SCT
SECRETARÍA DE COMUNICACIONES Y TRANSPORTES

Dirección General de Aeronáutica Civil

ANÁLISIS DE IMPACTO REGULATORIO

PROY-NOM-091/2-SCT3-2018

ADJUNTO 6.- LEGISLACIÓN EN OTROS PAÍSES

ELECTRONIC CODE OF FEDERAL REGULATIONS

e-CFR data is current as of February 16, 2018

Title 14: Aeronautics and Space
PART 91—GENERAL OPERATING AND FLIGHT RULES
Subpart C—Equipment, Instrument, and Certificate Requirements

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§91.225 Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment and use.

(a) After January 1, 2020, and unless otherwise authorized by ATC, no person may operate an aircraft in Class A airspace unless the aircraft has equipment installed that—

(1) Meets the performance requirements in TSO-C166b, Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Service-Broadcast (TIS-B) Equipment Operating on the Radio Frequency of 1090 Megahertz (MHz); and

(2) Meets the requirements of §91.227.

(b) After January 1, 2020, and unless otherwise authorized by ATC, no person may operate an aircraft below 18,000 feet MSL and in airspace described in paragraph (d) of this section unless the aircraft has equipment installed that—

(1) Meets the performance requirements in—

(i) TSO-C166b; or

(ii) TSO-C154c, Universal Access Transceiver (UAT) Automatic Dependent Surveillance-Broadcast (ADS-B) Equipment Operating on the Frequency of 978 MHz;

(2) Meets the requirements of §91.227.

(c) Operators with equipment installed with an approved deviation under §21.618 of this chapter also are in compliance with this section.

(d) After January 1, 2020, and unless otherwise authorized by ATC, no person may operate an aircraft in the following airspace unless the aircraft has equipment installed that meets the requirements in paragraph (b) of this section:

(1) Class B and Class C airspace areas;

(2) Except as provided for in paragraph (e) of this section, within 30 nautical miles of an airport listed in appendix D, section 1 to this part from the surface upward to 10,000 feet MSL;

(3) Above the ceiling and within the lateral boundaries of a Class B or Class C airspace area designated for an airport upward to 10,000 feet MSL;

(4) Except as provided in paragraph (e) of this section, Class E airspace within the 48 contiguous states and the District of Columbia at and above 10,000 feet MSL, excluding the airspace at and below 2,500 feet above the surface; and

(5) Class E airspace at and above 3,000 feet MSL over the Gulf of Mexico from the coastline of the United States out to 12 nautical miles.

(e) The requirements of paragraph (b) of this section do not apply to any aircraft that was not originally certificated with an electrical system, or that has not subsequently been certified with such a system installed, including balloons and gliders. These aircraft may conduct operations without ADS-B Out in the airspace specified in paragraphs (d)(2) and (d)(4) of this section. Operations authorized by this section must be conducted—

(1) Outside any Class B or Class C airspace area; and

(2) Below the altitude of the ceiling of a Class B or Class C airspace area designated for an airport, or 10,000 feet MSL, whichever is lower.

(f) Each person operating an aircraft equipped with ADS-B Out must operate this equipment in the transmit mode at all times.

(g) Requests for ATC authorized deviations from the requirements of this section must be made to the ATC facility having jurisdiction over the concerned airspace within the time periods specified as follows:

(1) For operation of an aircraft with an inoperative ADS-B Out, to the airport of ultimate destination, including any intermediate stops, or to proceed to a place where suitable repairs can be made or both, the request may be made at any time.

(2) For operation of an aircraft that is not equipped with ADS-B Out, the request must be made at least 1 hour before the proposed operation.

(h) The standards required in this section are incorporated by reference with the approval of the Director of the Office of the Federal Register under 5 U.S.C. 552(a) and 1 CFR part 51. All approved materials are available for inspection at the FAA's Office of Rulemaking (ARM-1), 800 Independence Avenue, SW., Washington, DC 20590 (telephone 202-267-9677), or at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202-741-6030, or go to *http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html.* This material is also available from the sources indicated in paragraphs (h)(1) and (h)(2) of this section.

(1) Copies of Technical Standard Order (TSO)-C166b, Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Service-Broadcast (TIS-B) Equipment Operating on the Radio Frequency of 1090 Megahertz (MHz) (December 2, 2009) and TSO-C154c, Universal Access Transceiver (UAT) Automatic Dependent Surveillance-Broadcast (ADS-B) Equipment Operating on the Frequency of 978 MHz (December 2, 2009) may be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, DOT Warehouse M30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785; telephone (301) 322-5377. Copies of TSO -C166B and TSO-C154c are also available on the FAA's Web site, at *http://www.faa.gov/aircraft/air_cert/design_approvals/tso/.* Select the link “Search Technical Standard Orders.”

(2) Copies of Section 2, Equipment Performance Requirements and Test Procedures, of RTCA DO-260B, Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Services-Broadcast (TIS-B), December 2, 2009 (referenced in TSO-C166b) and Section 2, Equipment Performance Requirements and Test Procedures, of RTCA DO-282B, Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance-Broadcast (ADS-B), December 2, 2009 (referenced in TSO C-154c) may be obtained from RTCA, Inc., 1828 L Street, NW., Suite 805, Washington, DC 20036-5133, telephone 202-833-9339. Copies of RTCA DO-260B and RTCA DO-282B are also available on RTCA Inc.'s Web site, at *http://www.rtca.org/onlinecart/allproducts.cfm.*

[Doc. No. FAA-2007-29305, 75 FR 30193, May 28, 2010; Amdt. 91-314-A, 75 FR 37712, June 30, 2010; Amdt. 91-316, 75 FR 37712, June 30, 2010; Amdt. 91-336, 80 FR 6900, Feb. 9, 2015; Amdt. 91-336A, 80 FR 11537, Mar. 4, 2015]

ELECTRONIC CODE OF FEDERAL REGULATIONS

e-CFR data is current as of February 16, 2018

Title 14: Aeronautics and Space
PART 91—GENERAL OPERATING AND FLIGHT RULES
Subpart C—Equipment, Instrument, and Certificate Requirements

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§91.227 Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment performance requirements.

(a) *Definitions.* For the purposes of this section:

ADS-B Out is a function of an aircraft's onboard avionics that periodically broadcasts the aircraft's state vector (3-dimensional position and 3-dimensional velocity) and other required information as described in this section.

Navigation Accuracy Category for Position (NAC_P) specifies the accuracy of a reported aircraft's position, as defined in TSO-C166b and TSO-C154c.

Navigation Accuracy Category for Velocity (NAC_V) specifies the accuracy of a reported aircraft's velocity, as defined in TSO-C166b and TSO-C154c.

Navigation Integrity Category (NIC) specifies an integrity containment radius around an aircraft's reported position, as defined in TSO-C166b and TSO-C154c.

Position Source refers to the equipment installed onboard an aircraft used to process and provide aircraft position (for example, latitude, longitude, and velocity) information.

Source Integrity Level (SIL) indicates the probability of the reported horizontal position exceeding the containment radius defined by the NIC on a per sample or per hour basis, as defined in TSO-C166b and TSO-C154c.

System Design Assurance (SDA) indicates the probability of an aircraft malfunction causing false or misleading information to be transmitted, as defined in TSO-C166b and TSO-C154c.

Total latency is the total time between when the position is measured and when the position is transmitted by the aircraft.

Uncompensated latency is the time for which the aircraft does not compensate for latency.

(b) *1090 MHz ES and UAT Broadcast Links and Power Requirements*—

(1) Aircraft operating in Class A airspace must have equipment installed that meets the antenna and power output requirements of Class A1, A1S, A2, A3, B1S, or B1 equipment as defined in TSO-C166b, Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Service-Broadcast (TIS-B) Equipment Operating on the Radio Frequency of 1090 Megahertz (MHz).

(2) Aircraft operating in airspace designated for ADS-B Out, but outside of Class A airspace, must have equipment installed that meets the antenna and output power requirements of either:

(i) Class A1, A1S, A2, A3, B1S, or B1 as defined in TSO-C166b; or

(ii) Class A1H, A1S, A2, A3, B1S, or B1 equipment as defined in TSO-C154c, Universal Access Transceiver (UAT) Automatic Dependent Surveillance-Broadcast (ADS-B) Equipment Operating on the Frequency of 978 MHz.

(c) *ADS-B Out Performance Requirements for* NAC_P*,* NAC_V*, NIC, SDA, and SIL*—

(1) For aircraft broadcasting ADS-B Out as required under §91.225 (a) and (b)—

(i) The aircraft's NAC_P must be less than 0.05 nautical miles;

(ii) The aircraft's NAC_V must be less than 10 meters per second;

(iii) The aircraft's NIC must be less than 0.2 nautical miles;

(iv) The aircraft's SDA must be 2; and

(v) The aircraft's SIL must be 3.

(2) Changes in NAC_P, NAC_V, SDA, and SIL must be broadcast within 10 seconds.

(3) Changes in NIC must be broadcast within 12 seconds.

(d) *Minimum Broadcast Message Element Set for ADS-B Out.* Each aircraft must broadcast the following information, as defined in TSO-C166b or TSO-C154c. The pilot must enter information for message elements listed in paragraphs (d)(7) through (d)(10) of this section during the appropriate phase of flight.

(1) The length and width of the aircraft;

(2) An indication of the aircraft's latitude and longitude;

(3) An indication of the aircraft's barometric pressure altitude;

(4) An indication of the aircraft's velocity;

(5) An indication if TCAS II or ACAS is installed and operating in a mode that can generate resolution advisory alerts;

(6) If an operable TCAS II or ACAS is installed, an indication if a resolution advisory is in effect;

(7) An indication of the Mode 3/A transponder code specified by ATC;

(8) An indication of the aircraft's call sign that is submitted on the flight plan, or the aircraft's registration number, except when the pilot has not filed a flight plan, has not requested ATC services, and is using a TSO-C154c self-assigned temporary 24-bit address;

(9) An indication if the flightcrew has identified an emergency, radio communication failure, or unlawful interference;

(10) An indication of the aircraft's “IDENT” to ATC;

(11) An indication of the aircraft assigned ICAO 24-bit address, except when the pilot has not filed a flight plan, has not requested ATC services, and is using a TSO-C154c self-assigned temporary 24-bit address;

(12) An indication of the aircraft's emitter category;

(13) An indication of whether an ADS-B In capability is installed;

(14) An indication of the aircraft's geometric altitude;

(15) An indication of the Navigation Accuracy Category for Position (NAC_P);

(16) An indication of the Navigation Accuracy Category for Velocity (NAC_V);

(17) An indication of the Navigation Integrity Category (NIC);

(18) An indication of the System Design Assurance (SDA); and

(19) An indication of the Source Integrity Level (SIL).

(e) *ADS-B Latency Requirements*—

(1) The aircraft must transmit its geometric position no later than 2.0 seconds from the time of measurement of the position to the time of transmission.

(2) Within the 2.0 total latency allocation, a maximum of 0.6 seconds can be uncompensated latency. The aircraft must compensate for any latency above 0.6 seconds up to the maximum 2.0 seconds total by extrapolating the geometric position to the time of message transmission.

(3) The aircraft must transmit its position and velocity at least once per second while airborne or while moving on the airport surface.

(4) The aircraft must transmit its position at least once every 5 seconds while stationary on the airport surface.

(f) *Equipment with an approved deviation.* Operators with equipment installed with an approved deviation under §21.618 of this chapter also are in compliance with this section.

(g) *Incorporation by Reference.* The standards required in this section are incorporated by reference with the approval of the Director of the Office of the Federal Register under 5 U.S.C. 552(a) and 1 CFR part 51. All approved materials are available for inspection at the FAA's Office of Rulemaking (ARM-1), 800 Independence Avenue, SW., Washington, DC 20590 (telephone 202-267-9677), or at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202-741-6030, or go to *http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html.* This material is also available from the sources indicated in paragraphs (g)(1) and (g)(2) of this section.

(1) Copies of Technical Standard Order (TSO)-C166b, Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Service-Broadcast (TIS-B) Equipment Operating on the Radio Frequency of 1090 Megahertz (MHz) (December 2, 2009) and TSO-C154c, Universal Access Transceiver (UAT) Automatic Dependent Surveillance-Broadcast (ADS-B) Equipment Operating on the Frequency of 978 MHz (December 2, 2009) may be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, DOT Warehouse M30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785; telephone (301) 322-5377. Copies of TSO -C166B and TSO-C154c are also available on the FAA's Web site, at *http://www.faa.gov/aircraft/air_cert/design_approvals/tso/.* Select the link “Search Technical Standard Orders.”

(2) Copies of Section 2, Equipment Performance Requirements and Test Procedures, of RTCA DO-260B, Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Services-Broadcast (TIS-B), December 2, 2009 (referenced in TSO-C166b) and Section 2, Equipment Performance Requirements and Test Procedures, of RTCA DO-282B, Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance-Broadcast (ADS-B), December 2, 2009 (referenced in TSO C-154c) may be obtained from RTCA, Inc., 1828 L Street, NW., Suite 805, Washington, DC 20036-5133, telephone 202-833-9339. Copies of RTCA DO-260B and RTCA DO-282B are also available on RTCA Inc.'s Web site, at *http://www.rtca.org/onlinecart/allproducts.cfm.*

[Doc. No. FAA-2007-29305, 75 FR 30194, May 28, 2010; Amdt. 91-314-A, 75 FR 37712, June 30, 2010; Amdt. 91-316, 75 FR 37712, June 30, 2010]

U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Airworthiness Approval of Automatic Dependent Surveillance - Broadcast OUT Systems

Date: 12/07/15

Initiated By: AIR-132

AC No: 20-165B

This advisory circular (AC) provides guidance for the installation and airworthiness approval of Automatic Dependent Surveillance - Broadcast (ADS-B) OUT systems in aircraft.

Susan J. M. Cabler
Acting Manager, Design, Manufacturing, &
Airworthiness Division
Aircraft Certification Service

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CHAPTER 1. GENERAL INFORMATION

1.1 **Purpose.**

This AC provides guidance for the initial installation and airworthiness approval of Automatic Dependent Surveillance - Broadcast (ADS-B) OUT equipment in aircraft.

1.1.1 Acceptable Means of Compliance.

This AC is not mandatory and does not constitute a regulation. This AC describes an acceptable means, but not the only means, to install ADS-B OUT equipment. However, if you use the means described in this AC, you must follow it entirely. The latest version of a document should be used where "()" follows its number.

1.1.2 Intent of This AC.

This AC is primarily intended for installations compliant with the aircraft requirements of Title 14 of the Code of Federal Regulations 14 CFR 91.225 and § 91.227. Airworthiness compliance will be evaluated based on the applicable intended function rule (such as §§ 23.1301, 25.1301, 27.1301, or 29.1301) recognizing that the intended function is to meet the equipment requirements in §§ 91.225 and 91.227. It is possible to receive airworthiness approval for your ADS-B OUT system with a different intended function; however, we strongly discourage this type of installation unless it is in accordance with the criteria for ADS-B OUT in foreign non-radar airspace (for example, Approved Means of Compliance (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).* Applicants using this AC to install ADS-B systems that are not compliant with §§ 91.225 and 91.227 must follow all aspects of this AC or propose alternate means, as appropriate, to the Federal Aviation Administration (FAA).

1.2 **Audience.**

This AC is for anyone who is applying for an initial type certificate (TC), supplemental type certificate (STC), amended TC, or amended STC for the installation and continued airworthiness of ADS-B OUT equipment.

1.3 **Cancellation.**

This AC supersedes AC 20-165A, *Airworthiness Approval of Automatic Dependent Surveillance - Broadcast (ADS-B) Out Systems*. Equipment previously approved pursuant to the guidance in the superseded ACs is still valid for the operations and conditions stated in their approvals.

1.4 **Where to Find This AC**

1.4.1 You may find this AC at http://www.faa.gov/regulations_policies/advisory_circulars/.

1.4.2 If you have any suggestions for improvements or changes, you may use the template provided at the end of this AC.

1.5 Scope.

1.5.1 This AC only addresses the installation of ADS-B OUT systems. Installation guidance for ADS-B IN can be found in the latest version of AC 20-172, *Airworthiness Approval for ADS-B In Systems and Applications*. Installation guidance for Flight Information Services - Broadcast (FIS-B) can be found in the latest version of AC 20-149, *Installation Guidance for Domestic Flight Information Services - Broadcast*. If Technical Standard Order (TSO)-C166b, *Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information Service - Broadcast (TIS-B) Equipment Operating on the Radio Frequency of 1090 Megahertz (MHz)*, or TSO-C154c, *Universal Access Transceiver (UAT) Automatic Dependent Surveillance Broadcast (ADS-B) Equipment Operating on Frequency of 978 MHz*, equipment being installed has a receive capability, but that receive capability is not integrated into the aircraft to support ADS-B IN display applications, you do not need to demonstrate specific ADS-B receive performance during the ADS-B OUT installation approval. **4.5.6Appendix A** to this AC provides a description of the message elements contained in ADS-B messages. Guidelines for qualifying position sources can be found in **4.5.6Appendix B.** Guidelines for accomplishing latency analysis can be found in **4.5.6Appendix C.** **4.5.6Appendix D** provides a list of definitions and acronyms that are used in this AC. The latest version of a document should be used where “()” follows its number. **4.5.6Appendix E** provides a list of related documents.

1.6 Background.

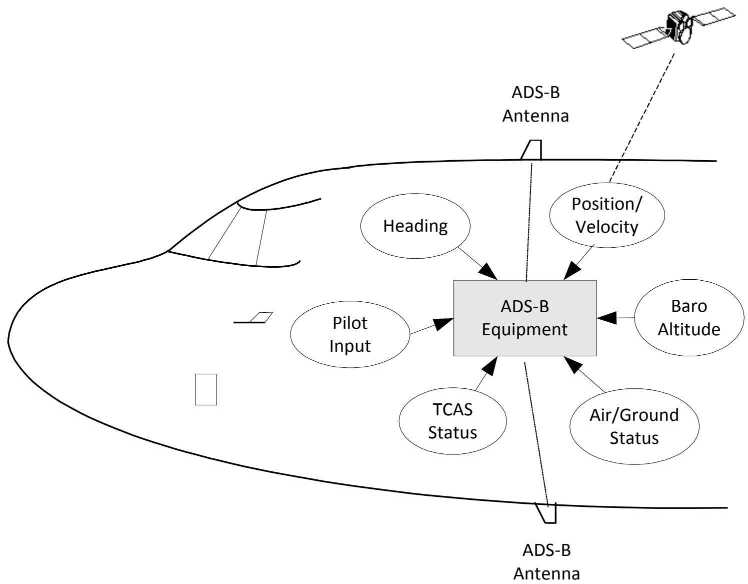
ADS-B is a next generation surveillance technology incorporating both air and ground aspects that provide air traffic control (ATC) with a more accurate picture of the aircraft’s three-dimensional position in the en route, terminal, approach, and surface environments. The aircraft provides the airborne portion in the form of a broadcast of its identification, position, altitude, velocity, and other information. The ground portion is comprised of ADS-B ground stations, which receive these broadcasts and direct them to ATC automation systems for presentation on a controller’s display. In addition, aircraft equipped with ADS-B IN capability can receive these broadcasts and display the information to improve the pilot’s situation awareness of other traffic.

1.6.1 <u>ADS-B Description.</u>

ADS-B is automatic because no external interrogation is required. It is dependent because it relies on onboard position sources and broadcast transmission systems to provide surveillance information to ATC and other users. **Figure 1** below provides a functional overview of an aircraft ADS-B system.

1.6.2 Functional Overview

Figure 1. Functional Overview of ADS-B OUT System



1.6.3 ADS-B OUT, ADS-B IN, TIS-B and ADS-R.
ADS-B OUT refers to an aircraft broadcasting own-ship information. ADS-B IN refers to an aircraft's ability to receive ADS-B information, such as ADS-B messages from other aircraft or Traffic Information Services-Broadcast (TIS-B), and Automatic Dependent Surveillance - Rebroadcast (ADS R) from the ground infrastructure.

1.6.4 ADS-B links.
There are two ADS-B link options: 1090 extended squitter (1090ES) and universal access transceiver (UAT). The 1090ES equipment operates on 1090 MHz and has performance requirements specified in TSO-C166b. The UAT operates on 978 MHz and has performance requirements specified in TSO-C154c. This AC addresses installing equipment meeting the requirements of either TSO.

Note: § 91.225 requires 1090ES in Class A airspace.

CHAPTER 2. THE APPROVAL PROCESS AND NECESSARY DOCUMENTATION

2.1 ADS-B OUT System Approval Process.

This AC addresses the initial airworthiness approval through the type certification or supplemental type certification process of an ADS-B OUT system that meets the performance requirements of the applicable TSO and the requirements of § 91.227. Information on the STC and TC processes can be found in the latest revisions of AC 21-40, *Guide for Obtaining a Supplemental Type Certificate*, and FAA Order 8110.4, *Type Certification.* Parties interested in approving ADS-B IN systems should refer to AC 20-172(),*Airworthiness Approval for ADS-B In Systems and Applications*

2.1.1 Installation of ADS-B OUT Equipment.

This AC covers installation of the ADS-B OUT equipment, updates to the flight manual, updates to the instructions for continued airworthiness (ICA), guidance for interfacing systems, ground test, and flight test.

2.1.2 The ADS-B OUT System.

The ADS-B OUT system is depicted in **figure 1** above and includes the ADS-B equipment, a position source, a barometric altitude source, an air-ground status source, a Traffic Alert and Collision Avoidance System (TCAS) II source if the aircraft is equipped with TCAS II, an optional heading source, and all associated antennas and displays. Applicants should list the components that make up the ADS-B system in their master drawing list. You may demonstrate interoperability with multiple components for a given function. For example, you may request approval for a secondary position source, or add multiple unique position sources to the STC.

2.2 Aircraft Flight Manual.

Include ADS-B OUT operating limitations, normal operating procedures, and a system description in the Airplane Flight Manual (AFM), Rotorcraft Flight Manual (RFM), AFM Supplement (AFMS), or RFM Supplement (RFMS). The flight manual must also state that the installation meets the requirements of § 91.227. This can be accomplished by adding the following statement to the General or Normal Procedures section of the flight manual:

The installed ADS-B OUT system has been shown to meet the equipment requirements of 14 CFR 91.227.

2.2.1 Operating Limitations.

The flight manual should describe any operating limitations necessary for safe operation because of design, installation, or operating characteristics.

2.2.2 Operating Procedures.

Describe normal and non-normal operating procedures for the system in the flight manual.

2.2.2.1 Describe any actions expected of the pilot.

2.2.2.2 Describe how to enter the Mode 3/A code, Flight ID, operate the IDENT function, and activate or deactivate emergency status. If the ADS-B system and transponder do not have a single point of entry for the Mode 3/A code, IDENT, and emergency status, the flight manual procedures must ensure conflicting information is not transmitted from the ADS-B system and transponder.

2.2.2.3 Describe any ADS-B OUT displays and provide instructions to the pilot on how to respond to any error conditions.

2.2.2.4 Describe how the ADS-B OUT system can be disabled, if there is an ability to disable the ADS-B OUT system. Also, describe the means through which the pilot can detect that the system has been disabled. The flight manual must address the effects of turning off the ADS-B OUT system, including the effects on the transponder and TCAS II if disabling the ADS-B OUT system also disables the transponder or the TCAS II.

2.2.2.5 Include guidance in the flight manual on when to enable the ADS-B OUT system. The ADS-B OUT system must be enabled (turned ON) during all phases of flight operation including airport surface movement operations. ADS-B IN surface applications and ATC surface surveillance will use ADS-B OUT broadcasts; thus, it is important for aircraft ADS-B OUT systems to continue to transmit on the airport surface. If the ADS-B OUT function is embedded in a Mode S transponder, the flight manual, checklists, and any operator procedures manuals must be updated accordingly with ADS-B OUT operations guidance.

Note: Historically, transponders have been turned on by the flightcrew when entering the runway for takeoff and turned off or to standby when exiting the runway after landing. When ADS-B is integrated into a Mode S transponder, the existing guidance for transponder operation must be updated to ensure the ADS-B system is operating during airport surface movement operations.

2.2.3 <u>System Description.</u>

Describe the ADS-B OUT system and the interface with other systems on the aircraft in the flight manual. If multiple position sources are interfaced to the ADS-B transmitter, describe the source selection mechanism and any related indications.

2.3 Continuing Airworthiness Requirements.

2.3.1 <u>ADS-B OUT Equipment.</u>

Follow the ADS-B equipment manufacturer’s guidance for periodic inspection and maintenance of the ADS-B system. ICA must be provided and must address any maintenance requirements to maintain the ADS-B equipment.

2.3.2 ADS-B Functionality in a Transponder.

Transponders that incorporate ADS-B functionality (such as with 1090ES) must continue to meet the operational requirements of 14 CFR 91.215, §91.217, and §91.413 and comply with the transponder system tests and inspections called out in 14 CFR part 43, appendix F. Refer to AC 43-6, *Altitude Reporting Equipment and Transponder System Maintenance and Inspection Practices*.

2.3.3 Altimetry Systems and Altitude Reporting Equipment.

Altitude reporting equipment connected to the ADS-B system must comply with all applicable 14 CFR 91.217, §91.411, and part 43, appendix E test and inspection requirements. Refer to AC 43-6. If the altimetry system is compliant with the Reduced Vertical Separation Minimum (RVSM) standards, the requirements and tolerances stated in the approved RVSM maintenance program must be met. ADS-B installation does not alter these requirements.

2.3.4 Maintenance and Design Changes to Interfacing Components.

The ADS-B system interfaces with multiple external components, such as position sources and altimetry sources. The installer should list all interfacing components in the ICA. It is important that any future maintenance or design changes to these interfacing components be accomplished in such a way that continued satisfactory performance of the overall ADS-B system is maintained.

2.3.4.1 Maintenance of the ADS-B System.

The ADS-B system installation must include ICA that meet the typical requirements for a system installation, which includes how to accomplish a complete functional check of the system.

2.3.4.2 ADS-B Source System Components.

Although the installer may not have access to the specific source system ICA to incorporate changes into those specific documents, the installer must do an analysis of the source systems to determine what maintenance actions on those source systems would require a functional test of the ADS-B system to verify that the system is operating properly. In particular, those systems providing a dedicated input to the ADS-B system that cannot be verified by other means should be tested as part of the ADS-B system as a whole. Once the installer identifies those actions, they must provide recommended language for the operator to include in their ICA. If the installer determines that removal and replacement of the Global Positioning System (GPS) receiver requires a full functional check of the ADS-B system because the GPS input to the ADS-B cannot be verified by other means, its instructions to the operator should indicate this. For example:

> Modify the R&R ICA instructions in your GPS maintenance manual to include the following statement: "Removal and replacement of the GPS receiver also

requires a full functional check of the ADS-B system per MM XX-XX-XX, Pg xxx. Make a logbook entry for accomplishment of this test"..

2.3.4.3 Design Changes to Interfacing Components.

Ensuring continued airworthiness of the ADS-B system following upgrades of interfacing components could be problematic if the installer of the ADS-B system is unaware of design changes to interfacing components, or if the installer of the updated interfacing component is unaware of a potential impact to the ADS-B system. To avoid this problem, the ADS-B system installer must update the ICA for each interfacing system with a process that ensures continued airworthiness of the ADS-B system following design changes to the interfacing component.

CHAPTER 3. ADS-B OUT SYSTEM INSTALLATION GUIDANCE

3.1 General Installation Guidance.

3.1.1 Environmental Qualification.

Ensure the environmental qualification of the installed equipment is appropriate for the aircraft in accordance with AC 21-16G, *RTCA Document DO-160 versions D, E, F, and G, "Environmental Conditions and Test Procedures for Airborne Equipment"*.

3.1.2 System Safety Assessment.

The ADS-B System Design Assurance (SDA) parameter indicates the probability of an ADS-B system malfunction causing false or misleading position information or position quality metrics to be transmitted. SDA may be preset at installation for systems that do not use multiple position sources with different design assurance levels; otherwise the system must be capable of adjusting the SDA broadcast parameter to match the position source being employed at the time of transmission.

3.1.2.1 Compliant Architecture.

3.1.2.1.1 ADS-B equipment that meets the minimum performance requirements of TSO-C166b or TSO-C154c and is directly connected to a position source meeting the minimum performance requirements of any revision of the following TSOs may set the SDA = 2 without further analysis:

- TSO-C129, *Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)*;
- TSO-C145, *Airborne Navigation Sensors Using The Global Positioning System (GPS) Augmented By The Satellite Based Augmentation System (SBAS)*;
- TSO-C146, *Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented By the Satellite Based Augmentation System (SBAS)*; or
- TSO-C196, *Airborne Supplemental Navigation Sensors for Global Positioning System Equipment using Aircraft-Based Augmentation*.

3.1.2.1.2 For installations in aircraft with more complex system architectures, a system safety assessment, as described below, is required to set the SDA. Installations of uncertified ADS-B systems must set SDA = 0 with the following exception: experimental category aircraft, including experimental light-sport aircraft (E-LSA) (Part 91 aircraft), may install unapproved equipment and set the SDA in accordance with the equipment manufacturer's installation manual, provided the equipment has a statement of compliance to the performance requirements of § 91.227), from the equipment manufacturer(s).

3.1.2.2 Conducting the System Safety Assessment.

3.1.2.2.1 ADS-B systems using position sources not listed in section **3.1.2.1** or systems with intermediary devices such as data concentrators must accomplish a system safety assessment and set the SDA according to the results of the assessment. Systems integrated through a highly integrated data bus architecture must complete the system safety assessment. The system safety assessment must demonstrate that the installed system meets all TSO-C166b or TSO-C154c requirements to set the SDA = 2 or 3. This can be accomplished using the methods, for example, as described in—

- AC 25.1309-1(), *System Design and Analysis*;
- AC 23.1309-1(), *System Safety Analysis and Assessment for Part 23 Airplanes*;
- SAE International (SAE) Aerospace Recommended Practice (ARP) 4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*; or
- SAE ARP 4754A, *Guidelines for Development of Civil Aircraft and Systems*.

3.1.2.2.2 If the system contains different design assurance levels for hardware and software, the worst-case design assurance level should be used. For example, if the hardware assurance level is C, and the software assurance level is B, the SDA would indicate the system has been qualified commensurate with a Major failure condition. If the ADS-B system is integrated with a noncompliant GPS, (for example, a GPS not compliant with §3.1.2.1), the SDA must be set to “0”.

Note: Although the direct effects to your aircraft of an ADS-B failure may be minor, the ADS-B OUT information will be used by other ADS-B IN equipped aircraft and by ATC.Thus, the provisions in AC 23.1309-1() that allow reduction in failure probabilities and design assurance level for aircraft under 6,000 pounds do not apply to the ADS-B OUT system.

3.1.2.3 Existing Equipment Design Assurance.

The aircraft installation may make use of some equipment certified for use with an existing transponder system. There is no intent for this safety assessment to drive the replacement of existing altimetry, flightcrew controls, heading instruments, or antennas. In contrast, the position source installation must be compliant with the guidance in this AC, including design assurance considerations.

3.1.3 Position Latency.

Latency is the difference between the time when a measurement is taken to determine the aircraft’s geometric position and the time when the aircraft’s ADS-B equipment transmits that position measurement. Limiting the latency in ADS-B systems minimizes the errors in the reported position. TSO-C166b and TSO-C154c ADS-B equipment compensate for latency by extrapolating the position based on velocity information. All applicants must demonstrate compliance with the latency requirements in section **3.1.3.1**. This can be done by equipping with a compliant architecture such as the one listed in section **3.1.3.2** or performing an analysis such as the one detailed in section **3.1.3.3**. Latency terms are further defined in **4.5.6Appendix C** of this AC.

Note 1: To demonstrate compliance with § 91.227, you must calculate latency from the position source time of measurement (TOM). Do not calculate latency from the position source time of applicability, as defined in RTCA, Inc. (RTCA) document (DO)-260B, *Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B),* with corrigendum 1, and RTCA/DO-282B, *Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast*, with corrigendum 1.

3.1.3.1 Position Latency Requirements.

There are two position latency requirements associated with ADS-B OUT:

1. Total latency. Total latency is defined as the difference between the time when the position is measured and when the position is transmitted from the aircraft. To meet § 91.227, the total latency must be less than or equal to 2.0 seconds.
2. Uncompensated latency. Uncompensated latency is the difference between the time of applicability for the transmitted position and the actual time the position is transmitted from the ADS-B system. To meet § 91.227, the uncompensated latency must be less than or equal to 0.6 seconds. The aircraft must compensate for any latency greater than 0.6 seconds but must not overcompensate (that is, lead the aircraft position) by more than 0.2 seconds.

Note: RTCA Special Committee 186, which developed the ADS-B OUT minimum operational performance standards, recommends ADS-B OUT systems transmit position information with an uncompensated latency of less than or equal to 0.4 seconds. This recommendation is to support future ADS-B IN applications. The § 91.227 latency requirements support ATC separation services and the initial basic ADS-B IN applications. However, we encourage you to minimize uncompensated latency as much as possible in your installation. Recommendations for minimizing latency are included in **4.5.6Appendix C** of this AC.

3.1.3.2 Compliant Architecture.

ADS-B systems that directly connect a position source meeting the minimum performance requirements of any revision of TSO-C145, TSO-C146, or TSO-C196 with ADS-B equipment meeting the minimum performance requirements of TSO-C166b or TSO-C154c satisfy the total latency and uncompensated latency requirements. Systems with a compliant architecture do not need to accomplish a position and velocity latency analysis.

3.1.3.3 Position Latency Analysis.

If you are installing an ADS-B system that does not have a compliant architecture described in section **3.1.3.2**, you must accomplish a latency analysis to demonstrate that the installed ADS-B system meets the total latency and uncompensated latency requirements. Systems integrated through a highly integrated data bus architecture must complete the latency analysis. **4.5.6Appendix C** of this AC provides for an acceptable method to complete the latency analysis.

3.1.4 Integrity Metric Latency.

There is an allowance for Global Navigation Satellite System (GNSS) position sources to delay the update of the integrity containment radius while attempting to detect and exclude faulted satellites. § 91.227 allows up to 12 seconds for the ADS-B system to transmit a change in the Navigation Integrity Category (NIC). This 12-second allowance is available for any position source, not just GNSS position sources. The 12 seconds includes both the time for the position source to detect the fault and time for the ADS-B system to transmit the fault indication. The requirement to indicate a change in NIC applies to the time between when a faulted position is first transmitted and when the updated NIC is transmitted indicating the fault. The total time to update the NIC is based on the cumulative effect of (1) the position source fault detection and exclusion time, and (2) the worst-case asynchronous transmission difference between when the faulted position is transmitted and when the NIC indicating the fault is transmitted.

3.1.4.1 Compliant Architecture.

ADS-B equipment meeting the minimum performance requirements of TSO-C166b or TSO-C154c that is directly connected to a position source meeting the minimum performance requirements of any revision of TSO-C145, TSO-C146, or TSO-C196 will typically meet the integrity latency requirements. For these systems you only need to demonstrate, through analysis, that a non-isolated GNSS satellite fault detected by the position source is properly passed to the ADS-B equipment and that the ADS-B equipment indicates an invalid position by transmitting the position integrity and accuracy metrics equal to zero.

Note: ARINC Characteristic 743A-5, *GNSS Sensor*, allows flexibility in how information is transferred during a GNSS satellite fault; thus, it is necessary to ensure a non-isolated satellite failure results in the ADS-B indicating an invalid position.

3.1.4.2 Integrity Metric Latency Analysis.

If you are installing an ADS-B system without a compliant architecture, like the one described above, you must accomplish a latency analysis to demonstrate the ADS-B system meets the integrity metric latency requirements. The latency analysis should include the maximum time for a position source to indicate an integrity fault, any delay added by an intermediary device such as a data concentrator, and the delay added by the ADS-B equipment.

3.1.5 System Design Assurance (SDA) and Source Integrity Level (SIL) Latency.

§ 91.227 requires broadcasting changes in the SDA or SIL within 10 seconds. Changes in the SDA or SIL will typically occur when all position sources are lost, or when a secondary position source is integrated into an ADS-B system and that secondary position source has a different SDA or SIL than the primary position source. If you integrate multiple position sources with different SDAs or SILs, demonstrate during ground testing that a change in position source results in an updated SDA and SIL within 10 seconds. If integrating an ADS-B transmitter with a noncompliant GPS, the SDA and SIL must be set to “0”.

3.1.6 Populating Message Elements.

§ 91.227 lists parameters that must be populated (that is, not a null value) for operation in airspace defined by § 91.225. All parameters transmitted by the ADS-B system must conform to the standards in TSO-C166b or TSO-C154c and may not contain false or misleading information.

3.2 ADS-B Equipment.

3.2.1 Equipment Eligibility.

ADS-B equipment must meet the performance requirements specified in TSO-C166b or TSO-C154c. A compliant installation must meet the requirements in § 91.227. To deviate from any rule requirements, you must obtain a deviation approval from the FAA, in accordance with § 91.225(c) and § 91.227(f). Under those provisions, as specified in 14 CFR 21.618, this requires showing that factors or design features provide an equivalent level of safety that compensates for the standards from which a deviation is requested.

3.2.2 Installation Guidance.

3.2.2.1 UAT Systems With Mode S Transponders.

Do not install a UAT ADS-B OUT system with the capability to transmit a random 24-bit address in an aircraft that also has a Mode S transponder unless the random 24-bit feature is disabled. The ATC automation system would interpret the different 24-bit addresses as two separate aircraft, and alert controllers to a conflict that does not actually exist.

3.2.2.2 Mixed Transmit/Receive Classifications.

TSO-C166b and TSO-C154c allow Class A transmit-only and Class A receive-only equipment configurations. There are no restrictions for installing a certain class of receive equipment with a different class of transmit equipment. For example, a Class A3 transmit-only unit can be used in the same aircraft with a Class A1 receive-only unit. It is also acceptable to have a TSO-C166b transmitter and a TSO-C154c receiver and vice versa.

3.2.2.3 Stand-Alone 1090ES Transmitters.

RTCA/DO-260B, section 2.2.2.2, only allows Class A0 and B0 1090ES stand-alone (not integrated with a transponder) transmitters. This AC does not cover installation approval for class A0 or B0 1090ES transmitters because they are not compliant with § 91.227.

3.2.2.4 Multiple ADS-B OUT Systems.

If the aircraft has the ability to operate a 1090ES and a UAT ADS-B OUT system at the same time, the systems must have a single point of entry for the emergency code, IDENT, and Mode 3/A code. Neither system may use the anonymity (random address) feature. If dual ADS-B OUT systems of the same link are installed (for example, to increase dispatch reliability), the installation must preclude operation of both systems simultaneously. Also, dual systems must be the same version level; that is, if the 1090ES system meets the requirements of RTCA/DO-260B (version 2), the UAT system must meet the requirements of RTCA/DO-282B (version 2).

Note: Installation of dual 1090ES and UAT ADS-B IN capability is acceptable and encouraged. Refer to AC 20-172() for ADS-B IN installation guidance.

3.2.3 Configuration of Associated Parameters.

This section provides additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in **4.5.6Appendix A** of the AC.

3.2.3.1 International Civil Aviation Organization (ICAO) 24-Bit Address.

You must set the ICAO 24-bit address during installation in accordance with the ADS-B equipment manufacturer’s instructions. For U.S. civil aircraft, the ICAO 24-bit address is currently established as a function of the aircraft’s registration or “N” number. You can determine the appropriate address for U.S. registered aircraft on the following FAA website: http://registry.faa.gov/aircraftinquiry/. Use of a random 24-bit address is discussed further in section **3.7.2.3** of this AC.

Note 1: The ICAO 24-bit address is also used by the Mode S transponder. For the addition of ADS-B (1090ES) in an existing Mode S transponder installation, verify that the ICAO 24-bit address decodes to the current aircraft registration number.

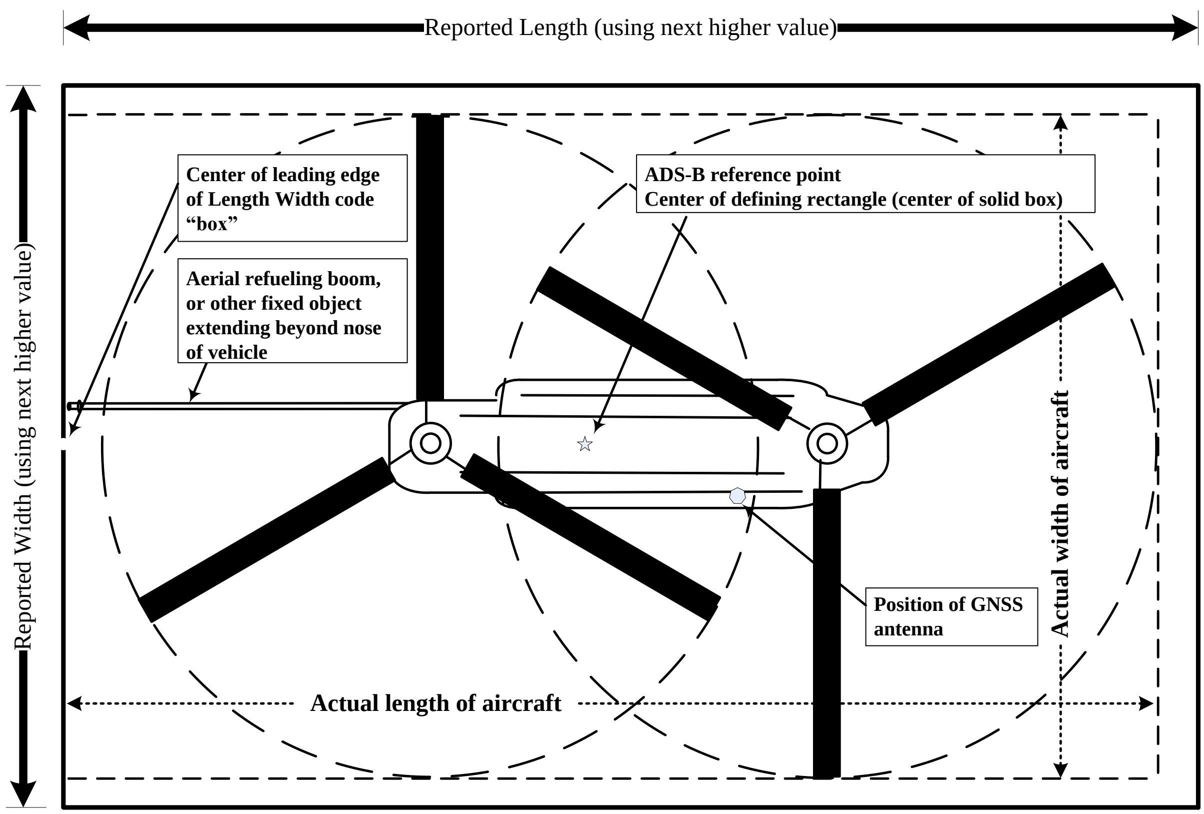
Note 2: The ICAO 24-bit address will have to be updated if the aircraft’s registration number changes.

Note 3: Installation instructions may require inputting the 24-bit address as an Octal, Decimal, or Hexadecimal number (that is, 50604331_{Octal} = $10684633_{Decimal}$ = $A308D9_{Hex}$). Ensure you use the correct base number when configuring the ADS-B system.

3.2.3.2 Aircraft Length and Width.

This parameter must be configured during installation. Do not set the length and width parameter to a value of "0," as the length and width code is required by § 91.227. The length and width code chosen should be the smallest value that encompasses the entire aircraft and any fixed objects. For fixed-wing aircraft, this may be the nose, or other fixed object forward of the nose, such as a pitot probe. For rotorcraft, this may be the most forward, aft and lateral point the rotor blades sweep or some other fixed object such as a refueling boom. See (refer to **figure 2** below).

Figure 2. Example of Aircraft Length and Width Code Determination



3.2.3.3 **ADS-B IN Capability.**

This parameter must be configured to indicate if the aircraft has an ADS-B IN system installed, and can process ADS-B messages to support at least one ADS-B IN application. For ease of installation, the parameter does not have to indicate the operational status of the ADS-B IN system. If the aircraft has both 1090ES ADS-B IN and UAT ADS-B IN systems installed, both the 1090ES ADS-B IN and UAT ADS-B IN capability should be set accordingly.

3.2.3.4 **Emitter Category.**

Set emitter category per manufacturer instructions. **Table 1** below provides guidance on setting the emitter category that is appropriate for the type of aircraft it is being install on.

Table 1. Emitter Category

Emitter Category	Description
No Emitter Category	Do not use this emitter category. If no emitter category fits your installation, seek guidance from the FAA as appropriate.
Light Airplane < 15,500 lbs	Any airplane with a maximum takeoff weight less than 15,500 pounds. This includes very light aircraft (light-sport aircraft) that do not meet the requirements of 14 CFR 103.1.
Small Airplane ≥ 15,500 to < 75,000 lbs	Any airplane with a maximum takeoff weight greater than or equal to15,500 pounds but less than 75,000 pounds.
Large Airplane ≥ 75,000 to < 300,000 lbs	Any airplane with a maximum takeoff weight greater than or equal to 75,000 pounds but less than 300,000 pounds that does not qualify for the high vortex category.
Large Airplane With High Vortex	Any airplane with a maximum takeoff weight greater than or equal to 75,000 pounds but less than 300,000 pounds that has been determined to generate a high wake vortex. Currently, the Boeing 757 is the only example.
Heavy ≥ 300,000 lbs	Any airplane with a maximum takeoff weight equal to or above 300,000 pounds.
High Performance > 5 G and > 400 TAS	Any airplane, regardless of weight, that can maneuver in excess of 5 G's and maintain true airspeed above 400 knots.
Rotorcraft	Any rotorcraft, regardless of weight.
Glider / Sailplane	Any glider or sailplane, regardless of weight.
Lighter Than Air	Any lighter-than-air (airship or balloon), regardless of weight.
Parachute / Sky Diver	For use by parachute / sky divers.
Ultralight Vehicle	A vehicle that meets the requirements of 14 CFR 103.1.Light sport aircraft should not use the ultralight emitter category unless they meet 14 CFR 103.1.
UAV	Any unmanned aerial vehicle or system regardless of weight.
Space/Trans-atmospheric Vehicle	For use by space/trans-atmospheric vehicles.
No ADS-B Emitter Category Information	Do not use this emitter category. Refer to category 0 above.
Surface Vehicle—Emergency Vehicle	For use by surface emergency vehicles.
Surface Vehicle—Service Vehicle	For use by surface vehicles.
Point Obstacle (Includes Tethered Balloons)	For use by point obstacles to include tethered Balloons.
Cluster Obstacle	For use by cluster obstacles.
Line Obstacle	For use by line obstacles.

3.3 Position Source.

3.3.1 Equipment Eligibility.

§ 91.227 is performance based and does not require any specific position source. The existing navigation equipment and airworthiness standards should be used; however, they must be augmented to address the unique issues associated with ADS-B. A TSO authorization alone is not sufficient to ensure ADS-B compatibility. The position source must also comply with the performance requirements in **4.5.6Appendix B** of this AC. Compliance with the **4.5.6Appendix B** requirements may be documented in the position source manufacturer's installation instructions.

