with DO260 avionics, a State may select lower encoded values for NUC in relation to accuracy and integrity when it is demonstrated by safety assessment that the 95 percentile accuracy, and containment radius values, identified in Table C-1 will continue to be met.

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Other useful documents include:

- Eurocae ED126 – Safety and Performance and Interoperability Requirements for ADS-B NRA Application (Ver 5.0 Nov 2006) (RTCA DO-303).
- Eurocae ED129 – Technical Specification for a 1090 MHz Extended Squitter ADS-B Surveillance System (Aug 2023) (RTCA DO-260C).
- Eurocontrol Asterix Category 021: - Specification for Surveillance Data Exchange Asterix Part 12 Category 21, Edition 2.6 (22 Dec 2021).
- AMC 20-24 (Effective 02/05/2008) Certification Considerations for the Enhanced ATS in Non-Radar using ADS-B Surveillance (ADS-B NRA) Application via 1090 MHz Extended Squitter.
- RTCA DO-318 (Effective 9/9/2009) – Safety, Performance and Interoperability Requirements Document for Enhanced Air Traffic Services in Radar-Controlled Areas Using ADS-B Surveillance.
- Eurocontrol Specification for ATM Surveillance System Performance - Vol 1 and 2. (ESASSP).
- A States own Regulatory Rules for the use of ADS-B.

Thank You

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