AMC 20-24
Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHZ Extended Squitter.

1 PREAMBLE

1.1 The scope of this Acceptable Means of Compliance (AMC) is the airworthiness and operational approval of the "Enhanced Air Traffic Services in Non-Radar Areas using ADS-B Surveillance" (ADS-B-NRA) application.

1.2 Operational benefits of the ADS-B-NRA application include the enhancement of the Air Traffic Control Service in current non-radar airspace. ADS-B-NRA would provide controllers with improved situational awareness of aircraft positions, and in consequence appropriate separation minima could be applied depending on the environment and the approval of the competent authority. Current non-radar airspace is controlled using procedural methods which demand large separations. ADS-B-NRA separation minima would be smaller than that used in current non-radar airspace. Alerting Services in non-radar airspace will be enhanced by more accurate information on the latest position of aircraft.

Hence, it is expected that in areas where radar coverage is not feasible or not economically justified this application will provide benefits to capacity, efficiency and safety in a way similar to what would be achieved by use of SSR radar.

1.3 The European CASCADE programme is the mechanism for co-ordination of the European implementation of ADS-B (ADS-B-NRA and other ADS-B based ground and airborne surveillance applications). One of the programme's aims is to ensure harmonisation and efficiency of implementation.

1.4 CASCADE uses the globally interoperable 1090 MHz Extended Squitter (ES) data link technology, compliant with ICAO SARPS in Annex 10 and in line with the recommendations of the Conference ICAO ANC-11.

1.5 In parallel, the FAA Airservices Australia and Nav Canada plan to deploy ADS-B using the same data link technology. It is assumed that aircraft will be interoperable with all implementation programmes using the EUROCAE/RTCA ADS-B-NRA standard (ED-126, DO-303).

1.6 The meaning of abbreviations may be found in Appendix 1.

2 PURPOSE

2.1 This AMC is for operators seeking to operate in airspace classifications A to E where ADS-B-NRA services have been implemented by the Air Navigation Service Provider. It provides the basis for approval of aircraft systems and identifies operational considerations.

It may also assist other stakeholders by alerting them to aircraft requirements, operator procedures and related assumptions. These other stakeholders could include airspace planners, air traffic service providers, ATS system manufacturers, surveillance data processing system manufacturers, communication service providers, aircraft and avionics equipment manufacturers and ATS regulatory authorities.

2.2 Acceptable Means of Compliance (AMC) illustrate a means, but not the only means, by which a requirement contained in an EASA airworthiness code or an implementing rule of the Basic Regulation, can be met.

An applicant correctly implementing this AMC in its entirety is assured of acceptance of compliance with the airworthiness considerations prior to use of the automatic dependent surveillance broadcast equipment. The operational considerations in this AMC are consistent with the operational considerations in the position paper 039 revision 8, that is endorsed by the JAA Operations Sectorial Team (OST). An Operator that, in conjunction with the airworthiness considerations, has correctly implemented this AMC

should be ensured of acceptance of compliance with the operations rules applicable in JAA Member States.

3 SCOPE

3.1 This AMC is applicable to the various ATS services contained in the ADS-B-NRA application, including separation services. This AMC fulfils the ADS-B-NRA Safety, Performance Requirements and Interoperability Requirements as established in EUROCAE ED-126[1], using the methodology described in EUROCAE document ED-78A[2].

AMC requirements are driven by the ED-126 requirements for a 5NM separation service (applicable to both en-route and TMA airspace).

Note: the actual choice of ADS-B-NRA ATC service provision, including of the applicable separation minima, is at the discretion of the implementing Air Traffic Service Provider, and should be based on local safety cases.

3.2 The AMC addresses the 1090 MHz Extended Squitter (ES) data link technology as the ADS-B transmit technology.[3]

4 REFERENCE DOCUMENTS

4.1 Related Regulatory Requirements

- CS/FAR 25.1301, 25.1307, 25.1309, 25.1322, 25.1431, 25.1581, or equivalent requirements of CS 23, 27 and 29, if applicable.
- EU-OPS 1.230, 1.420, 1.845, 1.865, 1040, 1.1045 and 1.1060, as amended, or, if applicable, equivalent requirements of JAR-OPS 3.
- National operating regulations.

4.2 Related EASA/JAA TGL/NPA/AMC (and FAA TSO) Material

- ETSO-2C112b: Minimum Operational Performance Specification for SSR Mode S Transponders (adopts ED-73B)
- ETSO-129A (TSO-129/TSO-129A): Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)
- ETSO-145/ETSO-146 (TSO-145/TSO-146; TSO-145A/TSO-146A): Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)
- AMC 20-13 Certification of Mode S Transponder Systems for Enhanced Surveillance
- JAA Temporary Guidance leaflet (TGL) 13, Revision 1: Certification of Mode S Transponder Systems for Elementary Surveillance

4.3 Related FAA Advisory Circular Material

- FAA AC20-138A: Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment

4.4 Related EUROCAE/RTCA Standards

- ED-126 (DO-303): Safety, Performance and Interoperability Requirements Document for ADS-B-NRA Application (December 2006)

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[1] ED-126: "Safety, Performance and Interoperability Requirements Document for ADS-B-NRA" Application

[2] ED-78A: Guidelines for approval of the provision and use of Air Traffic Services supported by Data communications

[3] Other, requirements compliant, ADS-B transmit systems (e.g. VDL Mode 4) are expected to be covered through separate regulatory material, as appropriate.