Note: Not all GNSS position sources will provide the same availability. Refer to **4.5.6Appendix B** for more information on GNSS availability. The FAA recommends TSO-C145 or TSO-C146 position sources that meet the **4.5.6Appendix B** requirements to maximize availability and ensure access to the airspace identified in § 91.225 after January 1, 2020.

3.3.2 Installation Guidance.

3.3.2.1 Installation Guidance.

The position source must be installed in accordance with the applicable guidance. New GNSS position sources must be installed in accordance with AC 20-138(), *Airworthiness Approval of Positioning and Navigation Systems*.

3.3.2.2 Position Source and ADS-B Equipment Interface.

Unless the ADS-B equipment manufacturer has analyzed the interface between the position source and the ADS-B equipment you are installing, and specifically listed the position source in the ADS-B equipment's installation manual, you must provide an analysis of the interface between the position source and the ADS-B equipment that demonstrates the position, velocity, position accuracy, position integrity, and velocity accuracy information taken from the position source is properly interpreted by the ADS-B equipment. When installing modifications to a position source, the installer must determine and test those portions of the ADS-B system that are impacted by the modification and ensure the ADS-B system is not adversely impacted.

Note: This analysis will require engineering design data from the ADS-B equipment manufacturer and/or the position source manufacturer.

3.3.2.3 Secondary Position Source.

There is no requirement to have a secondary position source input. However, if you interface a secondary position source to the ADS-B system, it must meet the requirements in **4.5.6Appendix B** of this AC.

Note: If a position source is unable to provide § 91.227 accuracy and integrity values, it will not qualify the aircraft to operate in airspace defined by § 91.225 after January 1, 2020.

3.3.2.4 Position Source Selection.

If multiple position sources (such as MMR/GPS, IRS/INS/ADIRU or GPS1 & GPS2) are interfaced to the ADS-B equipment, source selection can be accomplished manually by the pilot, automatically by the aircraft's navigation system, or by the ADS-B equipment. We discourage automatic selection of the ADS-B position source based solely on the navigation source in use because operational requirements sometimes dictate a navigation source that may not provide the best ADS-B performance. If the ADS-B equipment accomplishes the position source selection, it should do so in accordance with TSO-C166b or TSO-C154c. If multiple sources are interfaced to the ADS-B system, there should be a means for the flightcrew to readily determine which source is selected. Describing how this selection is performed in the AFM is one acceptable means of compliance.

Note: TSO-C166b and TSO-C154c require the ADS-B equipment to use a single position source for the latitude, longitude, horizontal velocity, accuracy metrics, and integrity metrics.

3.3.2.5 Position Source.

The ADS-B position source does not need to be the same position source used for navigation. It is acceptable for a GNSS position source to be embedded in the ADS-B equipment and provide position information to the ADS-B system without providing any navigation information to other onboard systems. As addressed in **4.5.6Appendix B** of this AC, an integrated GNSS position source should still meet the requirements of TSO-C145(), TSO-C146(), or TSO-C196().

3.3.2.6 GPS/UAT Time Mark Synchronization.

When integrating a UAT with an external GPS, the design of the hardware time mark must be interoperable. Some GPS synchronize the leading edge of the time mark to the UTC second. Other GPS allow the time mark pulse to be asynchronous to the UTC second, then record the time of the leading edge in the digital data along with the position solution. The UAT equipment must support the GPS time mark design. If the UAT equipment and GPS do not share a common time mark design, the UAT equipment will not be properly synchronized with the ground system and other aircraft.

3.3.3 <u>Configuration of Associated Parameters.</u>

This section provides additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in **4.5.6Appendix A**.

3.3.3.1 Latitude and Longitude.

The ADS-B equipment must set the latitude and longitude based on the real-time position information provided by the position source.

3.3.3.2 Horizontal Velocity.

The ADS-B equipment must set the horizontal velocity based on the real-time velocity information provided by the position source. The ADS-B equipment must transmit a north/south and an east/west velocity while airborne, and a combination of ground speed and ground track or heading while on the surface. Ensure the position source provides horizontal velocity in both formats or ensure the ADS-B equipment can properly convert between formats. We recommend transmitting heading instead of ground track while on the surface. Refer to section **3.5.3** of this AC for additional information on interfacing heading.

3.3.3.3 Source Integrity Level (SIL).

SIL is typically a static (unchanging) value and may be set at the time of installation if a single type of position source is integrated with the ADS-B system. SIL is based solely on the position source's probability of exceeding the reported integrity value and should be set based on design data from the position source equipment manufacturer. Installations that derive SIL from GNSS position sources that are compliant with any revision of TSO-C129, TSO-C145, TSO-C146, or TSO-C196 and output Horizontal Protection Level (HPL) or Horizontal Integrity Level (HIL) should set the SIL = 3 because HPL and HIL are based on a probability of 1x10-7 per-hour. Do not base NIC or SIL on Horizontal Uncertainty Level (HUL) information. If integrating with a noncompliant GPS, SIL must be set to "0".

3.3.3.4 Source Integrity Level Supplement (SIL_{SUPP}).

SIL_{SUPP} is based on whether the position source probability of exceeding the reported integrity value is calculated on a per-hour or per-sample basis and should be set based on design data from the position source equipment manufacturer. ADS-B systems interfaced with a GNSS position source compliant with any revision of TSO-C129, TSO-C145, TSO-C146, or TSO-C196 may preset SIL_{SUPP} to "ZERO," as GNSS position sources use a per-hour basis for integrity.

3.3.3.5 Navigation Integrity Category (NIC).

The ADS-B equipment must set the NIC based on the real-time integrity metric provided by the position source. When interfacing GNSS position sources, the NIC should be based on the HPL or HIL. However, although HPL values significantly smaller than 0.1 nautical mile (nm) can be output from single-frequency GNSS sources, the HPL may not actually achieve the reported level of protection as there are error contributions that are no longer considered negligible. You should review the position source design data to determine if all error sources are taken into consideration, or if the position source limits the HPL output, when computing an unaugmented Receiver Autonomous Integrity Monitoring (RAIM) based HPL. This applies to all TSO-C129() and TSO-C196() position sources, and to TSO-C145() and TSO-C146() position sources when operating in unaugmented modes where the HPL is based on RAIM. This may apply to some position sources even when operating in an augmented mode. If the position source does not account for all errors or accomplish the appropriate HPL limiting, you must ensure you interface the position source to ADS-B equipment that limits the NIC ≤ 8. Refer to section **4.5.6Appendix B**, of this AC for additional information regarding HPL considerations.

3.3.3.6 Navigation Accuracy Category for Position (NAC_P).

The ADS-B equipment must set the NAC_P based on the real-time 95-percent accuracy metric provided by the position source. When interfacing GNSS sources, the NAC_P should be based on a qualified Horizontal Figure of Merit (HFOM).

3.3.3.7 Navigation Accuracy Category for Velocity (NAC_V).

Set the NAC_V based on design data provided by the position source manufacturer. The NAC_V may be updated dynamically from the position source, or set statically based on qualification of the position source.

3.3.3.7.1 A NAC_V = 1 (< 10 m/s) may be permanently set at installation for GNSS equipment passing the tests identified in **4.5.6Appendix B** of this AC, or may be set dynamically from velocity accuracy output of a position source qualified in accordance with the guidance in **4.5.6Appendix B.**

3.3.3.7.2 A NAC_V = 2 (< 3 m/s) mustbe set dynamically from velocity accuracy output of a position source qualified in accordance with the **4.5.6Appendix B** guidance. Do not permanently pre-set a NAC_V = 2 at installation, even if the position source has passed the tests identified in **4.5.6Appendix B**.

3.3.3.7.3 A NAC_V = 3 or NAC_V = 4 should not be set based on GNSS velocity accuracy unless you can demonstrate to the FAA that the velocity accuracy actually meets the requirement.

3.3.3.8 Geometric Altitude.

Ensure the geometric altitude provided by the position source is based on Height-Above-Ellipsoid (HAE) instead of Height-Above-Geoid (HAG). Do not interface a position source that provides HAG or Mean Sea Level (MSL) altitude to the ADS-B equipment unless the ADS-B equipment has the ability to determine the difference between an HAG and HAE input, and the ADS-B equipment has demonstrated during design approval that it can properly convert HAG to HAE using the same model as the position source. It would also be acceptable to demonstrate that the error due to conversion of HAG to HAE does not cause the GVA to be exceeded.

3.3.3.9 Geometric Vertical Accuracy (GVA).

Set the GVA based on design data provided by the position source manufacturer. GNSS position sources may provide the geometric altitude accuracy through the Vertical Figure of Merit (VFOM). If the position source does not output a qualified vertical accuracy metric, the GVA parameter should be set to "0".

3.3.3.10 Ground Track Angle.

For installations that do not have heading information available, ground track from the position source must be transmitted while on the surface. Many position sources will provide accurate ground track information, but the ground track may only be accurate above certain ground speeds. If the position source ground track is inaccurate below a certain ground speed and the position source does not inhibit output of the ground track at these slower speeds, the installer should ensure the ADS-B equipment has the capability to invalidate the ground track when the GNSS ground speed falls below 7 knots. Erroneous ground track readings could be misleading for ATC surface operations and ADS-B IN applications. If the position source itself inhibits output of ground track at slower speeds where the ground track would be inaccurate, the installer may interface the position source ground track to the ADS-B equipment without any restrictions.

3.4 **Barometric Altitude Source.**

3.4.1 Equipment Eligibility.

3.4.1.1 Use barometric altitude from a barometric altimeter that meets the minimum performance requirements of 14 CFR 91.217. The following three subparagraphs are each an acceptable means of compliance.

3.4.1.1.1 TSO-C10, Altimeter, Pressure Actuated, Sensitive Type (any revision)

3.4.1.1.2 TSO-C106, *Air Data Computer* (any revision)

3.4.1.1.3 Ensure the equipment was tested and calibrated to transmit altitude data corresponding within 125 feet (on a 95-percent probability basis) of the indicated or calibrated datum of the altimeter normally used to maintain flight altitude, with that altimeter referenced to 29.92 inches of mercury for altitudes from sea level to the maximum operating altitude of the aircraft.

3.4.1.2 If appropriate, use a digitizer meeting the minimum performance requirements of any revision of TSO-C88, *Automatic Pressure Altitude Reporting Code-Generating Equipment*.

3.4.2 Installation Guidance.

3.4.2.1 The barometric altitude used for the ADS-B broadcast must be from the same altitude source as the barometric altitude used for the ATC transponder Mode C reply, if an altitude-encoding transponder is installed in the aircraft.

3.4.2.2 § 91.225 and § 91.227 do not alter any existing regulatory guidance regarding the barometric altitude accuracy or resolution. For example, if an operation requires a 25-foot altitude resolution or a part 91, appendix G (Operations in Reduced Vertical Separation Minimum (RVSM) Airspace) accuracy, that resolution and accuracy should be reflected in the ADS-B message.

3.4.2.3 If a secondary altitude source is used when a secondary transponder is selected or a secondary altitude source is selected for a single transponder, the altitude source for ADS-B must also be changed so the altitude source remains the same for both the transponder and ADS-B system.

3.4.3 Configuration of Associated Parameters.

This section provides additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in **4.5.6Appendix A**:

3.4.3.1 Barometric Altitude.

The ADS-B equipment must update the barometric altitude based on the real-time barometric altitude provided by the barometric altitude source.

3.4.3.2 Barometric Altitude Integrity Code (NIC_{BARO}).

You should verify the type of altitude source installed in the aircraft and interface the altitude system per the ADS-B equipment manufacturer's instructions. For aircraft with an approved, non-Gillham altitude source, NIC_{BARO} should be preset at installation to "ONE". For aircraft with a Gillham altitude source without an automatic cross-check, NIC_{BARO} must be preset at installation to "ZERO". For aircraft that dynamically cross-check a Gillham altitude source with a second altitude source, the NIC_{BARO} must be set based on the result of this cross-check. We recommend that ADS-B installations use non-Gillham altitude encoders to reduce the potential for altitude errors.

3.5 Heading Source.

3.5.1 Equipment Eligibility.

For installations that integrate heading on the airport surface, the heading source must meet the minimum performance requirements of any revision of TSO-C5, *Direction Instrument, Non-Magnetic (Gyroscopically Stabilized)*, or any revision of TSO-C6, *Direction Instrument, Magnetic (Gyroscopically Stabilized)*. The equipment must have the appropriate installation and airworthiness approval.

3.5.2 Installation Guidance.

3.5.2.1 The heading does not need to come from the same source as the position and velocity.

3.5.2.2 Interfacing heading is not required, but is highly encouraged if the aircraft has an approved heading source.

3.5.3 Configuration of Associated Parameters.

When the aircraft is on the surface, the ADS-B system is required to transmit either heading or ground track; however, we recommend transmitting heading if a source of heading information is available and valid. True heading is preferred, but magnetic heading is acceptable. Ensure the heading type (true or magnetic) interfaced to the ADS-B equipment matches the heading type transmitted from the ADS-B equipment.

3.6 TCAS Source.

3.6.1 Equipment Eligibility.

TCAS II systems should comply with TSO-C119a, *Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II*, or subsequent version, and be installed in accordance with AC 20-131A, *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders*, or any revision of AC 20-151, *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 and 7.1 and Associated Mode S Transponders*, as applicable. No ADS-B interface is available or required for TCAS I systems.

Note: Many aircraft will be equipped with a Mode S transponder with ADS-B functionality and a TCAS II. The Mode S transponder is considered to be a component of the TCAS II system and also a component of the ADS-B system.

3.6.2 Installation Guidance.

3.6.2.1 TCAS II Interface.

TCAS II is not a required part of the ADS-B system; however, if TCAS II is installed on your aircraft, the equipment must be integrated so the “TCAS installed and operational” and the “TCAS traffic status” parameters indicate the real-time status of the TCAS II.

3.6.2.2 TCAS II Hybrid Surveillance.

If an ADS-B IN system is installed in an aircraft equipped with a TCAS II hybrid surveillance system compliant with RTCA/DO-300(), *Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance*, the TCAS II will use ADS-B IN position data to reduce the interrogation rates of low-threat intruders. The information transmitted by ADS-B OUT systems installed in accordance with the guidance in this AC is suitable for use by TCAS II hybrid surveillance. Refer to AC 20-151() for more information on hybrid surveillance.

3.6.2.3 TCAS Messages.

The ADS-B transmission of the "TCAS operational" or "TCAS Resolution Advisory (RA) active" messages does not increase the hazard level of the ADS-B equipment defined in TSO-C166b or TSO-C154c.

3.6.3 Configuration of Associated Parameters.

This section provides additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in **4.5.6Appendix A** of this AC.

3.6.3.1 TCAS Installed and Operational.

This parameter must interface with the TCAS II system if a TCAS II system is installed on your aircraft. This parameter should be preset to "ZERO" if a TCAS II is not installed in your aircraft or if a TCAS I is installed in your aircraft. Typically, this parameter will already be provided to the Mode S transponder from the TCAS II. TCAS II systems compliant with TSO-C119() indicate they are operational and able to issue an RA when they transmit Reply Information (RI) = 3 or 4 to the transponder.

3.6.3.2 TCAS Traffic Status.

This parameter must be interfaced with the TCAS II system if a TCAS II system is installed on your aircraft. The TCAS traffic status parameter can be preset to "ZERO" in accordance with the ADS-B equipment manufacturer's instructions if a TCAS II is not installed.

3.7 Pilot Interface.

3.7.1 Equipment Eligibility.

There are no unique equipment requirements.

3.7.2 Installation Guidance.

3.7.2.1 System Status.

The installation must have a method to display system operational status to the flightcrew, and should be consistent with the overall flightdeck design philosophy. The system must display flightcrew inputs such as Mode 3/A code, emergency codes, IDENT, and call sign. If an existing transponder is used to input Mode 3/A codes, emergency codes, and IDENT into the ADS-B system, the current transponder control interface is sufficient. The following two failure annunciations must be included in the initial airworthiness certification (that is, STC or TC) type design data for the ADS-B OUT equipment, and should be consistent with the overall flightdeck design philosophy for surveillance equipment. These failure conditions are advisory only and do not constitute a caution or warning condition. For legacy Mode C installations that are adding a UAT device, the following two failure annunciations are optional.

3.7.2.1.1 ADS-B Device Failure.

If the ADS-B equipment is unable to transmit ADS-B messages, the system should provide an appropriate annunciation to the flightcrew.

3.7.2.1.2 ADS-B Function Failure.

The ADS-B system depends on a position source to provide the data to populate the ADS-B messages and reports. If the position source or its interface with the ADS-B equipment fails, the ADS-B system will not be able to broadcast the required ADS-B data. In this case, the ADS-B equipment has not failed, but it cannot perform its function due to a failure to receive the position source data. The ADS-B system should distinguish between a position source or interface failure and an ADS-B equipment failure. The installer must provide documentation, in the applicable flight manual, or flight manual supplement, that explains how to differentiate between annunciation of an equipment failure and a function failure if the failure annunciations are not independent. The ADS-B function failure must not cause a TCAS II system failure.

Note: Certain advanced ADS-B IN applications may require flightcrew knowledge of own-ship ADS-B OUT operational status. Refer to AC 20-172() for guidance regarding ADS-B IN installations.

3.7.2.2 Turning Off ADS-B.

14 CFR 91.225 and § 91.227 requires that all aircraft equipped with ADS-B OUT operate with the equipment turned on at all times. There are no requirements to disable ADS-B broadcasts at the request of ATC. When ADS-B functionality resides in the Mode S transponder, it is acceptable to disable the ADS-B transmissions by disabling the transponder (that is, “Standby” or “Off”). If this architecture is used, specify the impact in the flight manual or pilot’s guide (for example, loss of ADS-B, transponder, and TCAS functionality). Locate the ADS-B on/off controls to prevent inadvertent actuation.

3.7.2.3 Anonymity Feature.

§ 91.227 contains specific provisions allowing operators with TSO-C154c equipment to transmit a self-assigned (randomized) temporary 24-bit address and no call sign. No such provision is provided for TSO-C166b equipment. After January 1, 2020, and in the airspace identified in § 91.225, the UAT anonymous 24-bit address feature may only be used when the operator has not filed a flight plan and is not requesting ATC services. The UAT call sign may also be omitted, but only when the anonymous 24-bit address is chosen. We do not recommend integrating the anonymity features, as the operator will not be eligible to receive ATC services, may not be able to benefit from enhanced ADS-B search and rescue capabilities, and may impact ADS-B IN situational awareness benefits. The following considerations must be included in the ADS-B system design when installing equipment capable of using the anonymity feature:

3.7.2.3.1 When the ADS-B equipment is initially powered-on, the 24-bit address must default to the aircraft's assigned ICAO 24-bit address.

3.7.2.3.2 When the ADS-B equipment is initially powered-on, the call sign may not be blank (Not Available per RTCA/DO-282()). At initial power-on, it is acceptable for the call sign to revert to a non-blank call sign that existed before the ADS-B equipment being powered off, or to the aircraft registration number.

3.7.2.3.3 The ADS-B equipment can only allow an anonymous 24-bit address selection if the Mode 3/A code is set to "1200".

3.7.2.3.4 The ADS-B equipment may only allow selection of the anonymous 24-bit address via a dedicated pilot interface. The ADS-B OUT equipment may not automatically set an anonymous 24-bit address or set a blank (Not Available per RTCA/DO-282()) call sign based solely on pilot selection of the 1200 Mode 3/A code.

3.7.2.3.5 The ADS-B OUT equipment must automatically disable the anonymity feature if any Mode 3/A code other than 1200 is selected. The 24-bit address must automatically revert to the aircraft's assigned ICAO 24-bit address. If the call sign was blank, the call sign must automatically revert to the aircraft registration number.

3.7.2.3.6 Describe the effects of selecting the anonymity features in the flight manual or pilot's guide. Effects include the inability to receive Instrument Flight Rule (IFR) or Visual Flight Rule (VFR) separation services, potential loss of enhanced search and rescue benefits, and potential negative impacts to ADS-B IN applications.

3.7.3 <u>Configuration of Associated Parameters.</u>

This section provides additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in **4.5.6Appendix A** of this AC.

3.7.3.1 Call Sign/Flight ID.

The assigned aircraft registration number must be set as the call sign/flight ID during installation. Procedures for dynamically selecting a call sign must be included in the flight manual or pilot's guide if the ADS-B equipment provides a means to input a radio telephony call sign. If pilot-selectable, the call sign/flight ID should be readily apparent to the flightcrew. When the aircraft system is powered on, the call sign/flight ID must be filled. At initial power-on it is acceptable for the call sign/flight ID to revert to a previously set call sign that existed before the system being powered off, or to the aircraft registration number. Refer to section **3.7.2.3** of this AC for information on use of the anonymity feature.

Note: The preset call sign/flight ID will have to be updated if the aircraft's registration number changes.

3.7.3.2 Emergency Status.

The installation must provide a means for the pilot to enter the emergency status of the aircraft. Although TSO-C166b and TSO-C154c identify multiple emergency codes, only the codes for general emergency, no communications, and unlawful interference are required to be available for broadcast. It is acceptable to base the ADS-B emergency status on the emergency status code input into the transponder (that is, Mode 3/A codes 7500, 7600, and 7700). Refer to section **3.7.3.5** of this AC for information on single point of entry of the emergency status.

3.7.3.3 IDENT.

The installation must provide a means for the pilot to enter the IDENT feature. Refer to section **3.7.3.5** of this AC for information on single point of entry of the IDENT.

3.7.3.4 Mode 3/A Code.

The installation must provide a means for the pilot to enter the Mode 3/A code. Refer to section 3.7.3.5 of this AC for information on single point of entry of the Mode 3/A code.

3.7.3.5 Single Point of Entry.

Aircraft equipped with a separate transponder and ADS-B system should provide the pilot a single point of entry into both systems for the Mode 3/A code, IDENT, and emergency status. If ADS-B equipment sets the emergency status, IDENT, or Mode 3/A code based on entry of these parameters into a separate transponder, the STC/TC needs to identify the appropriate transponder interfaces. Experience in the FAA's Alaska CAPSTONE program demonstrated that operator mitigations to prevent differing codes from being entered in the transponder and ADS-B system were ineffective and resulted in numerous false and misleading proximity alerts for ATC. Additionally, there are workload and safety concerns of requiring the pilot to enter the Mode 3/A code, IDENT, and emergency codes multiple times. Thus, if you do not provide a single point of entry for the mode 3/A code, IDENT, and emergency code, you must accomplish a human factors evaluation and an additional system safety assessment as follows:

3.7.3.5.1 Human Factors Evaluation.

Installations not providing a single point of entry must accomplish an evaluation of the pilot interface controls to ensure the design minimizes the potential for entry errors by the flightcrew, and enables the flightcrew to detect and correct errors that do occur. Evaluate the system interface design to ensure dual entry of the emergency status, IDENT, and Mode 3/A code does not introduce significant additional workload, particularly when communicating an aircraft emergency. Refer to section **4.1.5.4** of this AC for additional information on the human factors evaluation.

3.7.3.5.2 System Safety Assessment.

Transmission of false or misleading information is considered to be a major failure effect and may not occur at a rate greater than $1x10^{-5}$ per flight hour for ADS-B systems. Installations not providing a single point of entry must accomplish a safety assessment that demonstrates that the probability of the transponder and ADS-B system ever transmitting differing Mode 3/A codes is less than $1x10^{-5}$ per flight hour. The analysis must consider the potential of all pilot errors.

3.8 ADS-B Antenna Interface.

3.8.1 <u>Antenna Location and Number Required.</u>

The aircraft ADS-B antenna is an important part of the overall ADS-B OUT system because antenna systems are major contributors to the system link performance. The location and number of antennas required for the airborne ADS-B OUT system is a function of the equipment class of the selected broadcast link (UAT or 1090ES). Single bottom-mounted antenna (TSO-C166b and TSO-C154c A1S and B1S classes) installations are allowed. For the UAT link, 16 watts minimum transmit power at the antenna output is required. For the 1090ES link, 125 watts minimum transmit power at the antenna output is required.

3.8.2 <u>Equipment Eligibility.</u>

ADS-B antennas must meet requirements defined in the ADS-B equipment manufacturer’s installation manual.

3.8.3 Installation Guidance.

3.8.3.1 Using an Existing Antenna.

When using an existing antenna system, if the installation does not modify the existing antenna(s), cabling, or output specifications, the antenna installation does not have to be reevaluated.

3.8.3.2 Installing a New Shared Transponder/ADS-B Antenna.

Follow the transponder antenna installation guidance in AC 20-151().

3.8.3.3 Installing a New Stand-Alone UAT ADS-B Antenna.

If the UAT system is installed in an aircraft without a transponder or the installation will not use the existing transponder antenna, use the following guidance:

3.8.3.3.1 Antenna Location.

Mount antennas as near as practical to the centerline of the fuselage and locate them in a position to minimize obstruction in the horizontal plane.

3.8.3.3.2 Antenna Distance From Other Antennas.

The spacing between the UAT antenna and any transponder (Mode S or Air Traffic Control Radar Beacon System (ATCRBS)) antenna must provide a minimum of 20 dB of isolation between the two antennas. If both antennas are conventional omni-directional matched quarter-wave stubs, 20 dB of isolation is obtained by providing a spacing of at least 20 inches between the centers of the two antennas. If either antenna is other than a conventional stub, the minimum spacing must be determined such that 20 dB or more of isolation is achieved.

3.8.3.3.3 Transmit Power.

Transmit power will be verified during ground test.

3.8.3.3.4 Structural Analysis.

You may need to submit a structural analysis of new antenna installation to show compliance with the applicable regulations.

3.8.3.4 Antenna Diplexers.

Diplexers manufactured in accordance with TSO-C154b or TSO-C154c may be installed so UAT ADS-B equipment and a transponder may share the same antenna. The TSO-C154b and TSO-C154c diplexer installation instructions are required to have a limitation that ensures insertion of the diplexer does not exceed the maximum cable attenuation allowance between the transponder and antenna.

3.8.3.5 Single Antenna.

Single antenna systems must use a bottom-mounted antenna.

3.8.4 <u>Configuration of Associated Parameters.</u>

This section provides additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in **4.5.6Appendix A** to this AC.

3.8.4.1 GNSS Antenna Offset and Position Offset Applied (POA).

Although not required to comply with § 91.227, it is highly encouraged for ADS-B equipment manufacturers to provide instructions to installers for setting this parameter and for installers to configure the offset during installation. The GNSS antenna offset information will be extremely valuable for surface ATC surveillance and future ADS-B IN surface situational awareness and surface collision alerting applications.

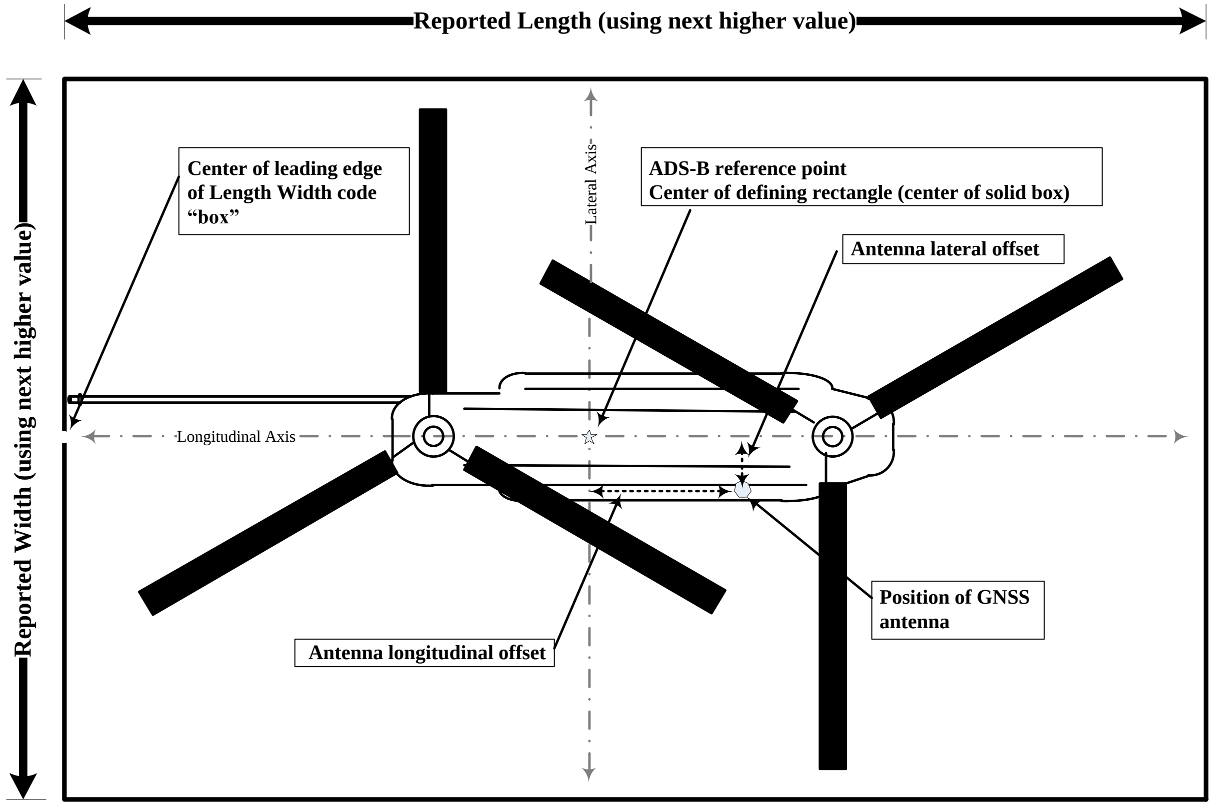
3.8.4.2 If the ADS-B equipment is interfaced to multiple GNSS position sources that use GNSS antennas in different locations on the aircraft, the installation must have provisions to ensure the appropriate GNSS antenna offset is being transmitted when the ADS-B equipment switches from one position source to another.

3.8.4.3 The POA setting of the GNSS antenna indicates if the broadcast position of the vehicle is referenced to either a) the aircraft's ADS-B position reference point, or b) the lateral distance from centerline and longitudinal distance from the most forward part of the aircraft, (reference **4.5.6B.4.1**).

Note: Either the transmitted position should be adjusted to the reference point described in paragraph 3.8.4.4 OR the GNSS antenna offsets should be provided. It is not required to do both.

3.8.4.4 The ADS-B position reference point is the center of the rectangle used to describe the length and width of the aircraft in the length and width code. Refer to section **3.2.3.2** and **figure 2** of this AC. For a more detailed description of POA, refer to RTCA/DO-338, *Minimum Aviation System Performance Standards (MASPS) for ADS-B Traffic Surveillance Systems and Applications (ATSSA)*, section 3.2.4.1.

Figure 3. Position Offset



3.8.4.5 Single Antenna Bit.

For aircraft using a single antenna, this parameter should be set to one, "True".

3.8.5 Mutual Suppression.

Follow the ADS-B equipment manufacturer's guidance on interfacing the ADS-B OUT equipment to the mutual suppression bus.

3.9 Vertical Rate Source.

We recommend that the ADS-B system output the vertical rate field when available. The vertical rate may come from a barometric air data computer, a GNSS source, or a system that filters barometric and geometric vertical rates. Vertical rate will typically come from a position source or an air-data computer. This section addresses this unique parameter, and augments section **3.3** and **3.4** of this AC, as applicable.

3.9.1 Equipment Eligibility.

Unlike position accuracy, vertical velocity accuracy is not transmitted in ADS-B messages. Thus it is important that vertical velocity sources integrated into the ADS-B system meet minimum performance requirements at installation. Use the following guidance:

3.9.1.1 Hybrid Vertical Rate Source.

Vertical rate may be taken from a hybrid system that filters barometric vertical rate with an Inertial Reference Unit (IRU) vertical rate and GNSS vertical rate, provided the hybrid system was tested and approved to provide a vertical rate output with an accuracy that is at least as good as barometric vertical rate sources (such as TSO-C106). Hybrid vertical rate could come from a Flight Management System (FMS), Air Data and Inertial Reference System (ADIRS), or IRU. ADS-B equipment should transmit hybrid vertical rate solutions as barometric vertical rates.

3.9.1.2 Blended Vertical Rate Source.

Vertical rate may be taken from a blended system that filters IRU vertical rate and barometric vertical rate, provided the blended system was tested and approved to provide a vertical rate output with an accuracy that is at least as good as barometric vertical rate sources (such as TSO-C106). Blended vertical rate could come from an FMS, ADIRS, or IRU. ADS-B equipment should transmit blended vertical rate solutions as barometric vertical rates.

3.9.1.3 Barometric Vertical Rate Source.

Barometric vertical rate may be taken from an air data computer meeting the minimum performance requirements of any revision of TSO-C106 or a vertical velocity instrument meeting the minimum performance requirements of applicable revisions of TSO-C8, *Vertical Velocity Instruments (Rate-of-Climb)*. We recommend you use any revision of a TSO-C106 compliant air data computer if you interface barometric vertical rate to the ADS-B OUT equipment.

3.9.1.4 GNSS Vertical Rate Source.

Geometric vertical rate may be taken from any revision of TSO-C129, TSO-C145, TSO-C146, or TSO-C196 GNSS equipment if the position source has been qualified to provide vertical rate in accordance with **4.5.6Appendix B** of this AC. Do not interface GNSS vertical velocity if the equipment has not been qualified in accordance with **4.5.6Appendix B**.

3.9.1.5 Inertial Vertical Rate Source.

Vertical velocity from an inertial sensor that is not blended with barometric altitude should not be transmitted from the ADS-B system.

3.9.1.6 Barometric Altitude Source.

ADS-B systems should not derive a barometric altitude rate by sampling barometric altitude measurements. This could lead to misleading vertical velocity information. If barometric vertical rate is not available, use geometric vertical rate.

3.9.2 Installation Guidance.

The vertical rate field can be populated with either barometric vertical rate or geometric vertical rate. There is no requirement to interface multiple vertical velocity sources. We recommend that you use the following priority scheme when selecting or interfacing multiple vertical rate sources:

1. Hybrid vertical rate or blended vertical rate.
2. Barometric vertical rate.
3. GNSS vertical rate.

3.9.3 Configuration of Associated Parameters.

This section provides additional guidance on setting key ADS-B OUT parameters:

3.9.3.1 Vertical Rate.

Interface vertical rate from one or more of the sources listed in section 3.9.1 above. Ensure the source provides vertical rate in feet per minute, or ensure the ADS-B equipment can recognize the vertical rate basis and convert the vertical rate to feet per minute.

3.9.3.2 Vertical Rate Source.

The source bit for vertical rate should be coded as barometric when using barometric rate from an air data computer, or when using a blended or hybrid vertical rate. The source bit for vertical rate should only be coded as geometric when using vertical rate from a GNSS source.

3.10 **Air-Ground Considerations.**

3.10.1 Length and Width Code.

The length and width code is required by § 91.227, and is only transmitted in the surface position message. Thus, to comply with the rule, the aircraft must automatically determine its air-ground status and transmit the surface position message, which includes the length and width code, when on the ground.

3.10.2 Air-Ground Status.

For aircraft with retractable landing gear, the air-ground status determination is typically provided through a landing gear weight-on-wheels (WOW) switch. For aircraft that have fixed gear, the ADS-B system must still be able to determine the air-ground status of the aircraft. Installations that provide a means to automatically determine air-ground status based on inputs from other aircraft sensors may be acceptable if they can be demonstrated to accurately detect the status. For example, air-ground status may be derived from WOW switch and GPS velocity; *or* GPS velocity, an airport database, and geometric altitude; *or* GPS velocity and airspeed. These algorithms should be tested and validated during the installation approval.

Note 1: We recommend that any automatic air-ground determination be more robust than just a simple comparison of ground speed to a single threshold value. Field experience has shown that this method can lead to false air-ground status.

Note 2: Manual selection of the air-ground status is not acceptable.

Note 3: Rotorcraft may require unique logic for providing an accurate air-ground state. A reliable method to determine the air-ground state should consider training requirements. Rotorcraft may consider hover taxi as in the air.

3.10.3 Mode S Transponder Inhibit.

TSO-C112d and TSO-C112e, *Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*, requires Mode S transponders to inhibit the reply to Mode A/C/S all-call and Mode S-only all-call interrogations on the surface. Mode S transponders with ADS-B functionality will now remain "ON" during surface operations; thus it is imperative that you ensure the transponder interface to the air-ground status is installed correctly and that the transponder does not reply to Mode A/C/S all-call or Mode S-only all-call interrogations on the surface.

Note: In deploying Airport Surface Detection Equipment version X (ASDE-X) at various airports, we have found transponder installations that have been improperly wired and therefore inappropriately respond to ATC and TCAS interrogations while on the airport surface.

3.11 Foreign Airspace Requirements.

3.11.1 Optional Parameters.

If operations are planned in a country that requires parameters not mandated in the United States, such as selected heading and selected altitude, follow the ADS-B equipment manufacturer's installation guidance to interface those parameters.

CHAPTER 4. TEST AND EVALUATION

4.1 Ground Test.

4.1.1 Systems Interface Testing.

Verify the installed ADS-B equipment meets its intended function and transmits the appropriate information from each of the interfaced systems (including the position source, barometric altitude source, heading source, TCAS II, pilot interface, etc). Coordinate with local ATC before broadcasting over the air to prevent being a source of interference to ATC or ADS-B IN equipped aircraft in the area. For example, transmitting airborne position reports with simulated airborne altitudes while on the surface will produce false targets for the ATC surveillance systems or airborne ADS-B IN equipped aircraft.

4.1.2 System Latency.

Latency is addressed through analysis rather than testing. Refer to section 3.1.3 and **4.5.6Appendix C** of this AC.

4.1.3 Rule Compliance.

Ensure the ADS-B system meets the requirements of § 91.227.

4.1.3.1 Accuracy and Integrity Performance.

Ensure the installed system meets its stated accuracy and integrity performance under expected operating conditions. We recommend that you accomplish a GNSS performance prediction for the applicable time of your test to ensure the ADS-B system meets the predicted performance. In absence of predicted GNSS performance, demonstrate that you meet all § 91.227(c)(1) requirements as listed in **Table 2**.

Table 2. Accuracy and Integrity Requirements

NIC ≥ 7	Rc < 370.4 m (0.2 nm)
NAC_P ≥ 8	EPU < 92.6 m (0.05 nm)
NAC_V ≥ 1	< 10 m/s
SIL ≥ 3	≤ 1×10^{-7} per-hour or per sample
SDA ≥ 2	≤ 1×10^{-5} per-hour

4.1.3.2 Parameters.

Per § 91.227(d), ensure the following parameters are properly populated and transmitted.

4.1.3.2.1 The length and width of the aircraft;

4.1.3.2.2 An indication of the aircraft's latitude and longitude;

4.1.3.2.3 An indication of the aircraft's barometric pressure altitude;

4.1.3.2.4 An indication of the aircraft's velocity;

4.1.3.2.5 An indication if TCAS II or ACAS is installed and operating in a mode that can generate resolution advisory alerts;

4.1.3.2.6 If an operable TCAS II or ACAS is installed, an indication if a resolution advisory is in effect;

4.1.3.2.7 An indication of the Mode 3/A transponder code specified by ATC;

4.1.3.2.8 An indication of the aircraft's call sign that is submitted on the flight plan, or the aircraft's registration number, except when the pilot has not filed a flight plan, has not requested ATC services, and is using a TSO-C154c self-assigned temporary 24-bit address;

4.1.3.2.9 An indication if the flightcrew has identified an emergency, radio communication failure, or unlawful interference;

4.1.3.2.10 An indication of the aircraft's "IDENT" to ATC;

4.1.3.2.11 An indication of the aircraft assigned ICAO 24-bit address, except when the pilot has not filed a flight plan, has not requested ATC services, and is using a TSO-C154c self-assigned temporary 24-bit address;

4.1.3.2.12 An indication of the aircraft's emitter category;

4.1.3.2.13 An indication of whether an ADS-B In capability is installed;

4.1.3.2.14 An indication of the aircraft's geometric altitude;

4.1.3.2.15 An indication of the Navigation Accuracy Category for Position (NACP);

4.1.3.2.16 An indication of the Navigation Accuracy Category for Velocity (NACV);

4.1.3.2.17 An indication of the Navigation Integrity Category (NIC);

4.1.3.2.18 An indication of the System Design Assurance (SDA); and

4.1.3.2.19 An indication of the Source Integrity Level (SIL).

4.1.3.3 Position Accuracy.

Position the aircraft on a surveyed location and validate the position transmitted from the ADS-B system. Ensure the position transmitted is within the allotted NAC_P accuracy limit. For example, if the aircraft reports a $NAC_P = 8$, the ADS-B position should be within 92.6 meters, 0.05 nm. If the aircraft reports a NAC_P = 10, the ADS-B position should be within 10 meters. Refer to **4.5.6Appendix A** of this AC for a complete list of NAC_P values. If the transmitted position accuracy is smaller or equal to the resolution of the test equipment, it is acceptable to use plus or minus one Least Significant Bit as the pass/fail criteria.

4.1.3.4 Barometric Altitude Accuracy.

Validate that the barometric altitude transmitted from the ADS-B system is accurate to within 125 feet. If the aircraft has a transponder installed, you must also validate that the ADS-B barometric altitude matches the transponder barometric altitude.

4.1.4 Electromagnetic Interface (EMI)/Electro Magnetic Compatibility (EMC) Testing.

Provide an EMI/EMC test plan that demonstrates compliance with 14 CFR 23.1431(a) and (b), 25.1353(a) and (b), 25.1431(a) and (c), 27.1301, 27.1309, 29.1353(a) and (b), and 29.1431(a) and (b) as appropriate. Accomplish EMI/EMC testing to ensure the ADS-B equipment does not provide an interference source on other installed systems on the aircraft. Additionally, ensure equipment already installed in the aircraft does not interfere with the ADS-B system. If the STC or TC only involves a software change to an existing approved Mode S transponder installation, and the software update will not affect the systems response to EMI, you do not need to accomplish EMI testing again.

4.1.5 Human Machine Interface.

Evaluate the flightcrew interface for the ADS-B OUT system, including the human-system interface and system behavior. The ADS-B OUT system must be compatible with the overall flightdeck design characteristics (such as access to controls, sunlight readability, night lighting, etc.) as well as the aircraft environment (such as vibrations).

4.1.5.1 Information Display.

Evaluate the ADS-B OUT system to ensure displayed information is easily and clearly discernible, and has enough luminance, size, and visual contrast for the pilots to see and interpret it. Ensure the pilots have a clear, unobstructed, and undistorted view of the displayed information elements. Ensure information elements are distinct and permit the pilots to determine the source of the information elements if necessary, when there are multiple sources of the same kind of information.

4.1.5.2 Controls and Labeling.

Evaluate the controls for the pilot interface to ensure they are plainly marked as to their intended function, provide convenient operation, and prevent confusion and inadvertent operation of both the ADS-B system, and the other systems with which they interact. Evaluate the acronyms, labels, and annunciations to ensure they are used consistently in the flightdeck, and do not cause confusion or errors. If a control performs more than one function, evaluate the labels to ensure the labels include all intended functions, unless the function of the control is obvious. During evaluation, consider line select keys, touch screens or cursor controlled devices (such as trackballs) as these can be susceptible to unintended mode selection resulting from their location in the flightdeck (for example, proximity to a footrest or temporary stowage area).

4.1.5.3 Annunciations and Alerts.

Evaluate all ADS-B annunciations and alerts to ensure they are clear and unambiguous, and provide attention-getting and saliency appropriate to the type of alert. Compliance with AC 25.1322-1, *Flightcrew Alerting*; AC 27.1322 (in AC 27-1B, *Certification of Normal Category Rotorcraft*); and AC 29.1322 (in AC 29-2C, *Certification of Transport Category Rotorcraft*) should be considered when evaluating ADS-B annunciations and alerts. The colors yellow/amber and red should be restricted to cautions and warnings, respectively. Evaluate the annunciations and indications to ensure they are operationally relevant and limited to minimize the adverse effects on flightcrew workload. When an annunciation is provided for the status or mode of a system, it is recommended that the annunciation indicate the actual state of the system, and not just the position of a switch.

4.1.5.4 Pilot Interface Errors.

Installations not providing a single point of entry for the ADS-B and transponder for the Mode 3/A code, IDENT, and emergency status must accomplish an evaluation of the pilot interface controls to determine that they are designed to minimize entry errors by the flightcrew, and enable the flightcrew to detect and correct errors that do occur. System interface design must also be evaluated to ensure dual entry of the Mode 3/A code, IDENT, and emergency status does not introduce significant additional workload, and that the controls are acceptable for data entry, accuracy, and error rates, particularly when communicating an aircraft emergency. Evaluations should consider pilot-detected and undetected error rates, pilot workload, and training times. Refer to section **3.7.3.5** of this AC for additional information on transponder and ADS-B system single point of entry.

4.1.5.5 Lighting.

Evaluate all foreseeable conditions relative to lighting, including failure modes such as lighting and power system failure, and day and night operations.

4.1.6 Transponder Regression Testing.

At a minimum, use the procedures outlined in AC 43-6(), *Altitude Reporting Equipment and Transponder System Maintenance and Inspection Practices,* to validate that the transponder is operating normally following the ADS-B installation. Use the procedures outlined in AC 20-151() for ADS-B systems that include installation of a new or modified Mode S transponder. If you are installing a new air-ground status capability for the ADS-B system and this functionality is also interfaced to the transponder, you must ensure replies to the Mode A/C and ATCRBS/Mode S all-call interrogations are inhibited on the ground.

4.1.7 ICAO 24-Bit Address.

For U.S. civil aircraft, demonstrate that the 24-bit address transmitted by the system correlates to the aircraft registration number. If the system has a separate Mode S transponder and UAT ADS-B system installed, ensure both the transponder and ADS-B system transmit the same correct ICAO 24-bit address. For non-U.S. registered aircraft, verify that the ICAO 24-bit address is the address assigned to the aircraft by the responsible State authority.

4.1.8 Self Test.

Evaluate the ADS-B self-test features (if provided) and failure mode annunciations to ensure the pilot is able to determine whether the system is functioning properly.

4.1.9 Position Source Failure.

Demonstrate that a failure or loss of the position source results in an indication to the operator of an ADS-B function failure. If a secondary position source is interfaced to the ADS-B equipment, ensure it meets all guidance in this AC. If the change from the primary position source to the secondary position source requires a change in SIL or SDA, ensure these changes are accomplished within 10 seconds.

4.1.10 Air-Ground Status.

Verify that the air-ground inputs (or algorithms) are functioning properly and that the ADS-B system transmits the appropriate airborne messages or surface messages based on the air-ground status. This can be accomplished with simulated inputs to the appropriate sensors or accomplished in conjunction with the flight test. Rotorcraft may consider hover taxi as in the air.

4.1.11 Transmit Power.

Transmit power testing must be accomplished if a new antenna has been installed, an existing antenna has been relocated, a diplexer has been installed into an existing antenna system, or the output specifications on the transponder have changed. Perform the following testing to validate transmit power:

Note: Upgrading a previously installed and approved TSO-C112() Mode S transponder to include ADS-B functionality does not require transmit power testing unless a new antenna has been installed, the antenna location has changed, or the output specifications on the transponder have changed.

4.1.11.1 1090ES Transmitter.

Verify that the peak pulse power at the antenna end of the transmission line meets the minimum and maximum power levels summarized in **Table 3**, considering the test equipment antenna gain and path loss. Repeat the measurement in each quadrant of the antenna pattern (forward, aft, left, right).

Table 3. Minimum and Maximum Transmitted Power From TSO-C166b

Tested Transmitter Class	Minimum Power	Maximum Power
A1	21.0 dBW	27.0 dBW
A1S	21.0 dBW	27.0 dBW
B1	21.0 dBW	27.0 dBW
B1S	21.0 dBW	27.0 dBW
A2	21.0 dBW	27.0 dBW
A3	23.0 dBW	27.0 dBW

4.1.11.2 UAT Transmitter.

Verify that the peak pulse power at the antenna end of the transmission line meets the minimum and maximum power levels summarized in **Table 4**, considering the test equipment antenna gain and path loss. Repeat the measurement in each quadrant of the antenna pattern (forward, aft, left, right).

Table 4. Minimum and Maximum Transmitted Power From TSO-C154c

Tested Transmitter Class	Minimum Power	Maximum Power
A1H	12.0 dBW	16.0 dBW
A1S	12.0 dBW	16.0 dBW
B1	12.0 dBW	16.0 dBW
B1S	12.0 dBW	16.0 dBW
A2	12.0 dBW	16.0 dBW
A3	20.0 dBW	24.0 dBW

4.1.12 TCAS.

If a TCAS II system is installed on the aircraft, ensure the proper messages are transmitted by the ADS-B system when the TCAS II is on and operating in a mode that can provide RAs. No TCAS II system regression testing beyond the ground interface testing covered in this section is required.

4.1.13 Transponder All-call Inhibit.

When ADS-B functionality resides in a Mode S transponder, conduct a test demonstrating that replies to Mode A/C/S all-call and Mode S-only all-call interrogations are inhibited on the ground. Also demonstrate that replies to discrete interrogations are not inhibited.

4.1.14 Mode 3/A Code and Emergency Code.

Demonstrate that the correct Mode 3/A code and IDENT is transmitted. Do not transmit the 7500, 7600, or 7700 emergency codes over the air during ground or flight testing. If testing emergency codes is desired, contact the local ATC facility and coordinate testing to prevent a nuisance emergency response.

4.2 Flight Test.

This section provides information on flight testing ADS-B systems.

4.2.1 Electromagnetic Interference.

During all phases of flight, survey the flight deck EMI to determine that the ADS-B OUT equipment is not a source of objectionable conducted or radiated interference to previously installed systems or equipment, and that operation of the ADS-B OUT equipment is not adversely affected by conducted or radiated interference from previously installed systems and equipment.

4.2.2 Other System Performance.

Demonstrate the proper performance of any previously installed aircraft systems that required changes as a result of the ADS-B installation in accordance with the applicable policy. This can be accomplished with standard regression test procedures for the other installed systems, and does not require a unique test for ADS-B.

4.2.3 User Interface.

Exercise all user inputs. If separate user inputs are required for the transponder and ADS-B systems, evaluate the flight manual procedures for ensuring the same Mode 3/A code, IDENT, and emergency codes are transmitted from both systems.

4.3 Flight Test With FAA Ground System.

Perform a flight test to show that the installed system performs properly with the FAA ground system. The test will verify that the FAA ground system properly receives the aircraft's ADS-B broadcast messages, there are no dropouts, and the information transmitted is complete and correct. Currently the only method available to accomplish the flight test is to fly within ADS-B service coverage and accomplish a post-flight analysis of the data received from the FAA. This test is intended to evaluate the design interface for the position source and the ADS-B equipment.

Note 1: This flight test is intended to complete a design approval under an STC or TC application; it is not intended for the alteration of individual aircraft.

Note 2: Follow your standard process for requesting flight test authorization; there are no unique flight test authorization requirements for ADS-B flight tests.

4.3.1 Preflight Coordination.

4.3.1.1 Data Retrieval.

Flight test data can be requested for two distinct types of flight testing, operational checkout of a previously certified system, and testing of a first-of-kind ADS-B system.

4.3.1.1.1 Previously Certified Systems.

In the context of this AC, a previously certified system is an ADS-B system that holds a Type Certificate, Supplemental Type Certificate or is listed on an Approved Model Listing. Aircraft owners may request a flight test compliance report to verify a previously approved ADS-B system has been installed and configured correctly. Interested parties can email 9-AWA-AFS-300-ADSB-AvionicsCheck@faa.gov and request an ADS-B Aircraft Operation Compliance Report (ACR). When requesting an ACR, include aircraft registration number ("N" number), location, date, and approximate local time of flight. All requests should be made after the test flight has taken place.

4.3.1.1.2 First-of-Kind Systems.

System integration teams may request flight test data for first-of-kind ADS-B systems. First-of-kind systems are those that are part of a TC, STC, or Approved Model List (AML) effort. At least 48 hours before the flight, notify the FAA by emailing 9-avs-air-130flttest@FAA.gov that you require data to support first-of-kind testing of a new ADS-B system. Contacting the FAA before a test flight will better ensure flight test data will be provided in a timely manner. Upon initial contact, the FAA will provide a flight test request sheet. When contacting the FAA for flight test data, it is recommended you carbon copy any certifying officials you may be working with within the Aircraft Certification Office, Military Certification Office, Flight Standards District Office, or Flight Inspection District Office. Flight test data can usually be provided to the requester within 48 hours. An analysis report may take up to 30 days if it is determined necessary.

4.3.1.2 ATC Coordination.

There is no ADS-B specific requirement to coordinate the flight test in advance with ATC. Follow normal flight test procedures for coordinating with ATC.

4.3.2 Flight Test Profile.

This profile is intended to be flown on all ADS-B system approvals. The profile need not be flown exactly, and variances for ATC clearances and vectors are acceptable. The flight test should be at least 1 hour long. If the profile is completed in less than 1 hour, continue the flight until enough data is collected. The flight test may not be performed using the random UAT 24-bit address feature, since the 24-bit address is a key field in retrieving the ATC flight profile data. The profile discussed in section 4.3.2.3 through 4.3.4.6 below may be flown in any order.

4.3.2.1 Location of Flight.

The flight may be accomplished in any airspace that has FAA ADS-B ground station coverage. As of December 1, 2015 the ADS-B ground network is completely deployed across the continental United States, Hawaii, Puerto Rico, and Guam. The ADS-B ground network has been installed in Alaska but does not cover the entire state. Refer to the following website for information on existing ADS-B coverage in the National Airspace System (NAS): http://www.faa.gov/nextgen/programs/adsb/coverageMap/

4.3.2.2 Distance From Ground Station.

This flight profile does not specify the distance the aircraft must be from an ADS-B ground station. Transmit power is evaluated through ground testing instead of demonstrating a minimum air-to-ground reception distance.

4.3.2.3 Altitude.

Fly the aircraft at multiple altitudes throughout the flight within ADS-B coverage. There is no maximum or minimum altitude required for the flight test.

4.3.2.4 Turns.

Verify the ADS-B system performs properly during turning maneuvers. During the flight, place the aircraft in various normal configurations such as takeoff, approach, landing, and cruise configuration if appropriate for the airframe. During the flight, perform at least two left and two right 360-degree turns. **Table 5** below provides the suggested altitude, speed, and bank angle at which these turns should be made. The intent of this test is to ensure the ADS-B system operates properly over the normal flight regimes of the aircraft under test. Variations on altitude, speed, and bank angle are acceptable as long as the intent of the test is met.

Table 5. Turns

Part 23 Aircraft			
Configuration	Altitude Range (in feet AGL)	Speed Range	Bank Angle
Takeoff	3000-5000	1.4 V_S	30°
Approach or Landing	2000-7000	1.4 V_S	30°
Cruise	7000-10000	1.5 V_S to 1.8 V_S	30°
Part 25 Aircraft			
Configuration	Altitude Range	Speed Range	Bank Angle
Takeoff	3000-5000	V_2 + 20 kts	30°
Approach or Landing	2000-7000	V_{APP} + 20 kts	30°
Cruise	7000-10000	1.5 V_S to 1.8 V_S	30°
Part 27 Rotorcraft			
Configuration	Altitude Range	Speed Range	Bank Angle
Landing	1000-3000	V_Y + 10 kts	30°
Cruise	2000-5000	0.8 V_{NE} or 0.8 V_H	30°
Part 29 Rotorcraft			
Configuration	Altitude Range	Speed Range	Bank Angle
Landing	1000-3000	V_Y + 10 kts	30°
Cruise	2000-10000	0.8 V_{NE} or 0.8 V_H	30°

4.3.2.5 Climbs/Descents.

Verify the ADS-B system performs properly during climbs and descents. **Table 6** provides a suggested airspeed at which climbs should be made during the test flight. **Table 7** provides a suggested airspeed at which descents should be made during the test flight. Climbs and descents should be at least one minute in length. The intent of this test is to ensure the ADS-B system operates properly over the flight regime of the aircraft under test. Variations on climb and descent rates are acceptable as long as the intent of the test is met.

Table 6. Climb Speeds

Configuration	Part 23 Aircraft	Part 25 Aircraft	Part 27 Rotorcraft	Part 29 Rotorcraft
Take off	V_Y	V_{FE} - 10 kts	V_Y	V_Y
Cruise	V_H	V_{MO} - 10 kts	0.8 V_{NE} or 0.8 V_H	0.8 V_{NE} or 0.8 V_H

Table 7. Descent Speeds

Configuration	Part 23 Aircraft	Part 25 Aircraft	Part 27 Rotorcraft	Part 29 Rotorcraft
Cruise	V_{NE} - 10	V_{MO} - 10 kts	0.8 V_{NE} or 0.8 V_H	0.8 V_{NE} or 0.8 V_H
Approach	V_{FE} - 10	V_{FE} - 10 kts	V_Y + 10 kts	V_Y + 10 kts
Landing	V_{FE} - 10	V_{FE} - 10 kts	N/A	N/A

4.3.2.6 Position Accuracy.

Using a known waypoint, fly a north/south course that crosses the defined waypoint followed by an east/west course that crosses the same defined waypoint.

4.3.3 Post-Flight Data Analysis.

You must accomplish a post-flight data analysis to ensure the aircraft is transmitting accurate ADS-B information. Ensure all data associated with the track is consistent, such as position, 24-bit address, velocity, flight ID, barometric altitude, Mode 3/A code, emitter category, and geometric altitude. The post-flight data analysis should also reveal if there were any unexpected data dropouts that might be caused by intermittent wiring interfaces or interface incompatibility. The flight test does not require the use of a truth source to accomplish post-flight data analysis; however, the FAA will provide radar data when available to help analyze the flight track. At a minimum, analyze the following areas:

4.3.3.1 Rule Compliance.

Review the data from the FAA ground system for the flight to ensure the installed system meets its stated accuracy and integrity performance under flight conditions. We recommend that you accomplish a GNSS performance prediction for the applicable time of your test and ensure the ADS-B system meets the predicted performance. Due to the design of existing GNSS receivers and typical GPS constellation configurations, there will be time periods when unaugmented GNSS solutions drop below the NIC and NAC_P performance required by the rule. Such outages usually do not occur for more than 20 minutes, and many are of much shorter durations. If the integrity and accuracy of an existing GNSS installation does not meet the rule requirements during the test flight, the applicant should show that poor performance was caused by the constellation during the period of time that the flight occurred. If that cannot be established as the cause of the poor performance, there may be a problem with the position sensor installation that needs to be investigated and resolved. Resolution of this type of issue will probably require the involvement of the position source manufacturer. There may also be short periods where position messages transmit NIC = 0, velocity messages transmit $NAC_V = 0$, and status messages transmit $NAC_P = 0$, SIL = 0. These can be caused by antenna shadowing and switching effects, and do not indicate an installation problem if they are infrequent and of short duration. All such outages must be less than 5 seconds in duration to avoid operational impacts. This condition may not occur more often than once every 1000 position transmissions when averaging all outages over the flight duration. If this condition occurs more often during the flight test, the applicant must establish root cause and provide a solution before granting installation approval. Demonstrate that you meet all § 91.227(c)(1) accuracy and integrity requirements, listed in **Table 8**, during flight.

Table 8. Accuracy and Integrity Requirements During Flight

Ensure NIC ≥ 7 throughout the flight.	Rc <370.4 m (0.2 nm)
Ensure $NAC_P \geq 8$ throughout the flight.	EPU <92.6 m (0.05 nm)
Ensure $NAC_V \geq 1$ throughout the flight.	< 10 m/s
Ensure SIL = 3 throughout the flight	$\leq 1x10^{-7}$
Ensure SDA ≥ 2 throughout the flight	$\leq 1x10^{-5}$

4.3.3.2 Position Accuracy/Integrity.

Compare the track received by the FAA ground system with the actual flight track. There is no specific tolerance for this test; rather, the applicant must show there are no gross position errors, track offsets or discontinuities, or other obvious anomalies.

4.3.3.3 Velocity Accuracy.

Compare the velocity received by the FAA ADS-B ground system with the actual velocities flown. There is no specific tolerance for this test; rather, you must show that they compare reasonably, and that there are no gross velocity errors.

4.3.3.4 Geometric Altitude Accuracy.

Compare the geometric altitude received by the FAA ground system with the geometric altitude flown. There is no specific tolerance for this test;

rather, you must show that they compare reasonably, and that there are no gross geometric altitude errors.

4.3.3.5 Barometric Pressure Altitude Accuracy.

Compare the barometric pressure altitude received by the FAA ground system with the actual barometric pressure altitude flown. There is no specific tolerance for this test; rather, you must show that they compare reasonably, and that there are no gross barometric pressure altitude errors.

4.3.3.6 Validity Checks.

The FAA plans to use radar, multilateration, and UAT passive ranging as independent validity checks for ADS-B. The validity check will indicate "valid" when the independent check is able to validate the ADS-B position, "invalid" when it determines the ADS-B position is out of tolerance, and "unknown" if it is unable to accomplish the validity check. If a validity or enhanced validity status is provided in the flight test data, you must show that it never indicates "invalid".

Note: Validity checks are planned to ensure the ADS-B position is within 0.56 nm in terminal airspace and 1.9 nm in en-route airspace. Enhanced validity checks are planned to ensure the ADS-B position is within 0.2 nm within approximately 15 nm of terminal radars and close proximity to airports with Airport Surface Detection Equipment, Model X (ASDE-X) systems.

4.4 International Flight Test Options.

If the aircraft is being flight tested outside of the United States, it is acceptable to perform the flight test against another Air Navigation Service Provider's (ANSP) ground system. Other ANSP's ground systems must be fully operational and appropriately qualified to provide ATC separation services. Other ANSP ground systems must also be able to provide all parameters required by § 91.227. You will have to work with the foreign ANSP to retrieve the necessary data.

4.5 Subsequent Flight Test Data Reuse.

The flight test guidelines in section **4.3** of this AC apply to initial TC/STC applications. Flight test data from a similar installation, covered under a previous TC/STC, may be used instead of a new flight test if the following conditions can be confirmed through the documentation of the previous STC:

4.5.1 Position Source Equipment.

The position source must be identical to that of the other Amended Type Certificate (ATC), TC, or STC documentation. Equipment families that use the same baseline design may make a case for equivalence.

4.5.2 ADS-B Equipment.

The ADS-B equipment must be identical to that of the other ATC/TC/STC documentation. Equipment families that use the same baseline design may make a case for equivalence.

4.5.3 System Interface.

A direct interface must be used between the position source and the ADS-B equipment, and that interface must be identical to that of the previous ATC/TC/STC. Aircraft with data concentrators will have to re-accomplish the flight test, even if the equipment is identical.

4.5.4 Air-Data Interface.

The air-data interface to the ADS-B equipment must be identical to that of the previous ATC/TC/STC. The actual air-data source may be different equipment; only the interface to the ADS-B equipment needs to be identical. However, if the air-data source is different, more extensive ground testing should be accomplished, to include a dynamic test where the air-data source has simulated inputs from sea level to the maximum certified operating altitude of the aircraft. Care should be taken to ensure broadcast of simulated altitude information does not cause interference with ATC or ADS-B IN applications.

4.5.5 Heading Interface.

The heading interface to the ADS-B equipment (if applicable) must be identical to that of the previous ATC/TC/STC. The heading source may be different; only the interface to the ADS-B equipment needs to be identical. If the heading source is different, testing should be accomplished, to include positioning the aircraft at multiple headings on the surface to verify heading accuracy.

4.5.6 TCAS Interface.

The TCAS interface to the ADS-B equipment must be identical to that of the previous ATC/TC/STC. The TCAS equipment may be different; only the interface to the ADS-B equipment needs to be identical.

APPENDIX A. MESSAGE ELEMENT DESCRIPTIONS

A.1 Purpose.

This appendix provides a description of the message elements that may be contained in an ADS-B OUT message.

A.2 Message Elements.

A.2.1 ADS-B IN Capability.

Two messages indicate the ADS-B IN status of the aircraft. The 1090 ADS-B IN message indicates if the aircraft has the ability to receive 1090ES ADS-B messages installed. The UAT ADS-B IN message indicates if the aircraft has the ability to receive UAT ADS-B messages installed. An indication of ADS-B IN capability is important because TIS-B and ADS-R services are provided specific to an aircraft's position relative to other aircraft. The FAA may only provide complete TIS-B and ADS-R services to aircraft that indicate they are ADS-B IN capable. ADS-B IN capability is required to be transmitted by § 91.227.

A.2.2 Airspeed.

Optionally, true airspeed or indicated airspeed may be transmitted. The airspeed source should be approved to output airspeed data. An air data computer meeting the minimum performance requirements of TSO-C106 is one acceptable source. Do not interface an airspeed source to the ADS-B that has not been approved for cockpit display.

A.2.3 Barometric Pressure Altitude.

This parameter indicates the aircraft's barometric pressure altitude referenced to standard sea level pressure of 29.92 inches of mercury or 1013.2 hectopascals. The barometric pressure altitude is required to be transmitted by § 91.227.

A.2.4 Call Sign/Flight ID.

The term "aircraft call sign" is the radiotelephony call sign assigned to an aircraft for voice communications purposes. (This term is sometimes used interchangeably with "flight identification" or "flight ID"). For general aviation aircraft, the aircraft call sign is normally the national registration number; for airline and commuter aircraft, the call sign is usually comprised of the company identification and flight number (and therefore not linked to a particular airframe) and, for the military, it usually consists of numbers and code words with special significance for the operation conducted. The call sign or aircraft registration number is required to be transmitted by § 91.227 except when using the TSO-C154c anonymity feature.

A.2.5 Emergency Status.

This parameter alerts ATC that the aircraft is experiencing emergency conditions and indicates the type of emergency. Applicable emergency codes are found in ICAO

Annex 10 Volume 4, Surveillance Radar and Collision Avoidance Systems. This information alerts ATC to potential danger to the aircraft so it can take appropriate action. Emergency status is required to be transmitted by § 91.227.

A.2.6 Emitter Category.

The emitter category provides an indication of the aircraft's size and performance capabilities. Emitter categories are defined in TSO-C166b and TSO-C154c. Emitter category is designed primarily to provide information on the wake turbulence that an aircraft produces. Emitter category is required to be transmitted by § 91.227.

A.2.7 Geometric Altitude.

The geometric altitude is a measure of altitude provided by a satellite-based position service and is not affected by atmospheric pressure. Geometric altitude is only available with a GNSS position source. Geometric altitude for ADS-B purposes is the height above the World Geodetic System 1984 (WGS-84) ellipsoid (HAE). Geometric altitude is required to be transmitted by § 91.227.

A.2.8 Geometric Vertical Accuracy (GVA).

The GVA indicates the 95-percent accuracy of the reported vertical position (geometric altitude) within an associated allowance.

A.2.9 GNSS Antenna Offset and Position Offset Applied (POA).

A.2.9.1 The GNSS antenna offset indicates the longitudinal distance between the most forward part of the aircraft and the GNSS antenna, and the lateral distance between the longitudinal center line of the aircraft and the GNSS antenna. Also, refer to section **3.8.4.1 – 3.8.4.3** and **Figure 3** of this AC.

A.2.9.2 The POA setting of the GNSS antenna offset indicates that the broadcast position is referenced to the aircraft's ADS-B position reference point versus the GNSS antenna location. Also, refer to section 3.8.4.1 **- 3.8.4.3**and **Figure 3** of this AC. For further details about POA, refer to RTCA/DO-338, section 3.2.4.1.

A.2.10 Ground Speed.

This parameter is also derived from the position sensor and provides ATC with the aircraft's speed over the ground. This parameter is reported in the surface position message.

A.2.11 Ground Track Angle.

The ground track angle is the direction of the horizontal velocity vector over the ground. Ground track or heading is required to be transmitted while on the ground to transmit complete velocity information.

A.2.12 Heading.

Heading indicates the direction in which the nose of the aircraft is pointing. There is no heading accuracy metric. Heading or ground track is required to be transmitted while on the ground to transmit complete velocity information.

A.2.13 Horizontal Velocity.

The horizontal velocity provides the rate at which an aircraft changes its horizontal position with a clearly stated direction. Horizontal velocity is provided with the north/south velocity and the east/west velocity parameters while airborne. Horizontal velocity is provided by a combination of the ground speed and heading or ground track while on the surface. TSO-C166b and TSO-C154c require that the north/south velocity, east/west velocity, ground speed, and ground track come from the same source as the position. Heading information may come from a separate source. Horizontal velocity is required to be transmitted by § 91.227.

A.2.14 ICAO 24-bit Address.

The ICAO 24-bit address is a unique address assigned to an aircraft during the registration process. ICAO 24-bit addresses are defined blocks of addresses assigned for participating countries or states worldwide. In the United States, civil aircraft are assigned an address from an encoding scheme based on the aircraft registration number ("N" number). Additional information regarding the 24-bit address can be found in ICAO Annex 10, Part I, Volume III, appendix to Chapter 9, A World-Wide Scheme for the Allocation, Assignment and Application of Aircraft Addresses. The ICAO 24-bit address is required to be transmitted by § 91.227 except when using the TSO-C154c anonymity feature.

A.2.15 IFR Capability.

This parameter existed in TSO-C166a and TSO-C154b compliant equipment, but was removed from TSO-C166b and TSO-C154c equipment.

A.2.16 IDENT.

IDENT is a flag manually set by the pilot at the request of ATC in ATCRBS, Mode S, and ADS-B messages. The pilot manually enables the IDENT state, which highlights their aircraft on the controller's screen. IDENT is required to be transmitted by § 91.227.

A.2.17 Latitude and Longitude.

These parameters are derived from the position source and provide a geometric based position. Reference all geometric position elements broadcast from the ADS-B unit to the WGS-84 ellipsoid. Latitude and longitude are required to be transmitted by § 91.227.

A.2.18 Length and Width of Aircraft.

This parameter provides ATC and other aircraft with quick reference to the aircraft's dimensions while on the surface. Aircraft length and width is required to be transmitted by § 91.227.

A.2.19 Mode 3/A Code.

Currently ATC automation relies on the Mode 3/A code to identify aircraft under radar surveillance and correlate the target to a flight plan. The mode 3/A code is a four digit number ranging from 0000 to 7777. Secondary Surveillance Radars (SSR) and ADS-B will concurrently provide surveillance, so the Mode 3/A code is included in the ADS-B OUT message and is required to be transmitted by § 91.227.

Note: ADS-B systems will not transmit the Mode 3/A code if the Mode 3/A code is set to 1000.

A.2.20 Navigation Accuracy Category for Position (NAC_P).

The NAC_P specifies the accuracy of the aircraft's horizontal position information (latitude and longitude) transmitted from the aircraft's avionics. The ADS-B equipment derives a NAC_P value from the position source's accuracy output, such as the HFOM from the GNSS. The NAC_P specifies with 95 percent probability that the reported information is correct within an associated allowance. A minimum NAC_P value of "8" must be transmitted to operate in airspace defined in § 91.227. **Table A-1** provides the applicable NAC_P values.

Table A-1. NAC_P Values

NAC_P	Horizontal Accuracy Bound
0	EPU ≥ 18.52 km (10nm)
1	EPU < 18.52 km (10nm)
2	EPU < 7.408 km (4nm)
3	EPU < 3.704 km (2nm)
4	EPU < 1852 m (1nm)
5	EPU < 926 m (0.5nm)
6	EPU < 555.6 m (0.3nm)
7	EPU < 185.2 m (0.1nm)
8	EPU < 92.6 m (0.05nm)
9	EPU < 30 m
10	EPU < 10 m
11	EPU < 3 m

A.2.21 Navigation Accuracy Category for Velocity (NAC_V).

The NAC_V is an estimate of the accuracy of the horizontal geometric velocity output. The coding of "ZERO," indicating that the accuracy is unknown or either equal to or worse than 10 meters per second (m/s), is of little value to ADS-B applications. There is no vertical rate accuracy metric. A NAC_V of greater than or equal to "1" is required by § 91.227. **Table A-2** provides the applicable NIC values

Table A-2. NAC_V

Value	Velocity Accuracy Bound (Estimated Velocity Uncertainty)
0	≥ 10 m/s or unknown
1	< 10 m/s
2	< 3 m/s
3	< 1 m/s
4	< 0.3 m/s

A.2.22 Navigation Integrity Category (NIC).

The NIC parameter specifies a position integrity containment radius. NIC is reported so surveillance applications, such as ATC or other aircraft, may determine whether the reported geometric position has an acceptable level of integrity for the intended use. The NIC parameter is closely associated with the SIL. While NIC specifies the integrity containment radius, SIL specifies the probability of the actual position lying outside that containment radius without indication. ADS-B systems should derive the NIC from an approved position source's integrity output, such as the HPL from the GNSS. A minimum NIC value of "7" must be transmitted to operate in airspace defined in § 91.225. **Table A-3** provides the applicable NIC values.

Table A-3. NIC Values

NIC	Containment Radius
0	Unknown
1	RC < 37.04 km (20.0 nm)
2	RC < 14.816 km (8.0 nm)
3	RC < 7.408 km (4.0 nm)
4	RC < 3.704 km (2.0 nm)
5	RC < 1.852 km (1.0 nm)
6 Sup A=1 Sup B=1	RC < 1111.2 m (0.6 nm)
6 Sup A=0 Sup B=0	RC < 926 m (0.5 nm)
6 Sup A=0 Sup B=1	RC < 555.6 m (0.3 nm)
7	RC 370.4 m (0.2 nm)
8	RC < 185.2 m (0.1 nm)
9	RC < 75 m
10	RC < 25 m
11	RC < 7.5 m

A.2.23 NIC_{BARO}.

NIC_{BARO} indicates if pressure altitude is provided by a single Gillham encoder or another more robust altitude source. Because of the potential for an undetected error in a Gillham encoding, many Gillham installations are cross-checked against a second altitude source. NIC_{BARO} annotates the status of this cross-check.

A.2.24 Position.

These parameters are derived from the position source and provide a geometric based position. Reference all geometric position elements broadcast from the ADS-B unit to the WGS-84 ellipsoid. Latitude and longitude is required to be transmitted by § 91.227.

A.2.25 Receiving ATC Services.

This parameter is a bit set in the ADS-B system of an aircraft indicating that the Mode A code is not set to “1200”. This parameter existed in TSO-C166a and TSO-C154b compliant equipment, but was removed from TSO-C166b and TSO-C154c equipment.

A.2.26 Single Antenna Bit.

This parameter indicates if the ADS-B equipment is transmitting through a single antenna.

A.2.27 <u>Source Integrity Level (SIL).</u>

The SIL field defines the probability of the reported horizontal position exceeding the radius of containment defined by the NIC, without alerting, assuming no avionics faults. Although the SIL assumes there are no unannunciated faults in the avionics system, the SIL must consider the effects of a faulted Signal-In-Space (SIS), if a SIS is used by the position source. A SIL value of "3" must be transmitted to operate in airspace defined in § 91.225. **Table A-4** outlines the SIL values.

Note 1: The probability of an avionics fault causing the reported horizontal position to exceed the radius of containment defined by the NIC, without alerting, is covered by the SDA parameter.

Note 2: The SIL probability can be defined as either per sample or per-hour as defined in the SIL supplement (SIL_{SUPP}).

Table A-4. SIL Values, Probability of Exceeding the NIC Containment Radius

SIL Value	Probability of exceeding the NIC containment radius
0	> $1x10^{-3}$ Per-hour or Sample or Unknown
1	≤ $1x10^{-3}$ Per-hour or Sample
2	≤ $1x10^{-5}$ Per-hour or Sample
3	≤ $1x10^{-7}$ Per-hour or Sample

A.2.28 <u>Source Integrity Level Supplement (SIL_{SUPP}).</u>

The SIL_{SUPP} defines whether the reported SIL probability is based on a per-hour probability or a per-sample probability as defined in **Table A-5**.

Table A-5. Source Integrity Level Supplement

SIL Supplement	Basis for SIL Probability
0	Probability of exceeding NIC containment radius is based on per-hour.
1	Probability of exceeding NIC containment radius is based on per-sample.

A.2.29 <u>System Design Assurance (SDA).</u>

The SDA parameter defines the failure condition that the ADS-B system is designed to support as defined in **Table A-5**. The supported failure condition will indicate the probability of an ADS-B system malfunction causing false or misleading position information or position quality metrics to be transmitted. This should include the probability of exceeding the containment radius without annunciation. Because the installer of ADS-B OUT equipment does not know how the broadcast data will be used, the installer cannot complete a Functional Hazard Assessment (FHA) evaluating the use of the broadcast data. The SDA provides a surrogate for such a FHA by identifying the potential impact of an erroneous position report caused by an equipment malfunction. The definitions and probabilities associated with the supported failure effect are defined in AC 25.1309-1, AC 23.1309-1(),and AC 29-2 (Changes 1-3 incorporated). The SDA includes the position source, ADS-B equipment, and any intermediary devices that process the position data. § 91.227 requires an SDA of 2 or 3 as defined in **Table A-6**.

Table A-6. System Design Assurance

SDA Value	Supported Failure Condition Note 2	Probability of Failure Causing Transmission of False or Misleading Information Note 3,4	Software & Hardware Design Assurance Level Note 1,3
0	Unknown/ No safety effect	$> 1x10^{-3}$ Per-hour or Unknown	N/A
1	Minor	$\leq 1x10^{-3}$ Per-hour	D
2	Major	$\leq 1x10^{-5}$ Per-hour	C
3	Hazardous	$\leq 1x10^{-7}$ Per-hour	B

Note 1: Software design assurance pursuant to RTCA/DO-178C, *Software Considerations in Airborne Systems and Equipment Certification*, or equivalent. Airborne electronic hardware design assurance pursuant to RTCA/DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*, or equivalent.

Note 2: Supported failure classification defined in AC 25.1309-1(), AC 23.1309-1(), and AC 29-2().

Note 3: Because the broadcast position can be used by any ADS-B IN equipped aircraft or by ATC, the provisions in AC 23.1309-1() that allow reduction in failure probabilities and design assurance level for aircraft under 6,000 pounds do not apply for the ADS-B OUT system.

Note 4: Includes probability of transmitting false or misleading latitude, longitude, or associated position accuracy and integrity metrics.

A.2.30 TCAS Installed and Operational.

This parameter indicates whether the aircraft is fitted with a TCAS II and if the TCAS II is turned on and operating in a mode that can generate resolution advisory alerts. The TCAS installed and operational parameter is required to be transmitted by § 91.227.

A.2.31 TCAS Traffic Status.

This parameter indicates if a TCAS II equipped aircraft is currently generating a TCAS resolution advisory. The TCAS traffic status parameter is required to be transmitted by § 91.227 if the aircraft is TCAS II equipped.

A.2.32 Trajectory Change Report Capability.

This information is permanently set to "zero" in TSO-C166b or TSO-C154c equipment. No installation interface is required. Trajectory change reports are reserved for future use.

A.2.33 Vertical Rate.

The vertical rate is the barometric or geometric rate at which the aircraft is climbing or descending, measured in feet per minute. The vertical rate is typically generated by an air data computer or GNSS position source, or equipment that blends barometric vertical rate with inertial vertical rate and/or GNSS vertical rate.

A.2.34 Version Number.

The applicable TSO Minimum Operational Performance Standard (MOPS) level is communicated through the version number, which is fixed at the time the ADS-B equipment is manufactured. Version 2 applies to ADS-B equipment that meets MOPS documents RTCA/DO-260B with corrigendum 1 or RTCA/DO-282B with corrigendum 1. ADS-B equipment outputting version 2 or higher is required by § 91.227.

APPENDIX B. IDENTIFYING AND QUALIFYING ADS-B POSITION SOURCES

B.1 Purpose.

This appendix defines the minimum requirements for position sources interfaced to ADS-B systems. The appendix also defines appropriate position source qualification methods when the existing GNSS TSOs do not contain specific requirements or test procedures. The position source manufacturer should provide design data where appropriate, preferably in the GNSS equipment installation manual, so the installer can properly interface the position source to the ADS-B system. Position source suppliers must ensure any supplied data is incorporated into the article design, and changes to any documented characteristics result in a change to the part number.

B.2 Organization.

This appendix includes general guidance that applies to all position sources, as well as GNSS-specific guidance. The appendix also provides high-level requirements for tightly-coupled GNSS/IRU position sources and non-GNSS position sources. Unless otherwise specified, all references in this AC to TSO-C129, TSO-C145, TSO-C146, and TSO-C196 refer to any revision of the TSO.

B.3 General Guidance for All Position Sources.

B.3.1 Position.

The position source must provide a latitude and longitude output. Requirements and test procedures in TSO-C129/145/146/196 are sufficient and GNSS equipment with Technical Standard Order Authorization (TSOA) for the aforementioned TSOs require no additional qualification for the position output.

B.3.2 Horizontal Velocity.

The position source must output north/south and east/west velocities. We recommend the position source also output the velocity in a ground speed and track angle format.

B.3.3 Position Accuracy (Vertical).

The position source should output a vertical position accuracy metric. The vertical position accuracy metric must have been qualified during the system's TSOA or design approval. This output must describe the vertical position accuracy with 95 percent probability under fault-free conditions.

B.3.4 Position Accuracy (Horizontal).

The position source must have a horizontal position accuracy output, and the output must have been qualified during the system's TSOA or design approval. This output must describe the radius of a circle in the horizontal plane, with its center being at the true position that describes the region assured to contain the indicated horizontal position with at least 95 percent probability under fault-free conditions.

B.3.5 Position Integrity (Horizontal).

The position source must have a horizontal position integrity output qualified during the system's TSOA or design approval. This integrity output should describe the radius of a circle in the horizontal plane, with its center being at the true position that describes the region assured to contain the indicated horizontal position with at least 99.99999 percent probability under fault-free avionics conditions. Position sources that degrade from a 99.99999 percent probability to a 99.999 percent probability (such as a tightly-coupled inertial/GNSS system after the loss of GNSS) can still be installed; however, they will not meet § 91.227 following the degradation. In this case, the position source must have a way of indicating the change to the ADS-B equipment. Additionally, if the change of probability is due to a change in position source, the new position source must meet all of the requirements in this appendix.

B.3.5.1 Mode.

If interpretation of the integrity output of the position source can change due to a change in the position source mode, the position source must have a way of communicating that change of mode to the ADS-B equipment. Additionally, the position source manufacturer should provide a description of the modes and a description of how the position source outputs the mode indication.

B.3.5.2 Validity Limit.

If the integrity value of the output cannot be trusted beyond a certain limit, indicate this limitation in the design documentation.

B.3.5.3 Integrity Fault.

The position source must be able to identify, and output, an indication of an integrity fault. This indication should occur within 8 seconds of output of an erroneous position. The position source manufacturer must provide information on how this integrity fault is output.

B.3.6 Position Integrity (Probability).

The position source manufacturer must provide information describing the basis for the probability of exceeding the horizontal integrity containment radius. This basis must indicate the probability of exceeding the integrity containment radius as well as the sampling duration (per-hour or per-sample).

B.3.7 SIS Error Detection.

The position source should provide a means to detect a SIS error when the system uses a SIS. The probability of missed detection for a faulty SIS should be less than $1x10^{-3}$. GNSS equipment provides the appropriate SIS error detection.

B.3.8 Velocity Accuracy.

The position source should have a velocity accuracy output that was qualified in conjunction with the system's TSOA or design approval. Instead of a dynamic output, the position source manufacturer may demonstrate a worst case velocity accuracy that can be assumed based on testing. A test for GNSS position sources is contained in the latest revision of AC 20-138, appendix 4. The position source manufacturer may propose a test method for non-GNSS sources or an alternate test for GNSS sources during the TSOA or design approval.

B.3.9 Design Assurance.

The position source must support a major or greater failure effect. This includes software compliant with RTCA/DO-178C, Level C, and airborne electronic hardware (AEH) compliant with RTCA/DO-254, Level C. For airborne electronic hardware determined to be simple, RTCA/DO-254, section 1.6 applies. Because the broadcast position can be used by any ADS-B IN equipped aircraft or by ATC, the provisions in AC 23.1309-1() that allow reduction in failure probabilities and design assurance level for aircraft under 6,000 pounds do not apply for the ADS-B OUT system. The overall probability of a position source malfunction causing a position to be output that exceeds the output integrity radius must be less than $1x10^{-5}$ per-hour.

B.3.10 Geometric Altitude.

The position source must have a geometric altitude output. The geometric altitude must be referenced to the WGS-84 ellipsoid.

B.3.11 Update Rate.

The position source must output a new position at least once per second. Faster position update rates reduce latency of the transmitted position and are encouraged.

B.3.12 Position Source Latency.

The position source manufacturer must provide position source latency information. Specifically, the manufacturer must provide the amount of position source total latency and uncompensated latency. Because the latency requirements are based on the entire ADS-B OUT system, and not just the position source, the following position source latency targets are only guidelines. Position source uncompensated latency should be less than 200 ms, compensated latency should be less than 500 ms, and total latency should be less than 700 ms.

Note 1: System latency requirements are described in section **3.1.3** and **Appendix C** of this AC.

Note 2: This section addresses position latency only.

B.3.13 Position, Velocity, and Accuracy Time of Applicability.

For each position output by the source, a velocity, horizontal position accuracy metric, and horizontal velocity accuracy metric must also be output. All measurements and metrics must have the same time of applicability. A horizontal position integrity metric must also be output, but its time of applicability may lag the position. Refer to TSO-C145, TSO-C146, or TSO-C196 for additional information on the integrity time to alert.

B.3.14 Time Mark.

Position sources should output a time mark identifying the Coordinated Universal Time (UTC) time of applicability of the position. The time mark can be used by the ADS-B equipment to reduce uncompensated latency.

B.3.15 Availability.

§ 91.225 and § 91.227 do not define an availability requirement; however, it is a significant operational factor when selecting the position source (refer to **Table B-2**, Estimated GNSS Availabilities (Minimum Threshold Constellation), below).

B.4 GNSS Position Sources.

Compliance to the applicable TSOs for GNSS position sources does not guarantee that the unit is suitable as an ADS-B position source. The information in this section describes an acceptable means to demonstrate compliance with ADS-B requirements not addressed by GNSS TSOs when using GNSS position sources for ADS-B.

B.4.1 Position.

GNSS position sources must provide a latitude and longitude output. Requirements and test procedures in TSO-C129/145/146/196 are sufficient and GNSS equipment with TSOA for the aforementioned TSOs require no additional qualification for the position output. Some GNSS position outputs are referenced to the center of navigation of the aircraft. Manufacturers should document under what conditions the position is output in this manner. Installers must configure the ADS-B installation to account for any position offset from the surveillance reference point or GNSS antenna position as applicable.

Note: The intent is to output position, velocity, and HFOM in a consistent manner for time of applicability (refer to RTCA/DO-229D, *Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment*, sections 2.1.2.6 and 2.1.2.6.2).

B.4.1.1 TSO-C129.

The requirements outlined for 2D accuracy in section (a)(3)(xvi) of TSO-C129 do not ensure full compliance for the GNSS unit. Additional means of compliance for this TSO require GNSS manufacturers to substantiate that the latitude/longitude is output and referenced to WGS-84 coordinate system.

B.4.1.2 TSO-C129a.

The requirements outlined for 2D accuracy in section (a)(3)(xvi) of TSO-C129a do not ensure full compliance for the GNSS unit. Additional means of compliance for this TSO require GNSS manufacturers to substantiate that the latitude/longitude is output and referenced to WGS-84 coordinate system.

B.4.1.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229C, section 2.1.2.6.

B.4.1.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229C, sections 2.1.4.8 and 2.1.5.8.

B.4.1.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, section 2.1.2.6.

B.4.1.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.4.8 and 2.1.5.8.

B.4.1.7 TSO-C196/196a.

Means of compliance for this TSO are defined in RTCA/DO-316, *Minimum Operational Performance Standards for Global Positioning System/Aircraft Based Augmentation System*, section 2.1.2.6.

B.4.2 Position Source Latency.

GNSS position source manufacturers must provide position source latency information.

B.4.2.1 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to document the position source latency from time of measurement (TOM) to time of position output. If this latency exceeds 0.9 seconds, it may not support the 2-second ADS-B transmission latency at the aircraft level.

B.4.2.2 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to document the position source latency from TOM to time of position output. If this latency exceeds 0.9 seconds, it may not support the 2-second ADS-B transmission latency at the aircraft level.

B.4.2.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229C, section 2.1.2.6.2.

B.4.2.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229C, sections 2.1.2.6.2 and 2.1.5.8.2.

B.4.2.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, section 2.1.2.6.2.

B.4.2.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.2.6.2 and 2.1.5.8.2.

B.4.2.7 TSO-C196/196a.

Means of compliance for this TSO are defined in RTCA/DO-316, section 2.1.2.6.2.

B.4.3 Availability.

B.4.3.1 Analysis has shown the following estimated availability for TSO GPS receivers using a 2-degree antenna mask angle (refer to **Table B-2**), assuming the minimum threshold GPS satellite constellation. The Minimum Threshold Constellation is the probability of slots filled with healthy satellites. For **Table B-1**, the FAA uses the modified interagency forum on operational requirements (IFOR) constellation probabilities that provides a conservative estimate of predicted GNSS availability. The modified IFOR probabilities are not guaranteed by the U.S. Air Force, but are intended to be consistent with the Global Positioning System Standard Positioning Service Performance Standard, revision 4, dated September 2008. Modified IFOR threshold constellation state probabilities based on this performance standard (a 0.99999-percent probability of 20 healthy satellites or satellite pairs in expanded slot configuration) are shown in **Table B-1**.

Table B-1. Modified IFOR Threshold Constellation State Probabilities

Number of Healthy Satellites	Probability That Exactly a Given Number of Satellites Are Healthy	Probability That at Least a Given Number of Satellites Are Healthy
24	0.72%	0.72%
23	0.17%	0.89%
22	0.064%	0.954%
21	0.026%	0.98%
20	0.01999%	0.99999%
19	0.000005%	0.999995%
18	0.000005%	1.0000%

B.4.3.2 The FAA plans to integrate the availability of backup surveillance systems with ADS-B, including SSR and Wide Area Multilateration, to mitigate the impact of loss of GNSS performance due to current limitations of operator GNSS receivers and the health of the constellation. Backup surveillance will not be available in all airspace, and operators should select an ADS-B positioning source that provides the necessary availability for their route of flight. The FAA plans to implement a preflight GPS service availability determination system to assist operators in determining surveillance availability for ADS-B before flight. This tool will consider the operator's GNSS equipage and the GPS constellation that is predicted to be available at the planned flight time. The tool will also consider the status of existing backup surveillance capability along with the required positioning performance for the separation standard ATC is authorized to apply along the operator's defined route of flight.

Table B-2. Estimated GNSS Availabilities (Minimum Threshold Constellation)

Positioning Service (Receiver Standard)	Predicted Availability (ADS-B Compliance)
GPS (TSO-C129) (SA On)	≥ 89.0%
GPS (TSO-C196) (SA Off)	≥ 99.0%
GPS/SBAS (TSO-C145/TSO-C146)	≥ 99.9%

B.4.4 <u>Horizontal Position Integrity.</u>

GNSS position sources must have a horizontal position integrity (such as HIL or HPL) output qualified during the system's TSOA or design approval to determine NIC.

B.4.4.1 TSO-C129.

The requirements outlined for Class A, B, and C equipment provide horizontal integrity through RAIM algorithms under RTCA/DO-208 change 1, *Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)*, section 2.2.1.13. However, there is no requirement to compute or output HPL. To properly comply with the ADS-B requirements, additional means of compliance for this TSO require GNSS manufacturers to provide substantiation data showing that the equipment outputs a $1x10^{-7}$/hr HPL based on the RAIM algorithm at least once per second that meets a 10-second time to alert. This AC recommends an 8-second time to alert. The protection level value is acceptable as an HPL if the equipment performs the test in RTCA/DO-208 change 1, section 2.5.2.5 using this protection level value for comparison against the alarm limit. Equipment using the least-squares residual RAIM method recommended in RTCA/DO-208 change 1, appendix F provides an acceptable HPL.

B.4.4.2 TSO-C129a.

The requirements outlined for Class A, B, and C equipment provide horizontal integrity through RAIM algorithms under RTCA/DO-208 change 1, section 2.2.1.13. However, there is no requirement to compute or output HPL. To properly comply with the ADS-B requirements, additional means of compliance for this TSO require GNSS manufacturers to provide substantiation data showing that the equipment outputs a $1x10^{-7}$/hr HPL based on the RAIM algorithm at least once per second that meets a 10-second time to alert. This AC recommends an 8-second time to alert. The protection level value is acceptable as an HPL if the equipment performs the test in RTCA/DO-208 change 1, section 2.5.2.5 using this protection level value for comparison against the alarm limit. Equipment using the least-squares residual RAIM method recommended in RTCA/DO-208 change 1, appendix F provides an acceptable HPL.

B.4.4.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229C, sections 2.1.2.6, 2.1.2.2.2, and 2.1.3.2.2. A summary of the latter requirements can be found in RTCA/DO-229C, section 2.1.1.13.1.

B.4.4.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229C sections 2.1.2.6, 2.1.2.2.2, 2.1.3.2.2, 2.1.4.2.2, and 2.1.5.2.2. A summary of the latter requirements can be found in RTCA/DO-229C, section 2.1.1.13.1.

B.4.4.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.2.6, 2.1.2.2.2, and 2.1.3.2.2. Related requirements can be found in RTCA/DO-229D, sections 2.1.1.4 and 2.1.4.9.

B.4.4.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.2.6, 2.1.2.2.2, 2.1.3.2.2, 2.1.4.2.2, and 2.1.5.2.2. Related requirements can be found in RTCA/DO-229D, sections 2.1.1.4 and 2.1.4.9.

B.4.4.7 TSO-C196/196a.

Means of compliance for this TSO are defined in RTCA/DO-316, sections 2.1.2.6, 2.1.2.2.2, and 2.1.3.2.

B.4.5 Position Integrity (Probability).

GNSS position source manufacturers must provide information describing the basis for the probability of exceeding the horizontal integrity containment radius.

B.4.5.1 TSO-C129.

Means of compliance for TSO-C129 are defined in RTCA/DO-208 change 1, section 2.2.1.13.1, referring to table 2-1.

B.4.5.2 TSO-C129a.

Means of compliance for TSO-C129a are defined in RTCA/DO-208 change 1, section 2.2.1.13.1, referring to table 2-1.