- ED78A (DO-264): Guidelines for Approval of the Provision and Use of Air Traffic Services Supported by data communications;
- ED-102 (DO-260): MOPS for 1090MHz for ADS-B
- DO-260A: MOPS for 1090MHz for ADS-B
- ED-73B (DO-181C): Minimum Operational Performance Specification for Secondary Surveillance Radar Mode S Transponders
- ED-26: MPS for airborne altitude measurements and coding systems

4.5 Related ICAO Standards and Manuals

- PANS-ATM, Doc 4444, Amendment 4: Procedures for Air Navigation Services – Air Traffic Management
- Annex 10 (Volume III & IV): Aeronautical Telecommunications

5 ASSUMPTIONS

Applicants should note that this AMC is based on the following assumptions.

5.1 Air Traffic Service Provider (ATSP)

ATSP implements the ADS-B-NRA application compliant with relevant requirements of the safety, performance and interoperability requirements of EUROCAE standard ED-126. Deviations from, or supplements to the established standards are assessed by the ATSP. Deviations that potentially impact the airborne domain should be assessed in coordination with relevant stakeholders as per ED78A.

Section 8 of this document, "Airworthiness Considerations", lists permissible deviations from the target requirements related to the use of existing aircraft installations in support of initial implementations[4]. These deviations are currently considered operationally acceptable under the assumption that ground mitigation means as discussed in the following subsections, are implemented, at the descretion of the ATSP.

5.1.1 Consistency of position quality indicators with associated position information at time of transmission

In cases where position quality indicators are not consistent with actual position quality (e.g., due to uncompensated latency in position transmissions), the implementing ATSP might:

- treat the higher quality indicator encodings as an advised lower one (e.g. NUC=7 may be treated as NUC=5) or,
- consider, for separation purpose, a quality indicator more stringent than the one stated in ED-126 (e.g. NUC =5 rather than NUC=4).

5.1.2 Encoding of NUC Quality Indicator (DO-260 compliant transponders)

In order to mitigate the encoding of the NUC quality indicator based on accuracy quality information (HFOM) in the case of the unavailability of the GPS RAIM function (i.e. unavailability of HPL information), the implementing ATSP may, for instance, rely on the analysis of the frequency and duration of the unavailability of the RAIM function (as part of the local safety assessment).

5.1.3 Transmission of generic emergency indicator only

In order to mitigate the transmission of only the generic emergency indicator (and not also the discrete codes selected by the flight crew), It is assumed that appropriate operational procedures have been established by the implementing ATSP and that pilots and controllers have been trained in their use.

[4] Refer to sections 8.3.3, 8.3.5 and 8.8.2.

5.1.4 Communications Service Provider (CSP)

In case of CSPs providing (part of) the ground surveillance data communication services (operation of ADS-B ground stations and/or surveillance data networks), the CSP is committed to provide communication services to ATSPs with the expected Quality of Service as defined in a specific Service Level Agreement.

The Service Level Agreement is bilaterally agreed between the CSP and an ATSP. The terms of reference of the Service Level Agreement are consistent with the performance requirements of the ED-126 document.

5.2 Aeronautical Information Service

Each State publishes in its AIP/NOTAM, or equivalent notification, information related to the surveillance provisions, schedule, relevant procedures and confirmation of compliance with ED-126.

6 SYSTEM DESCRIPTION

The basic concept of ADS-B involves the broadcasting of surveillance information from aircraft via a data link.

To support the ADS-B-NRA application, the overall ADS-B avionics system (in the following referred to as "**ADS-B System**") would need to provide the following functions:

- Adequate surveillance data provision capability;
- ADS-B message processing (encoding and generation);
- ADS-B message transmission (1090 MHz ES airborne surveillance data-link);

Whereas the latter two functions are incorporated in the 1090 MHz ES ADS-B transmit system, the surveillance data provision is realised through various on-board surveillance data sources (e.g. horizontal position source, barometric altimetry, ATC transponder control panel).

The horizontal position accuracy and integrity requirements of the ADS-B-NRA application are associated with quality indicators which form part of the air-to-ground ADS-B message exchange. The interconnecting avionics architecture is part of the ADS-B System.

7 FUNCTIONAL CRITERIA

Note: ICAO and EUROCAE/RTCA interoperability references, including aspects of range and resolution of the various data items listed hereafter, for both ED-102/DO-260 and DO-260A equipment-based ADS-B transmit systems, are presented in Appendix 4.

7.1 In line with ED-126 (section 4), the ADS-B System needs to meet the following surveillance data transmission requirements, as a minimum:

- A unique ICAO 24 bit aircraft address (contained within each ADS-B message transmission);
- Horizontal Position (latitude and longitude);
- Horizontal Position Quality Indicator(s) (position integrity for both ED-102/DO-260 and DO-260A based ADS-B transmit systems, as well as accuracy for DO-260A based ADS-B transmit systems);
- Barometric Altitude;
- Aircraft Identification;
- Special Position Identification (SPI);
- Emergency Status and Emergency Indicator;

- Version Number (in aircraft operational status message, if avionics are DO-260A compliant).

7.2 In line with ED-126 (section 4), it is recommended that the ADS-B System meets the following optional surveillance data transmission requirement:

- Ground Velocity.

8 AIRWORTHINESS CONSIDERATIONS

8.1 Airworthiness Certification Objectives

For the purposes of the ADS-B-NRA application, the ADS-B System installed in the aircraft needs to be designed to deliver data that satisfy the airborne domain requirements in line with ED-126 Section 3.4, (Appendix 3 provides a summary for information purposes).