B.4.5.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229C, section 2.1.2.2.2.1 for Satellite-Based Augmentation System (SBAS) based integrity. This requirement references appendix J, section J.2.1, defining position integrity. (Integrity probability is for HPL_{SBAS} only). For additional guidance on an acceptable scaling method, GNSS manufacturers can refer to RTCA/DO-229C, appendix U, section 4. FDE requirements can be found in section 2.1.2.2.2.2.2.

B.4.5.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229C, section 2.1.2.2.2.1 for SBAS-based integrity. This requirement references appendix J, section J.2.1, defining position integrity. (Integrity probability is for HPL_{SBAS} only). For additional guidance on an acceptable scaling method, GNSS manufacturers can refer to RTCA/DO-229C, appendix U, section 4. FDE requirements can be found in section 2.1.2.2.2.2.2.

B.4.5.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, section 2.1.2.2.2.1 for SBAS-based integrity. This requirement references to appendix J, section J.3.1, defining position integrity. (Integrity probability is for HPL_{SBAS} only). For additional guidance on an acceptable scaling method, GNSS manufacturers can refer to RTCA/DO-229D appendix U, section 4. FDE requirements can be found in section 2.1.2.2.2.2.2.

B.4.5.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, section 2.1.2.2.2.1 for SBAS-based integrity. Appendix J, section J.3.1 provides a background definition for position integrity. (Integrity probability is for HPL_{SBAS} only). For additional guidance on an acceptable scaling method, GNSS manufacturers can refer to RTCA/DO-229D, appendix U, section 4. FDE requirements can be found in section 2.1.2.2.2.2.2.

B.4.5.7 TSO-C196/196a.

Means of compliance for this TSO are defined in RTCA/DO-316, section 2.1.2.2.2.2. For additional guidance on an acceptable scaling method, GNSS manufacturers can refer to RTCA/DO-316, appendix U, section 4.

B.4.6 Integrity Fault Alerts.

GNSS position source manufacturers must provide design data on the maximum time the position source can take to indicate an integrity fault. If the fault indication is mode specific, data on all modes must be included. It is recommended that the indication of an integrity fault be provided within 8 seconds across all modes. All revisions of TSO-C145, TSO-C146, and TSO-C196 GNSS equipment meet this requirement. No revisions of TSO-C129 GNSS equipment meet this requirement without meeting further qualifications outlined below. Receivers compliant with ARINC Characteristic 743A-5, *GNSS Sensor*, dated May 2009, represent the condition where a satellite fault has been detected but the receiver was unable to exclude the faulted satellite by setting bit 11 of label 130. This bit must be interpreted to set the position invalid regardless of the indicated HIL or HPL.

B.4.6.1 TSO-C129.

The requirements in RTCA/DO-208 change 1, section 2.2.1.13.1 cover the time to alarm for different phases of flight. To properly comply with the overall 12-second integrity fault output for ADS-B, additional means of compliance for TSO-C129 require GNSS manufacturers to provide information in the installation instructions describing the equipment integrity fault latency output with interface instructions and/or limitations for meeting the 12-second allocation set by § 91.227.

B.4.6.2 TSO-C129a.

The requirements in RTCA/DO-208 change 1, section 2.2.1.13.1 cover the time to alarm for different phases of flight. To properly comply with the overall 12-second integrity fault output for ADS-B, additional means of compliance for TSO-C129a require GNSS manufacturers to provide information in the installation instructions describing the equipment integrity fault latency output with interface instructions and/or limitations for meeting the 12-second allocation set by this AC.

B.4.6.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229C, sections 2.1.1.13 and 2.1.2.2.2.2.1 through 2.1.2.2.2.2.4.

B.4.6.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229C, sections 2.1.1.13, 2.1.2.2.2.2.1 through 2.1.2.2.2.2.4, and 2.1.4.2.2.2.1 through 2.1.4.2.2.2.3.

B.4.6.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.1.13 and 2.1.2.2.2.2.1 through 2.1.2.2.2.2.4.

B.4.6.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.1.13, 2.1.2.2.2.2.1 through 2.1.2.2.2.2.4, and 2.1.4.2.2.2.1 through 2.1.4.2.2.2.3.

B.4.6.7 TSO-C196/196a.

Means of compliance for this TSO are defined in RTCA/DO-316, sections 2.1.1.11 and 2.1.2.2.2.1 through 2.1.2.2.2.4.

B.4.7 Position Integrity Limits.

This requirement was previously called Integrity Validity Limit. Single-frequency RAIM-based HPL computations have been designed to support navigation applications and provide an appropriate error bound down to approximately 0.1 nm. Although HPL values significantly smaller than 0.1 nm can be output from single-frequency GNSS sources, if the HPL value was computed using RAIM, it may not actually achieve the reported level of protection as there are error contributions that are no longer negligible and should be taken into consideration. Such error sources specifically include correlation of ionospheric errors across satellites, tropospheric delay compensation errors, multipath, and receiver noise errors. This issue is not unique to unaugmented GPS position sources, as all revisions of TSO-C145 and TSO-C146 GNSS position sources also calculate integrity based on RAIM when Satellite-Based Augmentation System (SBAS) integrity is not used. Even when using SBAS augmentation, the integrity calculation is not required to account for these error sources except when in LNAV/VNAV or LPV/LP approach modes. ADS-B capable position sources must provide design information to the installer that identifies the following:

B.4.7.1 Whether a TSO-C129 or TSO-C196 position source limits the HPL output to greater than 75 meters. If the position source does not limit its HPL output, the position source manufacturer should provide guidance to the ADS-B system installer to ensure the ADS-B equipment limits the NIC to ≤ 8. Although single-frequency RAIM-based HPL values are only accurate down to approximately 0.1 nm, for ADS-B purposes, the position source only need limit the HPL to greater than 75 meters, because an HPL greater than 75 meters ensures the ADS-B equipment will only set a NIC of ≤ 8.

B.4.7.1.1 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration.

B.4.7.1.2 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration.

B.4.7.1.3 TSO-C196/196a.

Means of compliance for this TSO require GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration.

B.4.7.2 Whether a TSO-C145 or TSO-C146 position source limits the HPL in non-SBAS augmented modes to greater than 75 meters. If the position source does not limit the HPL output in non-augmented modes, the position source manufacturer should provide guidance to the ADS-B system installer to ensure the ADS-B equipment limits the NIC to ≤ 8 in non-augmented modes. The position source manufacturer should also provide instructions on how to determine the position source mode if appropriate.

B.4.7.2.1 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO require GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration.

B.4.7.2.2 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration. Installations intending to support NIC ≥ 9 must use LNAV/VNAV or LPV/LP approach requirements (RTCA/DO-229C, section 2.1) at the time of HPL output, in accordance with TSO-C145/C146 Rev a, but the enroute through LNAV K-Factor (6.18 vs. 6) must be applied (refer to RTCA/DO-229C, appendix J, section 2.1 and appendix U, section 4). Either the GNSS source equipment sets the K-Factor for HPL, or the ADS-B equipment applies proper scaling. The GNSS manufacturer must present substantiation data on which K-Factor is used and provide proper installation instructions for the ADS-B integration.

B.4.7.2.3 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO require GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration.

B.4.7.2.4 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration. Installations intending to support NIC ≥ 9 must use LNAV/VNAV or LPV/LP approach requirements (RTCA/DO-229D, section 2.1) at the time of HPL output, in accordance with TSO-C145/C146 Rev b/c, but the enroute through LNAV K-Factor (6.18 vs. 6) must be applied (refer to RTCA/DO-229D appendix J, section 3.1 and appendix U, section 4).

Either the GNSS source equipment sets the K-Factor for HPL, or the ADS-B equipment applies proper scaling. The GNSS manufacturer must present substantiation data on which K-Factor is used and provide proper installation instructions for the ADS-B integration.

B.4.8 Horizontal Position Accuracy.

GNSS position sources should provide an HFOM output that was demonstrated during the position source's design approval or during an installation approval. GNSS certified under TSO-C145b/c, TSO-C146b/c/d, or all revisions of TSO-C196 are required to provide the HFOM output. TSO-C129, TSO-C145a, and TSO-C146a do not contain a horizontal position accuracy output requirement; however, all equipment must provide a HFOM output to be considered an ADS-B compliant position source.

Note: The intent is to output position, velocity, and HFOM in a consistent manner for time of applicability (refer to RTCA/DO-229D, sections 2.1.2.6 and 2.1.2.6.2).

B.4.8.1 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data showing the equipment computes and outputs HFOM. Refer to the test described in AC 20-138(), appendix 4, section A4-11 for an acceptable HFOM test.

B.4.8.2 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data showing the equipment computes and outputs HFOM. Refer to the test described in AC 20-138(), appendix 4, section A4-11 for an acceptable HFOM test.

B.4.8.3 TSO-C145/146 Rev a Class 1. Means of compliance for this TSO require GNSS manufacturers to provide substantiation data based on the test described in AC 20-138(), appendix 4, section A4-11 for an acceptable HFOM test.

B.4.8.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data based on the test described in AC 20-138(), appendix 4, section A4-11 for an acceptable HFOM test.

B.4.8.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, section 2.1.2.6 (also refer to section 1.7.1 and appendix H of RTCA/DO-229D).

B.4.8.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, section 2.1.2.6 (also refer to section 1.7.1 and appendix H of RTCA/DO-229D).

B.4.8.7 TSO-C196/196a.

Means of compliance for this TSO are defined in RTCA/DO-316, section 2.1.2.6 (also refer to section 1.7.1 and appendix H of RTCA/DO-316).

B.4.9 Geometric Altitude.

All GNSS position sources must output a geometric altitude. Geometric altitude for ADS-B purposes is the height above the WGS-84 ellipsoid (that is, it is not MSL). We recommend that the GNSS position source output geometric altitude as Height-Above-Ellipsoid (HAE). Some GNSS position sources provide Height-Above-Geoid (HAG) instead of HAE. The position source manufacturer must provide data on whether the position source outputs HAE or HAG.

B.4.9.1 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to provide data to substantiate the output of HAE. The data produced to substantiate vertical position accuracy pursuant to the test described in AC 20-138(), appendix 4, section A4-10 is sufficient. For GPS equipment that outputs other altitude measures, the installation instructions must specify a deterministic method to perform conversion to HAE.

B.4.9.2 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to provide data to substantiate the output of HAE. The data produced to substantiate vertical position accuracy pursuant to the test described in AC 20-138(), appendix 4, section A4-10 is sufficient. For GPS equipment that outputs other altitude measures, the installation instructions must specify a deterministic method to perform conversion to HAE.

B.4.9.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data showing the equipment outputs HAE. The data produced to substantiate vertical position accuracy pursuant to the test described in AC 20-138(), appendix 4, section A4-10 is sufficient.

B.4.9.4 TSO-C145/146 Rev a Class 2/3.

For Class 2 equipment, the means of compliance for this TSO require GNSS manufacturers to provide substantiation data showing the equipment outputs HAE. The data produced to substantiate vertical position accuracy pursuant to the test described in AC 20-138(), appendix 4, section A4-10 is sufficient. Class 3 equipment complies with the ADS-B geometric altitude requirement pursuant to RTCA/DO-229C, section 2.1.5.8.

B.4.9.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data showing the equipment outputs HAE. The data produced to substantiate vertical position accuracy pursuant to the test described in AC 20-138(), appendix 4, section A4-10 is sufficient.

B.4.9.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data showing the equipment outputs HAE. The data produced to substantiate vertical position accuracy pursuant to the test described in AC 20-138(), appendix 4, section A4-10 is sufficient.

B.4.9.7 TSO-C196/196a.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data showing the equipment outputs HAE. The data produced to substantiate vertical position accuracy pursuant to the test described in AC 20-138(), appendix 4, section A4-10 is sufficient.

B.4.10 Update Rate.

The position source must output a new position at a minimum of once per second. Faster position update rates reduce latency of the transmitted position and are encouraged.

B.4.10.1 TSO-C129.

Means of compliance for TSO-C129 are described in RTCA/DO-208 change 1, section 2.1.11 for displays. This requirement is modified by TSO-C129 section (a)(3)(vi) for navigation data used for display in Class A equipment. Class B and Class C equipment are modified by sections (a)(4)(v) and section (a)(5)(v) respectively.

B.4.10.2 TSO-C129a.

Means of compliance for TSO-C129a are described in RTCA/DO-208 change 1, section 2.1.11 for displays. This requirement is modified by TSO-C129a, section (a)(3)(vi) for navigation data used for display in Class A equipment. Class B and Class C equipment are modified by sections (a)(4)(v) and (a)(5)(v) respectively.

B.4.10.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229C, section 2.1.2.6.1.

B.4.10.4 TSO-C145/146 Rev a Class 2.

Means of compliance for this TSO are defined in RTCA/DO-229C, sections 2.1.2.6.1 and 2.1.5.8.1.

B.4.10.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, section 2.1.2.6.1.

B.4.10.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.2.6.1 and 2.1.5.8.1.

B.4.10.7 TSO-C196/196a.

Means of compliance for this TSO are defined in RTCA/DO-316, section 2.1.2.6.1

B.4.11 Horizontal Velocity.

The position source must output north/south and east/west velocities. It is recommended the position source also output the velocity in a ground speed and track angle format.

Note: The intent is to output position, velocity, and quality metrics in a consistent manner for time of applicability (refer to RTCA/DO-229D, sections 2.1.2.6 and 2.1.2.6.2).

B.4.11.1 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to perform the velocity test in AC 20-138(), appendix 4 and provide information substantiating the data is output.

B.4.11.2 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to perform the velocity test in AC 20-138(), appendix 4 and provide information substantiating the data is output.

B.4.11.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229C, section 2.1.2.6 along with the test defined in AC 20-138(), appendix 4.

B.4.11.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229C, section 2.1.2.6 along with the test defined in AC 20-138(), appendix 4.

B.4.11.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, section 2.1.2.6. The TSO requirement is only to output velocity, but there is no accuracy requirement. Satisfying this ADS-B requirement means the GNSS manufacturer must also comply with the horizontal velocity accuracy requirements and tests described in AC 20-138(), appendix 4.

B.4.11.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, section 2.1.2.6. The TSO requirement is only to output velocity, but there is no accuracy requirement. Satisfying this ADS-B requirement means the GNSS manufacturer must also comply with the horizontal velocity accuracy requirements and tests described in AC 20-138(), appendix 4.

B.4.11.7 TSO-C196/196a.

Means of compliance for this TSO are defined in RTCA/DO-316, section 2.1.2.6. The TSO requirement is only to output velocity, but there is no accuracy requirement. Satisfying this ADS-B requirement means the GNSS manufacturer must also comply with the horizontal velocity accuracy requirements and tests described in AC 20-138(), appendix 4.

Note: The velocity test found in AC 20-138() is also defined in section 2.3.6.4 of RTCA/DO-316.

B.4.12 Ground Speed.

It is recommended that the position source output ground speed. GNSS manufacturers choosing to output ground speed may show compliance as described below for the appropriate TSO.

B.4.12.1 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (that is, in a ground speed format versus north/east velocity format) and the protocols used.

B.4.12.2 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (that is, in a ground speed format versus north/east velocity format) and the protocols used.

B.4.12.3 TSO-C145/146 Rev a Class 1.

The Gamma equipment requirements outlined in RTCA/DO-229C, section 2.2.1.4.10 for the display resolution of ground speed are insufficient to show ADS-B compliance. A recommendation for GNSS manufacturers on label 103 and label 112 can be found in RTCA/DO-229D, appendix H. Additional means of compliance for TSO-C145/146 Rev a Class 1 require GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (that is, in a ground speed format versus north/east velocity format) and the protocols used.

B.4.12.4 TSO-C145/146 Rev a Class 2/3.

The Gamma equipment requirements outlined in RTCA/DO-229C, section 2.2.1.4.10 for the display resolution of ground speed are insufficient to show ADS-B compliance. A recommendation for GNSS manufacturers on label 103 and label 112 can be found in RTCA/DO-229D, appendix H. Additional means of compliance for TSO-C145/146 Rev a Class 2/3 require GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (that is, in a ground speed format versus north/east velocity format) and the protocols used.

B.4.12.5 TSO-C145/146 Rev b/c/d Class 1.

Gamma-1 equipment requirements outlined in RTCA/DO-229D, section 2.2.1.4.10 for the display resolution of ground speed are insufficient to show ADS-B compliance. A recommendation for GNSS manufacturers on label 103 and label 112 can be found in RTCA/DO-229D, appendix H. Additional means of compliance for TSO-C145/146 Rev b/c/d Class 1 require GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (that is, in a ground speed format versus north/east velocity format) and the protocols used.

B.4.12.6 TSO-C145/146 Rev b/c/d Class 2/3.

Gamma-2 and Gamma-3 equipment requirements outlined in RTCA/DO-229D, section 2.2.1.4.10 for the display resolution of ground speed are insufficient to show ADS-B compliance. A recommendation for GNSS manufacturers on label 103 and label 112 can be found in RTCA/DO-229D, appendix H. Additional means of compliance for TSO-C145/146 Rev b/c/d Class 2/3 require GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (that is, in a ground speed format versus north/east velocity format) and the protocols used.

B.4.12.7 TSO-C196/196a.

Means of compliance for this TSO require GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (that is, in a ground speed format versus north/east velocity format) and the protocols used. A recommendation for GNSS manufacturers on label 103 and label 112 can be found in RTCA/DO-316, appendix H.

B.4.13 <u>Time of Applicability.</u>

The GNSS equipment must output a time of applicability.

Note: The intent is to output position, velocity, and HFOM with a consistent time of applicability (refer to RTCA/DO-229D, sections 2.1.2.6 and 2.1.2.6.2).

B.4.13.1 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to use a manufacturer-defined test and/or analysis to determine the latency between the time satellite measurements are collated for processing and the time the equipment calculates a filtered (impulse response) position solution. For example; the receiver does not make observations at a single moment in time but instead staggers them, perhaps to reduce throughput. In that case, the observations would need to be extrapolated to a common moment. There are many extrapolation methods but some use filtering that may induce latency. This would need to be addressed in the latency analysis. Since there are filters involved, measuring the impulse response may be one way of observing this delay. Furthermore, as another example; a receiver uses a Costas filter that has a specific bandwidth as part of the tracking loop. That bandwidth constrains the speed at which a dynamic maneuver will propagate through the tracking loop and thus to the resulting position. Again, measuring the impulse response of the Costas loop would provide insight into delay that would be observed when installed. Bearing this in mind, the equipment must meet a 500-millisecond TOM-to-time-of-applicability requirement and account for the impulse response of the position solution.

B.4.13.2 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to use a manufacturer-defined test and/or analysis to determine the latency between the time satellite measurements are collated for processing and the time the equipment calculates a filtered (impulse response) position solution. The equipment must meet a 500-millisecond TOM-to-time-of-applicability requirement and account for the impulse response of the position solution.

B.4.13.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229C sections 2.1.2.6 and 2.1.2.6.2.

B.4.13.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229C, sections 2.1.2.6, 2.1.2.6.2, and 2.1.5.8.2.

B.4.13.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.2.6 and 2.1.2.6.2.

B.4.13.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.2.6, 2.1.2.6.2, and 2.1.5.8.2.

B.4.13.7 TSO-C196/196a.

Means of compliance for this TSO are defined in RTCA/DO-316, sections 2.1.2.6 and 2.1.2.6.2.

B.4.14 Velocity Accuracy.

The GNSS position source manufacturer must provide design data to assist the installer in setting the NAC_V. Scaling the reported GNSS position accuracy (HFOM and VFOM) is not an acceptable means to determine NAC_V.

B.4.14.1 $NAC_V = 1$.

For installations intending to support $NAC_V = 1$, the GNSS manufacturer must perform the velocity tests in AC 20-138D, appendix 4, section A4-1 through A4-8 associated with $NAC_V = 1$. The GNSS manufacturer must indicate that the equipment satisfies the requirements for $NAC_V =1$ in the installation instructions for the ADS-B integration.

B.4.14.2 $NAC_V = 2$.

For installations intending to support $NAC_V = 2$, the GNSS manufacturer must perform the velocity tests in AC 20-138D, appendix 4, sections A4-1 through A4-9 associated with $NAC_V = 1$ and $NAC_V = 2$. The GNSS manufacturer must present substantiation data that the equipment dynamically outputs $HFOM_v$ and $VFOM_v$ (refer to AC 20-138(), appendix 4, sections A4-5 and A4-8) and that the equipment velocity and accuracy outputs have passed the velocity tests associated with $NAC_V = 1$ and $NAC_V = 2$. The GNSS manufacturer must indicate that the equipment satisfies the requirements for $NAC_V = 2$ in the installation instructions for the ADS-B integration.

B.4.14.3 $NAC_V = 3$ or 4.

No standard for performance has been developed to support NACv = 3 or $NAC_V = 4$. A $NAC_V = 3$ or $NAC_V = 4$ should not be set based on GNSS velocity accuracy unless you can demonstrate to the FAA that the error contributions have been adequately modeled to meet those levels of performance.

B.4.14.4 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data based on the $NAC_V =1$ and $NAC_V = 2$ test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration. Refer to AC 20-138(), appendix 4, section A4-2d(3) for additional guidance relative to using the noise environment in RTCA/DO-235B for the velocity tests.

B.4.14.5 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data based on the $NAC_V =1$ and $NAC_V = 2$ test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration. Refer to AC 20-138() appendix 4, section A4-2d(3) for additional guidance relative to using the noise environment in RTCA/DO-235() for the velocity tests.

B.4.14.6 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data based on the NAC_V =1 and NAC_V = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration.

B.4.14.7 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data based on the NAC_V =1 and NAC_V = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration.

B.4.14.8 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data based on the NAC_V =1 and NAC_V = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration.

B.4.14.9 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data based on the NAC_V =1 and NAC_V = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration.

B.4.14.10 TSO-C196/196a.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data based on the NAC_V =1 and NAC_V = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration.

B.4.15 Vertical Position Accuracy.

The GNSS should output vertical position accuracy. The vertical accuracy should specify a 95-percent probability bound on the reported vertical position. No revisions of TSO-C129 or TSO-C196 have vertical accuracy or integrity requirements, and TSO-C145 /146 only has vertical accuracy requirements for certain approach modes. None of the GNSS TSOs have a requirement to continuously output the vertical position accuracy data. If vertical position accuracy is output, it must have been qualified during design approval of the position source.

B.4.15.1 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in AC 20-138(), appendix 4, section A4-10.

B.4.15.2 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in AC 20-138(), appendix 4, section A4-10.

B.4.15.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in AC 20-138(), appendix 4, section A4-10.

B.4.15.4 TSO-C145/146 Rev a Class 2.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in AC 20-138(), appendix 4, section A4-10.

B.4.15.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in AC 20-138(), appendix 4, section A4-10.

B.4.15.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in AC 20-138(), appendix 4, section A4-10.

B.4.15.7 TSO-C196/196a.

Means of compliance for this TSO require GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in AC 20-138(), appendix 4, section A4-10.

B.4.16 Mode Output.

If interpretation of the integrity output of the position source can change due to a change in the position source mode, the position source must have a way of communicating that change of mode to the ADS-B equipment. Additionally, the position source manufacturer should provide a description of the modes and a description of how the position source outputs the mode indication.

B.4.16.1 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing the modes available (if affecting interpretation of integrity output) and how the position source outputs the mode indication (refer to Position Integrity Limits, section paragraph **B.4.7**, of this appendix).

B.4.16.2 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing the modes available (if affecting interpretation of integrity output) and how the position source outputs the mode indication (refer to Position Integrity Limits, paragraph **B.4.7**, of this appendix).

B.4.16.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing the modes available (if affecting interpretation of integrity output) and how the position source outputs the mode indication (refer to Position Integrity Limits, paragraph **B.4.7**, of this appendix).

B.4.16.4 TSO-C145/146 Rev a Class 2.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing the modes available (if affecting interpretation of integrity output) and how the position source outputs the mode indication (refer to Position Integrity Limits, paragraph **B.4.7**, of this appendix).

B.4.16.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing the modes available (if affecting interpretation of integrity output) and how the position source outputs the mode indication (refer to Position Integrity Limits, paragraph **B.4.7**, of this appendix).

B.4.16.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing the modes available (if affecting interpretation of integrity output) and how the position source outputs the mode indication (refer to Position Integrity Limits, paragraph **B.4.7**, of this appendix).

B.4.16.7 TSO-C196/196a.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing the modes available (if affecting interpretation of integrity output) and how the position source outputs the mode indication (refer to Position Integrity Limits, paragraph **B.4.7**, of this appendix).

B.4.17 Approach Mode Integrity.

SBAS equipment certified under any revision of TSO-C145 or TSO-C146 is required to have several modes of operation depending on the availability of augmentation. For example, when operating in an augmented mode intended for LPV approach guidance, the position source may determine HPL based on a lateral error versus a horizontal error and an exposure time based on the duration of the approach versus flight hour (refer to RTCA/DO-229D, appendix J). If the position source outputs the HPL on lateral error and approach exposure time, it is possible that the ADS-B transmitter would need to inflate the HPL by 3 percent in approach modes to ensure the integrity is appropriately bounded. GBAS equipment is required to comply with the GNSS or SBAS requirements for the output of position data. This is an integration issue between the GPS and ADS-B transmitter. The position source manufacturer must provide information to the system integrator to determine if the integrity output needs to be scaled (that is, by applying an inflation factor). Although we do not address the interface of a GBAS differentially-corrected position source in this AC, it will have similar considerations in approach modes as SBAS.

B.4.17.1 TSO-C129.

This is not applicable to this TSO as no HPL scaling is applied.

B.4.17.2 TSO-C129a.

This is not applicable to this TSO as no HPL scaling is applied.

B.4.17.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229C, sections 2.1.1.13.1 and 2.1.3.2.2.

B.4.17.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229C, sections 2.1.1.13.1, 2.1.3.2.2, 2.1.4.2.2, and 2.1.5.2.2.

B.4.17.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.1.13.1 and 2.1.3.2.2.

B.4.17.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.1.13.1, 2.1.3.2.2, 2.1.4.2.2, and 2.1.5.2.2.

B.4.17.7 TSO-C196/196a.

This is not applicable to this TSO as no HPL scaling is applied.

B.4.18 Track Angle Validity.

GNSS position sources can provide a track angle; however, the GNSS track angle may become invalid below a certain velocity. Optimally, the position source should either invalidate or remove the track angle when it is no longer valid. If the position source does not invalidate the track angle or remove the track angle when it is potentially invalid, the position source manufacturer must provide information on velocity limitations for GNSS track angle.

Note: The interference levels used to demonstrate velocity accuracy compliance can be used for track angle validity as well.

B.4.18.1 TSO-C129.

Means of compliance for TSO-C129 require GNSS manufacturers to use the test environment and guidance defined in AC 20-138(), appendix 4, section 4-12. It is recommended that manufacturers use RTCA/DO-229D, appendix H for outputting track angle (ARINC 743 all revisions, label 103) for those using ARINC 429 characteristics.

B.4.18.2 TSO-C129a.

Means of compliance for TSO-C129a require GNSS manufacturers to use the test environment and guidance defined in AC 20-138(), appendix 4, section 4-12. It is recommended that manufacturers use RTCA/DO-229D, appendix H for outputting track angle (ARINC 743 all revisions, label 103) for those using ARINC 429 characteristics.

B.4.18.3 TSO-C145/146 Rev a Class 1.

Means of compliance for TSO-C145/146 Rev a Class 1 require GNSS manufacturers to use the test environment and guidance defined in AC 20-138(), appendix 4, section 4-12. It is recommended that manufacturers use RTCA/DO-229C, appendix H for outputting track angle (ARINC 743 all revisions, label 103) for those using ARINC 429 characteristics.

B.4.18.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for TSO-C145/146 Rev a Class 2/3 require GNSS manufacturers to use the test environment and guidance defined in AC 20-138(), appendix 4, section 4-12. It is recommended that manufacturers use RTCA/DO-229C, appendix H for outputting track angle (ARINC 743 all revisions, label 103) for those using ARINC 429 characteristics.

B.4.18.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for TSO-C145/146 Rev b/c/d Class 1 require GNSS manufacturers to use the test environment and guidance defined in AC 20-138(), appendix 4, section 4-12. It is recommended that manufacturers use RTCA/DO-229D, appendix H for outputting track angle (ARINC 743 all revisions, label 103) for those using ARINC 429 characteristics.

B.4.18.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to use the test environment and guidance defined in AC 20-138(), appendix 4, section 4-12. It is recommended that manufacturers use RTCA/DO-229D, appendix H for outputting track angle (ARINC 743 all revisions, label 103) for those using ARINC 429 characteristics.

B.4.18.7 TSO-C196/196a.

Means of compliance for this TSO require GNSS manufacturers, using test or analysis to use the test environment and guidance defined in AC 20-138(), appendix 4 section 4-12. It is recommended that manufacturers use RTCA/DO-316, appendix H for outputting track angle (ARINC 743 all revisions, label 103) for those using ARINC 429 characteristics.

B.4.19 Time Mark.

GNSS position sources should output a UTC time mark identifying time of applicability with the successive position output. In modern sensors computing and outputting position multiple times per second, this time mark typically is associated with only one of the position outputs per second. The time mark can be used by the ADS-B equipment to reduce uncompensated latency. For 1090ES, the time mark output is not required for installations to be rule compliant. When integrating a UAT with an external GPS, the design of the hardware time mark must be interoperable. Some GPS synchronize the leading edge of the time mark to the UTC second. Other GPS let the time mark pulse be asynchronous to the UTC second and then record the time of the leading edge in the digital data along with the position solution. The UAT equipment must support the GPS time mark design. If the UAT equipment and GPS do not share a common time mark design, the UAT equipment will not be properly synchronized with the ground system and other aircraft.

B.4.19.1 TSO-C129.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

B.4.19.2 TSO-C129a.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

B.4.19.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

B.4.19.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

B.4.19.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

B.4.19.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

B.4.19.7 TSO-C196/196a.

Means of compliance for this TSO require GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

B.4.20 SIS Error Detection.

The position source should provide a means to detect a SIS error when the system uses a SIS. The probability of missed detection for a faulty SIS should be less than $1x10^{-3}$. GNSS equipment provides the appropriate SIS error detection.

B.4.20.1 TSO-C129.

Means of compliance for this TSO are defined in RTCA/DO-208 change 1, section 2.2.1.13.1, referring to Table 2-1 (refer to Table 2-1, note D). However, TSO-C129 equipment has no requirement for pseudorange step detection. This requires GNSS manufacturers to provide substantiation data documenting that their RAIM algorithm includes pseudorange step detection pursuant to TSO-C129a, section (a)(3)(xv)5.

B.4.20.2 TSO-C129a.

Means of compliance for this TSO are defined in RTCA/DO-208, change 1, section 2.2.1.13.1, referring to Table 2-1 (refer to Table 2-1, note D) and TSO-C129a, section (a)(3)(xv)5.

B.4.20.3 TSO-C145/146 Rev a Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.1.3 and 2.1.1.5 for SBAS, section 2.1.1.2 for GPS health message, and section 2.1.2.2.2.2.2 for FDE.

Note: The SBAS SIS includes health monitoring/fault information, which is why these general signal processing requirements are included.

B.4.20.4 TSO-C145/146 Rev a Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.1.3 and 2.1.1.5 for SBAS, section 2.1.1.2 for GPS health message, and section 2.1.2.2.2.2.2 for FDE.

Note: The SBAS SIS includes health monitoring/fault information, which is why these general signal processing requirements are included.

B.4.20.5 TSO-C145/146 Rev b/c/d Class 1.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.1.3 and 2.1.1.5 for SBAS, section 2.1.1.2 for GPS health message, and section 2.1.2.2.2.2.2 for FDE.

Note: The SBAS SIS includes health monitoring/fault information, which is why these general signal processing requirements are included.

B.4.20.6 TSO-C145/146 Rev b/c/d Class 2/3.

Means of compliance for this TSO are defined in RTCA/DO-229D, sections 2.1.1.3 and 2.1.1.5 for SBAS, section 2.1.1.2 for GPS health message, and section 2.1.2.2.2.2.2 for FDE.

Note: The SBAS SIS includes health monitoring/fault information, which is why these general signal processing requirements are included.

B.4.20.7 TSO-C196/196a.

Means of compliance for this TSO are defined in RTCA/DO-316, sections 2.1.1.2, 2.1.1.3, and 2.1.2.2.2.2.

B.5 Tightly-Coupled GNSS/IRS Position Sources.

This section provides high-level guidance on the issues that will need to be addressed to qualify a tightly-coupled Global Navigation Satellite System/Inertial Reference System (GNSS/IRS) for use in an ADS-B system. You must propose to the FAA the method to approve a tightly-coupled GNSS/IRS for use in an ADS-B system.

B.5.1 <u>Tightly-Coupled GNSS/IRS Outputs.</u>

The tightly-coupled GNSS/IRS outputs must meet the requirements, including validation, of either RTCA/DO-229(), appendix R, or RTCA/DO-316, appendix R.

B.5.2 <u>Horizontal Velocity Accuracy.</u>

The ADS-B system must address the horizontal velocity accuracy.

B.5.3 <u>GNSS Performance.</u>

The GNSS sensor should meet the minimum performance requirements for any revision of TSO-C129, TSO-C145, TSO-C146, or TSO-C196. Additionally, the GNSS sensor should meet all applicable GNSS requirements of this appendix as applicable.

B.5.4 GNSS Installation.

Install the GNSS sensor(s) in accordance with AC 20-138().

B.5.5 NIC Containment Radius.

§ 91.227 requires a SIL = 3, which means the probability of exceeding the NIC containment radius should be less than $1x10^{-7}$ per hour or per sample. The tightly-coupled GNSS/IRS system should transmit the integrity quality metric on a per-hour basis. After loss of GNSS or GNSS RAIM, the hybrid system should report the integrity containment radius of $1x10^{-7}$ probability on a per-sample basis rather than on a per-hour basis. Doing so would allow the GNSS/IRS system to transmit at a probability of $1x10^{-7}$ for a longer period of time.

B.5.5.1 RTCA/DO-229D, appendix R, section 2.1 requires tightly-coupled systems to meet two integrity limits. The integrity limit for the faulted satellite case is $1x10^{-7}$. The integrity limit for fault-free (rare normal) case is $1x10^{-5}$. RTCA/DO-229D, appendix R, section 2.1.1 acknowledges that in tightly integrated systems, inertial coasting may cause the rare normal limit to be dominant over the limit for the faulted conditions in times of poor satellite coverage. If the HPL output from the tightly-coupled position source changes from the fault detection $1x10^{-7}$ basis to the fault free $1x10^{-5}$ basis, the position source needs to indicate this change to the ADS-B equipment. We recommend the position source use a $1x10^{-7}$ integrity basis in all modes.

B.5.5.2 If the integrity containment probability output of the tightly-coupled GNSS/IRS position source changes from per-hour to per sample following a loss of GNSS or a loss of GNSS RAIM, the position source must indicate this change to the ADS-B equipment (that is, SIL_{SUPP}).

B.5.5.3 If the tightly-coupled GNSS/IRS scales the inertial integrity from $1x10^{-5}$ to $1x10^{-7}$, the scaling must have been demonstrated during design approval of the position source. If the inertial basis is per-sample and is scaled to per-hour, this scaling must have been demonstrated during the position source design approval.

B.5.6 GNSS Integrity Performance in the Flight Manual.

If a tightly-coupled GNSS/IRS position source is intended to be used as an ADS-B position source after the loss of GNSS, include integrity coasting performance in the flight manual. Specifically address the following:

B.5.6.1 If inertial coasting will meet § 91.227 requirements, such as NAC_P = 8, NIC = 7, SIL = 3, and SDA = 2.

B.5.6.2 Estimated length of time following a loss of GNSS for which inertial coasting is expected to meet the § 91.227 requirements. The estimate should assume the system met minimum § 91.227 requirements just before the loss of GNSS or GNSS RAIM. This estimate will be helpful to operators in developing a means to ensure that the system can meet § 91.227 requirements during predicted GNSS degradations.

B.6 Non-GNSS Position Sources.

The FAA does not know of any currently available non-GNSS position sources that can meet the performance requirements of § 91.227. However, you may wish to integrate a backup ADS-B OUT capability in the event of loss of GNSS. Such a backup is not required. We do not expect any ATC operational advantages for systems that provide a non-GNSS backup unless that backup capability meets the performance requirements of § 91.227. This section provides high-level guidance on the issues that will need to be addressed to qualify a non-GNSS position source for use in an ADS-B system without regard to § 91.227 requirements. If you choose to integrate this capability, use the guidance below and propose to the FAA the method to approve a non-GNSS position source for use in an ADS-B system

B.6.1 Distance Measuring Equipment (DME/DME).

B.6.1.1 The DME/DME Area Navigation (RNAV) system must meet the minimum performance requirements of TSO-C66c, *Distance Measuring Equipment (DME) Operating within the Radio Frequency Range of 960-1215 Megahertz*.

B.6.1.2 There are no industry standards for use of a DME/DME system to determine position integrity or velocity accuracy. You must propose a method to derive these parameters.

B.6.1.3 The DME/DME system must only use DME facilities listed in the Airport/Facility Directory (A/FD).

B.6.1.4 The DME/DME system must only use operational DME facilities. The system must exclude non-operational facilities by checking the identification. Operational mitigations, such as manually excluding (blackballing) DME stations or any action that requires pilot action or monitoring of the DME/DME system, are not permissible for ADS-B qualified position sources.

B.6.1.5 Reasonableness Checks.

The DME/DME system must incorporate reasonableness checking. Refer to AC 90-100(), *U.S. Terminal and En Route Area Navigation (RNAV) Operations*, for additional information on reasonableness checks.

B.6.2 VOR/DME.

ADS-B position sources may not use Very High Frequency Omnidirectional Range (VOR) information. Do not interface any position solution that uses VOR information as the performance of the VOR cannot be assumed throughout the region in which the signal is received.

B.6.3 Inertial Navigation System/Inertial Reference Unit (INS/IRU) Loosely Coupled With DME or GNSS.

B.6.3.1 The GNSS equipment or DME equipment must meet the requirements in this appendix.

B.6.3.2 Loosely coupled INS/IRU equipment must meet 14 CFR part 121, appendix G.

B.6.3.3 The loosely coupled INS/IRU position source must provide all of the required position source outputs listed in this appendix. Qualify the outputs during installation approval of the ADS-B system; refer to section **B.3** of this appendix. Velocity accuracy may be qualified and set statically. Update the position accuracy and position integrity metrics dynamically.

B.6.3.4 § 91.227 requires a SIL = 3, which means the probability of exceeding the NIC containment radius should be less than $1x10^{-7}$ per hour or per sample. A GNSS/IRS that continues to provide the integrity containment radius based on a $1x10^{-7}$ probability after loss of GNSS or GNSS RAIM is preferred. Potential errors, caused by GNSS updating before the loss of GNSS, must continue to be bounded.

B.6.3.4.1 If the integrity containment probability output of a loosely coupled GNSS/IRS position source changes from $1x10^{-7}$ to $1x10^{-5}$ following a loss of GNSS or a loss of GNSS RAIM, the position source must relay this change to the ADS-B equipment. The overall system time to transmit a change in SIL must be 10 seconds or less.

B.6.3.4.2 If the integrity containment probability output of a loosely coupled GNSS/IRS position source changes from per-hour to per-sample following a loss of GNSS or a loss of GNSS RAIM, the position source must relay this change to the ADS-B equipment.

B.7 Future Position Sources.

It is expected that future position sources such as dual frequency GPS and GPS/Galileo sources will be acceptable position sources for ADS-B and meet the performance requirements of § 91.227. Future revisions of this AC will address new position source technology when it becomes available.

APPENDIX C. LATENCY ANALYSIS

C.1 Purpose.

The purpose of this appendix is to provide guidelines for accomplishing a latency analysis on your ADS-B system.

C.2 Analysis.

Accomplish the analysis by determining the applicable latencies for each component and totaling all of the individual component latencies. You must include all sources of position latency, including but not limited to: the position source, intermediary devices between the position source and ADS-B equipment, and ADS-B equipment. Use the following guidelines to determine latency for each component:

C.2.1 Position Source Latency Considerations.

In general, the latency information should be generated by the position source manufacturer and presented as part of the latency analysis. The latency measurement should begin at the TOM and end when the position is output from the position source.

C.2.1.1 TSO-C145, TSO-C146, and TSO-C196 GNSS.

Use the TSO latency standards in the latency analysis or use actual latency information generated by the GNSS manufacturer to determine the position source maximum total latency and uncompensated latency. If the GNSS equipment is classified as Class 3 pursuant to any revision of TSO-C145, there are tighter latency standards for the LPV modes. If the Class 3 standard is implemented across all modes, the tighter latency numbers may be used; however, if the tighter latency standards are only met when in approach mode, use the worst-case latency across all modes.

C.2.1.2 TSO-C129 GNSS.

There are no latency standards for any revision of TSO-C129 GNSS equipment. Latency information must be generated by the GNSS manufacturer and included as part of the latency analysis.

C.2.1.3 Tightly-Coupled GNSS/Inertial.

There are no latency standards for tightly-coupled GNSS/Inertial equipment. Total and uncompensated latency information should be generated by the position source manufacturer and presented as part of the latency analysis. Base the latency analysis on the update rate of the inertial sensor, as 10-second or 20-second GNSS updates to the inertial sensor are not impacting the latency of the position output. However, the GNSS update latency does affect the position accuracy and should be appropriately reflected in the position source accuracy output.

C.2.1.4 Other Position Sources.

Total and uncompensated latency information should be generated by the position source manufacturer and included as part of the latency analysis.

C.2.2 Intermediary Device.

Intermediary devices are typically data concentrators. The latency information should be generated by the intermediary device manufacturer and presented as part of the latency analysis. If the intermediary device latency is variable, use the worst-case latency.

C.2.3 ADS-B Equipment.

Use the TSO-C166b and TSO-C154c latency standards for the latency analysis or use the actual latency information generated by the ADS-B equipment manufacturer. TSO-C166b and TSO-C154c require the uncompensated latency of the ADS-B equipment to be less than 100 ms.

C.2.4 Asynchronous Delay.

Total latency analysis must include the maximum asynchronous delay caused by position updates arriving at the ADS-B equipment out-of-synch with when the ADS-B system transmits the position. This delay is a factor of the position source update rate rather than the ADS-B equipment transmission rate. For example, a 1 Hz position source could provide a position update immediately after an ADS-B position transmission. This position would be extrapolated, up to 1 second, until the next position update arrives from the position source. Thus, a 1 Hz position source can introduce 1 second of total latency. This 1 second must be included in the total latency calculation.

C.3 Equipment Latency Budget.

C.3.1 Position Source.

We recommend using position sources where the latency of the position, velocity, and position accuracy metrics are less than or equal to 500 ms between the position TOM and the position time of applicability, and that the position is output in less than 200 ms after the position time of applicability.

Note: All revisions of TSO-C145, TSO-C146, and TSO-C196 equipment meet these recommendations.

C.3.2 Position Source to ADS-B Interface.

Directly connecting the position source to the ADS-B equipment is the preferred method of installation. Alternately, if this architecture is not used, we recommend that any latency introduced between the position source output and the ADS-B equipment input be less than 100 ms (refer to RTCA/DO-260B, appendix U).

C.3.3 ADS-B Equipment.

The latency requirements for the ADS-B equipment are included in TSO-C166b and TSO-C154c and allow for the ADS-B equipment to introduce no more than 100 ms of uncompensated latency. TSO-C166b or TSO-C154c are required by § 91.225 and § 91.227.

C.4 General Latency Issues.

C.4.1 Recommendations for Reducing Latency.

C.4.1.1 Directly connect the position source to the ADS-B equipment.

C.4.1.2 Use a TSO-C145, TSO-C146, or TSO-C196 position source (any revision).

C.4.1.3 Use a position source that provides position updates at greater than 1 Hz.

C.4.1.4 Use the GNSS time mark in TSO-C166b systems to reduce position source and intermediary device uncompensated latency. (Use of the GNSS time mark is required by TSO-C154c).

C.4.2 Latency Applicability.

The 2.0 second total latency requirement applies to the aircraft position (latitude and longitude), velocity, and the velocity accuracy metric (NAC_V). The 0.6 second uncompensated latency requirement only applies to the aircraft position (latitude and longitude).

C.4.3 Mean Latency Versus Maximum Latency.

In instances where the latency is variable, use the worst-case latency under fault-free conditions in the analysis. Variable latency, for example, can occur due to variance in loading of a data concentrator or the asynchronous nature of a GNSS to ADS-B interface. As the applicant, you must propose to the FAA how to deal with variable latencies introduced by intermediary devices such as data concentrators.

C.4.4 Compensating for Interface Latency in Unsynchronized Systems.

It is acceptable to install ADS-B equipment that compensates for latency that occurs outside of the ADS-B equipment, even if the position source and ADS-B equipment are not time synchronized. Establishing the proper corrections for external latency is problematic because the TSO-C166b equipment may be interfaced to numerous different aircraft architectures. These architectures could include different position sources, with different latencies, as well as different data concentrators with different delays. To interface unsynchronized ADS-B equipment that compensates for external latencies, the ADS-B equipment manufacturer must provide a list of the acceptable equipment and the acceptable architectures. Typically this type of ADS-B equipment will only be installed in closely-integrated architectures. You may not attempt to integrate ADS-B equipment that compensates for external latencies unless the ADS-B equipment manufacturer has expressly documented the installation architecture and design data is available for each component. The total amount of time that can be used for compensation is still limited by the requirement to limit total latency to within 2.0 seconds.

C.4.5 Overcompensating.

It is possible for compensation algorithms to "overcompensate" for the effects of latency, essentially transmitting a position that is out in front of the actual aircraft position rather than behind the actual aircraft position. This type of system is acceptable as long as the transmitted position is no further ahead than 200 ms, (refer to RTCA/DO-260B, appendix U).

C.4.6 Extrapolation During Loss of Position Data.

TSO-C166b equipment compliant with RTCA/DO-260B, sections 2.2.3.2.3.7.4 and 2.2.3.2.3.8.4, allows extrapolation of the position for up to 2 seconds when the position data is not available from the position source. This allowance is in case position data is lost for a single sample, and it does not have to be considered in the total latency calculation, provided it is a non-normal condition. If the position data is lost, several position updates could exceed the latency requirement, but the position would then be invalidated within 2 seconds, pursuant to TSO-C166b.

C.4.7 UTC Epoch Synchronization.

The position transmitted from the ADS-B equipment may be aligned with a UTC epoch. TSO-C154c requires UAT systems to extrapolate the position to the 1.0 second or 0.2 second UTC epoch. TSO-C166b allows 1090ES systems to extrapolate to the 0.2 second UTC epoch or transmit asynchronously. To synchronize the position output with the UTC epoch, the position source needs to provide a time mark. The ADS-B equipment uses this time mark to extrapolate the position to the UTC epoch. Typically the time mark will be from a GNSS position source. Implementation of the time synchronization in the 1090ES systems will help minimize uncompensated latency.

C.4.8 Latency Points of Measurement.

Latency is defined as the time between when the position is measured by the position source to when it is transmitted by the ADS-B equipment.

C.4.8.1 Time of Measurement (TOM).

The latency analysis starts at the position source TOM. The position source TOM for GNSS sources is the time when the last GNSS signal used to determine the position arrives at the aircraft GNSS antenna. TOM for an inertial position source or a GNSS-aided inertial position source is the time of the last accelerometer measurement. TOM for an RNAV system using multiple DME signals would be the time the last DME signal arrives at the aircraft's DME antenna.

Note: To demonstrate compliance with § 91.227, you must calculate latency from the position source TOM. Do not calculate latency from the position source time of applicability, as defined in RTCA/DO-260B with corrigendum 1 and RTCA/DO-282B with corrigendum 1.

C.4.8.2 Transmit Time of Applicability.

The transmit time is the time when the ADS-B system broadcasts the position. The transmitted position's time of applicability for synchronized systems is the appropriate UTC epoch. The transmitted position's time of applicability for unsynchronized systems is the actual time the ADS-B equipment begins transmission of the message that contains the position.

Note: Synchronized ADS-B systems randomly vary the position transmission around the UTC epoch to avoid interference with other ADS-B transmitters. This randomization should not be included in the latency analysis.

C.4.9 Minor Changes to Position Source Type Design.

If the ADS-B installation relies on position source latency performance, versus a TSO latency standard, the ADS-B system installer must update the ICA for the position source with a process that ensures continued airworthiness of the ADS-B system following design changes to the position source.

C.5 **Latency Analysis Example.**

This example uses a GNSS meeting the minimum performance requirements of TSO-C145 (any revision) directly connected to TSO-C166b ADS-B equipment. This installation is a T = 0 installation; thus it is unsynchronized. The example in **Table C-1** is considered a compliant architecture.

Table C-1. Latency Analysis Example

Item	Uncompensated Latency	Compensated Latency	Total Latency	Notes
Position Source	≤ 200 ms	≤ 500 ms	≤ 700 ms	
Position Source to ADS-B Interface	0	0	0	Directly connected
ADS-B Equipment	≤ 100 ms	Note 1	≤ 100 ms	
Asynchronous Delay	0	≤ 1.0 second	≤ 1.0 second	1 Hz position source
Total	≤ 300 ms	≤ 1.5 second	≤ 1.8 second	

Note 1: ADS-B equipment compensated latency is bounded by the asynchronous nature of the position source delivery and ADS-B system transmission. Thus ADS-B equipment compensated latency is included in the asynchronous delay row.

Note 2: The latency between the position source TOM and the position source time of applicability is required to be compensated by all revisions of TSO-C145, TSO-C146, and TSO-C196.

APPENDIX D. DEFINITIONS AND ACRONYMS

D.1 **Definitions.**

The following definitions are specific to this AC and may differ from definitions contained in other references.

D.1.1 Automatic Dependent Surveillance Broadcast (ADS-B).

An advanced surveillance technology where ADS-B OUT equipped aircraft share position, altitude, velocity, and other information with ATC and other appropriately equipped aircraft.

D.1.2 ADS-B IN.

Receipt, processing, and display of other aircraft's ADS-B transmissions. ADS-B IN is necessary to use airborne applications.

D.1.3 ADS-B OUT.

Transmission of an aircraft's position, altitude, velocity, and other information to other aircraft and ATC ground-based surveillance systems.

D.1.4 Automatic Dependent Surveillance - Rebroadcast (ADS-R).

Retransmission of UAT ADS-B messages from aircraft on the 1090ES link and 1090ES messages on the UAT link. ADS-R ensures aircraft equipped with different links can receive messages from one another when equipped with ADS-B IN.

D.1.5 Area Navigation (RNAV).

A method of navigation that permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

D.1.6 Barometric Altitude Integrity Code (NIC_{BARO}).

Indicates if pressure altitude is provided by a single Gillham encoder or another, more robust altitude source. Because of the potential for an undetected error in a Gillham encoding, many Gillham installations are cross-checked against a second altitude source. NIC_{BARO} annotates the status of this cross-check.

D.1.7 Flight Information System - Broadcast (FIS-B).

A ground broadcast service provided over the UAT data link. The FAA FIS-B system provides pilots and flightcrews of properly equipped aircraft with a cockpit display of certain aviation weather and aeronautical information.

D.1.8 Flight Manual.

A generic term used throughout this AC to represent the AFM, RFM, AFM supplement, or RFM supplement.

D.1.9 Galileo.

A European satellite-based radio navigation system being developed that will provide a global positioning service.

D.1.10 Global Navigation Satellite System (GNSS).

The generic term for a satellite navigation system, such as GPS, that provides autonomous worldwide geo-spatial positioning and may include local or regional augmentations.

D.1.11 Global Positioning System (GPS).

A U.S. satellite-based radio navigation system that provides a global positioning service. The service provided by GPS for civil use is defined in the Global Positioning System Standard Positioning Service Performance Standard, 4th edition, dated September 2008, available at http://www.gps.gov/technical/ps/2008-SPS-performance-standard.pdf.

D.1.12 GNSS Time of Applicability.

The time when the position output from the GNSS sensor is applicable.

D.1.13 GNSS Time of Measurement (TOM).

The time when the last GNSS signal used to determine the position arrives at the aircraft GNSS antenna.

D.1.14 Horizontal Figure of Merit (HFOM).

The radius of a circle in the horizontal plane, with its center being at the true position, that describes the region assured to contain the indicated horizontal position with at least 95 percent probability under fault-free conditions at the time of applicability.

D.1.15 Horizontal Protection Level Fault Detection (HPLFD).

The radius of a circle in the horizontal plane, with its center being at the true position, that describes the region assured to contain the indicated horizontal position. HPLFD is a horizontal region where the missed alert and false alert requirements are met for the chosen set of satellites when autonomous fault detection is used. It is a function of the satellite and user geometry and the expected error characteristics; it is not affected by actual measurements. Its value is predictable given reasonable assumptions regarding the expected error characteristics.

D.1.16 Horizontal Protection Level Fault Free (HPLFF).

Fault-free horizontal protection level. Refer to RTCA/DO-229D, appendix R.

D.1.17 Mode Control Panel

The Mode Control Panel, (MCP) contains controls that allow aircrew to interface with the autopilot system. The MCP can be used to instruct the autopilot to perform tasks such as; hold a specific altitude, change altitudes at a specific rate, hold a specific heading, turn to a new heading, and or follow the directions of a flight management computer. The MCP is not the autopilot, it just controls the mode in which the autopilot operates.

D.1.18 Navigation Accuracy Category for Position (NAC_P).

Used to indicate, with 95 percent certainty, the accuracy of the aircraft reported horizontal position. **Table D-1** provides a list of possible NAC_P values. A NAC_P of 8 or greater is required by § 91.227.

Table D-1. NAC_P Encoding

Value	Horizontal Accuracy Bound (Estimated Position Uncertainty)
0	EPU ≥ 18.52 km (10.0 nm)
1	EPU < 18.52 km (10.0 nm)
2	EPU < 7.408 km (4.0 nm)
3	EPU < 3.704 km (2.0 nm)
4	EPU < 1.852 m (1.0 nm)
5	EPU < 926 m (0.5 nm)
6	EPU < 555.6 m (0.3 nm)
7	EPU < 185.2 m (0.1 nm)
8	EPU < 92.6 m (0.05 nm)
9	EPU < 30 m
10	EPU < 10 m
11	EPU < 3 m

D.1.19 Navigational Accuracy Category for Velocity (NAC_V).

Used to indicate, with 95 percent certainty, the accuracy of the aircraft reported horizontal velocity. **Table D-2** provides a list of possible NAC_V values. A NAC_V of 1 or greater is required by § 91.227.

Table D-2. NAC_V

Value	Velocity Accuracy Bound (Estimated Velocity Uncertainty)
0	≥ 10 m/s or unknown
1	< 10 m/s
2	< 3 m/s
3	< 1 m/s
4	< 0.3 m/s

D.1.20 Navigation Integrity Category (NIC).

A parameter that specifies an integrity containment radius. **Table D-3** provides a list of possible NIC values. A NIC of 7 or greater is required by § 91.227.

Table D-3. NIC Encoding

Value	Radius of Containment
0	Unknown
1	R_C < 37.04 km (20.0 nm)
2	R_C < 14.816 km (8.0 nm)
3	R_C < 7.408 km (4.0 nm)
4	R_C < 3.704 km (2.0 nm)
5	R_C < 1.852 km (1.0 nm)
6	R_C < 1.111 km (0.6 nm)
6	R_C < 926 m (0.5 nm)
6	R_C < 555.6m (0.3 nm)
7	R_C < 370.4 m (0.2 nm)
8	R_C < 185.2 m (0.1 nm)
9	R_C < 75 m
10	R_C < 25 m
11	R_C < 7.5 m

D.1.21 Position Source.

The on-board avionics equipment that provides the latitude, longitude, geometric altitude, velocity, position and velocity accuracy metrics, and position integrity metric. Additionally, the position source may provide the vertical rate parameters.

D.1.22 Receiver Autonomous Integrity Monitoring (RAIM).

Any algorithm that verifies the integrity of the position output using GPS measurements, or GPS measurements and barometric aiding, is considered a RAIM algorithm. An algorithm that uses additional information (such as a multi-sensor system with inertial reference system) to verify the integrity of the position output may be acceptable as a RAIM equivalent. Within this AC, the term RAIM is a synonym for aircraft-based augmentation system (ABAS) and is used to refer to both RAIM and RAIM-equivalent algorithms.

D.1.23 Satellite-Based Augmentation System (SBAS).

A wide coverage augmentation system in which the user receives augmentation information from a satellite-based transmitter. In the United States, this is referred to as Wide Area Augmentation System (WAAS).

D.1.24 Selective Availability (SA).

A protection technique employed by the Department of Defense that degraded GPS accuracy. Selective availability was discontinued on May 1, 2000.

D.1.25 Source Integrity Level (SIL).

The probability of the reported horizontal position exceeding the radius of containment defined by the NIC without alerting, assuming the avionics has no faults. **Table D-4** provides a list of possible SIL values. A SIL of 3 is required by § 91.227.

Table D-4. SIL Encoding

Value	Probability
0	$> 1x10^{-3}$ or unknown
1	$\leq 1x10^{-3}$
2	$\leq 1x10^{-5}$
3	$\leq 1x10^{-7}$

D.1.26 System Design Assurance (SDA).

The failure condition that the position transmission chain is designed to support. **Table D-5** provides a list of possible SDA values. An SDA of 2 or greater is required by § 91.227. Refer to A.2.29 for more information.

Table D-5. SDA Encoding

Value	Probability of Undetected Fault Causing the Transmission of False or Misleading Information
0	$> 1 \times 10^{-3}$ or unknown
1	$\leq 1 \times 10^{-3}$
2	$\leq 1 \times 10^{-5}$
3	$\leq 1 \times 10^{-7}$

D.1.27 **Traffic Collision Avoidance System.**

Collision Avoidance systems which rely on transponder interrogations and replies of other airborne aircraft.

D.1.28 **Traffic Collision Avoidance System I.**

TCAS I is the first generation of collision avoidance technology. TCAS I systems are able to monitor the traffic situation around an aircraft and offer information on the approximate bearing and altitude of other aircraft. It can also generate collision warnings in the form of a "Traffic Advisory" (TA). The TA warns the pilot that another aircraft is in near vicinity, announcing "Traffic, traffic", but does not offer any suggested remedy

D.1.29 **Traffic Collision Avoidance System II.**

TCAS II is the second and current generation of instrument warning TCAS. It offers all the benefits of TCAS I, but also offers the pilot direct, vocalized instructions to avoid danger, known as a "Resolution Advisory" (RA). TCAS II systems coordinate their resolution advisories before issuing commands to the pilots, so that if one aircraft is instructed to descend, the other will typically be told to climb — maximizing the separation between the two aircraft.

D.1.30 Traffic Information Service - Broadcast (TIS-B).

TIS-B is a ground broadcast service provided from an ADS-B ground system network over the UAT and 1090ES links that provides position, velocity, and other information on traffic detected by a secondary surveillance radar, but is not transmitting an ADS-B position.

D.1.31 Total Latency.

The total time between when the position is measured by the position source (GNSS TOM for GNSS systems) and when the position is transmitted from the aircraft (ADS-B time of transmission).

D.1.32 Uncompensated Latency.

Any latency in the ADS-B system that is not compensated through extrapolation. Uncompensated latency can be represented as the difference between the time of applicability of the broadcast position and the actual time of transmission.

D.1.33 Wide Area Augmentation System (WAAS).
The U.S. implementation of SBAS.

D.2 Acronyms.

The following acronyms are specific to this AC and may differ from definitions contained in other references.

- **14 CFR** Title 14 of the Code of Federal Regulations
- **AC** Advisory Circular
- **ACO** Aircraft Certification Office
- **ACR** ADS-B Aircraft Operation Compliance Report
- **ADIRS** Air Data And Inertial Reference System
- **ADS-B** Automatic Dependent Surveillance - Broadcast
- **ADS-R** Automatic Dependent Surveillance - Rebroadcast
- **A/FD** Airport/Facility Directory
- **AFM** Airplane Flight Manual
- **AFMS** Airplane Flight Manual Supplement
- **ANSP** Air Navigation Service Provider
- **ARP** Aerospace Recommended Practice
- **ASDE-X** Airport Surface Detection Equipment, Model X
- **ATC** Air Traffic Control
- **ATCRBS** Air Traffic Control Radar Beacon System
- **dB** Decibel
- **DME** Distance Measuring Equipment
- **EASA** European Aviation Safety Agency
- **EMC** Electro Magnetic Compatibility
- **EMI** Electromagnetic Interference
- **EPU** Estimated Position Uncertainty
- **FAA** Federal Aviation Administration
- **FCU** Flight Control Unit
- **FHA** Functional Hazard Assessment
- **FIS-B** Flight Information Services - Broadcast
- **FMS** Flight Management System

- **GBAS** Ground Based Augmentation System
- **GNSS** Global Navigation Satellite System
- **GNSS/IRS** Global Navigation Satellite System/Inertial Reference System
- **GPS** Global Positioning System
- **GVA** Geometric Vertical Accuracy
- **HAE** Height Above Ellipsoid
- **HAG** Height Above Geoid
- **HFOM** Horizontal Figure of Merit
- **HIL** Horizontal Integrity Level
- **HPL** Horizontal Protection Level
- **HUL** Horizontal Uncertainty Level
- **Hz** Hertz
- **ICAO** International Civil Aviation Organization
- **ICA** Instructions for Continued Airworthiness
- **IFR** Instrument Flight Rules
- **INS** Inertial Navigation System
- **IRS** Inertial Reference System
- **IRU** Inertial Reference Unit
- **kts** Knots
- **LPV** Localizer Performance with Vertical Guidance
- **m/s** Meters per second
- **MCP** Mode Control Panel
- **MHz** Megahertz
- **MOPS** Minimum Operational Performance Standards
- **MSL** Mean Sea Level
- **NAC_P** Navigational Accuracy Category for Position
- **NAC_V** Navigational Accuracy Category for Velocity
- **NAS** National Aerospace System
- **NIC** Navigational Integrity Category
- **NIC_{BARO}** Barometric Altitude Integrity Code
- **NM** Nautical Mile

- **POA** Position Offset Applied
- **RA** Resolution Advisory
- **Rc** Radius of containment
- **RAIM** Receiver Autonomous Integrity Monitoring
- **RFM** Rotorcraft Flight Manual
- **RFMS** Rotorcraft Flight Manual Supplement
- **RVSM** Reduced Vertical Separation Minimum
- **SA** Selective Availability
- **SBAS** Satellite-Based Augmentation System
- **SDA** System Design Assurance
- **SIL** Source Integrity Level
- **SIL_{SUPP}** SIL Supplement
- **SIS** Signal-in-Space
- **SSR** Secondary Surveillance Radar
- **STC** Supplemental Type Certificate
- **TC** Type Certificate
- **TCAS** Traffic Alert and Collision Avoidance System
- **TCAS I** Traffic Alert and Collision Avoidance System (generation 1)
- **TCAS II** Traffic Alert and Collision Avoidance System (generation 2)
- **TIS-B** Traffic Information Service - Broadcast
- **TOM** Time of Measurement
- **TSO** Technical Standard Order
- **TSOA** Technical Standard Order Authorization
- **UAT** Universal Access Transceiver
- **UTC** Coordinated Universal Time
- **VFR** Visual Flight Rules
- **VFOM** Vertical Figure of Merit
- **VOR** Very High Frequency Omnidirectional Range
- **V_{APP}** Target approach airspeed
- **V_{FE}** Maximum flap extended speed
- **V_H** Maximum speed in level flight at maximum continuous power

- **V_{MO}** Maximum operating limit speed
- **V_{NE}** Never-exceed speed
- **V_S** Stalling speed or the minimum steady flight speed at which the airplane is controllable
- **V_Y** Speed for best rate of climb
- **V_2** Takeoff safety speed
- **WAAS** Wide Area Augmentation System
- **WGS-84** World Geodetic System 1984

APPENDIX E. RELATED DOCUMENTS

E.1 FAA Documents.

E.1.1 Title 14 of the Code of Federal Regulations.

FAA regulations can be obtained at https://bookstore.gpo.gov/.

E.1.2 Advisory Circulars.

Order copies of ACs from the U.S. Department of Transportation, Subsequent Distribution Office, M-30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785. You can also get copies from our website at www.faa.gov/regulations_policies/advisory_circulars/.

- AC 20-131(), *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders*.
- AC 20-138(), *Airworthiness Approval of Positioning and Navigation Systems*.
- AC 20-149(), *Installation Guidance for Domestic Flight Information Services - Broadcast.*
- AC 20-151(), *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders*.
- AC 20-172(), *Airworthiness Approval for ADS-B In Systems and Applications*.
- AC 21-16(), *RTCA Document DO-160 versions D, E, F, and G, "Environmental Conditions and Test Procedures for Airborne Equipment"*.
- AC 21-40(), *Guide for Obtaining a Supplemental Type Certificate*.
- AC 23.1309-1(), *System Safety Analysis and Assessment for Part 23 Airplanes*.
- AC 25.1309-1(), *System Design and Analysis*.
- AC 25.1322-1, *Flightcrew Alerting*.
- AC 27-1(), *Certification of Normal Category Rotorcraft*.
- AC 29-2(), *Certification of Transport Category Rotorcraft*.
- AC 43-6(), *Altitude Reporting Equipment and Transponder System Maintenance and Inspection Practices*.

E.1.3 Technical Standards Orders.

You can find a current list of TSOs on the FAA Regulatory and Guidance Library website at http://rgl.faa.gov/. You will also find the TSO Index of Articles at the same site.

- TSO-C5, *Direction Instrument, Non-Magnetic (Gyroscopically Stabilized).*
- TSO-C6, *Direction Instrument, Magnetic (Gyroscopically Stabilized).*

- TSO-C8(), *Vertical Velocity Instruments (Rate-of-Climb)*.
- TSO-C10(), *Altimeter, Pressure Actuated, Sensitive Type*.
- TSO-C66(), *Distance Measuring Equipment (DME) Operating Within the Radio Frequency Range of 960-1215 Megahertz*.
- TSO-C88(), *Automatic Pressure Altitude Reporting Code-Generating Equipment*.
- TSO-C106(), *Air Data Computer*.
- TSO-C112(), *Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*.
- TSO-C119(), *Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II With Hybrid Surveillance*.
- TSO-C129(), *Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)*.
- TSO-C145(), *Airborne Navigation Sensors Using The Global Positioning System Augmented By The Satellite Based Augmentation System (SBAS)*.
- TSO-C146(), *Stand-Alone Airborne Navigation Equipment Using The Global Positioning System Augmented By The Satellite Based Augmentation System (SBAS)*.
- TSO-C154c, *Universal Access Transceiver (UAT) Automatic Dependent Surveillance Broadcast (ADS-B) Equipment Operating on Frequency of 978 MHz*.
- TSO-C166b, *Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information Service - Broadcast (TIS-B) Equipment Operating on the Radio Frequency of 1090 Megahertz (MHz)*.
- TSO-C196(), *Airborne Supplemental Navigation Sensors for Global Positioning System Equipment using Aircraft-Based Augmentation*.

E.1.4 **FAA Orders.**

FAA orders can be obtained from the FAA Regulatory and Guidance Library website at http://rgl.faa.gov/.

E.1.5 **FAA Other Documents**

FAA Policy Memorandum: *Installation Approval for ADS-B OUT Systems*, dated December, 2015, is in the same location as AC 20-165B, on the rgl website: http://rgl.faa.gov/.

FAA letter *Changes to the TIS-B Service beginning in late 2015* dated March 31, 2015 can be found in the same location as TSO-C195B, on the rgl website: http://rgl.faa.gov/.

FAA SBS *Surveillance and Broadcast Services Description Document, SRT-047 Revision 02*, dated November 15, 2013, can be found in the same location as TSO-C195B, on the rgl website: http://rgl.faa.gov/.

E.2 RTCA, Inc. Documents.

You can order copies of RTCA documents from RTCA, Inc., 1150 18th Street NW., Suite 910, Washington, DC 20036; telephone: (202) 833-9339; website: http://www.rtca.org.

- RTCA/DO-160D, E, F or G, *Environmental Conditions and Test Procedures for Airborne Equipment*.
- RTCA/DO-178C, *Software Considerations in Airborne Systems and Equipment Certification*.
- RTCA/DO-208 change 1, *Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)*.
- RTCA/DO-229D, *Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment*
- RTCA/DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*.
- RTCA/DO-260B, *Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information Services - Broadcast*, with corrigendum 1.
- RTCA/DO-282B, *Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast*, with corrigendum 1.
- RTCA/DO-300A, *Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance*.
- RTCA/DO-316, *Minimum Operational Performance Standards for Global Positioning System/Aircraft Base Augmentation System*.
- RTCA/DO-338, *Minimum Aviation System Performance Standards (MASPS) for ADS-B Traffic Surveillance Systems and Applications (ATSSA*.

E.3 ARINC Documents

ARINC Characteristic 743A-5, *GNSS Sensor*, can be obtained from ARINC Industry Activities, 16701 Melford Blvd, Suite 120, Bowie, MD 20715, or by calling (240) 334-2578, or from the ARINC Standards Store at the following address: http://www.aviation-ia.com/cf/store/.

E.4 SAE International Documents.

Order SAE documents from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001; telephone: (724) 776-4970; fax: (724) 776-0790. Also, order copies online at www.sae.org.

- SAE ARP 4754A, *Guidelines for Development of Civil Aircraft and Systems*.

- SAE ARP-4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*.

E.5 European Aviation Safety Agency (EASA) Documents.

EASA publications can be obtained from the European Aviation Safety Agency, Postfach 10 12 53, D-50452 Cologne, Germany, or from https://easa.europa.eu .

- EASA 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*.
- ED Decision 2013/031/R, Decision 2013/031/R of the Executive Director of the Agency Adopting Certification Specifications for Airborne Communications Navigation and Surveillance (CS ACNS) CS-ACNS dated 17 December, 2013.

Advisory Circular Feedback

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by emailing this form to john.d.fisher@faa.gov or alex.j.rodriguez@faa.gov.

Subject: AC 20-165B Date:

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph Click here to enter text. on page Click here to enter text.

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☐ In a future change to this AC, please cover the following subject:
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Submitted by: ________________________________ Date: __________________________

European Aviation Safety Agency

Certification Specifications
and
Acceptable Means of Compliance

for

Airborne Communications, Navigation and Surveillance

CS-ACNS

Initial Issue

17 December 2013[1]

[1] For the date of entry into force of this Amendment, kindly refer to Decision 2013/031/R in the **Official Publication** of the Agency.

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CS ACNS - Airborne Communications, Navigation and Surveillance

BOOK 1

BOOK 2

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Book 1
Certification Specifications

Subpart A — General

CS ACNS.A.GEN.001 Applicability

These Certification Specifications are applicable to all aircraft for the purpose of compliance with equipage requirements with respect to on-board Communication, Navigation and Surveillance systems. Furthermore, compliance with the appropriate section of these Certification Specifications ensures compliance with the following European regulations:

(a) Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council

(b) Commission Regulation (EU) No 1207/2011, of 22 November 2011 laying down requirements for the performance and the interoperability for surveillance for the single European sky; and

(c) Commission Regulation (EU) No 1206/2011, of 22 November 2011 laying down requirements on aircraft identification for surveillance for the single European sky.

(d) Commission Regulation (EC) No 29/2009 of 16 January 2009 laying down requirements on data link services for the Single European Sky; and

(e) Commission Implementing Regulation (EU) No 1079/2012 of 16 November 2012 laying down requirements for voice channels spacing for the Single European Sky.

CS ACNS.A.GEN.005 Definitions

This section contains the definitions of terms used in these Certification Specifications and not defined in CS-definitions.

ICAO 24-bit Aircraft Address means a technical address used by Mode S protocols to identify the transponder on the 1030/1090 Mhz RF network. Each aircraft uses a unique 24-bit aircraft address allocated by their state of registry. This address may also be used by other types of avionics equipment for other purpose.

Advisory Alerts means the level or category of alert for conditions that require flight crew awareness and may require subsequent flight crew response.

ADS-B means automatic dependent surveillance - broadcast, a surveillance technique in which aircraft automatically provide, via a data link, data derived from on-board navigation and position-fixing systems. It refers to a surveillance technology where ADS-B Out equipped aircraft broadcast position, altitude, velocity, and other information in support of both air-to-ground and air-to-air surveillance applications.

ADS-B Device Failure refers to a condition announced to the flight crew whereby the ADS-B transmit unit is unable to transmit ADS-B messages.

ADS-B Function Failure refers to a condition announced to the flight crew whereby the position source(s) or interconnecting avionics fail to provide horizontal position data to the ADS-B transmit unit.

ADS-B Out system refers to the overall set of avionics that generate, transport, process, and transmit ADS-B data.

ADS-B Transmit Unit refers to that part of the ADS-B Out system that resides within the transponder and transmits 1090 MHz ES ADS-B data, including the data processing within that system.

Aircraft Identification means an alphanumeric chain that contains information allowing operational identification of individual flights. It contains either the Aircraft Identification as registered in item 7 of the flight plan or the aircraft registration if no flight plan has been filed.

Airship means a power-driven lighter-than-air aircraft.

Alert means a generic term used to describe a flight deck indication meant to attract the attention of and identify to the flight crew a non-normal operational or aeroplane system condition. Alerts are classified at levels or categories corresponding to Warning, Caution, and Advisory. Alert indications also include non-normal range markings (for example, exceedances on instruments and gauges).

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

ATN B1 mean Aeronautical Telecommunication Network Build 1.

ATS communications management service (ACM) means a service that provides automated assistance to flight crews and air traffic controllers for conducting the transfer of ATC communications (voice and data).

ATS Clearance and Information service (ACL) means a service that provides flight crews and controllers with the ability to conduct operational exchanges.

ATS microphone check service (AMC) means a service that provides air traffic controllers with the capability to send an instruction to one or several data link equipped aircraft, at the same time, in order to instruct flight crew(s) to verify that his/their voice communication equipment is not blocking a given voice channel.

Aural Alert means a discrete sound, tone, or verbal statement used to annunciate a condition, situation, or event.

Automatic Altitude Control System means any system that is designed to automatically control the aircraft to a referenced pressure altitude

Barometric Altitude Rate means the rate of climb estimated by using the difference of pressure.

Barometric Pressure Setting means the barometric pressure setting used by the pilot when flying the aircraft.

Comm-B: A 112-bit Mode S reply containing a 56-bit MB message field containing the extracted transponder register.

Caution means the level or category of alert for conditions that require immediate flight crew awareness and a less urgent subsequent flight crew response than a warning alert.

Continuity (system continuity) is the probability that a system will perform its required function without unscheduled interruption, assuming that the system is available at the initiation of the intended operation.

Controlled Flight Into Terrain (CFIT) means an accident or incident in which an aircraft, under the full control of the pilot, is flown into terrain, obstacles, or water.

CPDLC is the ICAO standardised procedure for Controller-Pilot Data Link Communications. CPDLC takes the form of an application, present on both aircraft and ground-based ATC centres that provides support for the Data Link Communications Initiation Capability (DLIC), ATS communications management service (ACM), ATS Clearance and Information service (ACL) and ATS microphone check service (AMC).

Data Link is a communication technology where 'Data Link' equipped aircraft communicate with 'Data Link' capable ground units to exchange digital information (bi-directional exchange).

Data Link Communications Initiation Capability (DLIC) means a service that enables the exchange of the necessary information for the establishment of data link communications between the ground and aircraft data link systems.

Data Quality Indicator refers to integrity and/or accuracy quality metrics that are associated with some of the ADS-B Out surveillance data, in particular with the horizontal position.

Downlink is a transfer of information, generated by an aircraft (not necessarily airborne) and sent to the ground for further processing by an ATC Centre.

Emergency indicators mean specific Mode A Code values: 7500 unlawful interference, 7600 radio failure, 7700 general emergency.

Failure condition terms are defined in AMC 25.1309, FAA AC 23.1309-1( ), AC 27-1B or AC 29-2C.

FANS 1/A means Future Air Navigation System 1 or Future Air Navigation System A,.

False Alert means an incorrect or spurious alert caused by a failure of the alerting system including the sensor

FMS Selected Altitude: The level altitude used by the FMS to manage the vertical profile of the aircraft.

Forward Looking Terrain Avoidance (FLTA) Looks ahead of the aeroplane along and below the aeroplane's lateral and vertical flight path and provides suitable alerts if a potential CFIT exists.

Global Navigation Satellite System (GNSS). A worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring.

Ground-Initiated Comm-B means a protocol which allows the interrogator to extract Comm-B replies containing data from a defined source.

Ground speed. The speed of an aircraft relative to the surface, or relative to a horizontal plane at present position.

Group Aircraft is a group of aircraft with similar altitude keeping equipment configurations and performance characteristics that are combined together for the purposes of statistical generic performance evaluation. Typically group aircraft refers to aircraft constructed to the same Type Certificate, Service Bulletin or Supplementary Type Certificate.

Hazard means a state or set of conditions that together with other conditions in the environment can lead to an accident.

Horizontal Velocity refers to the ground speed vector information.

Inertial Vertical Velocity means the rate of climb measure along the axis estimated using different sources including inertial reference.

Integrity (system integrity) is measured as the probability per operating hour of an undetected failure of a functional element that results in corrupted (erroneous) data, or a failure in the processing as specified, leading to the (partial) loss of otherwise available data.

Magnetic Heading means the angle between the aircraft centreline and magnetic North (angle between the direction to which the aircraft nose is pointing and the magnetic North).

MCP/FCU Selected Altitude means the level selected by the flight crew on the MCP or FCU of the aircraft. This altitude constitutes the level-off target input to the auto-pilot.

Mode S Elementary Surveillance refers to the use of Mode S surveillance data to downlink aircraft information from airborne installations.

Mode S Enhanced Surveillance refers to the use of other airborne information in addition to data used for Elementary Surveillance.

Non-group aircraft refers to an aircraft that is not a group aircraft but which is submitted for airworthiness approval on the characteristics of the unique airframe

Nuisance Alert means an alert generated by a system that is functioning as designed but which is inappropriate or unnecessary for the particular condition.

Qualitative Probability terms are defined in AMC 25.1309, FAA AC 23.1309-1( ), AC 27-1B or AC 29-2C.

Required Obstacle Clearance (ROC) means required vertical clearance expressed in ft between an aircraft and an obstruction.

Required Terrain Clearance (RTC) A Terrain Awareness and Warning System (TAWS) FLTA mode that alerts when the aeroplane is above the terrain in the aeroplane's projected flight path, but the projected amount of terrain clearance is considered unsafe for the particular phase of flight.

Roll Angle means the angle of wings compared to horizon representing the angle of rotation around the roll axis going along the centreline of the aircraft

RVSM Flight Envelope may be considered to be in two parts; the basic RVSM flight envelope and the full RVSM flight envelope. The basic envelope includes those ranges of Mach numbers and gross weights at which the aircraft can most frequently be expected to operate at RVSM levels (i.e. FL 290 to FL 410 (or maximum attainable altitude)). The full envelope refers to the entire range of Mach numbers, gross weights and altitude values that the aircraft can be operated in RVSM airspace.

RVSM operational flight envelope is the Mach number, W/δ, and altitude ranges over which an aircraft can be operated in cruising flight within the RVSM airspace.

Search Volume means a volume of airspace around the aeroplane's current and projected path that is used to define a TAWS alert condition.

Static Source Error (SSE) is the difference between the pressure sensed by the static system at the static port and the undisturbed ambient pressure.

Static Source Error Correction (SSEC) is the correction for the residual static error to ensure compliance with performance requirements.

Terrain Cell means a grid of terrain provided by the TAWS database which identifies the highest terrain elevation within a defined geographical area. Terrain cell dimensions and resolution can vary depending on the needs of the TAWS system and availability of data. If a supplier desires, obstacle height can be included in the terrain elevation.

Transponder means a device that transmits airborne surveillance data spontaneously or when requested. The transmissions are performed on 1090 MHz RF band and the interrogations are received on 1030 MHz RF band using SSR/Mode S protocols. It is also named Secondary Surveillance Radar transponder.

Track Angle Rate means the rate of change of the track angle.

Transmit refers to the provision of surveillance data by the transponder.

Transponder level means an indication of which Mode S data-link protocols are supported by a transponder. There are 5 transponder levels defined by ICAO.

Transponder register means a transponder data buffer containing different pieces of information. It has 56 bits which are split in different fields. The definition of the transponder registers can be found in ICAO Doc 9871 edition 2 and in transponder MOPS ED-73E with the ICAO document being the reference document in case of conflict. Transponder registers are numbered in hexadecimal (00hex to FFhex). The register number is also known as the BDS code (Comm-B data selector). In this documentation a register is named: register XY_{16} or register addressed by BDS code X,Y. Outside this document, it is also often referenced as just BDS X,Y.

True Track angle means the angle between the track (course over ground or path) of the aircraft and true north.

Uplink is a transfer of information, issued from any ground-based entity (typically: the ATC Centre under which the aircraft is under responsibility) to an aircraft (not necessarily airborne).

Warning means the level or category of alert for conditions that require immediate flight crew awareness and immediate flight crew response.

Worst case avionics means a combination of tolerance values, specified by the aircraft constructor for the altimetry fit into the aircraft which gives the largest combined absolute value for residual SSE plus avionics errors.

CS ACNS.A.GEN.010 Instructions for continued airworthiness

(See AMC1 ACNS.A.GEN.)

Instructions for continued airworthiness for each system, part or appliance as specified in this CS ACNS and any information related to the interface of those systems, parts or appliances with the aircraft are to be provided.

Subpart B — Communications (COM)

SECTION 1 – VOICE CHANNEL SPACING (VCS)

General

CS ACNS.B.VCS.001 Applicability

The section provides standards for aircraft voice communication systems operating in the band 117,975-137 MHz.

System functional requirements

CS ACNS.B.VCS.010 Voice Communication System

(see AMC1 ACNS.B.VCS.010)

(a) The voice communication system is capable of 8.33 kHz and 25 kHz channel spacing

(b) Voice communication system is capable of operating with off-set carrier frequencies on 25 kHz channel spacing.

System performance requirements

CS ACNS.B.VCS.020 Performance Requirements

The voice communication systems conforms to the performance requirements of the following sections of ICAO Annex 10, Volume III, Part 2 (Second Edition — July 2007 incorporating Amendment No 85) Chapter 2 'Aeronautical Mobile Service':

(a) Section 2.1 'Air-ground VHF communication system characteristics'.

(b) Section 2.2 'System characteristics of the ground installations' of ICAO.

(c) Section 2.3.1 'Transmitting function'.

(d) Section 2.3.2 'Receiving function' excluding sub-section 2.3.2.8 'VDL — Interference Immunity Performance'.

CS ACNS.B.VCS.025 Integrity

The voice communication systems is designed commensurate with a 'major' failure condition.

CS ACNS.B.VCS.030 Continuity

The continuity of the voice communication system is designed to an allowable qualitative probability of 'remote'.

Installation requirements

CS ACNS.B.VCS.040 Flight Deck Interface

(see AMC1 ACNS.B.VCS.040)

A means is provided to:

(a) select the voice communications channel;

(b) display the selected voice communications channel to the flight crew;

(c) indicate the non-operational status or failure of the system without undue delay;

SECTION 2 –DATA LINK SERVICES (DLS)

General

CS ACNS.B.DLS.B1.001 Applicability

(See GM1 ACNS.B.DLS.B1.001)

This section provides the airworthiness standard for ATN B1 with VDL Mode 2 data link aircraft systems to be installed on aircraft intended to be used for CPDLC Communications.

CS ACNS.B.DLS.B1.005 Installation Requirements

(See AMC1 ACNS.B.DLS.B1.005)

The data link system includes a means to enable data communication and flight deck annunciations and controls.

Flight deck control and indication capabilities

CS ACNS.B.DLS.B1.010 Flight Deck Interface

(See AMC1 ACNS.B.DLS.B1.010)

(a) A means is provided:

  (1) to inform clearly and unambiguously when uplinked messages are received;

  (2) for the flight crew to initiate the data link services;

  (3) for the flight crew to know in real time the identifier of the ATS provider(s) connecting with the aircraft;

  (4) to display all messages, with minimal flight crew action, in a format that is easy to comprehend and distinguishable from each other;

  (5) for the flight crew to respond to ATS messages;

  (6) to inform the flight crew that pending or open messages are waiting for a response;

  (7) for the flight crew to determine the status of the data link system;

(b) A means is provided to prohibit the deletion, confirmation, or clearance of a message until the entire message is displayed.

CS ACNS.B.DLS.B1.015 Dual Data Link Capabilities (Dual stack)

(See AMC1 ACNS.B.DLS.B1.015)

For aircraft integrating both FANS 1/A and ATN B1 CPDLC applications:

(a) Control and display: Messages with the same intent that are transmitted or received through these technologies are displayed in the same way.

(b) Alerting: Where a common alerting is not demonstrable, a mean is provided to distinguish between the alerting scheme in a format that is easy to comprehend .

ATN B1 data link

CS ACNS.B.DLS.B1.020 Data Link Services

(See AMC1 ACNS.B.DLS.B1.020 and GM1 ACNS.B.DLS.B1.020)

The data link system provides the following services:

(a) Data Link Initiation Capability (DLIC);

(b) ATC Communications Management (ACM);

(c) ATC Clearances and Information (ACL); and

(d) ATC Microphone Check (AMC).

CS ACNS.B.DLS.B1.025 Protection mechanism

(See AMC1 ACNS.B.DLS.B1.025, AMC2 ACNS.B.DLS.B1.025, AMC3 ACNS.B.DLS.B1.025, GM1 ACNS.B.DLS.B1.025, GM2 ACNS.B.DLS.B1.025 and GM3 ACNS.B.DLS.B1.025)

A means is provided to protect the integrity of the message.

System performance requirements

CS ACNS.B.DLS.B1.030 Integrity

The data link system integrity is designed commensurate with a 'major' failure condition.

CS ACNS.DLS.B1.035 Continuity

The data link system continuity is designed to an allowable qualitative probability of 'probable'.

Time

CS ACNS.B.DLS.B1.040 Universal Time Coordinated (UTC)

(See AMC1 ACNS.B.DLS.B1.040)

For time synchronisation a valid UTC time source is used.

Data link initiation capability (DLIC) service messages

CS ACNS.B.DLS.B1.050 DLIC Uplink Messages

(see AMC1 ACNS.B.DLS.B1.050)

The data link system is capable of receiving and processing the following messages for the DLIC logon and contact functions:

Function	Message
Logon	CMLogonResponse
Contact	CMContactRequest

CS ACNS.B.DLS.B1.055 DLIC Downlink Messages

(see AMC1 ACNS.B.DLS.B1.055)

The data link system is capable of sending the following messages for the DLIC logon and contact functions:

Function	Message
Logon	CMLogonRequest
Contact	CMContactResponse

CS ACNS.DLS.B.B1.060 DLIC Initiation when in CPDLC Inhibited State (Uplink)

When the data link system is in the 'CPDLC inhibited' state, DLIC Contact Request is processed but the system is remaining in the 'CPDLC inhibited' state.

CPDLC Messages

CS ACNS.B.DLS.B1.070 CPDLC Uplink Messages

(See AMC1 ACNS.B.DLS.B1.070, AMC2 ACNS.B.DLS.B1.070, GM1 ACNS.B.DLS.B1.070 and GM2 ACNS.B.DLS.B1.070)

The data link system is capable of receiving, processing and displaying the following message elements:

ID	Message
UM0	UNABLE
UM1	STANDBY
UM3	ROGER
UM4	AFFIRM
UM5	NEGATIVE
UM19	MAINTAIN [level]
UM20	CLIMB TO [level]
UM23	DESCEND TO [level]
UM26	CLIMB TO REACH [level] BY [time]
UM27	CLIMB TO REACH [level] BY [position]
UM28	DESCEND TO REACH [level] BY [time]
UM29	DESCEND TO REACH [level] BY [position]
UM46	CROSS [position] AT [level]
UM47	CROSS [position] AT OR ABOVE [level]
UM48	CROSS [position] AT OR BELOW [level]
UM51	CROSS [position] AT [time]
UM52	CROSS [position] AT OR BEFORE [time]
UM53	CROSS [position] AT OR AFTER [time]

ID	**Message**
UM54	CROSS [position] BETWEEN [time] AND [time]
UM55	CROSS [position] AT [speed]
UM61	CROSS [position] AT AND MAINTAIN
UM64	OFFSET [specifiedDistance] [direction] OF ROUTE
UM72	RESUME OWN NAVIGATION
UM74	PROCEED DIRECT TO [position]
UM79	CLEARED TO [position] VIA [routeClearance]
UM80	CLEARED [routeClearance]
UM82	CLEARED TO DEVIATE UP TO [specifiedDistance] [direction] OF ROUTE
UM92	HOLD AT [position] AS PUBLISHED MAINTAIN [level]
UM94	TURN [direction] HEADING [degrees]
UM96	CONTINUE PRESENT HEADING
UM106	MAINTAIN [speed]
UM107	MAINTAIN PRESENT SPEED
UM108	MAINTAIN [speed] OR GREATER
UM109	MAINTAIN [speed] OR LESS
UM116	RESUME NORMAL SPEED
UM117	CONTACT [unitname] [frequency]
UM120	MONITOR [unitname] [frequency]
UM123	SQUAWK [code]
UM133	REPORT PRESENT LEVEL
UM148	WHEN CAN YOU ACCEPT [level]
UM157	CHECK STUCK MICROPHONE [frequency]
UM159	ERROR [errorInformation]
UM162	SERVICE UNAVAILABLE
UM165	THEN
UM171	CLIMB AT [verticalRate] MINIMUM
UM172	CLIMB AT [verticalRate] MAXIMUM
UM173	DESCEND AT [verticalRate] MINIMUM
UM174	DESCEND AT [verticalRate] MAXIMUM
UM179	SQUAWK IDENT
UM183	[freetext]
UM190	FLY HEADING [degrees]
UM196	[freetext]
UM203	[freetext]
UM205	[freetext]

ID	Message
UM211	REQUEST FORWARDED
UM213	[facilitydesignation] ALTIMETER [altimeter]
UM215	TURN [direction] [degrees]
UM222	NO SPEED RESTRICTION
UM231	STATE PREFERRED LEVEL
UM232	STATE TOP OF DESCENT
UM237	REQUEST AGAIN WITH NEXT UNIT

The data link system is capable of receiving and processing the following message elements:

UM160	NEXT DATA AUTHORITY [facility]
UM227	LOGICAL ACKNOWLEDGEMENT

CS ACNS.B.DLS.B1.075 CPDLC Downlink Messages

(See AMC1 ACNS.B.DLS.B1.075, GM1 ACNS.B.DLS.B1.075, GM2 ACNS.B.DLS.B1.075 and GM3 ACNS.B.DLS.B1.075)

The data link system is capable of preparing and send the following downlink message elements:

ID	Message
DM0	WILCO
DM1	UNABLE
DM2	STANDBY
DM3	ROGER
DM4	AFFIRM
DM5	NEGATIVE
DM6	REQUEST [level]
DM18	REQUEST [speed]
DM22	REQUEST DIRECT TO [position]
DM32	PRESENT LEVEL [level]
DM62	ERROR [errorInformation]
DM63	NOT CURRENT DATA AUTHORITY
DM65	DUE TO WEATHER
DM66	DUE TO AIRCRAFT PERFORMANCE
DM81	WE CAN ACCEPT [level] AT [time]
DM82	WE CANNOT ACCEPT [level]
DM89	MONITORING [unitname] [frequency]
DM98	[freetext]
DM99	CURRENT DATA AUTHORITY

ID	Message
DM100	LOGICAL ACKNOWLEDGEMENT
DM106	PREFERRED LEVEL [level]
DM107	NOT AUTHORIZED NEXT DATA AUTHORITY
DM109	TOP OF DESCENT [time]

Data link services requirements

CS ACNS.B.DLS.B1.080 Data Link Initiation Capability (DLIC) Service

(See AMC 1 ACNS.B.DLS.B1.080 and GM1 ACNS.B.DLS.B1.080)

The data link system for DLIC conforms with section 4.1, 4.2.2 and 4.3.2 of EUROCAE Document ED-120 Safety and Performance Requirements Standard For Initial Air Traffic Data Link Services In Continental Airspace, including change 1 and change 2 and section 2.2.1 and 4.1 of EUROCAE Document ED-110B Interoperability Requirements Standard for Aeronautical Telecommunication Network Baseline 1.

CS ACNS.B.DLS.B1.085 ATC Communications Management (ACM) Service

(See AMC1 ACNS.B.DLS.B1.085 and GM1 ACNS.B.DLS.B1.085)

The data link system for ACM conforms with section 5.1.1, 5.1.2.3 (excluding requirements relating to downstream clearance) and 5.1.3.2 of EUROCAE Document ED-120 Safety and Performance Requirements Standard For Initial Air Traffic Data Link Services In Continental Airspace, including change 1 and change 2.

CS ACNS.B.DLS.B1.090 ACL Service Safety Requirements

(See AMC1 ACNS.B.DLS.B1.090 and GM1 ACNS.B.DLS.B1.090)

The data link system for ACL conforms with section 5.2.1, 5.2.2.3 and 5.2.3.2 of EUROCAE Document ED-120 Safety and Performance Requirements Standard For Initial Air Traffic Data Link Services In Continental Airspace, including change 1 and change 2.

CS ACNS.B.DLS.B1.095 ATC Microphone Check (AMC) Service

The data link system for AMC conforms with section 5.3.1, 5.3.2.3 and 5.3.3.2 of EUROCAE Document ED-120 Safety and Performance Requirements Standard For Initial Air Traffic Data Link Services In Continental Airspace, including change 1 and change 2.

Interoperability Requirements

CS ACNS.B.DLS.B1.100 Network Layer Requirements

(See AMC1 ACNS.B.DLS.B1.100 and GM1 ACNS.B.DLS.B1.100)

The ATN Router conforms to Class 6 with the capability to support Inter-domain routing protocol (IDRP) .

CS ACNS.B.DLS.B1.105 Transport Layer Protocol Requirements

(See AMC1 ACNS.B.DLS.B1.105 and GM1 ACNS.B.DLS.B1.105)

The ATN Connection Oriented Transport Protocol (COTP), conforms to Transport Protocol Class 4.