8.2 ADS-B System

8.2.1 The (overall) ADS-B System integrity level with respect to the processing of horizontal position data and horizontal position quality indicators, covering the processing (and data exchange) chain from horizontal position data source(s) to ADS-B transmit data string encoding) needs to be 10^{-5}/fh (refer also to Table 1 in Appendix 3).

Note 1: this integrity level is required to adequately protect against the corruption of horizontal position data and horizontal position quality indicators when applying separation.

Note 2: These performance figures have been set for the "ADS-B out" function, to be used in ADS-B NRA operations as laid down by the Operational Safety Assessment in Annex C of ED 126.

Note 3: Compliance with these performance figures do not constitute per se a demonstration that the safety objectives of ADS-B NRA operations allocated to avionics are achieved.

Note 4: Also refer to § 3.1.

8.2.2 The (overall) ADS-B System continuity level needs to be $2*10^{-4}$/fh (refer also to Table 1 in Appendix 3).

Note 1: These performance figures have been set for the "ADS-B out" function, to be used in ADS-B NRA operations as laid down by the Operational Safety Assessment in Annex C of ED 126;

Note 2: Compliance with these performance figures do not constitute per se a demonstration that the safety objectives of ADS-B NRA operations allocated to avionics are achieved;

Note 3: Also refer to § 3.1.

8.2.3 The latency of the horizontal position data, including any uncompensated latency, introduced by the (overall) ADS-B System does not exceed 1.5 second in 95% and 3 seconds in 99.9% of all ADS-B message transmission cases (refer also to Table 1 in Appendix 3).

8.3 ADS-B Transmit System

8.3.1 Compliance with the air-ground interoperability requirements, as specified in ED-126 and presented in Section 7.1 and Appendix 4, needs to be demonstrated.

8.3.2. For 1090 MHz Extended Squitter ADS-B transmit systems, this should be demonstrated by the relevant tests documented in:

- ED-73B/ETSO-2C112b (or DO-181C);

- ED-102, as a minimum, or an equivalent standard which is acceptable to the Agency (e.g. DO-260 or DO-260A).

8.3.3 ADS-B transmit systems need to transmit horizontal position quality indicators consistent with the associated position information at the time of transmission.

For the expression of the position accuracy quality, the related indicator should therefore reflect:

- The quality (in terms of both integrity and accuracy) of the position measurement itself; and
- Any (uncompensated) latency incurring prior to transmission.

Note: guidance on the quality indicators is provided in Appendix 4.

The applicant needs to demonstrate the correctness of consistent quality indicator encodings in line with (minimum) position source quality and any (uncompensated) maximum latency as expressed in 8.2.3.

Permissible deviation for initial implementations:

For initial implementations, some aircraft installations may not take into account any (uncompensated) latency in the encoding of the position accuracy quality indicator as applicable at the time of transmission. Hence, such installations might transmit horizontal position quality indicators that are consistent with the associated position information only for lower quality indicator encodings[5] (e.g. NUC=5 or NAC=5) but not higher ones (e.g. NUC=7 or NAC=7). Such deviation from the above target requirement need to be listed in the Aircraft Flight Manual (refer to Section 9.3).

8.3.4 The value of the horizontal position quality indicators need to be based on the integrity information for the encoding of the ED-102/DO-260 related NUC and the DO-260A related NIC quality indicator, as related to the horizontal position sources.

In addition, the encoding of the DO-260A NAC quality indicator needs to be based on the accuracy information of the horizontal position sources.

8.3.5 In case of ED-102/DO-260 based ADS-B transmit systems, the NUC Quality Indicator value need to be encoded based on the integrity containment radius[6] only.

Permissible deviation for initial implementations:

For initial implementations, some GNSS position source based aircraft installations may encode the NUC Quality Indicator on accuracy quality information (HFOM) under rare satellite constellation circumstances leading to the temporary unavailability of the integrity monitoring (RAIM) function (i.e. unavailability of integrity containment radius calculation). Such deviation from the above target requirement need to be listed in the Aircraft Flight Manual (refer to Section 9.3).

8.3.6 If the ADS-B transmit system does not have a means to determine an appropriate integrity containment radius and a valid position is reported, then the Quality Indicator (i.e. NUC or NIC) need to be encoded to indicate that the integrity containment radius is unknown (i.e. NUC/NIC should be set to 'zero').

8.3.7 Transmitter antenna installation needs to comply with guidance for installation of ATC transponders to ensure satisfactory functioning. (Also refer to ED-73B)

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[5] This is a consequence of the definition of the quality indicator encoding describing an interval of values between a lower and an upper bound (refer also to Appendix 4.2). For instance, a NUC=5 encoding expresses an upper bound of position accuracy quality indication of 0.3NM whilst a NUC=7 encoding expresses an upper bound of 0.05NM. Therefore, in case of e.g. the actual GNSS position source performance, a NUC=5 encoding provides sufficient margin to also correctly express the effects of on-board uncompensated latency whilst this is not the case for a NUC=7 encoding any more.

[6] I.e. GNSS conformant HPL/HIL information.

8.3.8 If more than one ADS-B transmit system is installed, simultaneous operation of both transmit systems needs to be prevented.

8.4 Horizontal Position Data Sources

8.4.1 The requirements on horizontal position data sources are based on the ED-126 safety and performance assessments.

8.4.2 Components of horizontal position data sources external to the aircraft ADS-B system (such as the GNSS space segment) fall outside these airworthiness considerations. Such external components are assumed to operate in accordance with their specified nominal performance[7].