CS ACNS.B.DLS.B1.110 Session Layer Requirement

(See AMC1 ACNS.B.DLS.B1.110)

ATN Session protocol is capable of supporting the following session protocol data units (SPDUs):

Abbreviation	Full SPDU Name
SCN	Short Connect
DRPSAC	Short Accept
SACC	Short Accept Continue
SRF	Short Refuse
SRFC	Short Refuse Continue

CS ACNS.B.DLS.B1.115 Presentation Layer Requirements

(See AMC ACNS.B.DLS.B1.115)

ATN Presentation protocol is capable of supporting the presentation protocol data units (PPDUs) listed in the following table:

Abbreviation	Full PPDU Name
SHORT-CP	Short Presentation Connect, unaligned PER
SHORT-CPA	Short Presentation Connect Accept, unaligned PER
SHORT-CPR	Short Presentation Connect Reject

CS ACNS.B.DLS.B1.120 Application Layer Requirements

(See AMC1 ACNS.B.DLS.B1.120 and GM1 ACNS.B.DLS.B1.120)

The Application Layer is application-independent (also known as ‘Layer 7a’), and composed of a Convergence Function supporting operations of an Application Control Service Element (ACSE).

CS ACNS.B.DLS.B1.125 Database

The Network Service Access Point (NSAP) address database is capable of being updated.

Subpart C — Navigation (NAV)

(Reserved)

Subpart D — Surveillance (SUR)

Section 1 — Mode A/C only surveillance

GENERAL

CS ACNS.D.AC.001 Applicability

This section provides standards for Mode A/C only airborne surveillance installations.

SYSTEM FUNCTIONAL REQUIREMENTS

CS ACNS.D.AC.010 Transponder characteristics

(See AMC1 ACNS.D.AC.010)

(a) The transponder is approved and has Mode A and Mode C capability.

(b) The transponder replies with Mode A and Mode C replies to Mode A/C interrogations, to Mode A/C-only all-call interrogations, and to Mode A/C/S all-call interrogations.

(c) The peak pulse power available at the antenna end of the transmission line of the transponder is more than 125 W (21 dBW) and not more than 500 W (27 dBW) for aircraft that operate at altitudes exceeding 4 570m (15 000 ft) or with a maximum cruising speed exceeding 90 m/s (175 knots).

(d) The peak pulse power available at the antenna end of the transmission line of the transponder is more than 70 W (18.5 dBW) and not more than 500 W (27 dBW) for aircraft operating at or below 4 570m (15 000 ft) with a maximum cruising airspeed of 90 m/s (175 knots) or less.

CS ACNS.D.AC.015 Data transmission

(See AMC1 ACNS.D.AC.015)

The surveillance system provides the following data in the replies:

(a) The Mode A identity code in the range 0000 to 7777 (Octal).

(b) The pressure altitude corresponding 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 1.01325 10^5 Pa),used on board the aircraft to adhere to the assigned flight profile. The pressure altitude ranges from minus 304 m (1 000 ft) to the maximum certificated altitude of aircraft plus 1520 m (5 000 ft)

(c) Special Position Indication (SPI) for 15 to 30 seconds after an IDENT (SPI) command has been initiated by the pilot.

CS ACNS.D.AC.020 Altitude source

(See AMC1 ACNS.D.AC.020)

(a) The reported pressure altitude is obtained from an approved source.

(b) The altitude resolution is equal to or less than 30.48 m (100 ft.).

(c) The altitude source connected to the active transponder is the source being used to fly the aircraft.

CS ACNS.D.AC.025 Flight deck interface

(See AMC1 ACNS.D.AC.025)

A means is provided to:

(a) select Mode A Code including emergency indicators;

(b) initiate the IDENT (SPI) feature;

(c) notify the flight crew when the transmission of pressure altitude information has been inhibited if a means to inhibit the transmission of pressure altitude is provided;

(d) select the transponder to the 'standby' or 'OFF' condition;

(e) indicate the non-operational status or failure of the transponder system without undue delay and without the need for flight crew action;

(f) display the selected Mode A code to the flight crew; and

(g) select the pressure altitude source to be connected to the active transponder.

SYSTEM PERFORMANCE REQUIREMENTS

CS ACNS.D.AC.030 Integrity

The Mode A/C only airborne surveillance system integrity is designed commensurate with a 'minor' failure condition .

CS ACNS.D.AC.035 Continuity

The Mode A/C airborne surveillance system continuity is designed to an allowable qualitative probability of 'probable'.

INSTALLATION REQUIREMENTS

CS ACNS.D.AC.040 Dual/multiple transponder installation

(See AMC1 ACNSD.D.AC.040)

If more than one transponder is installed, simultaneous operation of the transponders is prevented.

CS ACNS.D.AC.045 Antenna installation

(See AMC1 ACNS.D.AC.045)

The installed antenna(s) has (have) a radiation pattern which is vertically polarised, omnidirectional in the horizontal plane, and has sufficient vertical beam width to ensure proper system operation during normal aircraft manoeuvres.

Section 2 — Mode S elementary surveillance

GENERAL

CS ACNS.D.ELS.001 Applicability

(See **AMC1 ACNS.D.ELS.001**)

This section provides the standards for airborne Mode S Elementary Surveillance installations.

SYSTEM FUNCTIONAL REQUIREMENTS

CS ACNS.D.ELS.010 Transponder characteristics

(See AMC1 ACNS.D.ELS.010)

(a) The transponder(s) is (are) an approved level 2 or greater Mode S transponder(s) with Elementary Surveillance and Surveillance Identifier (SI) capability.

(b) The transponder(s) of aircraft that have ACAS II installed is (are) ACAS compatible

(c) The peak pulse power available at the antenna end of the transmission line of the transponder is more than 125 W (21 dBW) and not more than 500 W (27 dBW) for aircraft that operate at altitudes exceeding 4 570 m (15 000 ft) or with a maximum cruising speed exceeding 90 m/s (175 knots).

(d) The peak pulse power available at the antenna end of the transmission line of the transponder is more than 70 W (18.5 dBW) and not more than 500 W (27 dBW) for aircraft operating at or below 4 570 m (15 000 ft) with a maximum cruising airspeed of 90 m/s (175 knots) or less.

CS ACNS.D.ELS.015 Data transmission

(See AMC1 ACNS.D.ELS.015)

(a) The surveillance system provides the following data in the Mode S replies:

  (1) The Mode A Code in the range 0000 to 7777 (Octal);

  (2) The pressure altitude corresponding to within plus or minus 38 m (125 ft), on a 95 per cent 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. The pressure altitude ranges from minus 300 m (1 000 ft) to the maximum certificated altitude of aircraft plus 1 500 m (5 000 ft);

  (3) On-the-ground status information;

  (4) The Aircraft Identification as specified in Item 7 of the ICAO flight plan or the aircraft registration;

  (5) Special Position Indication (SPI);

  (6) Emergency status (Emergency, Radio communication failure, Unlawful interference);

  (7) The data link capability report;

  (8) The common usage GICB capability report;

  (9) The ICAO 24-bit aircraft address; and

  (10) Aircraft that have ACAS II installed provide the ACAS active resolution advisory report.

(b) All other data transmitted is verified.

(1) If the system transmits one or more additional downlink airborne parameters in addition to those listed in paragraph (a), then the relevant sub specifications of CS ACNS.D.EHS.015 are also complied with.

(2) If the system transmits additional parameters on the extended squitter and if their full compliance with CS ACNS.D.ADSB has not been verified, as a minimum the aircraft identification, pressure altitude, ICAO 24-bit aircraft address is identical to those transmitted in the Mode S replies. Additionally the position and velocity quality indicators reports the lowest quality.

CS ACNS.D.ELS.020 On-the-ground status determination

(See **AMC1 ACNS.D.ELS.020**)

(a) The on-the-ground status is not set by a manual action.

(b) If automatic~~ally~~ determination of the On-the-ground status is not available, the On-the ground status is set to airborne.

CS ACNS.D.ELS.025 Altitude source

(See **AMC1 ACNS.D.ELS.025**)

(a) The reported pressure altitude is obtained from an approved source.

(b) The altitude resolution is equal to or less than 30.48 m (100 ft.).

(c) The altitude source connected to the active transponder is the source being used to fly the aircraft.

CS ACNS.D.ELS.030 Flight deck interface

(See AMC1 ACNS.D.ELS.030)

(a) A means is provided :

(1) to select Mode A Code, including emergency indicators;

(2) to initiate the IDENT (SPI) feature;

(3) for an aircraft identification to be inserted by the flight crew if the aircraft uses variable aircraft identification;.

(4) to notify the flight crew when the transmission of pressure altitude information has been inhibited, if a means to inhibit the transmission of pressure altitude is provided;

(5) to select the transponder to the 'standby' or 'OFF' condition;

(6) to indicate the non-operational status or failure of the transponder system without undue delay and without the need for flight crew action;

(7) to display the selected Mode A code to the flight crew;

(8) to display the aircraft identification to the flight crew; and

(b) Input which is not intended to be operated in flight, is not readily accessible to the flight crew.

SYSTEM PERFORMANCE REQUIREMENTS

CS ACNS.D.ELS.040 Integrity

The Mode S ELS airborne surveillance system integrity is designed commensurate with a 'minor' failure condition.

CS ACNS.D.ELS.045 Continuity

The Mode S ELS airborne surveillance system continuity is designed to an allowable qualitative probability of 'remote'..

INSTALLATION REQUIREMENTS

CS ACNS.D.ELS.050 Dual/multiple transponder installation

(See AMC1 ACNS.D.ELS.050)

If more than one transponder is installed, simultaneous operation of transponders is prevented.

CS ACNS.D.ELS.055 ICAO 24-bit Aircraft address

The ICAO 24-bit aircraft address assigned by the competent authority is correctly implemented on each transponder.

CS ACNS.D.ELS.060 Antenna installation

(See AMC1 ACNS.D.ELS.)

(a) The installed antenna(s) has (have) a resulting radiation pattern which is (are) vertically polarised, omnidirectional in the horizontal plane, and has (have) sufficient vertical beam width to ensure proper system operation during normal aircraft manoeuvres.

(b) Antenna(s) is/are located such that the effect on the far field radiation pattern(s) by the aircraft structure are minimised.

CS ACNS.D.ELS.065 Antenna diversity

(See AMC1 ACNS.D.ELS.)

Aircraft with a maximum certified take-off mass in excess of 5700 kg or a maximum cruising true airspeed capability, under International Standard Atmosphere (ISA) conditions, in excess of 130 m/s (250 knots) operates with an antenna diversity installation.

Section 3 — Mode S Enhanced Surveillance

GENERAL

CS ACNS.D.EHS.001 Applicability

(See AMC1 ACNS.D.EHS.001)

(a) This section provides standards for airborne Mode S EHS installations which provide on request (through Mode S replies elicited by Mode S interrogations) airborne parameters in addition to parameters provided by ELS installations compliant with Section 2.

Note: The criteria that are applicable to airborne installations providing spontaneously (through ADS-B Extended Squitters) airborne parameters are specified in Section 4.

(b) This certification specification is applied together with Mode S Elementary Surveillance certification specification defined in Section 2.

SYSTEM FUNCTIONAL REQUIREMENTS

CS ACNS.D.EHS.010 Transponder characteristics

(See AMC1 ACNS.D.EHS.)

The transponder is an approved Mode S transponder with EHS capability.

CS ACNS.D.EHS.015 Data transmission

(See AMC1 ACNS.D.EHS.)

(a) The surveillance system provides in the Mode S reply the following downlink aircraft parameters in addition to those specified in CS ACNS.D.ELS.:

(1) MCP/FCU Selected Altitude;

(2) Roll Angle;

(3) True Track Angle;

(4) Ground Speed;

(5) Magnetic Heading;

(6) Indicated Airspeed or Mach No ;

(7) Vertical rate: Barometric Altitude rate or Inertial vertical Velocity. When barometric altitude rate field is provided, it is derived solely from barometric measurement;

(8) Barometric Pressure Setting in use minus 80 000 Pascal; and

(9) Track Angle Rate or True Airspeed.

(b) The sensor sources connected to the active transponder are the sensors relevant to the aircraft flight profile.

(c) All transmitted parameters are correct and are correctly indicated as available.

SYSTEM PERFORMANCE REQUIREMENTS

CS ACNS.D.EHS.020 Integrity

The Mode S EHS airborne surveillance system integrity is designed commensurate with a 'minor' failure condition for the downlink aircraft parameters listed in CS ACNS.D.EHS.015.

CS ACNS.D.EHS.025 Continuity

The Mode S EHS airborne surveillance system continuity is designed to an allowable qualitative probability of 'probable' for the downlink aircraft parameters listed in CS ACNS.D.EHS.015.

Section 4 — 1090 MHz Extended Squitter ADS-B

GENERAL

CS ACNS.D.ADSB.001 Applicability

(See **GM1 ACNS.D.ADSB.001**)

This section provides standards for 1090 MHz Extended Squitter (ES) ADS-B Out installations.

SYSTEM FUNCTIONAL REQUIREMENTS

CS ACNS.D.ADSB.010 ADS-B Out system approval

(See **AMC1 ACNS.D.ADSB.010**)

The equipment contributing to the ADS-B Out function is approved.

ADS-B OUT DATA

CS ACNS.D.ADSB.020 ADS-B Out Data Parameters

(See **AMC1 ACNS.D.ADSB.020(a-b)**)

(a) The ADS-B Out system provides the following minimum set of data parameters:

(1) Aircraft Identification;

(2) Mode A Code;

(3) ICAO 24-bit aircraft address;

(4a) Airborne Horizontal Position — Latitude and Longitude;

(4b) Airborne Navigation Integrity Category: NIC;

(4c) Airborne/Surface Navigation Accuracy Category for Position: NACp;

(4d) Airborne/Surface Source Integrity Level: SIL;

(4e) Airborne/Surface System Design Assurance: SDA;

(5) Pressure Altitude (incl. NICbaro);

(6) Special Position Identification (SPI);

(7a) Emergency Status;

(7b) Emergency Indication;

(8) 1090 ES Version Number;

(9a) Airborne velocity over Ground — (East/West and North/South);

(9b) Airborne/Surface Navigation Accuracy Category for Velocity: NACv;

(10) Emitter Category;

(11) Vertical Rate;

(12a) Surface Horizontal Position — Latitude and Longitude;

(12b) Surface Navigation Integrity Category: NIC;

(13) Surface Ground Track;

(14) Movement (surface ground speed);

(15) Length/width of Aircraft;

(16) GPS Antenna Longitudinal Offset;

(17a) Geometric Altitude; and

(17b) Geometric Altitude Quality: GVA.

(b) Where available in a suitable format, the ADS-B Out system provides the following data parameters:

(1) Selected Altitude;

(2) Barometric Pressure Setting; and

(3) ACAS Resolution Advisory.

CS ACNS.D.ADSB.025 Provision of Data

(See AMC1 ACNS.D.ADSB.025(a)(c))

(a) All data provided by the ADS-B Out system comes from approved sources.

(b) The data transmitted by the ADS-B Out system originates from the same data source as used in the transponder replies to Mode S interrogations.

(c) When a data quality indication is required, it is provided to the ADS-B transmit unit together with the associated data parameter and it expresses the actual quality of the respective data as valid at the time of applicability of the measurement.

ADS-B TRANSMIT UNIT

CS ACNS.D.ADSB.030 ADS-B Transmit Unit Approval

(See **AMC1 ACNS.D.ADSB.**)

The ADS-B transmit unit is approved and it is integrated in the Mode S transponder.

CS ACNS.D.ADSB.035 ICAO 24-bit Aircraft address

The ICAO 24 bit aircraft address is implemented as specified in CS ACNS.D.ELS.055.

CS ACNS.D.ADSB.040 Antenna diversity

(See **AMC1 ACNS.D.ADSB.040**)

The ADS-B transmit unit employs antenna diversity under the same conditions as specified in **CS ACNS.D.ELS.065**.

CS ACNS.D.ADSB.045 Antenna installation

The antenna is installed as specified in CS ACNS.D.ELS.060.

CS ACNS.D.ADSB.050 Transmit power

The ADS-B transmit unit has a peak transmit power as specified in CS ACNS.D.ELS.010(c);(d).

CS ACNS.D.ADSB.055 Simultaneous operation of ADS-B transmit units

(See **AMC1 ACNS.D.ADSB.**)

If more than one ADS-B transmit unit is installed, simultaneous operation of the transmit systems is prevented.

CS ACNS.D.ADSB.060 On-the-ground status determination

(See **AMC1 ACNS.D.ADSB.**)

(a) The on-the-ground status is determined and validated by the ADS-B Out system.

(b) The on-the-ground status is not set by a manual action.

HORIZONTAL POSITION AND VELOCITY DATA SOURCES

CS ACNS.D.ADSB.070 Horizontal Position and Velocity Data Sources

(See **AMC1 ACNS.D.ADSB.**)

(a) The horizontal position is derived from GNSS data.

(b) The GNSS receiver based horizontal position and velocity data source is approved and performs, as a minimum, horizontal position receiver autonomous integrity monitoring (RAIM) and fault detection and exclusion (FDE).

(c) Horizontal velocity data stems from the same source as horizontal position data.

OTHER DATA SOURCES

CS ACNS.D.ADSB.080 Data Sources as defined by Mode S Elementary and Enhanced Surveillance

(See **AMC1 ACNS.D.ADSB.080**)

The data source requirements as defined for in section 2 and 3 of this subpart, are applicable.

CS ACNS.D.ADSB.085 Geometric Altitude

(See **AMC1 ACNS.D.ADSB.**)

(a) Geometric Altitude is provided by the horizontal position and velocity source (see CS ACNS.D.ADSB.070).

(b) Geometric Altitude is transmitted as height above WGS-84 ellipsoid.

FLIGHT DECK CONTROL AND INDICATION CAPABILITIES

CS ACNS.D.ADSB.090 Flight deck interface

(See **AMC1 ACNS.D.ADSB.090(a)** and AMC1 ACNS.D.ADSB.090(b))

(a) The control and display of surveillance data items is as per CS ACNS.D.ELS.030.

(b) A means is provided to indicate the non-operational status or failure of the ADS-B Out system without undue delay.

SYSTEM PERFORMANCE REQUIREMENTS

CS ACNS.D.ADSB.100 Integrity

(a) The ADS-B Out system integrity is designed commensurate with a 'major' failure condition for the transmission of the following parameters:

(1) ICAO 24-bit aircraft address;

(2) Airborne Horizontal Position — Latitude and Longitude;

(3) Airborne Navigation Integrity Category: NIC;

(4) Airborne/Surface Navigation Accuracy Category for Position: NACp;

(5) Airborne/Surface Source Integrity Level: SIL;

(6) Airborne/Surface System Design Assurance: SDA;

(7) 1090 ES Version Number;

(8) Airborne velocity over Ground — East/West and North/South;

(9) Airborne/Surface Navigation Accuracy Category for Velocity: NACv;

(10) Emitter Category;

(11) Surface Horizontal Position — Latitude and Longitude;

(12) Surface Navigation Integrity Category: NIC;

(13) Surface Ground Track;

(14) Movement (surface ground speed);

(15) Length/width of Aircraft;

(16) GPS Antenna Offset;

(17) Geometric Altitude;

(18) Geometric Altitude Quality: GVA;

(b) The ADS-B Out system integrity is designed commensurate with a 'minor' failure condition for the transmission of other data parameters.

CS ACNS.D.ADSB.105 Continuity

(a) The ADS-B Out system continuity is designed to an allowable qualitative probability of 'remote'.

HORIZONTAL POSITION AND VELOCITY DATA REFRESH RATE AND LATENCY

CS ACNS.D.ADSB.110 Horizontal Position and Velocity Data Refresh Rate

(See AMC1 ACNS.D.ADSB.)

A horizontal position and velocity source calculates position and velocity data with a rate of at least 1 Hertz.

CS ACNS.D.ADSB.115 Horizontal Position and Velocity Total Latency

(See **AMC1 ACNS.D.ADSB.115 and 120**)

Measured from the time of applicability within the source, the total latency of the horizontal position and horizontal velocity data introduced by the ADS-B Out system does not exceed 1.5 second.

CS ACNS.D.ADSB.120 Horizontal Position Uncompensated Latency

(See **AMC1 ACNS.D.ADSB.115 and 120**)

The uncompensated latency of the horizontal position data introduced by the ADS-B Out System does not exceed 0.6 second.

Subpart E — Others

SECTION 1 – TERRAIN AWARENESS AND WARNING SYSTEM (TAWS)

General

CS ACNS.E.TAWS.001 Applicability

(See GM1 ACNS.E.TAWS.001)

This section provides the airworthiness standards applicable to Terrain Awareness and Warning System Class A and Class B for aeroplanes.

CS ACNS.E.TAWS.005 TAWS Equipment Approval

(See AMC1 ACNS.E.TAWS.005)

The TAWS is Class A or Class B approved equipment.

System functional requirements

CS ACNS.E.TAWS.010 Required Functions and Interfaces

(See AMC1 ACNS.E.TAWS.010, AMC2 ACNS.E.TAWS.010)

TAWS Class A or Class B provides suitable alerting and warning capabilities and other system interfaces to support the following functions:

TAWS System Function		**Class A TAWS**	**Class B TAWS**
Alerting	Imminent contact with ground indications (GPWS functions) including: (19) excessive Rates of Descent; (20) negative Climb Rate or Altitude Loss After Take-Off or Go-around. A Voice callout when descending through a predefined altitude above the terrain or nearest runway elevation.	X With a 500 ft call out	x With a 500 ft call out
	A forward Looking Terrain Avoidance (FLTA) function, including: • a Reduced Required Terrain Clearance (RTC) function; • an Imminent Terrain Impact function; • a FLTA Turning Flight function.	x	x
	A Premature Descent Alert (PDA) function, including detection and alerting for Premature Descents Along the Final Approach Segment	x	x

TAWS System Function		Class A TAWS	Class B TAWS
	Excessive Closure Rate to Terrain	x	
	Flight Into Terrain When not in Landing Configuration	x	
	Excessive Downward Deviation from a glide slope or glide path	x	
	TAWS and sensor failure monitoring and annunciation function	x	x
	Capability to initiate the TAWS self-test function on the ground and where feasible in the air	x	x

TAWS System Interfaces		Class A TAWS	Class B TAWS
	A terrain display capability	x	
	Capability to drive a terrain display		x
	The use of position source input	x	x
	The use of landing guidance deviation input	x	
	The use of radio altimeter sensor input	x	
	The use of Terrain and Airport information	x	x
	Interface with the flight recording system to record TAWS alerts and inhibition of the FLTA or PDA functions	x	x
	The use of landing gear and flaps position	x	
	The use of roll attitude input	x	
	The interface with flight deck audio systems	x	

CS ACNS.E.TAWS.015 FLTA function requirements

(See AMC1 ACNS.E.TAWS.015)

Provide an FLTA function that:

(a) Provides an Forward Looking Terrain Avoidance (FLTA) function that looks ahead of the airplane along and below the airplane's lateral and vertical flight path and provides suitable alerts if a potential CFIT threat exists.

(b) Provides a Required Terrain Clearance (RTC) alerts when the aeroplane is currently above the terrain in the aeroplane's projected flight path but the projected amount of terrain clearance is considered unsafe for the particular phase of flight.

TAWS REQUIRED TERRAIN CLEARANCE (RTC) BY PHASE OF FLIGHT	TAWS (RTC) Level Flight	TAWS (RTC) Descending /climbing
En route	215 m (700 ft)	150 m (500 ft)
Terminal (Intermediate Segment)	105 m (350 ft)	90 m (300 ft)
Approach	45 m (150 ft)	30 m (100 ft)
Departure (above 400 ft)	30 m (100 ft)	30 m (100 ft)

TABLE 1

(c) gives Imminent Terrain Impact alerts when the aeroplane is currently below the elevation of a terrain cell along the aeroplane's lateral projected flight path and, based upon the vertical projected flight path, the equipment predicts that the terrain clearance will be less than the value given in the RTC column of Table 1.

(d) gives alerts for the Imminent Terrain Impact and Required Terrain Clearance functions when the aeroplane is in turning flight.

CS ACNS.E.TAWS.020 PDA function requirements

(See GM1 ACNS.E.TAWS.020)

Provide a Premature Descent Alert function:

(a) to determine if the aeroplane is significantly below the normal approach flight path to a runway and in such a case issue an alert, based on the current position and flight path information of the aeroplane, as determined from a suitable navigation source and airport database;

(b) that is available on all types of instrument approaches including straight-in approaches, circling approaches and approaches that are not aligned within 30 degrees of the runway heading.

CS ACNS.E.TAWS.025 Class A TAWS inhibition

(See AMC1 ACNS.E.TAWS.025)

A means is provided to:

(a) the flight crew to inhibit the FLTA and PDA functions together with appropriate annunciation of the inhibited condition. Inhibiting FLTA and PDA does not impact the Basic GPWS functions;

(b) indicate to the flight crew of the 'Inhibit status'.

CS ACNS.E.TAWS.030 Terrain information display

(See AMC1 ACNS.E.TAWS.030)

(a) When terrain information is provided it is clearly visible to the flight crew.

(b) Terrain information is displayed as follows:

(1) The terrain is depicted relative to the aeroplane's position such that the pilot may estimate the relative bearing and distance to the terrain of interest.

(2) The terrain depicted is oriented in accordance with the orientation of the navigation information used on the flight deck.

(3) Variations in terrain elevation depicted relative to the aeroplane's elevation (above and below) are visually distinguishable.

(4) Terrain that generates alerts is displayed in a manner to distinguish it from non-hazardous terrain, consistent with the caution and warning alert level.

(5) If the terrain is presented on a multi-function display, the terrain mode and terrain information is distinguishable from weather and other features.

(6) Terrain information is readily available and displayed with sufficient accuracy and in a manner to allow the flight crew to determine if it is a terrain threat to the aeroplane.

(c) The display of terrain data complements and is compatible with the terrain alerting function of the TAWS.

(d) The terrain information is clear and unambiguous, available without potential confusion during day and night operations under all ambient conditions expected in service.

(e) Where additional terrain views are provided, they must present information consistent and compatible with (a) to (e) above.

CS ACNS.E.TAWS.035 Aural and visual alerts

(See AMC1 ACNS.E.TAWS.035)

(a) The TAWS provides suitable aural and visual alerts for each of its functions.

(b) Aural and visual alerts are initiated simultaneously, except when suppression of aural alerts is necessary to protect pilots from nuisance aural alerting.

(c) Each aural alert identifies the reason for the alert.

(d) The system is capable of accepting and processing aeroplane performance related data or aeroplane dynamic data and providing the capability to update aural and visual alerts at least once per second.

(e) The aural and visual outputs is compatible with the standard cockpit displays and auditory systems.

(f) The visual display of alerting information is continuously displayed until the situation is no longer valid.

System performance requirements

CS ACNS.E.TAWS.040 Integrity

(a) Integrity of the TAWS (including un-enunciated loss of the terrain alerting function) is designed commensurate with a major failure condition.

(b) False terrain alerting is designed commensurate with a minor failure condition.

(c) Failure of the installed TAWS does not degrade the integrity of any critical system interfacing with the TAWS.

CS ACNS.E.TAWS.045 Continuity

Continuity of the TAWS is designed to an allowable qualitative probability of 'probable'.

CS ACNS.E.TAWS.050 GPWS

The predictive terrain hazard warning functions, does not adversely affect the functionality, reliability or integrity of the basic GPWS functions.

CS ACNS.E.TAWS.055 Terrain and airport information

(See AMC1 ACNS.E.TAWS.055)

(a) Terrain and airport information are developed in accordance with an acceptable standard.

(b) TAWS is capable of accepting updated terrain and airport information.

CS ACNS.E.TAWS.060 Positioning information

(See AMC1 ACNS.E.TAWS.060)

(a) The positioning information (i.e. horizontal and vertical position, velocity, or rate of information) is provided from an approved positioning source.

(b) For Class B TAWS, GNSS is the only approved horizontal positioning source.

(c) When the TAWS positioning source is the same as the one used by the primary navigation system and provided that, applicable performance requirements are satisfied for navigation, a failure of the TAWS (including loss of electrical power to the TAWS) does not degrade the primary navigation capability.

(d) When a positioning source generates a fault indication or any flag indicating the position is invalid or does not meet performance requirements, the TAWS is to stop utilising that positioning source.

(e) The positioning source for the predictive terrain hazard warning system accuracy is suitable for each phase of flight and/or region of operations.

(f) The TAWS provides indications, as appropriate, regarding degradation or loss of function associated with the loss of the positioning source.

Installation requirements

CS ACNS.E.TAWS.070 Failure mode

(a) A failure of the TAWS does not disable other protection functions (e.g. windshear or weather radar).

(b) The failure of the GPWS functions, except for power supply failure, input sensor failure, or other failures external to the TAWS functions, does not negatively alter the FLTA function, PDA function, or Terrain Display and vice versa.

(c) Where the terrain information is displayed on a multi-function display, failure of the TAWS does not prevent the normal functioning of other systems using that display.

CS ACNS.E.TAWS.075 Prioritisation scheme

(See AMC1 ACNS.E.TAWS.075)

The prioritisation scheme for Class A TAWS alerts is compatible and consistent with other alerts including voice call outs from all alerting systems.

CS ACNS.E.TAWS.080 Pop-up mode

(See AMC1 ACNS.E.TAWS.080)

(a) If implemented, the design of an automatic pop-up function ensures that:

(1) the terrain information is automatically displayed on all crew member terrain displays, when either a predictive terrain caution or a predictive terrain warning alert occurs;

(2) the TAWS pop-up function is consistent with pop-up weather and traffic alerts;

(3) it is evident that an automatic pop-up has occurred;

(4) the terrain display mode is annunciated on the display;

(5) manual switching back to the original display mode is simple.

SECTION 2 – REDUCED VERTICAL SEPARATION MINIMUM (RVSM)

General

CS ACNS.E.RVSM.001 Applicability

(SEE AMC1 ACNS.E.RVSM.001)

This section provides airworthiness standard for aircraft to operate a 300 m (1000 ft) vertical separation within RVSM airspace.

CS ACNS.E.RVSM.005 RVSM system

(See AMC1 ACNS.E.RVSM.005)

The RVSM system includes:

(a) two independent altitude measurement systems. Each system is composed of the following elements:

  (1) Cross-coupled static source/system, with ice protection if located in areas subject to ice accretion;

  (2) Equipment for measuring static pressure sensed by the static source, converting it to pressure altitude;

  (3) Equipment for providing a digitally encoded signal corresponding to the displayed pressure altitude, for automatic altitude reporting purposes;

  (4) Static source error correction (SSEC), as required to meet the performance criteria as specified in CS ACNS.E.RVSM.035; and

  (5) Signals referenced to a pilot selected altitude for automatic control and alerting derived from one altitude measurement system.

(b) an altitude alerting system;

(c) an automatic altitude control system; and

(d) a secondary surveillance radar (SSR) transponder with altitude reporting system that can be connected to the altitude measurement system in use for altitude keeping.

System functional requirements

CS ACNS.E.RVSM.010 Required functions

(See AMC1 ACNS.E.RVSM.010)

The system:

(a) provides indication to the flight crew of the pressure altitude being flown;

(b) based on the signal produced by the altimetry system, automatically maintains a selected flight level with its altitude control system;

(c) provides an alert to the flight crew when the altitude displayed to the flight crew deviates from the selected altitude by a value of ±60 m (±200 ft) or greater;

(d) automatically reports pressure altitude;

(e) provides an output to the aircraft transponder.

System performance requirements

CS ACNS.E.RVSM.020 Integrity

The RVSM system integrity is designed commensurate with a major failure condition.

CS ACNS.E.RVSM.025 Continuity

The RVSM system continuity is designed to an allowable qualitative probability of 'remote'.

CS ACNS.E.RVSM.030 RVSM system performance

(See AMC1 ACNS.E.RVSM.030)

(a) The automatic altitude control system controls the altitude within ±20 m (65 ft) about the selected altitude, when the aircraft is operated in straight and level flight under non-turbulent non-gust conditions.

(b) The tolerance of the alert issued when the altitude displayed to the flight crew deviates from the selected altitude by a value of ±60 m (±200 ft) or greater is no greater than ±15 m (±50 ft).

(c) Where an altitude select/acquire function is provided, the altitude select/acquire control panel is configured such that an error of no more than ±8 m (±25 ft) exists between the value selected by, and displayed to, the flight crew, and the corresponding output to the control system.

CS ACNS.E.RVSM.035 Altimetry system accuracy

(See AMC1 ACNS.E.RVSM.035, GM1 ACNS.E.RVSM.035)

(a) For Group aircraft, the altimetry system accuracy meets the following criteria in the full envelope:

   (1) At the point of the flight envelope where the mean ASE (ASEmean) reaches its largest absolute value that value does not exceed 25 m (80 ft);

   (2) At the point of the flight envelope where the absolute mean ASE plus three standard deviations of ASE (ASE3SD) reaches its largest absolute value, the absolute value does not exceed 60 m (200 ft).

(b) For RVSM installations on a non-group aircraft, the altimetry system accuracy meets the following criteria:

   (1) For all conditions in the basic envelope:

   | residual static source error +worst case avionics | does not exceed 50 m (160 ft).

   (2) For all conditions in the full envelope (outside the basic envelope):

   | residual static source error +worst case avionics | does not exceed 60 m (200 ft).

CS ACNS

Book 2

Acceptable Means of Compliance (AMC)
and
Guidance Material (GM)

(a) GENERAL

Book 2 contains Acceptable Means of Compliance (AMC) and Guidance Material (GM).

(b) PRESENTATION

(1) The Acceptable Means of Compliance and Guidance Material are presented in full page.

(2) A numbering system has been used in which the Acceptable Means of Compliance and Guidance Material use the same number as the paragraph in Book 1 to which they are related. The number is introduced by the letters AMC (Acceptable Means of Compliance) or GM (Guidance Material) to distinguish the material from Book 1. Reference to the Acceptable Means of Compliance and/or Guidance Material, when applicable, is included in the heading of each Book 1 paragraph

(3) Explanatory Notes, not forming part of the AMC text, appear in italic typeface.

(4) The units of measurement used in this document are in accordance with the International System of Units (SI) specified in Annex 5 to the Convention on International Civil Aviation. Non-SI units are shown in parentheses following the base units. Where two sets of units are quoted, it should not be assumed that the pairs of values are equal and interchangeable. It may be inferred, however, that an equivalent level of safety is achieved when either set of units is used exclusively.

Subpart A — General

AMC1 ACNS.A.GEN.010 Instructions for Continued Airworthiness

(a) Transponder testing

The Instructions for Continued Airworthiness should include the following measures and precautions in order to minimise the possibility of causing nuisance warnings to ACAS equipped aircraft.

(1) When not required, ensure all transponders are selected to ‘OFF‘ or ‘Standby‘.

(2) Before starting any test, contact the local Air Traffic Control Unit and advise them of your intention to conduct transponder testing. Advise the Air Traffic Unit of your start time and test duration. Also inform them of the altitude(s) at which you will be testing, your intended Aircraft Identification (Flight Id) and your intended Mode A code.

Note: Certain altitudes may not be possible due to over flying aircraft.

(3) Set the Mode A code to 7776 (or other Mode A code agreed with Air Traffic Control Unit).

Note: The Mode A code 7776 is reserved for SSR ground transponder monitoring. This code may be used for transponder testing after having received agreement from the Air Traffic Control Unit.

(4) Set the Aircraft Identification (Flight Id) with the first 8 characters of the company name. This is the name of the company conducting the tests.

(5) Set the on-the-ground status for all Mode S replies, except when an airborne reply is required (e.g. for altitude testing).

(6) Where possible, perform the testing inside a hangar to take advantage of any shielding properties it may provide.

(7) As a precaution, use antenna transmission covers whether or not testing is performed inside or outside.

(8) When testing the altitude (Mode C or S) parameter, radiate directly into the ramp test set via the prescribed attenuator.

(9) In between testing, i.e., to transition from one altitude to another, select the transponder to ‘standby’ mode.

(10) If testing transponder parameters other than ‘altitude‘, set altitude to minus 300 m (minus 1 000 feet) or over 18 250 m (60 000 feet). This will minimise the possibility of ACAS warning to airfield and overflying aircraft.

(11) When testing is complete, select the transponder(s) to ‘OFF‘ or ‘Standby’.

(b) Reduced Vertical Separation Minima

When developing the instructions for continued airworthiness, attention should be given to the following items:

(1) All RVSM equipment should be maintained in accordance with the component manufacturers' maintenance instructions and the performance criteria of the RVSM approval data package.

(2) Any repairs, not covered by approved maintenance documents, that may affect the integrity and accuracy of the altimeter system , e.g. those affecting the alignment of pitot/static probes, repairs to dents or deformation around static plates should be subject to a design review which is acceptable to the competent authority.

(3) Airframe geometry or skin waviness checks should be performed following repairs or alterations which have an effect on airframe surface and airflow.

(4) The maintenance and inspection programme for the autopilot should ensure continued accuracy and integrity of the automatic altitude control system.

Subpart B — Communications (COM)

SECTION 1 - VOICE CHANNEL SPACING (VCS) (8.33 KHZ)

AMC1 ACNS.B.VCS.010 Voice Communication Systems

The VCS equipment composing of the system should be approved in accordance with ETSO-2C37e, ETSO-2C38e or ETSO-2C169a.

For the 25 kHz channel spacing off-set carrier frequency operations the equipment composing the system should conform with the requirements of EUROCAE document ED-23C

In airspace where 8.33 kHz channel spacing communication equipment is mandatory and the carriage of two radios is required, both radios should be 8.33 kHz capable (as opposed to one 8.33 kHz system and one 25 kHz system).

AMC1 ACNS.B.VCS.040 Flight Deck Interface

Flight Crew control and display of communication frequencies information should be consistent with the overall crew flight deck design philosophy.

SECTION 2 –DATA LINK SERVICES

General

GM1.ACNS.B.DLS.B1.001 Applicability

Controller pilot communications through data link is used in different airspaces worldwide. Different technologies are used, and this CS is intended to provide the airworthiness standard for such installations. Additionally, controller pilot communications over ATN B1 data link technology has been mandated in Europe, through the Regulation (EC) No 29/2009. Installations intended to operate within EU Airspace defined in mentioned regulation, should fully comply with all requirements of 'DATA LINK SERVICES' section, in its entirety.

Installations not intended to operate within EU Airspace, are not required to comply with mentioned section.

Note: Requirements CS ACNS.B.DLS.B1.010 and 015 are also applicable for CPDLC installations where, additionally to ATN B1 over VDL M2, other means of communications and other services are also provided.

GM1 ACNS.B.DLS.B1.005 Data Link System Installation

An example of installation may be a system comprising the following components or inputs:

A VHF Data Radio (VDR) with Mode 2 capability and its associated antenna.

A Unit for Communication Management with Mode 2 and ATN capabilities

A display unit with means for crew to be notified of ATS Requests and Clearances, and issue downlink crew requests to controllers or responses to outstanding messages (from controllers).

An adequate source for UTC time e.g. a Global Navigation Satellite System (GNSS).

An adequate source for conducted flight plan information (Departure Airport, Destination Airport, Estimated Time of Arrival) e.g. Flight Management System (FMS)

An adequate source of aeroplane position e.g. Flight Management System (FMS), or a Global Navigation Satellite System (GNSS) or both

An adequate source for Air/Ground Status information e.g. an interface with the landing gear or Flight Management System (FMS) or both

An adequate aural attention getter for announcements.

Adequate indication means of system and service availability.

Adequate control means for the crew.

Flight Deck Control and Indication Capabilities

AMC1 ACNS.B.DLS.B1.010 Flight Deck Interface

Flight crew control and display of data link related information (connectivity status, outstanding messages, etc.) should be consistent with the overall crew flight deck design philosophy.

Flight crew control and display of data link messages should satisfy integrity and interface design criteria appropriate for the intended purpose. Reference to the applicable CS xx.1309 requirements should be observed.

If a direct interface exists between the data link application and other on board systems, (e.g. flight planning and navigation), a means may be provided for the flight crew to initiate the use of the data contained in the message by the other on board system. The means provided should be separate from that used to respond to a message.

Flight deck annunciations should be compatible with the overall alerting scheme of the aircraft.

Audible and visual indications should be given by the data link system for each uplinked ATS message, including those messages not displayed immediately because of lack of crew response to an earlier ATS message. Visual alerts alone may be used for non-ATS messages.

Annunciation of the receipt of a message during critical flight phases should be inhibited until after the critical flight phase. The criteria that define critical flight phases should be consistent with the particular flight deck philosophy and the particular data link services supported.

Means should be provided for the flight crew to list, select, and retrieve the most recent ATS messages received and sent by the flight crew during the flight segment. The status of each message, the time it was received or sent, should be accessible.

When CPDLC messages are displayed:

(a) such location should be in the Primary Field of View.

(b) messages should be provided in a dedicated display (or in a dedicated window of a display). Shared use of CPDLC and other applications in a common display (or in the same window of a display) should be avoided.

Note 1: (a) and (b) are intended for future extension of CPDLC use beyond en-route flight phase. Installations not in accordance with these recommendations are liable to be limited for CPDLC operations in the en-route or prior departure flight phase.

Note 2: Where data link messages are displayed on a shared display or on a shared display area, selection of another display format or function should not result in the loss of uplinked messages which are waiting for a response. In case the pilot is working on another task and a message is uplinked, the uplinked message should not interrupt the current work, nor result in the loss of any uplinked message and/or data entered while accomplishing the other task.

(c) messages from the ATS should remain displayed until responded, cleared or the flight crew selects another message.

(d) means should be provided for the flight crew to clear uplinked messages from the display. However, this capability should be protected against inadvertent deletion.

Means should be provided for the flight crew to create, store, retrieve, edit, delete, and send data link messages.

The data link system should indicate when message storage and/or printing is not available.

A flight deck printer could be used as a means of storing data communications messages received or sent during flight.

If a message intended for visual display is greater than the available display area and only part of the message is displayed, a visual indication shall be provided to the pilot to indicate the presence of remaining message.

Data link messages from the ATS should be displayed and remain displayed until responded, cleared or the flight crew selects another message.

The status of each message (i.e. source, time sent, open/closed) should be displayed together with the message.

AMC1.ACNS.B.DLS.B1.015 Dual Data Link Capabilities (Dual stack)

Note: A Dual stack system is either a bilingual system capable of automatically selecting the data link network or a dual system that use manual selection with an interlock system.

The data link system should comply with ED-154A, interoperability requirements IR-207, IR-209, IR-210, IR-211, IR-212, IR-214, and IR-215 to ensure seamless transition between two adjacent ATSUs, one using FANS 1/A+ and the other using ATN B1.

The data link system should demonstrate common accessibility to the FANS 1/A and ATN B1 CPDLC applications. Accessibility demonstration should include common controls (i.e. line select keys) or, where different, the potential to introduce confusion or unacceptable flight crew workload should be evaluated.

The data link system should demonstrate common control and input procedures for retrieving and responding to FANS 1/A and ATN B1 uplink messages.

The data link system should demonstrate common control and input procedures for composing and sending FANS 1/A and ATN B1 downlink messages.

The data link system should demonstrate common flight deck indications for incoming FANS 1/A and ATN B1 messages. Where common alerting is not demonstrable, the alerting scheme evaluate to ensure that neither confusion nor unnecessary flight crew workload is introduced.

Annunciations and indications should be clear, unambiguous, timely, and consistent with the flight deck philosophy.

FANS 1/A differentiates messages alerting between normal and Urgent. Upon receipt of a high alert CPDLC message, the data link system should indicate it to the flight crew.

Note: FANS 1/A standard (ED-100A) identifies the term 'IMMEDIATELY', within the phraseology standardised for CPDLC communications. This term is to be understood within the required communications performance scope (RCP), which for oceanic and remote operations is either 240 seconds or 400 seconds. The use of these terms 'IMMEDIATELY' and 'EXPEDITE' are not to be confused with the terminology used in material related to CS 25.1322. However, annunciations and indications should allow flight crews to easily identify these messages (associated with Urgent and Distress urgency attribute) among the normal messages.

Flight Deck Display of Messages from either FANS 1/A or ATN B1 CPDLC Applications:

A common flight deck display should be capable of displaying messages with the same operational intent resulting from same message elements that may be implemented differently between FANS 1/A and ATN B1 CPDLC applications. The common format to display FANS 1/A messages may be in accordance with the preferred format denoted in Annex A of ED 122, which is consistent with Doc 4444, 15th Ed, and ATN B1 message formats.

Dual Stack ATS Data Link System Status Indication:

The system should provide the flight crew with a means to clearly identify the status of different modes of the data link system that affect significant operational capability. Examples of different modes of data link may include situations when downlink messages are available in one airspace, but not the other; or messages that may or may not be loadable depending on system status, i.e., ATN B1 or FANS 1/A.

ATSU Connections and Handoffs:

The system should be capable of the following functions:

(1) Proper connection and termination for FANS 1/A ATSU.

(2) Proper connection and termination for ATN B1 ATSU.

(3) Transfer to next data authority (e.g., FANS 1/A ATSU to ATN B1 ATSU), in both directions. This should include proper connection, maintenance of connection and connection termination protocol to ensure that aircraft does not hold two simultaneous active CPDLC connections.

(4) Ability for flight crew to manually terminate existing connection and establish new connection, initiate a DLIC 'logon' in both directions (i.e., FANS 1/A-to-ATN B1 and ATN B1-to-FANS 1/A).

(5) Ability for flight crew to verify current and next facility designation or name.

Note: FAA AC 20-140A provides adequate guidance related to the application interoperability, sub-networks and performance designators. (refer to Tables 5.1 and 5.2).

ATN B1 Data link

AMC1 ACNS.B.DLS.B1.020 Data Link Services

When the aircraft has no CPDLC Current Data Authority, the data link aircraft equipment should provide crew members entering an airspace of a data link equipped ATS unit with the capability to initiate a DLIC ‘Logon’ function (e.g. send a CMLogonRequest message) with the applicable ATS unit, in order to identify the aircraft and initiate the use of data link services.

GM1 ACNS.B.DLS.B1.020 Data Link Services

.Community Specification EN 303 214 ‘Data Link Services (DLS) System’ provides a set of test scenarios that demonstrated using verified ground data link system or ground data link system simulator.

GM1 ACNS.B.DLS.B1.020 Data Link Services

(a) **Data Link Initiation Capability (DLIC) Service**

The DLIC service enables the exchange of information between aircraft and ground data link equipment necessary for the establishment of data link communications. It ensures:

(1) the unambiguous association of flight data from the aircraft with flight plan data used by an ATS unit,

(2) the exchange of the supported air–ground application type and version information,

(3) the delivery of the addressing information of the entity hosting the application.

(b) **ATC Communications Management (ACM) Service**

The ACM service provides automated assistance to flight crews for conducting the transfer of ATC communications (voice and data). It includes:

(1) the initial establishment of CPDLC with an ATS unit;

(2) the CPDLC ATC transfer instruction from one ATS unit to the next ATS unit;

(3) the CPDLC ATC instructions for a change in voice channel;

(4) the normal termination of CPDLC with an ATS unit.

(c) **ATC Clearances and Information (ACL) Service**

The ACL service provides flight crews with the ability to:

(1) send requests and reports to air traffic controllers;

(2) receive clearances, instructions and notifications issued by air traffic controllers to flight crews.

(d) **ATC Microphone Check (AMC) Service**

The AMC service provides CPDLC ATC instructions to flight crew(s) requesting him/them to verify the status of his/their voice communication equipment

AMC1 ACNS.B.DLS.B1.025 Protection mechanism

The data link system should comply with the following applicable ATN Baseline 1 standards:

- ICAO Document 9705 (Edition 2) for ICS (Sub-Volume V), ULCS (Sub-Volume IV), CM CPDLC (Sub-Volume II) ASE requirements;
- EUROCAE Document ED-110B;
- ICAO Document 9776 and ARINC 631-6 for VDL Mode 2 multi-frequency operations.

The data link aircraft equipment should provide support for the CPDLC application message integrity check mechanism , with support for 'default checksum algorithm' only.

AMC2 ACNS.B.DLS.B1.025 Protection mechanism

Testing demonstrations could be based in two main steps:

- Equipment testing (done by equipment manufacturer) using adequate simulation testing tools.
- System testing, at system test bench and/or at aircraft test level (either on ground or in flight).

Equipment qualification testing data may be reused from the avionics manufacturer, provided that full and unrestricted access to the compliance data is established and maintained. However, the applicant remains responsible for all test data used in the course of compliance demonstration.

AMC3 ACNS.B.DLS.B1.025 Protection mechanism

Where ARINC 631-6 identifies a specific deviation from ICAO Doc 9776 (Manual on VDL Mode 2), the provisions of the former should take precedence.

ARINC 631-6 also references ARINC 750 for definition of Signal Quality Parameter (SQP) levels. Measurements of SQP levels may be passed over the air-ground link as parameters in the XID exchanges.

GM1 ACNS.B.DLS.B1.025 Protection mechanism

EUROCAE Document ED-110B sections 3.3.5.1 and 3.3.6 mentions an 'ATN Message Checksum Algorithm' (or 'Application Message Integrity Check (AMIC)') that does not exist in ICAO Document 9705 Edition 2. These terms are correctly referenced in ICAO Doc 9705 PDR M60050001.

GM2 ACNS.B.DLS.B1.025 Protection mechanism

Both ICAO Document 9705 and EUROCAE Document ED-110B include requirements for the support of FIS and ADS-C applications. These two applications are not mandated for operations in European airspace. Data link aircraft implementations are free to support these applications and should notify their application availability in the DLIC logon function.

GM3 ACNS.B.DLS.B1.025 Protection mechanism

Further guidance material from EUROCONTROL is available on EUROCONTROL website (www.eurocontrol.int):

- LINK2000+/ATC DATA LINK OPERATIONAL GUIDANCE, Version 6.0, Date: 17 December 2012.
- LINK 2000+ Guidance to Airborne Implementers, Version 1.1, Date: 09 December 2009.
- LINK2000+/FLIGHT CREW DATA LINK OPERATIONAL GUIDANCE Version 5.0, Date: 17 December 2012.
- LINK2000+ Programme, Generic Interop Test Plan for Avionics - Part 1, Upper Layers and CM/CPDLC applications, Version 2.3, Date: 15th June 2010.

Time

AMC1 ACNS.B.DLS.B1.040 Universal Time Coordinated (UTC)

A Global Navigation Satellite System (GNSS) sensor provides an acceptable source of synchronised UTC time.

Time synchronisation is required by ICAO Annex II, chapter 3, section 3.5 as referred by EUROCAE Document ED-110B, section 3.3.2. It is also identified as a safety requirement in EUROCAE Document ED-120 (e.g. SR-ACL-15).

Data link initiation capability (DLIC) service messages

AMC1 ACNS.B.DLS.B1.050 DLIC Uplink Messages

Data link aircraft equipment should comply with ICAO Doc 9705 (Edition 2), section 2.1.4 and EUROCAE Document ED-110B, section 2.2.1.

AMC1 ACNS.B.DLS.B1.055 DLIC Downlink Messages

Data link aircraft equipment should comply with ICAO Doc 9705 (Edition 2), section 2.1.4 and EUROCAE Document ED-110B, section 2.2.1.

CPDLC messages

AMC1 ACNS.B.DLS.B1.070 CPDLC Uplink Messages

The data link system should comply with EUROCAE Document ED-110B section 2.2.3 and comply with the CPDLC message syntax ICAO Doc 9705 (Edition 2), section 2.1.4.

For the sole exception of UM117, the data link system should prepare the appropriate response downlink message to a received uplink message in compliance with EUROCAE Document ED-110B, section 2.2.3.3 Table 2-4. Received uplink messages with response type 'A/N' as indicated in the 'Response' column should be responded with either DM4 (AFFIRM) or DM5 (NEGATIVE). Received uplink messages with response type 'R' as indicated in the 'Response' column should be responded with DM3 (ROGER) or with DM1 (UNABLE). When UM117 CONTACT is received, no DM89 MONITORING message should be sent.

The data link aircraft system should also handle unsupported messages (i.e. uplink message not referenced in CS ACNS.B.DLS.B1.050) as specified in EUROCAE Document ED-110B, section 3.3.7.6.

AMC2 ACNS.B.DLS.B1.070 CPDLC Uplink Messages

EUROCAE Document ED-110B requires (in Table 4-3, item 6a) aircraft to send the DM89 (MONITORING [unitname] [frequency]) CPDLC message upon receipt of a UM117 (CONTACT) or UM120 (MONITOR) CPDLC message. The sending of DM89 could manually prepared and sent by the flight crew in response to UM120 but not for UM117.

GM1 ACNS.B.DLS.B1.070 Uplink Messages

The following table associates uplink CPDLC messages to the data link services.

ID	Message	ACM	ACL	AMC
UM0	UNABLE		x	
UM1	STANDBY		x	
UM3	ROGER		x	
UM4	AFFIRM		x	
UM5	NEGATIVE		x	
UM19	MAINTAIN [level]		x	
UM20	CLIMB TO [level]		x	
UM23	DESCEND TO [level]		x	
UM26	CLIMB TO REACH [level] BY [time]		x	
UM27	CLIMB TO REACH [level] BY [position]		x	
UM28	DESCEND TO REACH [level] BY [time]		x	
UM29	DESCEND TO REACH [level] BY [position]		x	
UM46	CROSS [position] AT [level]		x	
UM47	CROSS [position] AT OR ABOVE [level]		x	
UM48	CROSS [position] AT OR BELOW [level]		x	
UM51	CROSS [position] AT [time]		x	
UM52	CROSS [position] AT OR BEFORE [time]		x	
UM53	CROSS [position] AT OR AFTER [time]		x	
UM54	CROSS [position] BETWEEN [time] AND [time]		x	
UM55	CROSS [position] AT [speed]		x	
UM61	CROSS [position] AT AND MAINTAIN		x	
UM64	OFFSET [specifiedDistance] [direction] OF ROUTE		x	
UM72	RESUME OWN NAVIGATION		x	
UM74	PROCEED DIRECT TO [position]		x	
UM79	CLEARED TO [position] VIA [routeClearance]		x	
UM80	CLEARED [routeClearance]		x	
UM82	CLEARED TO DEVIATE UP TO [specifiedDistance] [direction] OF ROUTE		x	
UM92	HOLD AT [position] AS PUBLISHED MAINTAIN [level]		x	

ID	Message	ACM	ACL	AMC
UM94	TURN [direction] HEADING [degrees]		x	
UM96	CONTINUE PRESENT HEADING		x	
UM106	MAINTAIN [speed]		x	
UM107	MAINTAIN PRESENT SPEED		x	
UM108	MAINTAIN [speed] OR GREATER		x	
UM109	MAINTAIN [speed] OR LESS		x	
UM116	RESUME NORMAL SPEED		x	
UM117	CONTACT [unitname] [frequency]	x		
UM120	MONITOR [unitname] [frequency]	x		
UM123	SQUAWK [code]		x	
UM133	REPORT PRESENT LEVEL		x	
UM148	WHEN CAN YOU ACCEPT [level]		x	
UM157	CHECK STUCK MICROPHONE [frequency]			x
UM159	ERROR [errorInformation]	x	x	
UM160	NEXT DATA AUTHORITY [facility]	x		
UM162	SERVICE UNAVAILABLE		x	
UM165	THEN		x	
UM171	CLIMB AT [verticalRate] MINIMUM		x	
UM172	CLIMB AT [verticalRate] MAXIMUM		x	
UM173	DESCEND AT [verticalRate] MINIMUM		x	
UM174	DESCEND AT [verticalRate] MAXIMUM		x	
UM179	SQUAWK IDENT		x	
UM183	[freetext]	x	x	x
UM190	FLY HEADING [degrees]		x	
UM196	[freetext]		x	
UM203	[freetext]		x	
UM205	[freetext]		x	
UM211	REQUEST FORWARDED		x	
UM213	[facilitydesignation] ALTIMETER [altimeter]		x	
UM215	TURN [direction] [degrees]		x	
UM222	NO SPEED RESTRICTION		x	
UM227	LOGICAL ACKNOWLEDGEMENT	x	x	
UM231	STATE PREFERRED LEVEL		x	
UM232	STATE TOP OF DESCENT		x	
UM237	REQUEST AGAIN WITH NEXT UNIT	x	x	

GM2 ACNS.B.DLS.B1.070 Uplink Messages

The above ACL messages correspond to the common subset of ACL messages defined in EUROCAE Document ED-120 section 5.2.1.1.5 as required by Regulation (EC) No 29/2009.

AMC1 ACNS.B.DLS.B1.075 Downlink Messages

The data link system should comply with EUROCAE Document ED-110B section 2.2.3 and comply with the CPDLC message syntax ICAO Doc 9705 (Edition 2), section 2.1.4.

For the sole exception of UM117, data link aircraft equipment should prepare the appropriate response downlink message to a received uplink message in compliance with EUROCAE Document ED-110B, section 2.2.3.3 Table 2-4. When UM117 CONTACT is received, no DM89 MONITORING message should be sent.

GM1 ACNS.B.DLS.B1.075 Downlink Messages

The following table associates downlink messages to the data link services.

ID	Message	ACM	ACL	AMC
DM0	WILCO	x	x	
DM1	UNABLE	x	x	
DM2	STANDBY	x	x	
DM3	ROGER		x	
DM4	AFFIRM		x	
DM5	NEGATIVE		x	
DM6	REQUEST [level]		x	
DM18	REQUEST [speed]		x	
DM22	REQUEST DIRECT TO [position]		x	
DM32	PRESENT LEVEL [level]		x	
DM62	ERROR [errorInformation]	x	x	
DM63	NOT CURRENT DATA AUTHORITY	x		
DM65	DUE TO WEATHER		x	
DM66	DUE TO AIRCRAFT PERFORMANCE		x	
DM81	WE CAN ACCEPT [level] AT [time]		x	
DM82	WE CANNOT ACCEPT [level]		x	
DM89	MONITORING [unitname] [frequency]	x		
DM98	[freetext]	x	x	
DM99	CURRENT DATA AUTHORITY	x		
DM100	LOGICAL ACKNOWLEDGEMENT	x	x	
DM106	PREFERRED LEVEL [level]		x	
DM107	NOT AUTHORIZED NEXT DATA AUTHORITY	x	x	
DM109	TOP OF DESCENT [time]		x	

GM2 ACNS.B.DLS.B1.075 Downlink Messages

The above ACL messages correspond to the common subset of ACL messages defined in EUROCAE Document ED-120 section 5.2.1.1.5 as required by Regulation (EC) No 29/2009.

GM3 ACNS.B.DLS.B1.075 Optional ACL Downlink Messages

The data link system may also allow the sending the following ACL messages defined in EUROCAE Document ED-120 section 5.2.1.1.5. The message syntax should also comply with ICAO Doc 9705 (Edition 2), section 2.3.4.

ID	Message
DM9	REQUEST CLIMB TO [level]
DM10	REQUEST DESCENT TO [level]
DM27	REQUEST WEATHER DEVIATION UP TO [specifiedDistance] [direction] OF ROUTE

Note: To prevent costly retrofitting, implementation of the above optional messages is highly recommended.

Data link services requirements

AMC1 ACNS.B.DLS.B1.080 Data Link Initiation Capability (DLIC) Service

(a) The data link aircraft equipment DLIC logon function should comply with the aircraft system PR-DLIC-Init-ET_{RCTP} and PR-DLIC-Init-TT performance values, respectively 6 seconds and 4 seconds, as specified in EUROCAE Document ED-120 Table A-3.

(b) The data link aircraft equipment DLIC contact function should comply with the aircraft system PR-DLIC-Cont-ET_{RCTP} and PR-DLIC-Cont-TT performance values, respectively 12 seconds and 8 seconds, as specified in EUROCAE Document ED-120 Table A-3.

(c) The data link system should:

(1) not permit data link services when there are incompatible DLIC version numbers;

(2) reinitiate the service with the applicable ATSUs when any of the application or flight information changes;

(3) insert the relevant initiation data in the initiation messages;

(4) not affect the intent of the DLIC message during processing (data entry/encoding/ transmitting/decoding/displaying).

GM1 ACNS.B.DLS.B1.080 Data Link Initiation Capability (DLIC) Service

The Performance Tables in the main body of EUROCAE Document ED-120 for DLIC (Table 4-8 and Table 4-9), ACM (Table 5-21) and ACL (Table 5-31 and Table 5-32) provide the allocated values for the required transaction performance.

A detailed allocation for Aircraft delays is provided in EUROCAE Document ED-120 Annex A Table A-3.

AMC1 ACNS.B.DLS.B1.085 ATC Communications Management (ACM) Service

The data link system for ACM service should comply with the aircraft system PR-ACM-ET_{RCTP} and PR-ACM-TT performance values, respectively 6 seconds and 4 seconds, as specified in EUROCAE Document ED-120 Annex A Table A-3.

GM1 ACNS.B.DLS.B1.085 ATC Communications Management (ACM) Service

The Performance Tables in the main body of EUROCAE Document ED-120 for DLIC (Table 4-8 and Table 4-9), ACM (Table 5-21) and ACL (Table 5-31 and Table 5-32) provide the allocated values for the required transaction performance.

A detailed allocation for Aircraft delays is provided in EUROCAE Document ED-120 Annex A/Table A-3.

AMC1 ACNS.B.DLS.B1.090 ATC Clearances and Information (ACL) Service

The data link system for ACL service should comply with the aircraft system PR-ACL-ET_{RCTP} and PR-ACL-TT performance values, respectively 6 seconds and 4 seconds, as specified in EUROCAE Document ED-120 Annex A Table A-3.

GM1 ACNS.B.DLS.B1.090 ATC Clearances and Information (ACL) Service

The Performance Tables in the main body of EUROCAE Document ED-120 for DLIC (Table 4-8 and Table 4-9), ACM (Table 5-21) and ACL (Table 5-31 and Table 5-32) provide the allocated values for the required transaction performance.

A detailed allocation for Aircraft delays is provided in EUROCAE Document ED-120 Annex A Table A-3.

Interoperability requirements

AMC1 ACNS.B.DLS.B1.100 Network Layer Requirements

The ATN Router should comply with ICAO Document 9705 (Edition 2), sections 5.2.4.1, 5.2.4.3 with an IDRP Hold Time value of 900 seconds.

GM1 ACNS.B.DLS.B1.100 Network Layer Requirements

Compression Schemes

Airborne ATN Router may implement several distinct, yet complementary, compression schemes.

Airborne ATN Routers should support the CLNP Header Compression (also known as 'LREF Compression'). Other compression schemes in ICS are optional.

In addition to the CLNP Header Compression, data link ATN Routers that claims support for optional DEFLATE compression should also support ICAO PDU M0070002 ('Interoperability impact when deflate compression is used. Non-compliance with Zlib').

AMC1 ACNS.B.DLS.B1.105 Transport Layer Requirements

The ATN End System of the data link aircraft equipment should comply with the Transport Protocol Class 4 specified in ICAO Document 9705 (Edition 2), Sub-volume V, section 5.5.2.

The data link aircraft equipment should implement Transport Protocol Class 4 parameter settings in accordance with the following table:

Scope	Parameter	Definition	Value
Inactivity	Inactivity time (I)	A bound for the time after which a transport entity will, if it does not receive a Transport Protocol Data Unit (TPDU), initiate the release procedure to terminate the transport connection.	360 sec
Re-transmission	Retransmission time (T1)	A bound for the maximum time the transport entity will wait for acknowledgement before re-transmitting a TPDU. The retransmission time is adaptive.	Initial value 30 sec
	Maximum Retransmission (N)	Maximum number of TPDU retransmissions.	7
Window	Window time (W)	A bound for the maximum time a transport entity will wait before retransmitting up-to-date window information.	120 sec
Flow Control	Local Acknowledgement delay (Al)	A bound for the maximum time which can elapse between the receipt of a TPDU by the local transport entity from the network layer and the transmission of the corresponding acknowledgement.	1 sec

GM1 ACNS.B.DLS.B1.105 Transport Layer Requirements

Transport Protocol Classes

ICAO Doc 9705 (Edition 2), Sub-volume V, section 5.5 identifies both Connection Oriented and Connection-Less Transport Protocols (as specified in, respectively, ISO/IEC 8073 for COTP and ISO/IEC 8602 for CLTP). The only mandated support is for COTP (i.e. CLTP support is not required).

In addition, ISO/IEC 8073 identifies 5 distinct possible implementations for COTP support, ranging from Class 0 (the less constraining to implement, but also the less reliable) to Class 4 (most reliable). The fifth Class, i.e. COTP Class 4 (also known as 'TP4'), is the only mandated implementation (all other implementations classes are useless for the ATN COTP support).

Transport Protocol Classes

In the ATN Baseline 1 SARPS (i.e. Doc 9705, Edition 2), the Transport Class 4 - as known as TP4 - is as specified in ISO 8073, that mandates support for a 16-bits checksum. Such checksum is considered to be insufficient to detect, and thus compensate, all potential miss deliveries of CLNP Packets by the underlying network routers. The analysis that concluded of TP4 inability to detect and compensate all CLNP miss deliveries is available in ICAO PDR M00040002. The use of a 32-bits long checksum is identified as a solution to address this potential issue.

AMC1 ACNS.B.DLS.B1.110 Session Layer Requirement

(a) The ATN End System of the data link aircraft equipment should support a Session Protocol as specified in ICAO Doc 9705 (Edition 2), Sub-Volume IV, section 4.4 including the ISO/IEC 8327 Technical Corrigendum 1 (2002), listed in the following table.

Value (Hex)	Abbreviation	Full SPDU Name
E8	SCN	Short Connect
F0	SAC	Short Accept
D8	SACC	Short Accept Continue
E0-E3	SRF	Short Refuse E0: TC retained, transient refusal E1: TC retained, persistent refusal E2: TC released, transient refusal E3: TC released, persistent refusal
A0	SRFC	Short Refuse Continue

(b) The ATN End System Session Protocol of the data link system should make use of the value 'E3' to encode the Short Refuse (SRF) SPDU.

AMC1 ACNS.B.DLS.B1.115 Presentation Layer Requirement

(a) The ATN End System of the data link aircraft equipment should support a Presentation Protocol as specified in ICAO Doc 9705 (Edition 2), Sub-Volume IV, section 4.5, and listed in the following table:

Value (Hex)	Abbreviation	Full PPDU Name
02	SHORT-CP	Short Presentation Connect, unaligned PER
02	SHORT-CPA	Short Presentation Connect Accept, unaligned PER
x2	SHORT-CPR	Short Presentation Connect Reject Where x = reason code: 02: presentation-user 12: reason not specified (transient) 22: temporary congestion (transient) 32: local limit exceeded (transient) 42: called presentation address unknown (permanent) 52: protocol version not supported (permanent) 62: default context not supported (permanent) 72: user data not readable (permanent)

(b) The ATN End System Presentation Protocol of the data link aircraft equipment should make use of the value '02' to encode the SHORT-CPR PPDU.

AMC1 ACNS.B.DLS.B1.120 Application Layer Requirements

(a) The ATN End System of the data link system should support an ATN Convergence Function compliant with ICAO Doc 9705 (Edition 2), Sub-volume IV, section 4.3.

(b) The ATN End System of the data link system should support an ATN Association Control Service Element (ACSE) compliant with ICAO Doc 9705 (Edition 2), Sub-volume IV, section 4.6.

GM1 ACNS.B.DLS.B1.120 Application Layer Requirements

From an OSI perspective, the ATN Application layer is composed of three distinct parts:

- Layer 7a, that includes all application-independent services (Convergence Function + ACSE).
- Layer 7b, that includes all application-dependent service elements (such as the CPDLC-ASE).
- Layer 7c, that includes applications (such as the CPDLC application, that uses CPDLC-ASE for its communications with ground-based systems).

Appendix A — Background information for Voice Communication System

(a) General

This appendix provides additional references, background information, and guidance for maintenance testing, as appropriate to Voice Communication System installations.

(b) Related References

(1) EASA

i. ETSO-2C37e, VHF Radio Communication Transmitting Equipment Operating Within the Radio Frequency Range 117.975–137 Megahertz

ii. ETSO-2C38e,VHF Radio Communication Receiving Equipment Operating Within the Radio Frequency Range 117.975–137 Megahertz

iii. ETSO-2C169a VHF Radio Communications Transceiver Equipment Operating Within the Radio Frequency Range 117.975 To 137 Megahertz.

(2) ICAO

ICAO Annex 10, Volume III, Part II, Voice Communication Systems, Chapter 2 Aeronautical Mobile Service — Second Edition including amendment 85.

(3) EUROCAE

ED-23C June 2009 MOPS for airborne VHF Receiver-Transmitter operating in the frequency range 117.975 – 137.000 MHz.

Appendix B — Background information for Data Link System

(a) General

This appendix provides additional references, background information, and guidance for maintenance testing, as appropriate to Data Link System installations.

(b) Related References

(1) ICAO

i. ICAO Doc 4444 Air Traffic Management 15th Ed 2007

ii. ICAO Doc 9705 MANUAL OF TECHNICAL PROVISIONS FOR THE AERONAUTICAL TELECOMMUNICATION NETWORK (ATN) 2nd Ed 1999

iii. ICAO Doc 9776 Manual on VHF Digital Link (VDL) Mode 2 1st Ed 2001.

(2) ARINC

Specification 631-6 Guidelines for Design Approval of Aircraft Data Link Communication Systems Supporting Air Traffic Services (ATS) dated 11/2010

(3) FAA

AC 20-140B Guidelines for Design Approval of Aircraft Data Link Communication Systems Supporting Air Traffic Services (ATS) dated 27/09/2012

(4) EUROCONTROL

i. LINK2000+/ATC DATA LINK OPERATIONAL GUIDANCE, Version 6.0, Date: 17 December 2012.

ii. LINK 2000+ Guidance to Airborne Implementers, Version 1.1, Date: 09 December 2009.

iii. LINK2000+/FLIGHT CREW DATA LINK OPERATIONAL GUIDANCE Version 5.0, Date: 17 December 2012.

iv. LINK2000+ Programme, Generic Interop Test Plan for Avionics - Part 1, Upper Layers and CM/CPDLC applications, Version 2.3, Date: 15th June 2010.

(5) ISO/IEC

i. Document 8073 Information technology -- Open Systems Interconnection -- Protocol for providing the connection-mode transport service Edition 4,0 including amendment 1 dated 09/1998

ii. Document 8602 Information technology -- Protocol for providing the OSI connectionless-mode transport service Edition 2,0 including amendment 1 dated 12/1996

iii. ISO/IEC 8327-1:1996 Information technology — Open Systems Interconnection — Connection-oriented Session protocol: Protocol specification TECHNICAL CORRIGENDUM 1 Published 15/05/2002

(6) EUROCAE

i. ED-110B December 2007 Interoperability Requirements Standard for Aeronautical Telecommunication Network Baseline 1 (Interop ATN B1),

ii. ED-120 May 2004 Safety and Performance Requirements Standard For Initial Air Traffic Data Link Services In Continental Airspace (SPR IC) including change 1 and change 2.

iii. ED-122 February 2011 Safety and Performance Standard for Air Traffic Data Link Services in Oceanic and Remote Airspace (Oceanic SPR Standard)

iv. ED-154A March 2012 Future Air Navigation System 1/A (FANS 1/A) - Aeronautical Telecommunications Network (ATN) Interoperability Standard

Subpart C — Navigation (NAV)

Reserved

Subpart D — Surveillance (SUR)

Section 1 — Mode A/C only Surveillance

AMC1 ACNS.D.AC.010 Transponder characteristics

(a) Transponder capabilities.

(1) To be approved, the Mode A/C only transponder should hold an EASA equipment authorisation in accordance with European Technical Standard Order ETSO-C74d, or an equivalent standard that is consistent with ICAO Annex 10 Volume IV, and which is acceptable to EASA.

(2) The Mode A/C only transponder should be a class 2A / class 2B as defined in ETSO-C74d.

Note 1: ETSO-C74d Class 2 equipment meets EUROCAE Document 1/WG9 /71 June 1972 with amendment 1 and 2. Amendment 2 contains the requirements and tests to show that the transponder correctly replies to Mode A/C-only all call interrogations and to Mode A/C/S all-call interrogations used by Mode S radars.

Note 2: RTCA DO-144 does not include requirement to reply to Mode A/C/S All-Call and Mode A/C-Only All-Call interrogations and is, therefore, not sufficient to prove the compliance. RTCA DO-144A contains the requirements for the equipment to reply to Mode A/C/S All-Call and Mode A/C-Only All-Call interrogations.

(b) Minimum reply rate

(1) Mode A/C only transponders should be capable of continuously generating at least 500 replies per second for a 15-pulse coded reply.

(2) Transponder installations used solely below 4 500 m (15 000 ft), or below a lesser altitude established by the appropriate authority or by regional air navigation agreement, and in aircraft with a maximum cruising true airspeed not exceeding 90 m/s (175 knots) should be capable of generating at least 1 000 15-pulse coded replies per second for a duration of 0,1 s.

Note: The rate of 1 000 replies per second for a limited duration of 100ms is an acceptable deviation to ETSO-C74d.

(3) Transponder installations operated above 4 500 m (15 000 ft) or in aircraft with a maximum cruising true airspeed in excess of 90 m/s (175 knots) should be capable of generating at least 1 200 15-pulse coded replies per second for a duration of 0,1 s.

Note 1: A 15-pulse reply includes 2 framing pulses, 12 information pulses, and the SPI pulse.

Note 2: The transponder should be capable of replying to this short-term burst rate, even though the transponder may not be capable of sustaining this rate.

Note 3: The rate of 1 200 replies per second for a limited duration of 0,1 s is an acceptable deviation to ETSO-C74d.

(c) Minimum output power level

The transponder power output capability should be verified as follows depending on the aircraft capability:

(1) For aircraft that operate at altitudes exceeding 4 570 m (15 000 ft) or with maximum cruising speed exceeding 90 m/s (175 knots), the class of the transponder declared in the transponder DDP should be Class A.

(2) For aircraft operating at or below 4 570m (15 000 ft) with a maximum cruising airspeed of 90 m/s (175 knots) or less, the class of the transponder declared in the transponder DDP should be Class A or Class B.

AMC1 ACNS.D.AC.015 Data transmission

(a) Mode A Code verifications.

(1) Set the Mode A code to 7776 (or other Mode A code agreed with the local Air Traffic Control Unit) through the dedicated flight crew interface. Confirm receipt of correct code by using ground test equipment.

(2) For dual transponder installation with a common control panel, set the Mode A code to 7776 (or other Mode A code agreed with the local Air Traffic Control Unit) and verify that the correct code is received by the ground test equipment. Switch to transponder 2 and verify that the correct Mode A code is received by the ground test equipment.

Note: Agreement of Mode A code values is to be agreed with the local ATC if the transponder is in the visibility of an ATC cooperative surveillance system.

(b) Pressure Altitude verifications

(1) Verify that all Mode A/C transponders report the pressure-altitude encoded in the information pulses in Mode C replies.

Note: more details on the encoding of the altitude can be found in ICAO Annex 10, Vol IV, para 3.1.2.6.5.4.

(2) Select the altitude switch to the ON position and verify that the transponder provides the current aircraft altitude in response to Mode C interrogations.

(3) A sufficient number of test points should be checked to ensure that the altitude reporting equipment and transponder perform their intended function through their entire range while ascending or descending. Where a Gillham altitude encoder is used, tests of each altitude code segment of the encoder (2300, 2500, 3800, 4300, 4800, 6800, 14800 30800, 70800, 90800, 110800 and 126700 if available) should be sufficient to ensure proper operation of each altitude code segment of the encoder.

AMC1 ACNS.D.AC.020 Altitude source

(a) Altimeters compliant with JAA TGL No 6 are an approved and acceptable means of compliance for the altitude source.

(b) Altimeters with a pressure altitude resolution lower than or equal to 7,62 m (25 ft) is an approved and acceptable means of compliance.

Note: Altitude source resolution of 7,62 m (25 ft) or better is required for aeroplanes intended to be used for international air transport as defined in ICAO Annex 6 Part 1 — 6.19.

(c) An altimeter with a pressure altitude resolution lower than or equal to 30 m (100 ft) and greater than 7.62 m (25 ft) is an approved and acceptable means of compliance for aircraft provided that the flight deck interface provides a means to inhibit the transmission of pressure altitude information for aircraft equipped with Gillham encoded altitude

Note: It is not recommended to install altimeters with a Gillham altitude encoder interface.

(d) Manual or automatic selection of the altitude source are acceptable means of compliance

AMC1 ACNS.D.AC.025   Flight deck interface

Modes of operation should be identified. Attention should be closely paid to line select keys, touch screens or cursor controlled trackballs as these can be susceptible to unintended mode selection resulting from their location in the flight deck.

Note: Systems not utilising Gillham interfaces may or may not provide a means to inhibit the transmission of pressure altitude.

AMC1 ACNSD.D.AC.040   Dual/multiple transponder installation

When dual or multiple transponders are installed on an aircraft, it is highly recommended to use a common control interface/panel to ensure that only one transponder is active at a given time.

AMC1 ACNS.D.AC.045   Antenna Installation

(a) Antenna locations recommended by the aircraft manufacturer do not need to be revalidated.

(b) Antenna performance for new locations may be validated in flight, by ground measurements or simulation modelling.

Section 2 — Mode S Elementary Surveillance

AMC1 ACNS.D.ELS.001 Applicability

Provided that the differences listed in Appendix D have also been addressed, then previous compliance declarations with JAA TGL 13 Revision1 (Certification of Mode S Transponder Systems for Elementary Surveillance) supplemented with the additional assessments is another Acceptable Means of Compliance.

Note 1: A list of Mode S ELS related documents is provided in Book 2 Subpart D Appendix *B section (b).*

Note 2: More information on how the ELS information will be extracted and used by ground surveillance is available in Book 2 Subpart D Appendix *B section (c).*

Note 3: In accordance with EU Regulation No 1207/2011, aircraft operating flights as general air traffic in accordance with instrument flight rules in the airspace within the ICAO EUR and AFI regions where EU Member States are responsible for the provision of air traffic services are to be compliant with CS ACNS Book 1 Subpart D section 2.

AMC1 ACNS.D.ELS.010 Transponder characteristics

(a) Transponder capabilities.

(1) To be approved, the Mode S transponder should hold an EASA equipment authorisation in accordance with European Technical Standard Order ETSO-C112d, or an equivalent standard that is consistent with ICAO Annex 10 Volume IV and which is acceptable to the responsible certification authority

Note: ETSO-C112d requires compliance with EUROCAE ED-73E.

(2) The transponder class can be verified by checking that the transponder DDP declares the transponder level as .**'2', '3', '4', or '5'**.

Note: The definition of a level 2 transponder and associated functions can be found in EUROCAE ED-73E paragraph 1.4.2.1, 3.22 and 3.23.

(3) The SI code capability can be verified by checking that the transponder DDP indicates the letter '**s**' in the transponder capability declaration.

Note 1: The DDP indicates those requirements of ED-73E (or later version) with which the transponder is not compliant with.

Note 2: The transponder SI code capability can be found in EUROCAE ED-73E paragraph 3.18.4.34. SI codes have been allocated to Mode S radars used in Europe and it is, therefore, an important capability to ensure correct detection of the aircraft.

(4) The Elementary Surveillance functionality can be verified by checking that the transponder DDP indicates the letter '**l**' for ELS or '**n**' for EHS in the transponder capability declaration.

Note: Such transponders meet the requirements specified in EUROCAE ED-73E 3.29. According to ED-73E, a transponder with the Enhanced Surveillance capability has also the Elementary Surveillance capability.

(5) ACAS compatibility can be verified by checking that the transponder DDP indicates the letter '**a**' in the transponder capability declaration.

Note: Necessary capabilities to be an ACAS-compatible Mode S transponder are described in section 3.27 of EUROCAE ED-73E.

(b) Minimum output power level: The transponder power output capability should be verified as follows, depending on the aircraft capability:

(1) For aircraft that operate at altitudes exceeding 4 570m (15 000ft) or with maximum cruising speed exceeding 90 m/s (175 knots), the class of the transponder declared in the transponder DDP should be **Class 1**.

(2) For aircraft operating at or below 4570m (15 000ft) with a maximum cruising airspeed of 90 m/s (175 knots) or less, the class of the transponder declared in the transponder DDP should be **Class 1** or **Class 2**.

Note: Classes of equipment are defined in EUROCAE ED-73E 1.4.2.4. Power characteristic is defined in ICAO Annex 10 Volume IV 3.1.1.7.11.

AMC1 ACNS.D.ELS.015 Data transmission

Data transmission verifications

(a) Table 1 below provides the parameters that should be verified for Mode S Elementary Surveillance.

Table 1 — List of parameters to be verified on an ELS installation

Item	Parameters	Message/register	Remark
1	Mode A code and Emergency status	DF5 and DF21	Note 3
2	Pressure altitude	DF4 and DF20	See (b) and (c)
3	On-the-ground status	CA field in DF11 or FS field in DF4/5/20/21	
4	Aircraft Identification	Register 20_{16}	See (d)
5	SPI	DF4/5/20/21	See (e)
6a	Capability report	CA field in DF11	
6b	Data-link capability report and common usage GICB capability report	Register 10_{16} Register 17_{16}	(g)
7	ICAO 24 bit aircraft address	DF11	
8	RA report	Register 30_{16} + announcement in DF4/5/20/21	Only for ACAS installation see (f)

Note 1: Information about how Mode S ELS data are used by Mode S ground system can be found in Book 2 Appendix B *to this CS.*

Note 2: Downlink Formats (DF) are defined in ICAO Annex 10 Volume IV and EUROCAE ED-73E. A summary can also be found in Book 2 Appendix *B.*

Note 3: It is not recommended to have 2 transponders installed without a common control panel.

(b) Pressure Altitude

(1) The consistency of the altitude reported in Mode C replies and Mode S replies should be checked.

Note: An incorrect installation of altimeters using Gillham encoding may result in altitude transmitted in Mode C replies and no altitude transmitted in Mode S replies.

(2) For aircraft transmitting parameters via the Extended Squitter, for which compliance with Subpart D section 4 is not required, the pressure altitude data should be checked in the Extended Squitter register for airborne position (register 05_{16}).

(c) Pressure altitude resolution transmission

(1) The resolution of the transmitted pressure altitude should be 7.62 m (25 ft) for aircraft equipped with a pressure altitude source having a resolution better than 7.62 m (25 ft) for all altitudes except those above 15 298 m (50 187.5 ft).

(2) Aircraft equipped with altimeters that have a resolution greater than 7.62 m (25 ft) (e.g. 30.48 m (100 ft)) should report their altitude in 30.48 m (100 ft) encoding.

(3) Verify that the encoding of the altitude is appropriate to the altimeter resolution as defined in paragraphs 1 and 2 above.

(4) For aircraft transmitting parameters via the Extended Squitter, for which compliance with Subpart D section 4 is not required, the pressure altitude resolution data should be checked in the Extended Squitter register for airborne position (register 05_{16}).

(d) Aircraft Identification

(1) For aircraft transmitting parameters via the Extended Squitter, for which compliance with Subpart D section 4 is not required, the Aircraft Identification received via the Extended Squitter should be checked to ensure that it is identical to the information transmitted in register 20_{16}.

(e) Special Position Indication (SPI)

The FS field should report FS = 4 or 5 for 18 seconds (+/-1 second) in replies DF4, DF5, DF20 or DF21 after the SPI (IDENT) has been manually activated.

Note: Flight Status values can be found in ICAO Annex 10, Vol IV, paragraph 3.1.2.6.5.1.

(f) ACAS active Resolution Advisory report

For aircraft that have ACAS II installed, no undue RA report should be announced (DR field never set to 2, 3, 6 or 7) within (5 minutes).

(g) Common usage GICB capability report: BDS 17_{16} = 0 is an acceptable means of compliance for transponders that are strictly ELS (not transmitting other parameters).

(h) Transmission of other parameters

When one or more other airborne data items are transmitted, they should be verified as proposed in AMC1 ACNS.D.EHS..

Note 1: The minimum data transmission verification of transponder also having ADS-B ES capabilities has been defined above. Transponders that are transmitting parameters other than the minimum tested above, are encouraged to demonstrate compliance with Subpart D section 4.

Note 2: The implementation of registers $E3_{16}$, $E4_{16}$, $E5_{16}$ and $E6_{16}$ is recommended.

AMC1 ACNS.D.ELS.020 On-the-ground status determination

The automatic determination of the on-the-ground status should be obtained from:

(a) Weight On Wheel (WOW) sensor: When the aircraft is equipped with an automatic sensor to determine if the aircraft is on the ground (i.e. Weight On Wheel sensor), this sensor should be used as the on-the-ground status source of the transponder. For Aircraft with transponders that have access to at least one of the following parameters (ground speed, radio altitude, airspeed) the following validation check should be performed when detected 'on the ground' and the air/ground status should be overridden and changed to 'airborne' if [Ground speed > 50 m/s (100 knots) OR airspeed > 50 m/s (100 knots) OR radio altitude> 15 m (50 feet)].

Note: Care should be taken to ensure the wiring of the WOW to the correct transponder pins.

(b) automatic algorithm : If ground speed, radio altitude, or airspeed parameters are being used in the algorithm and the 'on-the-ground' condition is being reported or if the on-the-ground status has been commanded via the TCS subfield, the on-the-ground status is to be overridden and changed to 'airborne' if :

Ground Speed OR Airspeed > X or Radio height > 15 m (50 ft).

Note 1: Care should be taken to ensure that the chosen threshold values of X are such that the aircraft can never report 'on ground' status when in the air, and should be based on the aircraft nominal performance.

Note 2: Systems that support Enhanced Surveillance and ADS-B might use available airborne parameters in their automatic algorithm to determine if they are on the ground. More information can be found in Subpart D section 4.

AMC1 ACNS.D.ELS.025 Altitude source

(a) Altimeters compliant with JAA TGL No 6 are an approved and Acceptable Means of Compliance for the altitude source.

(b) Altimeters with a pressure altitude resolution lower than or equal to 7.62 m (25 ft) are an approved and Acceptable Means of Compliance.

Note: Altitude source resolution lower than or equal to 7.62 m (25 ft) is required for aeroplanes intended to be used for international air transport as defined in ICAO Annex 6 Part 1 — 6.19.

(c) An altimeter with a pressure altitude resolution lower than or equal to 30 m (100 ft) and greater than 7.62 m (25 ft) is an approved and Acceptable Means of Compliance for aircraft provided that the following provisions are implemented:

(1) There is no conversion of Gillham encoded data to another format before inputting to the transponder unless failure detection can be provided, and the resolution (quantisation) is set in the transmitted data to indicate 30 m (100 ft);

Note 1: It is not recommended to install altimeters with a Gillham altitude encoder interface as it supports a resolution of only 30 m (100 ft).

Note 2: Losses or errors of pressure altitude have an impact on the provision of separation by ATC. It is, therefore, important to design the altitude pressure source to minimise the loss of this data or the provision of erroneous data.

Note 3: Further guidance on altitude measurement and coding systems may be found in EUROCAE document ED-26.

(2) Altitude source comparison;

For aircraft equipped with ACAS II where the available source of pressure altitude information is only in Gillham encoded format, detection of an altitude source or encoder failure 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 transponder). Similar provision is also acceptable for alternative altitude information sources that do not signal erroneous data.

The flight deck interface should provide a means to inhibit the transmission of pressure altitude information for aircraft equipped with a Gillham encoded altitude interface.

(d) Manual or automatic selection of the altitude source are acceptable means of compliance.

AMC1 ACNS.D.ELS.030 Flight deck interface

Modes of operation should be identified. Attention should be closely paid to line select keys, touch screens or cursor controlled trackballs as these can be susceptible to unintended mode selection resulting from their location in the flight deck.

AMC1 ACNS.D.ELS.050 Dual/multiple transponder installation

When dual or multiple transponders are installed on an aircraft, a common control interface/panel should be provided to ensure that only one transponder is active at a given time, and to ensure that the Mode A code and Aircraft Identification changes are applied to the active transponder.

AMC1 ACNS.D.ELS.060 Antenna Installation

(a) Antenna locations recommended by the aircraft manufacturer do not need to be revalidated.

(b) Antenna performance for new locations should be validated in flight by ground measurements or simulation modelling.

(c) The distance between ATC Transponder antenna should be at least 40 cm and the distance between ATC Transponder antenna and other antenna (e.g. ACAS, DME) should satisfy the appropriate isolation and longitudinal separation limits.

(d) When the Mode S ELS surveillance installation is using two antennas, the horizontal distance between the two antennas should be less than 7.6m

AMC1 ACNS.D.ELS.065 Antenna Diversity

(a) The aircraft maximum cruising true airspeed may be determined using one of the 3 following options:

  (1) Where the Aircraft Flight Manual or Pilot's Operating Handbook gives more than one table of true airspeed values for a range of temperatures, the table which gives the maximum true airspeed, should be used;

  (2) For some aircraft, the maximum cruising true airspeed is not obtained at the maximum operating altitude. In those cases, the maximum true airspeed has to be considered and not the true airspeed at maximum operating altitude;

  (3) Aircraft which do not state the maximum cruising true airspeed under ISA conditions in their Aircraft Flight Manual or Pilot's Operating Handbook, may use the following alternative method to calculate maximum cruising true airspeed:

    (i) Use the maximum operating values of altitude and airspeed (i.e. VNO, or VMO/MMO as applicable) quoted in the Limitations section of the Aircraft Flight Manual or Pilot's Operating Handbook to calculate the maximum cruising true airspeed of the aircraft. If the aircraft is unpressurised, an altitude of 8 000 feet may be used as the maximum 'normal' operating altitude.

    (ii) For example, using a maximum 'normal' operating altitude of 2 400 m (8 000 feet) for an unpressurised aircraft, and a maximum operating airspeed of 110 m/s (215 knots), (as stated in the Aircraft Flight Manual or Pilot's Operating Handbook, e.g. VNO = 110 m/s (215 knots)) then the aircraft has an equivalent TAS capability of 128 m/s (250 knots) in the ICAO Standard atmosphere. The calculation may be made using a pilot's TAS computer.

(b) For airships, the applicant should demonstrate the need or otherwise for antenna diversity. The demonstration should be based on the construction techniques and size of the airship.

(c) The transponder DDP should indicate the letter **'d'** in the transponder capability declaration to indicate antenna diversity capability.

Section 3 — Mode S Enhanced Surveillance

AMC1 ACNS.D.EHS.001 Applicability

Provided that the differences listed in Appendix E have also been addressed, then previous compliance declarations with EASA AMC 20-13 (Certification of Mode S Transponder Systems for Enhanced Surveillance) supplemented with the additional assessments is another Acceptable Means of Compliance.

Note: In accordance with EU Regulation No 1207/2011, fixed wing aircraft having a maximum take off mass greater than 5 700 kg or a maximum cruising true airspeed greater than 128.6 m/s (250 knots) and operating flights as general air traffic in accordance with instrument flight rules in the airspace within the ICAO EUR and AFI regions where EU Member States are responsible for the provision of air traffic services are to be compliant with CS ACNS Book 1 Subpart D section 3.

AMC1 ACNS.D.EHS.010 Transponder characteristics

(a) The means of compliance defined in AMC1 ACNS.D.ELS.010 should be followed, with the exception that the transponder DDP should indicate a label 'n' in the transponder capability declaration to reflect ELS and EHS capabilities.

Note: Such transponders meet the requirements specified in EUROCAE ED-73E section 3.30 for EHS capabilities. If the transponder is compliant with EUROCAE ED-73E, it provides register format corresponding to a Mode S sub-network version 5.

(b) The Mode S sub-network format should be 3 or above.

Note : The use of the highest Mode S sub-network version format is recommended.

AMC1 ACNS.D.EHS.015 Data transmission

(a) The compliance verification should include a list of transponder registers supported by the installation, including the parameters that are available in each register. The list should contain the registers that are indicated as available in the Mode Specific Capability reports (18_{16} to $1C_{16}$), except the following registers:

(1) registers managed by the transponder to support the Mode S airborne initiated protocol (02_{16}, 03_{16}, 04_{16});

(2) registers containing extended squitters information (05_{16}, 06_{16}, 07_{16}, 08_{16}, 09_{16}, $0A_{16}$);

(3) aircraft capability reporting (10_{16} to $1F_{16}$);

(4) Aircraft Identification (20_{16});

(5) ACAS RA report (30_{16}); and

(6) transponder dependant information ($5F_{16}$, $E3_{16}$, $E4_{16}$, $E7_{16}$, EA_{16}).

Note 1: An example of a minimum list of registers to support EHS is provided in Subpart D Appendix C.

Note 2: An example of other registers and parameters is provided in Subpart D Appendix C.

(b) Verification of operation

(1) All the transponder registers containing data as defined in (a) should be verified to ensure correct data is transmitted by the Mode S transponder.

Note: Format and resolution of airborne parameters can be found in ED-73E Volume 2 or in ICAO Doc 9871 Edition 2.

(2) Where a register is declared available but a parameter within that register is not available, it is necessary to verify that the status of the parameter is declared invalid in the corresponding aircraft register.

Note 1: Some parameters are particularly difficult to measure statically. To ensure that these parameters (e.g. Roll Angle, Track Angle Rate, Inertial Vertical Velocity) are correctly received from the sensor and transmitted by the transponder, it is acceptable to test that the correct transponder register is transmitted (by the transponder), that the value of the parameter status bit is valid (status bit = 1), and the value of the parameter field is set to zero when aircraft is not moving on the ground. Alternatively, for such parameters which remain invalid in static condition, ground test may use simulation if simulated data bus signal meets sensor data bus specifications, the same data bus provides at least one other valid parameter which is tested and sensor specifications clearly establish availability conditions and format of the simulated data parameter.

Note 2: Due to the limitations of the static tests, a recommended option is to perform a flight and record the content of the different transponder registers (as extracted by a Mode S ground station) to verify that all parameters listed in (a) are changing in accordance with pilot input and aircraft attitude and manoeuvre.

Note 3: To minimise the certification effort for transponder follow-on installations, the applicant may claim from the responsible authority credit for applicable certification and test data obtained from equivalent aircraft installations. This is acceptable for a parameter only if all related equipment connected to the transponders are of the same type and same software revision number.

(c) Aircraft parameters

(1) Selected Altitude

(i) MCP/FCU Selected Altitude

Selected level input to the MCP or FCU should be used.

In case there is no MCP/FCU Selected Altitude function, it is accepted to use the information provided by an altitude alerter.

(ii) FMS Selected Altitude

When available, it is recommended that the FMS Selected altitude field is provided.

Note: This will allow the reporting of the intermediate selected altitudes during applications (e.g. Continuous Descent Operations) when the FMS provides the guidance input to the auto-pilot.