Nevertheless, failures of the external data source components are required to be detected through on-board monitoring (as expressed in section 8.4.3).

8.4.3 Any eligible horizontal position data source needs to meet the following minimum requirements (refer also to Table 2 in Appendix 3):

- Correct encoding of quality indicator information in line with the actual performance of the selected horizontal position data source(s), i.e. in relation to position integrity containment bound (ED-102/DO-260 and DO-260A ADS-B transmit systems) and position accuracy (DO-260A ADS-B transmit systems);
- Position source failure probability: 10^{-4} per hour[8];
- Position integrity alert failure probability, commensurate with the performance characteristics of GNSS integrity monitoring[9]: 10^{-3} (per position source failure event);
- Position integrity time to alert: 10 seconds.

8.4.4 If available and valid, integrity containment radius information should be provided to the ADS-B transmit system from the position data source, or equivalent, on the same interface as and together with each positional data.

8.4.5 If the integrity containment radius is not provided by the horizontal position data source, the ADS-B transmit system may use other means to establish an appropriate integrity containment radius[10], provided a requirements compliant integrity alert mechanism is available.

8.4.6 Use of GNSS Systems as Primary Position Data Source

8.4.6.1 GNSS is considered as primary horizontal position data source for the provision of an acceptable accuracy and integrity performance in support of the ATC separation services contained within the ADS-B-NRA application.

The ED-126 safety and performance assessments are based on the specified performance and characteristics of GNSS systems, including receiver autonomous integrity monitoring. Therefore, for GNSS systems as specified in section 8.4.6.2, a safety and performance demonstration is not required.

8.4.6.2 If GNSS is used as a positional source, the GNSS system should be either compatible with:

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[7] For GNSS based systems, this includes satellite constellation aspects.

[8] For GNSS based position sources, the failure occurs outside the aircraft system and is therefore expressed as per ATSU-hour. Proof of compliance of alternative solely aircraft based sources should take this into account and might have to express the requirement as 10^{-5} per flight hour (i.e. for the en-route environment).

[9] As realised through receiver autonomous integrity monitoring (RAIM), including its characteristics of increasingly less likely to fail for position errors beyond the horizontal protection limit. Within ED-126, the position source failure is modelled as a bias error that equals the integrity containment radius.

[10] E.g. HPL/HIL based upon known RAIM protection threshold.

- ETSO C-129A, TSO C-129 or TSO C-129A; or
- ETSO C-145/C-146 or TSO C-145A/C-146A,

capable of delivering position data with a periodic interval of at least 1.2 s [11].

8.4.6.3 For GNSS systems compatible with (E)TSO C-129 (any revision), it is highly desired that the system incorporates Fault Detection and Exclusion capability as defined in AC 20-138A, Appendix 1, "GPS as a Primary Means of Navigation for Oceanic/Remote Operations".

8.4.7 Use of Alternative Compliant Position Data Sources

As the ED-126 safety and performance assessments are based on the performance and characteristics of GNSS systems, for alternative position sources a dedicated safety and performance assessment is required to demonstrate compliance with the ED-126 requirements.

8.4.8 Use of Temporary Back-up Position Data Sources

Back-up position data sources not complying with the requirements referred to in section 8.4.3 may prove very useful in enhancing the continuity of ADS-B surveillance provision during temporary outages of the primary (or equivalent alternative) position data sources.

Any such back-up position data source needs to report its accuracy and integrity performance to the ADS-B transmit system, in a format compliant with ED-102/DO-260 or DO-260A, as appropriate.

8.5 Barometric Altitude Data Sources

8.5.1 Pressure altitude provided to the ADS-B transmit system needs to be in accordance with existing requirements for ATC transponders.

8.5.2 The digitizer code selected needs to correspond to within plus or minus 38.1 m (125 ft), on a 95% probability basis, with the pressure-altitude information (referenced to the standard pressure setting of 1013.25 hectopascals), used on board the aircraft to adhere to the assigned flight profile. (ICAO Annex 10, Vol IV, 3.1.1.7.12.2.4. See also EUROCAE ED-26).

The performance of the encoders and of the sensors needs to be independent from the pressure setting selected.

8.5.3 The transponder should indicate correctly the altitude resolution (quantisation) used, i.e. 25ft (from an appropriate source, default resolution) or 100ft (Gillham's coded source, permissible alternative resolution).

The conversion of Gillham's coded data to another format before inputting to the transponder is not permitted unless failure detection[12] can be provided and the resolution (quantisation) is set in the transmitted data to indicate 100ft.

8.5.4 In case more stringent barometric altimetry requirements are applicable in line with e.g. airspace requirements (e.g. RVSM) or other function requirements (e.g. ACAS II), then these requirements and their related regulation take precedence.

[11] ETSO C-145/C146 provides additional capabilities compared with ETSO C129A such as: processing of GPS without Selective Availability, processing of SBAS signals when available and Fault Detection Exclusion as a basic function. Therefore ETSO C145/146 usually provides higher quality integrity values than ETSO C-129A equipment.

[12] For instance, this need can be satisfied by means of dual independent altitude corrected sensors together with an altitude data comparator (which may be incorporated and enabled in the ADS-B transmit system).

8.6 Aircraft Identification

8.6.1 Identification needs to be provided to the ADS-B transmit system so that the information is identical to the filed ICAO flight plan. This information may be provided from:

- A flight management system; or
- A pilot control panel; or
- For aircraft, which always operate with the same flight identification (e.g. using registration as the flight identification) it may be programmed into equipment at installation.

8.6.2 In case no ICAO flight plan is filed, the Aircraft Registration needs to be provided to the ADS-B transmit system.

8.7 Special Position Identification (SPI)

For ATC transponder-based ADS-B transmit systems, the SPI capability needs to be provided. The SPI capability should be integrated into the transponder functionality and should be controlled from the transponder control panel.

8.8 Emergency Status/Emergency Indicator

8.8.1 When an emergency status (i.e. discrete emergency code) has been selected by the flight crew, the emergency indicator needs to be set by the ADS-B transmit system.

8.8.2 For ATC transponder-based ADS-B transmit systems, the discrete emergency code declaration capability should be integrated into the transponder functionality and should be controlled from the transponder control panel.

Permissible deviation for initial implementations:

For initial implementations, instead of the required transmission of the discrete emergency codes 7500, 7600 and 7700 when selected by the flight crew, the transmission of only the generic emergency indicator can satisfy this requirement. Such deviation from the above target requirement needs to be listed in the Aircraft Flight Manual (refer to Section 9.3).

8.9 Airworthiness Considerations regarding Optional Provisions

8.9.1 Ground Velocity (OPTIONAL)

Ground velocity, e.g. from an approved GNSS receiver, in the form of East/West and North/South Velocity (including a velocity quality indicator) is recommended to be provided.

8.9.2 Special Position Identification (SPI) (OPTIONAL)

For non-ATC transponder-based ADS-B transmit systems (i.e. installations based on dedicated ADS-B transmitters), a discrete input or a control panel should be provided to trigger the SPI indication.

8.9.3 Emergency Status/Emergency Indicator (OPTIONAL)

For non-ATC transponder-based ADS-B transmit systems (i.e. installations based on dedicated ADS-B transmitters), a discrete input or a control panel should be provided to indicate the emergency status (discrete emergency code).

8.9.4 Flight Deck Control Capabilities (OPTIONAL)

8.9.4.1 Means should be provided to the flight crew to modify the Aircraft Identification information when airborne.

8.9.4.2 Means should be provided to the flight crew to disable the ADS-B function on instruction from ATC without disabling the operation of the ATC transponder function.

Note: It is recommended to implement an independent ADS-B disabling function. For future ADS B application such flight deck capability may become mandatory. It should be recalled that disabling the operation of the transponder will disable also the ACAS function.

8.9.4.3 Means should be provided to the flight crew to disable the transmission of the barometric altitude.

9 COMPLIANCE WITH THIS AMC

9.1 Airworthiness

9.1.1 When showing compliance with this AMC, the following points should be noted:

a) The applicant will need to submit, to the Agency, a certification plan and a compliance statement that shows how the criteria of this AMC have been satisfied, together with evidence resulting from the activities described in the following paragraphs.

b) Compliance with the airworthiness requirements (e.g. CS-25) for intended function and safety may be demonstrated by equipment qualification, safety analysis of the interface between the ADS-B equipment and data sources, structural analyses of new antenna installations, equipment cooling verification, evidence of a human to machine interface, suitable for ADS-B-NRA.

c) The safety analysis of the interface between the ADS-B transmit system and its data sources should show no unwanted interaction under normal or fault conditions.

d) The functionality for ADS-B-NRA application may be demonstrated by testing that verifies nominal system operation, the aircraft derived surveillance data contained in the ADS-B messages, and the functioning of system monitoring tools/fault detectors (if any).

9.1.2 The functionality for ADS-B-NRA application may be further demonstrated by ground testing, using ramp test equipment where appropriate, that verifies nominal system operation, the aircraft derived surveillance data contained in the ADS-B messages, and the functioning of system monitoring tools/fault detectors (if any).

Note: this limited testing assumes that the air-ground surveillance systems have been shown to satisfactorily perform their intended functions in the flight environment in accordance with applicable requirements.

To minimise the certification effort for follow-on installations, the applicant may claim credit, from the Agency, for applicable certification and test data obtained from equivalent aircraft installations.

9.2 Performance

Where compliance with a performance requirement cannot readily be demonstrated by a test, then the performance may be verified by an alternative method such as analysis, including statistical analysis of measurements under operational conditions.

9.3 Aircraft Flight Manual

9.3.1 The Aircraft Flight Manual (AFM) or the Pilot's Operating Handbook (POH), whichever is applicable, needs to provide at least a statement of compliance that the ADS-B System complies with this AMC20-24 and if deviations are applicable. Deviations, including those stated in this document[13], as appropriate may be included or referred to.

9.4 Existing installations

9.4.1 The applicant will need to submit, to the Agency, a compliance statement, which shows how the criteria of this AMC have been satisfied for existing installations. Compliance may be supported by design review and inspection of the installed system to

[13] Refer to sections 8.3.3, 8.3.5 and 8.8.2.

confirm the availability of required features, functionality and acceptable human-machine interface.

9.4.2 Where this design review finds items of non-compliance, the applicant may offer mitigation that demonstrates an equivalent level of safety and performance. Items presented by the applicant which impact safety, performance and interoperability requirements allocation will need to be coordinated in accordance with ED-78A.

10 OPERATIONAL CONSIDERATIONS

10.1 General

10.1.1 The installation should be certified according to airworthiness considerations in section 8 prior to operational approval.

10.1.2 The assumptions in section 5, concerning Air Traffic and Communications Services Providers, and Aeronautical Information Services, should have been satisfied.

10.1.3 A unique ICAO 24 bit aircraft address should be assigned by the responsible authority to each airframe.

10.2 Operational Safety Aspects

10.2.1 In all cases, flight crews should comply with the surveillance provisions, schedules and relevant procedures contained in the Aeronautical Information Publications (AIP) published by the appropriate authorities.

10.2.2 Direct controller-pilot VHF voice communications should be available at all times.

10.2.3 If flight crew receive equipment indications showing that position being broadcast by the ADS-B system is in error (e.g. GPS anomaly), they should inform the ATSP, as appropriate, using any published contingency procedures.

10.2.4 When there is not an independent Flight Deck Control selection between the ADS-B function (ADS-B on/off) and the ATC transponder function, the crew must be fully aware that disabling the ADS B function will also lead to disable the ACAS function.

10.3 Operations Manual and Training

10.3.1 Operations Manual

10.3.1.1 The Operations Manual should include a system description, operational and contingency procedures and training elements for use of the ADS-B-NRA application.

10.3.1.2 The Operations Manual, preferably section B, should contain the operational aspects described in this guidance material.

10.3.1.3 Operators operating under the provisions of ICAO Annex 6 Part II "International General Aviation – Aeroplanes" are not required to have an operations manual.

However, in order to use ADS-B applications, the operator should develop similar training and operational procedures to the ones described in this guidance material. This material may need to be approved by the State of Registry of the operator in accordance with national practice and sight of this approval may be required by the ADS-B navigation service provider.

10.3.2 Flight Crew Training

10.3.2.1 Aircraft operators should ensure that flight crew are thoroughly familiar with all relevant aspects of ADS-B applications.

10.3.2.2 Flight crew training should address the:

a) General understanding of ADS-B-NRA operating procedures;

b) Specific ADS-B associated phraseology;

c) General understanding of the ADS-B technique and technology;

d) Characteristics and limitations of the flight deck human-machine interface, including an overview of ADS-B environment and system descriptions;

e) Need to use the ICAO defined format for entry of the Aircraft Identification or Aircraft Registration marking as applicable to the flight;

Note 1: ICAO Document 8168-OPS/611 Volume I (Procedures for Air Navigation Services) requires that flight crew of aircraft equipped with Mode "S" having an aircraft identification feature should set the aircraft identification into the transponder. This setting is required to correspond to the aircraft identification that has been specified at Item 7 of the ICAO flight plan and consists of no more than seven characters. If the aircraft identification consists of less than seven characters, no zeros, dashes or spaces should be added. If no flight plan has been filed, the setting needs to be the same as the aircraft's registration, again, up to a maximum of seven characters.

Note 2: The shortened format commonly used by airlines (a format used by International Airlines Transport Association (IATA)) is not compatible with ICAO provisions for the flight planning and ATC services used by ATC ground systems.

f) Operational procedures regarding the transmission of solely the generic emergency flag in cases when the flight crew actually selected a discrete emergency code (if implemented, refer to section 8.8) and SPI;

g) Indication of ADS-B transmit capability within the ICAO flight plan but only when the aircraft is certified according to this AMC;

h) Handling of data source errors (e.g. discrepancies between navigation data sources) (refer to 10.2.3);

i) Incident reporting procedures;

j) Crew Resources Management and associated human factors issues.

10.4 Incident reporting

Significant incidents associated with ATC surveillance information transmitted by the ADS-B data link that affects or could affect the safe operation of the aircraft will need to be reported in accordance with EU-OPS 1.420 (or national regulations, as applicable).

10.5 Minimum Equipment List

The MEL will need to be revised to indicate the possibility of despatch of aircraft with the ADS-B system unserviceable or partially unserviceable.

11 MAINTENANCE

11.1 Maintenance tests should include a periodic verification check of aircraft derived data including the ICAO 24 bit aircraft address using suitable ramp test equipment. The check of the 24 bit aircraft address should be made also in the event of a change of state of registration of the aircraft.

11.2 Maintenance tests should check the correct functioning of system fault detectors (if any).

11.3 Maintenance tests at ADS-B transmit system level for encoding altitude sensors with Gillham's code output should be based on the transition points defined in EUROCAE ED-26, Table 13.

11.4 Periodicity for the check of the ADS-B transmitter should be established.

12 AVAILABILITY OF DOCUMENTS

EASA documents are available from http://www.easa.europa.eu.

JAA documents are available from the JAA publisher Information Handling Services (IHS). Information on prices, where and how to order is available on both the JAA web site www.jaa.nl and the IHS web site www.avdataworks.com.

ICAO documents may be purchased from Document Sales Unit, International Civil Aviation Organisation, 999 University Street, Montreal, Quebec, Canada H3C 5H7, (Fax: 1 514 954 6769, e-mail: sales_unit@icao.org) or through national agencies.

EUROCAE documents may be purchased from EUROCAE, 102 rue Etienne Dolet, 92240 MALAKOFF, France, (Fax: 33 1 46556265). Web site: www.eurocae.org.

RTCA documents may be purchased from RTCA, Incorporated, 1828 L Street, Northwest, Suite 820, Washington, D.C. 20036-4001 U.S.A. Web site: www.rtca.org.

EUROCONTROL documents may be requested from EUROCONTROL, Documentation Centre, GS4, Rue de la Fusee, 96, B-1130 Brussels, Belgium; (Fax: 32 2 729 9109 or web site www.eurocontrol.int).

FAA documents may be obtained from Department of Transportation, Subsequent Distribution Office SVC-121.23, Ardmore East Business Centre, 3341 Q 75th Avenue, Landover, MD 20785, USA.

Australia CASA documents are available from http://www.casa.gov.au/.

Appendix 1.1: Common Terms

Reference should be made to EUROCAE document ED-126 for the definitions of terms.

Appendix 1.2: Abbreviations

ADS-B	Automatic Dependent Surveillance- Broadcast
ADS-B-NRA	Enhanced ATS in Non-Radar Areas using ADS-B Surveillance
AFM	Aircraft Flight Manual
ANC	Air Navigation Commission (ICAO)
ATSP	Air Traffic Service Provider
ATC	Air Traffic Control
ATS	Air Traffic Services
ATSU	Air Traffic Service Unit
ATM	Air Traffic Management
CASCADE	Co-operative ATS through Surveillance and Communication Applications Deployed in ECAC
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Administration
GNSS	Global Navigation Satellite System
HPL	Horizontal Protection Limit
HIL	Horizontal Integrity Limit
ICAO	International Civil Aviation Organisation
INTEROP	Interoperability Requirements
MEL	Minimum Equipment List
NIC	Navigation Integrity Category
NACp	Navigation Accuracy Category
NUC	Navigation Uncertainty Category
POH	Pilots Operating Handbook
RFG	Requirement Focus Group
SIL	Surveillance Integrity Level
SPI	Special Position Identifier
SPR	Safety and Performance Requirements
SSR	Secondary Surveillance Radar
OSED	Operational Services and Environment Definition
Rc	Horizontal Position Integrity Containment Radius
TMA	Terminal Manoeuvring Area

Appendix 2.1: Summary of core ADS-B-NRA Operational Assumptions

- The ADS-B-NRA application assumes implementation of the procedures contained in the PANS-ATM ADS-B amendment. Fallback procedures from the radar environment apply to ADS-B-NRA when necessary. For example, ATC could apply alternate procedural separation (e.g., a vertical standard) during degraded modes.
- En route traffic density is assumed to be the same as in the current environment in which single radar coverage would enable the provision of a 5NM separation service for en route regions. This corresponds to low or medium density.
- Direct Controller-Pilot Communication (VHF) is assumed to be available at all times.
- It is assumed that the ADS-B coverage is known to the Controller in the controlled airspace.

Appendix 2.2: Summary of core ADS-B-NRA Ground Domain Assumptions

- Controller operating procedures are assumed to be unaffected by the selection of an ADS-B data link, i.e., the ADS-B data link is assumed to be transparent to the controller.
- Air Traffic Controllers are assumed to follow existing procedures for coordination and transfer of aircraft. This applies to coordinating appropriate information with downstream units and complying with local agreements established between ATC units regarding separation standards to be established prior to entry into a bordering ATC unit.
- Appropriate ATS authorities are assumed to provide controllers with adequate contingency procedures in the event of ADS-B failures or degradation.
- It is assumed that there is a monitoring capability in the ADS-B Receive Subsystem that monitors the health and operation of the equipment and sends alerts and status messages to the Air Traffic Processing Subsystem.

Appendix 3: Summary of ADS-B-NRA Airborne Safety and Performance Requirements

Parameter	Requirement
Horizontal Position and Horizontal Position Quality Indicator(s)	10^{-5}/fh
ADS-B System Continuity	$2*10^{-4}$/fh
Horizontal Position Latency[1]	1.5 sec/95%

Table 1: Overall Minimum Airborne ADS-B System[2] Requirements

Parameter	Requirement
Horizontal Position Source	
• Accuracy (95%)	• 5 NM Sep: 926 m
• Integrity	
• Containment Radius (Rc)	• 5 NM Sep: Rc=2 NM
• Source Failure Probability	10^{-4}/h[3]
• Alert Failure Probability	10^{-3} (per position source failure event)
• Time to Alert	• 5 NM Sep: 10 sec

Table 2: Minimum Horizontal Position Source Requirements

Note: *for DO-260 based ADS-B transmit systems, the related encoding of the horizontal position quality indicator through the Navigation Uncertainty Category (NUC) effectively leads to a containment radius requirement of 1NM for a 5 NM separation service.*

Note: *accuracy and integrity containment radius requirements are expressed here as guidance to related horizontal position source regulation (refer to section 8.4).*

Note: *the containment bound requirements reflect the outcomes of both the collision risk assessment (CAP) and time-to-alert assessment.*

Note: *the accuracy and integrity containment radius requirements have to be met by the horizontal position source, taking into account the effects of on-board latency (if not compensated for).*

An uncompensated latency of 1.5 seconds translates into a dilution in the order of 450 metres (assuming an aircraft speed of 600 knots in en-route airspace). This value of 450 metres has to be added to the actual performance of the horizontal position source(s), the sum of which has to be within the required bounds.

The GNSS equipment specified in 8.4.6 meets the overall accuracy and integrity requirements, including the effects of an uncompensated latency of maximum 1.5 second accumulated up to the time of transmission.

[1] Uncompensated delay measured from to the time of validity of position measurement until ADS-B transmission (i.e. at RF level).
[2] As defined in section 6.
[3] For GNSS based functions, expressed as an assumption of GNSS performance.

Parameter	Requirement
Barometric Altitude	• Accuracy: as per the installed sensors (refer to section 8.5.2) • Maximum Latency: 1 sec (as for SSR)
Aircraft Identification, SPI, Emergency Status	As for SSR [AMC20-13].

Table 3: Other Minimum ADS-B Surveillance Data Requirements

Parameter	Loss	Corruption	Note
Barometric Altitude	Minor	Minor	As for SSR [AMC20-13].
Aircraft Identification	Minor	Minor	As for SSR.[AMC20-13]

Table 4: Failure Condition Categories

Appendix 4.1: Summary of ADS-B-NRA Air-to-ground Interoperability Requirements

The minimum set of parameters that **should** be provided to support the ADS-B-NRA application are summarised in the following table extracted from ED-126:[1]

Parameter		BDS register	Version 0		Version 1
			ICAO Annex 10 Amendment 79, VOL III, App to chap 5	DO-260/ED-102	DO-260A
Aircraft identification		0.8	§2.3.4	§2.2.3.2.5	§2.2.3.2.5
SPI [2]		0.5	§2.3.2.6	§2.2.3.2.3.2	§2.2.3.2.3.2
Emergency indicator		0.5	§2.3.2.6	§2.2.3.2.3.2	§2.2.3.2.3.2
Barometric altitude		0.5	§2.3.2.4	§2.2.3.2.3.4	§2.2.3.2.3.4
Quality indicator (NUC/NIC)		0.5	§2.3.1	§2.2.3.2.3.1	§2.2.3.2.3.1
Airborne Position	Latitude	0.5	§2.3.2.3	§2.2.3.2.3.7	§2.2.3.2.3.7
	Longitude	0.5	§2.3.2.3	§2.2.3.2.3.8	§2.2.3.2.3.8
Emergency status [3] [4]		6.1	Table 2-97	§2.2.3.2.7.9	§2.2.3.2.7.8
Quality indicator (NACp)		6.5	No definition	No definition	§2.2.3.2.7.2.7
Quality indicator (SIL)		6.5	No definition	No definition	§2.2.3.2.3.1.1
Version Indicator[5]		6.5	No definition	No definition	§A.1.4.10.5

Table 5: Mandatory ADS-B-NRA Parameters

[1] The notion of version "0" and "1" differentiates between DO-260/ED-102 and DO-260A transponders.
[2] If provided by flight deck controls.
[3] If provided by flight deck controls.
[4] For special conditions under which the non-transmission of selected discrete emergency codes is allowed, refer to Section 8.8.2.
[5] Only for D0-260A based ADS-B transmit systems.

The minimum set of parameters that **should** be provided to support the ADS-B-NRA application are summarised in the following table extracted from ED-126:

Parameter	BDS register	Version 0		Version 1
		ICAO Annex 10 Amendment 79, VOL III, App to chap 5	DO-260/ED-102	DO-260A
Airborne Ground Velocity	0.9	§2.3.5	§2.2.3.2.6	§2.2.3.2.6

Table 6: Optional ADS-B-NRA Parameters

Appendix 4.2: Guidance on Encoding of Positional Quality Indicators

In order to be able to check the compliance of the actually transmitted ADS-B data with the required quality on the recipient side, ADS-B message transmissions contain "Quality Indicators". These are expressed for ED-102/DO-260 and DO-260A compliant ADS-B transmit systems as follows:

- ED-102/DO-260: Navigation Uncertainty Category (NUC), a combined expression of (accuracy and) integrity requirements through a single parameter;
- DO-260A: Navigation Accuracy Category (NACp) to express the position accuracy (as a 95 percentile), Navigation Integrity Category (NIC) to express the integrity containment radius and Surveillance Integrity Level (SIL) to specify the probability of the true position lying outside that containment radius without alerting.

Minimum acceptable NUC and NIC/NACp values in support of 5 NM ADS-B-NRA separation services, based on the requirements summarised in Table 2 of Appendix 4, are as follows in line with the "NIC/NACp to NUC" conversion table below.

NUC values (encoding based on HPL, with the accuracy requirements met by GNSS systems by design and in line with the related NACp values in below conversion table):

- 5 NM separation: NUC = 4;

The corresponding NIC/NACp values are as follows.

- 5 NM separation: NIC = 4, NACp = 5,

The SIL value is established to SIL≥2 in line with the combination of the position source failure and position integrity alert failure requirements, as summarised in Table 2 of Appendix 4.

Note 1: In case the SIL value is not output by the position data sources, it is recommended that the ADS-B transmit system provides for the static setting of SIL as part of the installation procedure and as demonstrated for the applicable position data source configuration.

Note 2: ED-126 provides, based on its reference collision risk analysis only, arguments for an equally appropriate encoding of a SIL=2 as a matter of expressing the system integrity as well. As for the presentation of the values presented in this document, it is at the discretion of the ATSP to decide upon the appropriate threshold values required in support of the separation services in its airspace.

NUC (max Rc NM)		NIC (max Rc NM)		NACp (95% bound)	
9	(0.003)	**11**	(0.004)	**11**	(3 m)
8	(0.01)	**10**	(0.013)	**10**	(10 m)
	-	**9**	(0.04)	**9**	(30 m)
7	(0.1)	**8**	(0.1)	**8**	(0.05 NM)
6	(0.2)	**7**	(0.2)	**7**	(0.1 NM)
5	(0.5)	**6**	(0.6)	**6**	(0.3 NM)
4	(1.0)	**5**	(1.0)	**5**	(0.5 NM)
3	(2.0)	**4**	(2.0)	**4**	(1 NM)
	-	**3**	(4.0)	**3**	(2 NM)
	-	**2**	(8.0)	**2**	(4 NM)
2	(10)	**1**	(20)	**1**	(10 NM)
1	(20)	**1**	(20)	**1**	(10 NM)
0	(no integrity)	**0**	(> 20)	**0**	(unknown)

Table 7: NUC conversion to NIC and NACp