(iii) MCP/FCU mode bits

When data is available, it is recommended (optional) to provide information on autopilot mode which is selected by the flight crew.

Note: It is accepted to set this bit to zero rather than providing wrong information.

(iv) Target Altitude source bits

The target altitude source bits are used to indicate the source (e.g. FCU/MCP, FMS) which provides the next level at which the aircraft will level off. This is also referred to as the Target Altitude. However, the necessary data may be inconsistent or not accessible. In this case, the status of target altitude source bits should indicate no source information provided (set to zero).

Note: It is also acceptable that status of target altitude source bits is set to valid and target altitude source is set to 00 to indicate unknown.

(2) Vertical Rate

The Barometric Altitude Rate should contain value solely derived from barometric measurement.

When different sources are available, the Inertial Vertical Velocity should contain data coming from the most accurate and steady source.

Note 1: The vertical rate can be provided in the Barometric Altitude Rate and/or the Inertial Vertical Velocity fields of register 60_{16}. Both the Barometric Altitude Rate and the Inertial Vertical Velocity can be transmitted simultaneously.

Note 2: The Barometric Altitude Rate is usually very unsteady.

Note 3: The Inertial Vertical Velocity (derived from IRS, AHRS and/or GPS) information is more filtered and smoothed.

(3) Barometric Pressure Setting

If operating with reference to the standard pressure setting, the Barometric Pressure Setting field should indicate standard pressure value equivalent to $1.01325\ 10^5$ Pa.

(4) Track Angle Rate or True Airspeed

If Track Angle Rate data cannot be readily provided due to the aircraft configuration, True Airspeed data should be substituted.

(5) Roll Angle

It is difficult to test different values of Roll Angle when the aircraft is on the ground. To ensure that this parameter is correctly received from the sensor and transmitted by the transponder, it is acceptable to test that the Roll Angle field in register 50_{16} contains a credible value, consistent with aircraft roll angle on the ground, and the Roll Angle Status bit indicates valid data.

(6) True Track Angle

It is difficult to test different values of True Track Angle when the aircraft is on the ground. To ensure that this parameter is correctly received from the sensor and transmitted by the transponder, it is acceptable to test that the True Track Angle field in register 50_{16} contains a value and the True Track Angle Status bit indicates valid data.

(7) Ground Speed

It is difficult to test different values of Ground Speed when the aircraft is on the ground. To ensure that this parameter is correctly received from the sensor and transmitted by the transponder, it is acceptable to test that the Ground Speed field in register 50_{16} contains a value, consistent with the speed of the aircraft on the ground (close to zero if the aircraft is not moving) and the Ground Speed Status bit indicates valid data.

(8) Magnetic Heading

To ensure that this parameter is correctly received from the sensor and transmitted by the transponder, it is acceptable to test that the Magnetic Heading field in register 60_{16} contains a value, consistent with the magnetic heading of the aircraft, and the Magnetic Heading Status bit indicates valid data.

(9) Indicated Airspeed or Mach No

Indicated Airspeed and Mach No are considered as a single parameter. Both should be provided where available.

To ensure that these parameters are correctly received from the sensor and transmitted by the transponder, it is acceptable to test that the Indicated Airspeed or Mach fields in register 60_{16} contain a value, consistent with the indicated airspeed or Mach No generated via a test set, and the Indicated Airspeed or Mach Status bits indicate valid data.

(d) Sensor Sources

Particular attention should be given to the interface between data sources and transponders when multiple transponders and multiple sensors are employed. In this context, 'sensors' refers to FMS, IRS, AHRS, ADS, GPS, or Data Concentrator (or other) systems used to provide data to the transponder.

The crew should be aware, at all times, which sensors are providing information to the active transponder.

In an installation, where automatic sensor selection for the active transponder is not provided, the captain's side transponder should utilise the captain's side sensors, and the co-pilot's side transponder should utilise the co-pilot's side sensors.

Data parameters from different sensors of the same type should not be mixed.

Note: For example, Mode-C or Mode-S altitude reporting information from ADC source #1 should not be mixed with reporting of TAS, Baro Vertical Rate, Mach from ADC source #2. In this case, partially blocking of data output from either ADC source #1 or #2 will cause uncorrelated results. This could result in problems with ATC ground processing of the data.

Where only single sensors are available (i.e. single FMS), it is permissible to connect the single sensor to multiple transponders. It should be noted that this may result in reduced operational availability should the single sensor fail.

Section 4 — 1090 MHz Extended Squitter ADS-B Out

GM1 ACNS.D.ADSB.001 Applicability

With respect to 1 090 MHz ES ADS-B Out installations, the material in this section is to a large degree in line with the corresponding FAA AC 20-165A material. Differences between the two documents are listed in Appendix J . This guidance may be of use when showing of compliance with both documents is required.

The requirements of CS ACNS.D.ADSB fully cover (and exceed) the requirements of 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). Therefore, aircraft that comply with CS ACNS.D.ADSB also comply with AMC 20-24 but not vice versa.

The approval of on-board systems receiving and processing ADS-B messages in support of air-to-air applications is outside the scope of Subpart D section 4.

Note: In accordance with EU Regulation No 1207/2011, aircraft having a maximum take off mass greater than 5 700 kg or a maximum cruising true airspeed greater than 128.6 m/s (250 knots) and operating flights as general air traffic in accordance with instrument flight rules in the airspace within the ICAO EUR and AFI regions where EU Member States are responsible for the provision of air traffic services are to be compliant with CS ACNS Book 1 Subpart D section 4.

AMC1 ACNS.D.ADSB.010 ADS-B Out system approval

Equipment Qualification

For equipment qualification, refer to AMC1 ACNS.D.ADSB.030 through to AMC1 ACNS.D.ADSB.090.

The ADS-B Out functionality should be demonstrated by ground testing, using ramp test equipment where appropriate, that verifies during nominal system operation, the correctness of the aircraft derived surveillance data contained in the ADS-B messages, and the functioning of system monitoring tools/fault detectors including any ADS-B self-test features.

AMC1 ACNS.D.ADSB.020(a-b) ADS-B Out data parameters

During ADS-B Out system installation testing, all the parameters that are broadcast should be demonstrated to be correct for each installed ADS-B transmit unit, i.e. the transmitted data should be in line with the respective source data.

The Emitter Category, Aircraft Length and Width and GPS Antenna Offset parameters might be either configured as a fixed value during ADS-B Out system installation, or provided via a variable data interface. In both cases, during installation, the respective settings should be verified to be correctly set.

The ADS-B Horizontal Position System Design Assurance (SDA) parameter indicates the probability of an ADS-B Out system malfunction causing false or misleading position information or position quality metrics to be transmitted. SDA may be pre-set at installation for systems that do not utilise multiple position sources with different design assurance levels, otherwise the system should be capable of adjusting the SDA broadcast parameter to match the position source being employed at the time of transmission. ADS-B transmit equipment that is compliant with AMC1 ACNS.D.ADSB.030 and that is directly connected to a position source compliant with AMC1 ACNS.D.ADSB.070 may set the SDA to 'two' without further analysis. For more complex ADS-B installations, a system safety assessment is required to set the SDA. Basically, the lowest design assurance level of one system in the horizontal position data transmission chain should define the SDA value.

Additional guidance material on the required surveillance data parameters are provided in Appendix H Part 1 and Part 2.

Appendix H Part 6 provides matrices of the so-called BDS register fields as used by the 1090 ES ADS-B transmit unit to broadcast the ADS-B Out parameters. These matrices detail the ADS-B Out data requirements at data field level for general understanding and in support of integration testing, as appropriate.

If installations transmit ADS-B Out data that do not meet some requirements of the Subpart D Section 4, the respective data should only be transmitted with a 'zero' quality indication (if a quality indication is defined in the ADS-B Out transmit system).

AMC1 ACNS.D.ADSB.025(a) Provision of data — Approved sources

(a) See AMC1 ACNS.D.ADSB.070-090 for details on the approval of the respective data sources.

(b) For transmission of optional data items, the following provisions should be considered:

(1) Airspeed

In case of a loss of GNSS horizontal velocity data, the ADS-B transmit unit normally switches to broadcast airspeed information (using subtypes 3 and 4 of register 0916).

Therefore, if airspeed data is provided to the ADS-B transmit unit, it should be provided by an approved airspeed source that is providing data intended for use by the flight crew. An air data computer meeting the minimum performance requirements of holding an EASA equipment authorisation in accordance with ETSO-C106 (JTSO-C106) is an acceptable source.

(2) Heading

In case of a loss GNSS ground track and if heading is provided to the ADS-B transmit unit, the heading source should hold an EASA equipment authorisation in accordance with ETSO-C5e (JTSO-C5e) or any revision of ETSO-C6d (JTSO-C6d).

(3) Other Data Parameters

The Intent Change Flag should be set as appropriate to indicate the availability of information in the Mode S registers 40_{16} to 42_{16}.

If available, Selected Heading information should come from approved data sources.

The 1090 ES IN capability field should be set correctly.

AMC1 ACNS.D.ADSB.025(c) Provision of data – Data quality indication and associated data

Data quality indications for the horizontal position containment bound (NIC) and horizontal position accuracy bound (NACp) should be provided to the ADS-B transmit unit together with the corresponding horizontal position information within the same data set.

Data quality indications for the horizontal position source integrity level (SIL) and system design assurance level (SDA) may be preset at installation. Systems that utilise multiple GNSS-based position sources with different design assurance levels or source integrity levels, should be capable of adjusting the SDA and SIL quality indications to match the position source that is employed at the time of transmission.

The horizontal velocity accuracy bound (NACv) and vertical geometric altitude accuracy bound (GVA) should be dynamically provided to the ADS-B transmit unit together with the corresponding velocity and geometric altitude information within the same data set. However, NACv and GVA may be also preset at installation.

For further guidance on the ADS-B data quality indicators, refer to AMC1 ACNS.D.ADSB.070(a).

AMC1 ACNS.D.ADSB.030 ADS-B Transmit unit installation

To be approved, the ADS-B transmit unit should hold an EASA equipment authorisation in accordance with ETSO-C166b and ETSO-C112d, including any additional requirements as required to comply with the provision of the AMC's to Subpart D section 4 (e.g. On-the-ground status determination and maximum NIC encoding). Where such additional requirements apply, it is expected that the ADS-B transmit unit manufacturer supplies compliance information through a Declaration of Design and Performance (DDP), or an equivalent document

The broadcast of Selected Altitude and Barometric Pressure Setting are optional for equipment meeting ETSO-C166b and equipment should implement this optional functionality if available and in a suitable format

If using earlier versions of ETSO-C112( ), it should to be demonstrated that all applicable requirements from EUROCAE ED-102A have been implemented. This can be achieved by a positive deviation of compliance to previous versions of EUROCAE ED-73 that have been documented in the Declaration of Design and Performance (DDP).

AMC1 ACNS.D.ADSB.040 Antenna Diversity

The 1090 ES data protocol includes a bit to indicate, at any time, if only one or both antennas (if installed) are functional. The corresponding parameter for the Single Antenna bit is contained in register 65_{16} (message element bit '30') and should be set to the appropriate value.

Note 1: For detailed guidance on the required antenna diversity as a function of aircraft maximum cruising true airspeed capability, refer to AMC1 ACNS.D.ELS.065.

Note 2: For further guidance on antenna installations, see CS ACNS.D.ELS.060, CS ACNS.D.ELS.065, AMC1 ACNS.D.ELS.060 and AMC1 ACNS.D.ELS.065.

AMC1 ACNS.D.ADSB.055 Simultaneous operation of ADS-B transmit units

Manual switching between transmitters is considered acceptable.

Note: The requirement applies to ADS-B transmit units broadcasting on the same data link. It does not preclude simultaneous operation of dual link installations.

AMC1 ACNS.D.ADSB.060 On-the-ground status Determination

For aircraft with retractable landing gear, the on-the-ground status determination is typically provided through a landing gear weight-on-wheels switch. For aircraft that have fixed-gear, the ADS-B Out system should be able to determine the air-ground status of the aircraft using other means.

Installations that provide a means to automatically determine on-the-ground status based on input from other aircraft sensors are acceptable if they are demonstrated to accurately detect the status. Otherwise, ground status validation algorithms should be implemented, using speed thresholds that match the typical aircraft's rotation speed as closely as possible.

It is noted that for the validation of a directly determined on-the-ground status that is not validated outside the ADS-B transmit function, validation against the aircraft's typical rotation speed (rather than a fixed value of 50 m/s (100 knots)) might not have been tested in accordance with ETSO-C166b. If that is the case, it is expected that the ADS-B transmit unit manufacturer supplies compliance information through a Declaration of Design and Performance (DDP), or an equivalent document.

Detailed guidance material is provided in Appendix I.

AMC1 ACNS.D.ADSB.070 Horizontal Position and Velocity Data Sources

(a) GNSS Standards

(1) Basic GNSS System Approval

To be approved, the horizontal position and velocity data source should hold an EASA equipment authorisation in accordance with either ETSO-C129a, or ETSO-C196, or ETSO-C145/ETSO-C146, including the additional qualification requirements as specified in paragraph (2) below.

(2) Additional GNSS Receiver Qualification Requirements

In order to fully address the standard associated with ADS-B Out, an ETSO authorisation alone may not be sufficient to ensure ADS-B compatibility. The position and velocity source should also comply with the following requirements (i) to (vi).

It is expected that compliance with these requirements is demonstrated by the equipment manufacturer and documented in the Declaration of Design and Performance (DDP), or an equivalent document. Detailed guidance material on the qualification requirements is provided in Appendix H Part 5.

(i) GNSS system must provide a latitude and longitude output.

Note: ETSO-C129a does not cater for full compliance with this requirement.

(ii) The horizontal position integrity containment should have been qualified as per Appendix H Part 5 paragraph 1;

Note: Horizontal Uncertainty Level (HUL) information does not fulfil CS ACNS.D.ADSB.070.

(iii) The maximum time to alert for the indication of a signal-in-space data integrity failure should be 10 seconds as per Appendix H in Part 5 paragraph 1;

(iv) Navigation modes that would force the NIC value temporarily to ‘zero’ whilst the actual horizontal position integrity containment bound would meet the NIC requirements in Appendix H Part 3 Table 20, should not be installed.

(v) The horizontal position source accuracy output should have been qualified as per Appendix H Part 5 paragraph 2;

(vi) The horizontal position source latency and timing characteristics should have been documented (see Appendix H Part 5 paragraph 3);

(vii) The horizontal velocity accuracy output should have been qualified. If a dynamic horizontal velocity accuracy output is not provided, the transmitted horizontal velocity accuracy should be based on a worst case accuracy. If a dynamic horizontal velocity accuracy output is provided, the source should have been qualified for this quality indication accordingly as per Appendix H Part 5 paragraph 4.

In addition, a means should be provided to establish the condition when the horizontal velocity track angle accuracy exceeds plus/minus ‘eight’ degrees as per Appendix H Part 5 paragraph 4.

(3) Interface Interoperability Aspects

It should be verified that the position and velocity information (including their respective quality indicators) received from the source are correctly interpreted by the ADS-B equipment.

(i) Horizontal Position Integrity Containment Bound

Some approved horizontal position sources may incorrectly output horizontal position integrity containment bounds of less than 75 meters. In such cases, it is accepted that the transmit unit limits the NIC value to ’eight’.

It is expected that the ADS-B transmit unit manufacturer supplies compliance information through a Declaration of Design and Performance (DDP), or an equivalent document.

(ii) Horizontal Velocity Format

The position and velocity source manufacturer should provide information describing how the horizontal velocity information is output (i.e. in a ground speed/track angle format versus north/east velocity format) and the protocols used.

(4) Data Quality Indicator Testing

By design and under nominal GNSS satellite constellation conditions, an ADS-B Out system that is compliant with CS ACNS.D.ADSB.070 should meet the required values of the horizontal position NIC, NACp, SIL and horizontal velocity NACv quality indicators (refer to Appendix H Part 3 Table 20).

(b) Installation Guidance

The GNSS based position sources should be installed in accordance with FAA AC 20-138B (or later).

Note: EASA is developing GNSS installation guidance, once published, should be used instead of the FAA material.

(c) Multiple Position and Velocity Data Sources

(1) Multiple Source Approval

Any position and velocity source that is interfaced to the ADS-B transmit unit, should meet the requirements of CS ACNS.D.ADSB.070.

(2) Source Priority

If multiple horizontal position data sources are interfaced with the ADS-B transmit unit, priority should be given to the source that provides the best ADS-B performance with respect to the horizontal position integrity containment bound (NIC)..

A change of the selection between sources should only take place when the not selected source has exceeded the NIC performance of the selected source for several seconds.

(d) Interconnecting Avionics

Interconnecting avionics between a horizontal position and velocity data source and the ADS-B transmit unit are not recommended.

If installed, interconnecting avionics should:

(1) not output horizontal position and velocity data that has been blended with data from other sources;

(2) use GNSS horizontal velocity data to extrapolate the horizontal position data if extrapolation is deployed; and

(3) maintain full source resolution of the horizontal position and velocity data.

Interconnecting avionics that do not comply with the above may dilute the horizontal position accuracy achieved with GNSS-based sources, with detrimental effects on the usability of the ADS-B Out system.

Note: closely coupled GPS/IRS systems are not considered as interconnecting avionics.

AMC1 ACNS.D.ADSB.080 Data Sources as defined by Mode S Elementary and Enhanced Surveillance

(a) General Requirements

For the requirements and general guidance on the data sources providing the Mode S Elementary and Enhanced surveillance parameters, the following references to CS ACNS.D.ELS and CS ACNS.D.EHS apply:

(1) Aircraft Identification: CS ACNS.D.ELS.(a)(3);

(2) Mode A Code: CS ACNS.D.ELS.(a)(1);

(3) SPI: CS ACNS.D.ELS.(a)(2);

(4) Emergency Mode/Status: CS ACNS.D.ELS.(a)(1);

(5) Pressure Altitude: CS ACNS.D.ELS.025;

(6) MCP/FCU Selected Altitude: : AMC1 ACNS.D.EHS. (c)(1);

(7) Barometric Pressure Setting:AMC1 ACNS.D.EHS.;

(8) ACAS Operational/Resolution Advisory: AMC1 ACNS.D.ELS.015; and

(9) ICAO 24 bit Address: CS ACNS.D.ELS.050.

(b) Emergency Status

When transmitting the Mode A emergency status codes, the additional specific bits should be set (see Appendix H , Part 1, Definition 10).

(c) Pressure Altitude — NICbaro

For aircraft with an approved, non-Gillham altitude source, the Barometric Altitude Integrity Code 'NICbaro' should be set to 'one'.

For aircraft where the pressure altitude that is based on a Gillham coded input that has not been cross-checked against another source of pressure altitude, the 'NICbaro' should be set to 'zero'. Otherwise, the 'NICbaro' should be set to 'one'.

For general guidance on the ADS-B 'NICbaro' indicator that is associated with Pressure Altitude information, refer to Appendix H , Part 1, Definition 9.

(d) Vertical Rate

The Vertical Rate information should come from the most accurate and steady source.

In order to ensure that minimum performance requirements are met for Vertical Rate information, the following source prioritisation should be applied:

- Hybrid Vertical Rate Source: the information may be taken from a hybrid system which filters barometric vertical rate with an inertial reference unit (IRU) vertical rate and GNSS vertical rate, provided the accuracy of the vertical rate output is at least as good as barometric vertical rate sources (e.g. ETSO-C106).
- Blended Vertical Rate Source: the information may be taken from a blended system which filters IRU vertical rate and barometric vertical rate, provided the accuracy of the vertical rate output t is at least as good as barometric vertical rate sources (e.g. ETSO-C106).
- Barometric Vertical Rate Source: the information may be taken from an air data computer (ADC) holding an EASA equipment authorisation in accordance with ETSO-C106 or a vertical velocity instrument holding an EASA equipment authorisation in accordance with applicable revisions of ETSO-C8() .
- GNSS Vertical Rate Source: GNSS vertical velocity equipment which have not been qualified in accordance with CS-ACNS.D.ADSB.070 should not be interfaced with the ADS-B transmit unit.

Vertical Rate from an inertial sensor that is not blended with barometric altitude should not be transmitted. Neither should ADS-B transmit units derive a barometric altitude rate by sampling barometric altitude measurements.

The source bit for vertical rate (1090 ES register 09_{16}, message bit '36') should be coded as barometric when utilising barometric rate from an air data computer, or when using a blended or hybrid vertical rate. The source bit for vertical rate should only be coded as geometric when using vertical rate from a GNSS source.

Note: due to differences in the respective transmit formats, the above source prioritisation differs in some parts with the guidance applicable to Mode S Enhanced Surveillance as provided in AMC1 ACNS.D.EHS.015.

For general guidance on Vertical Rate data sources, refer to Appendix H , Part 1, Definition 14.

(e) Selected Altitude (and related Modes)

With respect to the various status and mode fields contained in register 62_{16} (subtype 1), the respective provisions of AMC1 ACNS.D.EHS. (c)(1) apply to the Selected Altitude Type, Status of MCP/FCU Mode Bits, VNAV Mode Engaged, Altitude Hold Mode, and Approach Mode information.

The population of the additional Autopilot Engaged and LNAV Mode Engaged fields status bits are optional but should be populated where the data is available.

AMC1 ACNS.D.ADSB.085 Geometric Altitude

(a) Geometric Altitude data source

The position source should output a vertical position accuracy metric to support the encoding of the Geometric Altitude GVA quality indicator.

GNSS position sources should provide the geometric altitude accuracy through the vertical figure of merit (VFOM). If that is the case, the vertical position source accuracy output by a GNSS receiver should have been qualified as per Appendix H Part 5 paragraph 5.

If the position source does not output a qualified vertical accuracy metric, the GVA parameter should be set to 'zero'.

For general guidance on the GVA encoding, refer to Definition 20 in Appendix H of Subpart D.

(b) Geometric Altitude Reference

A GNSS position source compliant with CS ACNS.D.ADSB.070 provides Geometric Altitude, in its native format, as geocentric height above the earth's ellipsoid shape. Height Above Ellipsoid (HAE) is described by the WGS-84 format.

Another altitude reference is described by the earth's geoid, a surface on which the gravitational potential is constant and which approximates the (local) mean levels of all the earth's seas. The difference between the mathematically idealised smooth ellipsoid and irregular geoid surfaces varies between +106m to -85m across the earth. The related Mean Sea Level (MSL) altitude is then established as the sum of the HAE altitude and those local differences (using look-up tables). MSL is sometimes also referred to as Height-Above-Geoid (HAG).

A position source that only provides HAG or MSL altitude (ARINC label 076) but not HAE (ARINC label 370) should not be interfaced to the ADS-B transmit unit unless the ADS-B transmit unit can properly convert HAG/MSL to HAE, using the same HAG/MSL model as the position source (typically NATO STANAG Appendix 6). This should be based on position source installation instructions that specify a deterministic method to perform conversion to HAE, and be demonstrated during ADS-B transmit unit design approval. It is expected that the respective compliance information is supplied by the position and velocity source, and ADS-B transmit unit manufacturers through a Declaration of Design and Performance (DDP) or an equivalent document.

Note: Horizontal position sources compliant with Class 3 equipment approved under ETSO-C145c/C146c are required to output HAE altitude. The requirement has been implemented from revision C of RTCA/DO-229 onwards.

(c) Geometric Altitude Accuracy Quality Indicator Testing

If a qualified vertical accuracy metric is available, under nominal GNSS satellite constellation and visibility conditions, the transmitted GVA value should be a minimum of 'one'.

AMC1 ACNS.D.ADSB.090(a) Flight Deck Interface

(a) Installations

(1) Data Transmission and Display Consistency

The data transmitted by the active ADS-B transmit unit with the data displayed to the flight crew should be consistent.

Note: The horizontal position data displayed to the flight crew might be based on data from more than the position source than that used for ADS-B transmissions.

(2) Single Point of Flight Crew Entry

Installations that do not provide a single point of flight crew entry for the transponder and the ADS-B transmit unit should be evaluated to ensure that dual entry of the Mode A code, SPI, and emergency status does not lead to the transmission by the active ADS-B transmit unit of inconsistent data, particularly when communicating an aircraft emergency.

(b) ADS-B Off Switch

If control is provided to enable or disable the ADS-B transmit unit, then the status of the active ADS-B transmit unit should clearly be indicated to the flight crew from their normal seated position.

The respective controls should be located such that inadvertent disabling is prevented.

AMC1 ACNS.D.ADSB.090(b) Flight Deck Interface

ADS-B device or function failures, should be indicated in amber or in accordance with the flight deck annunciation philosophy, without undue delay, i.e. a response time within the order of one second.

ADS-B device or function failures may be indicated independently of each other; however, detailed operating instructions should be developed to describe the means to interpret indications.

The ADS-B device or function failure indication should not be confused with an ACAS or Mode S system failure annunciations.

In case of an ADS-B function failure, it is expected that the transponder should continue to support the ACAS, Mode A/C and Mode S functions.

The proper indications of the ADS-B Out system failures should be tested.

AMC1 ACNS.D.ADSB.110 Horizontal Position and Velocity Data Refresh

For systems with a 1 Hertz computation rate, the output of position and velocity data can vary between 0.8 seconds and 1.2 seconds.

Note Faster position update rates reduce the latency of the transmitted position and velocity information and are therefore encouraged.

AMC1 ACNS.D.ADSB.115 and 120 Horizontal Position and Velocity Total and Uncompensated Latency

(a) Time of Applicability

With respect to the latency requirements in CS ACNS.D.ADSB.115 and CS ACNS.D.ADSB.120, the initial time of applicability (ITOA) is the time of validity of the position or velocity solution. Hence, the latency between the time of signal in space measurement (TOM) and this time of validity is excluded from the total latency budget.

The transmit time of applicability (TTOA) equals the initial time of applicability plus the amount of compensated latency (CL), as valid at the time at which the ADS-B transmit unit broadcasts the position (or velocity) information (TOT).

(b) Compliance Demonstration

Total latency (TL) is the difference between time of transmission (TOT) and initial time of applicability (ITOA). The analysis of total latency includes the maximum asynchronous delay caused by the time difference of position (or velocity) updates arriving at the ADS-B transmit unit and of transmitting the information. It is noted that for ADS-B transmit units compliant with AMC1 ACNS.D.ADSB.030, this asynchronous delay can be up to 1.1 second.

Uncompensated latency (UL, or more generically a latency compensation error) is the difference between total latency (TL) and amount of compensated latency (CL) thereof. Therefore, uncompensated latency determines the transmit time of applicability (TTOA). The GNSS time mark if provided to the transmit system, can be used by the ADS-B transmit unit to reduce uncompensated latency. It is possible for compensation algorithms to overcompensate for the effects of latency, also as a result of the desired attempt to account for latency external to the ADS-B transmit unit. This might lead to transmitting a position that is out in front of the actual aircraft position rather than behind the actual aircraft position. This is acceptable as long as the transmitted position is not further ahead than 0.2 s (200 ms).

The various latency related parameters are summarised in Figure 1.

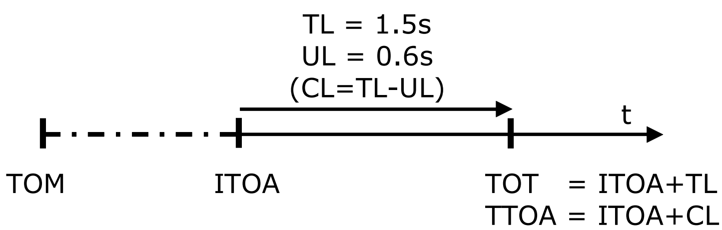


Figure 1: Latency Parameters

Latency should be addressed through analysis rather than testing. Total and uncompensated latency information should be generated by the respective manufacturers of the position source, ADS-B transmit unit and any interconnecting avionics and should be included as part of the latency analysis.

The latency analysis should determine the latency applicable to each component of the ADS-B Out system. The total of all of the individual component latencies should be established as the sum of their maximum latencies.

ADS-B Out systems whereby the transmit equipment compliant with AMC1 ACNS.D.ADSB.030 is directly connected to a position source compliant with AMC1 ACNS.D.ADSB.070, should meet the total latency and uncompensated latency requirements without further analysis.

For other ADS-B Out systems, the applicant should perform a detailed position and velocity latency analysis. This includes systems where ADS-B Out system components are interfaced through a highly integrated architecture.

For detailed guidance on horizontal position and velocity source latency qualification, refer to Appendix H Part 5.

It is expected that this compliance information is supplied by the position and velocity source manufacturer through a Declaration of Design and Performance (DDP) or an equivalent document.

(c) ADS-B Quality Indicator Change Latency

The ADS-B Quality Indicator change latency requirements are driven by the maximum time to alert for the indication of a data integrity failure with respect to exceeding integrity containment bound (CS ACNS.D.ADSB.070 and related AMC guidance).

For detailed guidance on time to alert qualification, refer to Appendix H Part 5.

(d) Horizontal Position Latency Compensation

The ADS-B transmit unit may compensate for horizontal position latency incurred outside the ADS-B transmit unit (see sub-paragraph 2 above). If such is implemented, a verifiable estimation of the delay between the time of applicability of the position measurement, and the provision of that measurement to the ADS-B transmit unit data interface should be performed

Appendix A — Background information for Mode A/C surveillance system

(c) General

This appendix provides additional references, background information, and guidance for maintenance testing, as appropriate to Mode A/C surveillance installations.

(d) Related References

(1) EASA

ETSO-C74d**,** Minimum Performance Standards for Airborne ATC Transponder Equipment.

(2) ICAO

(i) ICAO Annex 10, Volume IV, Aeronautical Communications (Surveillance Radar and Collision Avoidance Systems) — Amd. 85;

(ii) ICAO Document 8168-OPS/611 Volume I, Procedures for Air Navigation Services, Aircraft Operations;

(iii) ICAO Document 4444-ATM/501, Procedures for Air Navigation Service, Air Traffic Management; and

(iv) ICAO EUR Regional Air Navigation Plan, Part IV CNS Supplement SSR Code Allocation List for the EUR region, current edition.

(3) EUROCAE

(i) ED-43, Minimum Operational Performance Requirements for SSR Transponder and Alticoder; and

(ii) ED-26, Minimum Performance Specification for Airborne Altitude Measurement and Coding Systems.

(iii) EUROCAE document 1/WG9/71 June 1972 MPS for airborne secondary surveillance radar transponder apparatus - Including Amendment N°1 (measurement procedures)-April 1974 & Amendment N°2-January 2000

(4) RTCA

(i) DO-144A Minimum Operational Performance Standards (MOPS) for Air traffic Control Radar Beacon Systems (ATCRBS) Airborne Equipment

(e) Background Information

Airborne surveillance system

The following diagram presents the Mode A and C transponder and its main functional interfaces.

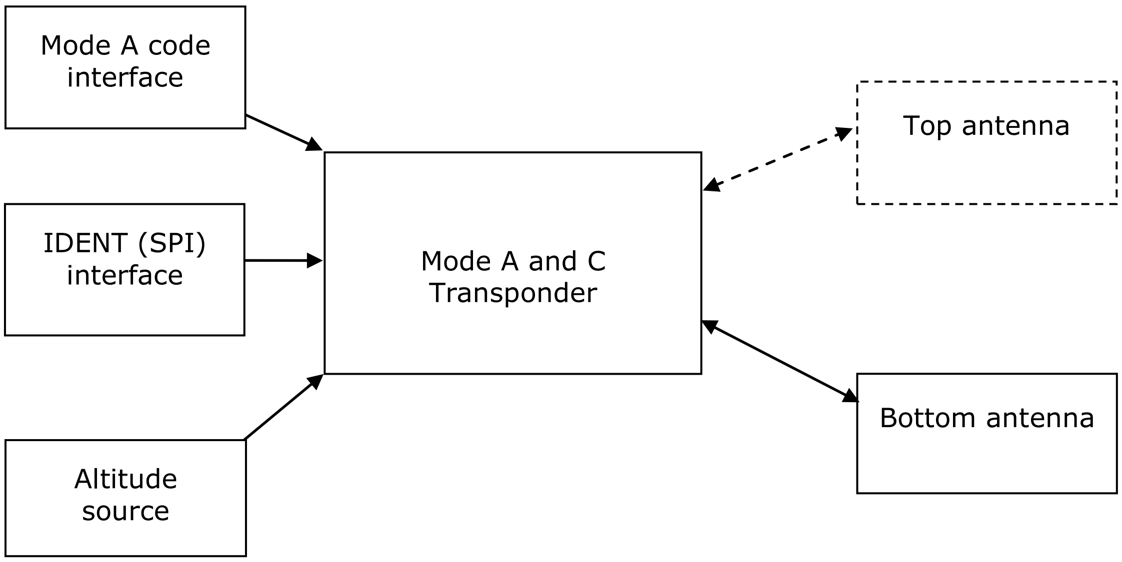


Figure 2: Mode A/C transponder interfaces

Appendix B — Background information on Mode S ELS

(a) General

This appendix provides background information on Elementary Surveillance (ELS) useful to understand ELS airborne surveillance system defined in the CS ACNS.D.ELS and its associated AMCs.

(b) Related Material

(1) EASA

ETSO-C112d**,** Minimum Operational Performance Specification for SSR Mode S Transponders. (Based on EUROCAE ED-73E).

(2) ICAO

(i) ICAO Annex 10, Volume IV, Amd. 85, Aeronautical Communications (Surveillance Radar and Collision Avoidance Systems);

(ii) ICAO Document 9871 Edition 2 (transponder register formats);

(iii) ICAO Document 8168-OPS/611 Volume I (Procedures for Air Navigation Services); and

(iv) ICAO Document Doc 4444-RAC/501 Procedures for Air Navigation Service, Air Traffic Management.

(3) EUROCAE

(i) ED-73E Minimum Operational Performance Specification for Secondary Surveillance Radar Mode S Transponders; and

(ii) ED-26 Minimum Performance Specification for Airborne Altitude Measurement and Coding Systems.

(4) RTCA

RTCA DO-181E.Minimum Operational Performance Specification for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment

(c) Background Information

Airborne surveillance system description

This section describes the ELS system including transponder, interfaces, and antenna.

The following diagram represents the Mode S Transponder and its main functional interfaces.

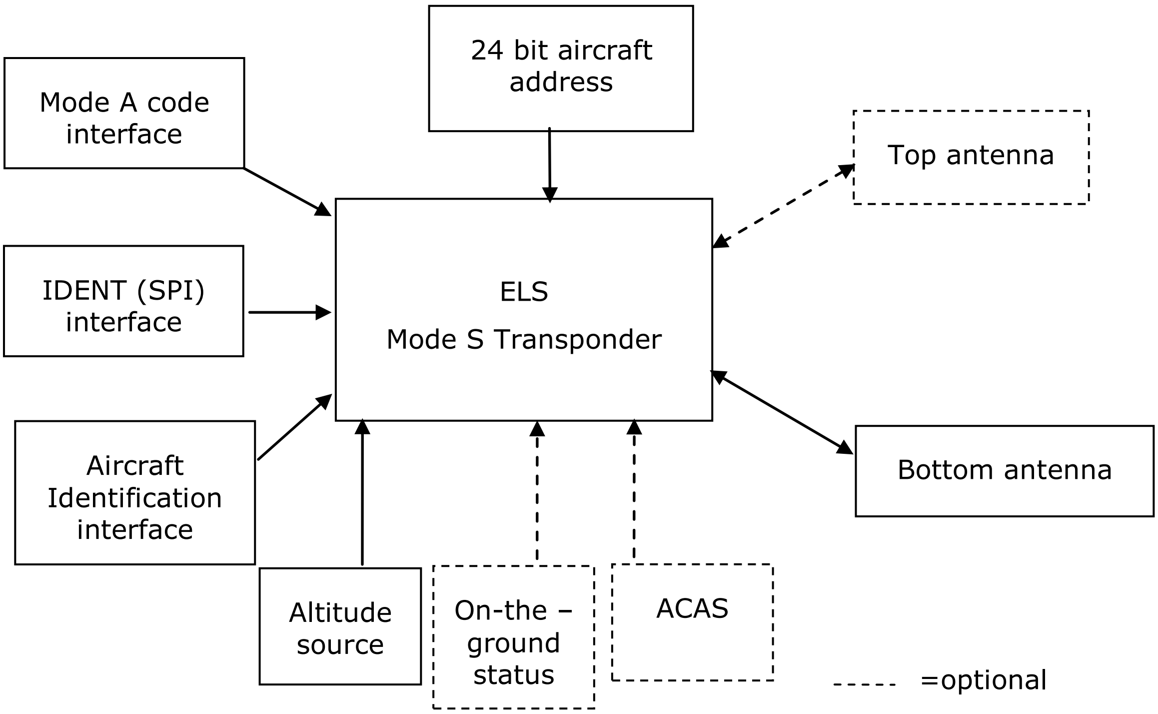


Figure 3: Mode S ELS transponder interfaces

(1) Acquisition of aircraft position by Mode S ELS radar

Aircraft entering the coverage of a Mode S radar is first acquired by All Call interrogations to which the transponder will reply if it is not on the ground. Therefore, it is important to test that the airborne surveillance system correctly takes into account the on-the-ground information. The on-the-ground status is also used by the ACAS systems to select aircraft which will be tracked.

During this acquisition phase the radar will acquire the Horizontal position and the 24-bit aircraft address corresponding to the aircraft technical address on the RF network.

The position and the aircraft address will be subsequently used to selectively interrogate the aircraft during the rest of its trajectory through the radar coverage.

Selective interrogations will be used:

(a) to update the horizontal position of the aircraft;

(b) to request the aircraft to not reply to the All Call interrogations specifically transmitted by the radar. This is known as lockout command;

(c) to request additional information such as Mode A code and altitude and

(d) to request further information to be downlinked from specific aircraft transponder registers such as the Aircraft Identification.

(2) Determination of the aircraft surveillance system capability

Ground surveillance system will need to establish the capabilities of the aircraft surveillance system to extract information only if it is available in the aircraft surveillance system. If this is not done, it could result in a situation where the aircraft would no longer reply to the interrogations used by the radar, and, therefore, the position of the aircraft could be lost. Hence, there is a need to have correct reporting of the aircraft surveillance system capability.

This process starts by determining whether the transponder is level 2 or above by checking the CA field of the Mode S All Call replies. The CA field is encoded with either 4,5,6,7 to indicate that the transponder is a level 2.

If the transponder is a level 2 or above transponder, the second step of the process is the verification of the data-link capability provided in register 10_{16}, the 'Data link capability report'. It contains different information about the data link capability of the airborne surveillance system

Elementary Surveillance System will use important information from this register, including:

(i) Aircraft Identification capability (bit 33 of register 10_{16}) to determine the availability of the register containing the Aircraft Identification;

(ii) Surveillance Identifier code (bit 35 of register 10_{16}) which indicates if SI protocol can be used to lockout the transponder; and

(iii) the Mode S Specific Services capability (bit 25 of register 10_{16}) which indicates that Mode S specific services; including additional registers used for enhanced surveillance; are supported; and that the particular capability reports should be checked.

If the 'Mode S Specific Services' bit is set in register $10_{16,}$ the availability of other registers will be checked by extracting register 17_{16}.

(3) Extraction of Aircraft Identification using Mode S protocol

Aircraft equipped with Mode S having an aircraft identification feature transmits its Aircraft Identification as specified in Item 7 of the ICAO flight plan, or when no flight plan has been filed, the aircraft registration.

Aircraft Identification information will be obtained by Mode S radar by extracting the transponder register 20_{16} at the track initialisation.

The Aircraft Identification is variable when it changes from one flight to another flight. It is, therefore, possible that input errors may occur. Whenever it is observed on the ground situation display that the Aircraft Identification transmitted by a Mode S-equipped aircraft is different from that expected from the aircraft, the flight crew will be requested to confirm and, if necessary, re-enter the correct Aircraft Identification.

When Aircraft Identification is modified, the transponder will indicate this change for 18s in its selective replies. This is done using the Mode S Comm-B Broadcast protocol (ICAO Annex 10 Volume IV 3.1.2.6.11.4). The Mode S ground station will extract the Comm–B Broadcast message to obtain the new value of the Aircraft Identification.

(4) Extraction of Mode A code using Mode S protocol

Ground Mode S surveillance system will extract Mode A code at track initialisation.

If the Mode A code is modified, the transponder will indicate this change for 18s in its selective replies. This is done by raising an alert bit which is set for 18s after the change. Once this alert is detected, the Mode S ground stations will extract the new Mode A code.

It is, therefore important, that the change of the Mode A code happens on the active transponder which is announcing the change for 18s.

Note: ED-73E contains additional requirement requiring the announcement of a Mode A code change when a transponder becomes active. This is not necessarily available on older Mode S transponders in which it may be necessary to follow a specified procedure on installations with no common control interface. In some instances, a ground system workaround, consisting of periodically extracting the Mode A code, has also been implemented.

(5) ACAS Resolution Advisory (RA) report extraction

When a resolution advisory has been produced, the transponder announces the presence of a 'RA report' for the time that the RA is active until 18s after it has ceased. The Mode S ground stations will extract the register 30_{16} to obtain the information

(6) Summary of registers used for ELS

Register 10_{16} to obtain information on data link capability of the airborne surveillance system.

Register 17_{16} to obtain information on additional services available. For ELS, it is possible that register 17_{16} is empty (=0).

Register 20_{16} to obtain the Aircraft Identification.

Register 30_{16} to obtain the RA Report

(7) Information on Mode S replies used to support ELS

The following Mode S reply types are used to track the aircraft and obtain additional data:

DF11: Mode S All Call replies containing the 24-bit Aircraft Address and the CA field indicating whether the transponder is level 2 or greater and whether the aircraft is on the ground or airborne. DF11 can also be spontaneously transmitted as acquisition squitters. These replies are used for aircraft acquisition.

DF4: Short Mode S reply containing Altitude information.

DF5: Short Mode S reply containing the selected Mode A code.

DF20: Long Mode S reply containing the Altitude information and the content of the transponder register requested.

DF21: Long Mode S reply containing the Mode A code and the content of the transponder register requested.

Appendix C — Background information on Mode S EHS

(a) Introduction

This appendix provides background information on Enhanced Surveillance (EHS) useful to understand EHS airborne surveillance system defined in the CS ACNS.D.EHS and its associated AMCs.

(b) Related Material

(1) EASA

ETSO-C112d, Minimum Operational Performance Specification for SSR Mode S Transponders. (Based on EUROCAE ED-73E).

(2) EUROCONTROL

(i) The Concept of Operations - Mode S in Europe, document SUR.ET2.ST02.1000-CNP-01-00, Edition 2, Nov 1996:

(ii) Operational Hazard Assessment of Elementary and Enhanced Surveillance, Edition 1.1, EATMP Infocentre Reference: 04/04/07-01, 07.04.2004; and

(iii) Preliminary System Safety Analysis for the Controller Access Parameter service delivered by Mode S Enhanced Surveillance, Edition 1.1, EATMP Infocentre Reference: 04/04/07-02, 07.04.2004

(3) ICAO

(i) ICAO Annex 10, Volume IV, Amd. 85, Aeronautical Communications (Surveillance Radar and Collision Avoidance Systems);

(ii) ICAO Document 9871 Edition 2;

(iii) ICAO Document 8168-OPS/611 Volume I (Procedures for Air Navigation Services); and

(iv) ICAO Document Doc 4444-RAC/501 Procedures for Air Navigation Service, Air Traffic Management.

(4) EUROCAE

(i) ED-73E Minimum Operational Performance Specification for Secondary Surveillance Radar Mode S Transponders;

(ii) ED-26 Minimum Performance Specification for Airborne Altitude Measurement and Coding Systems; and

(iii) ED-12C Software Considerations in Airborne Systems and Equipment Certification.

(5) RTCA

DO-181E Minimum Operational Performance Specification for Air Traffic Control Radar Beacon System/ Mode Select (ATCRBS/Mode S) Airborne Equipment.

(c) Background Information

(1) Airborne surveillance system description

This section describes the EHS system including transponder, interfaces, and antenna.

The following diagram represents the Mode S Transponder, and its main functional interfaces. It is to be noted that different interfaces coming from different parts of the avionics may need to be connected to the transponder to support EHS.

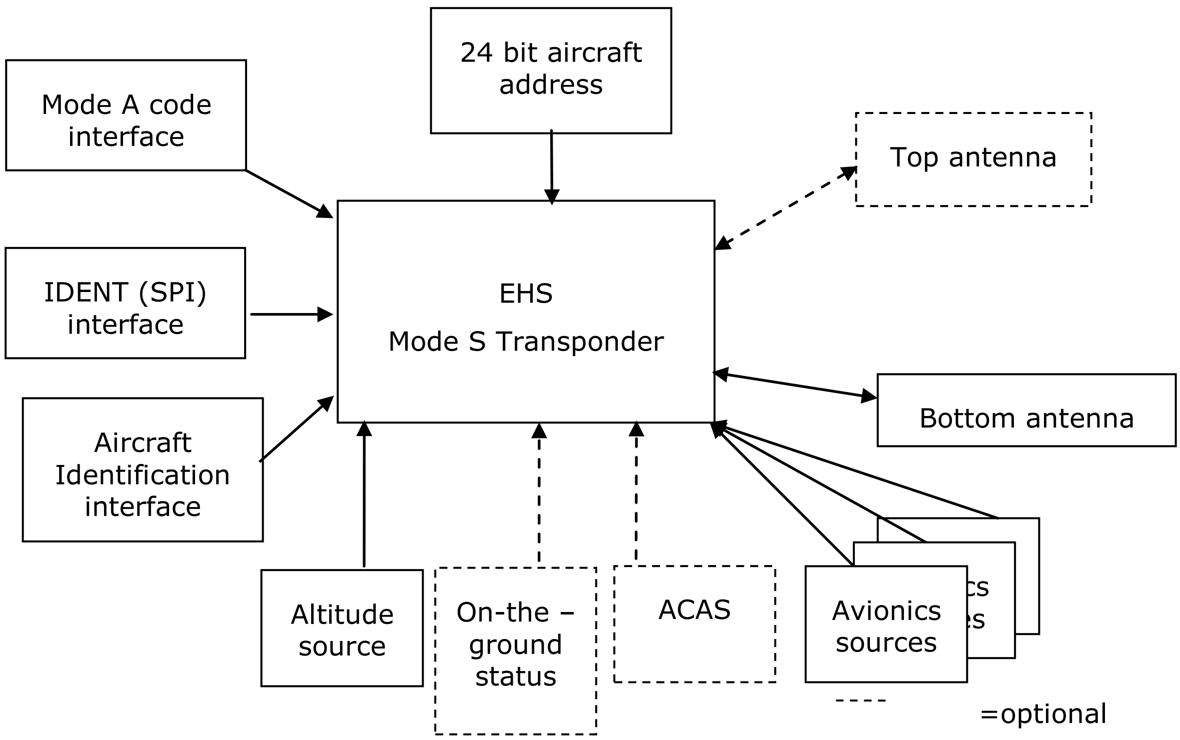


Figure 4: Mode S EHS transponder interfaces

(2) Registers used to support EHS capability

(i) Capability

In addition to the registers already used for ELS capability establishment, the EHS capability of the aircraft will be established using register 17_{16} and $1D_{16}$.

Register 17_{16} will indicate which other registers (e.g. 40_{16},50_{16},60_{16}) are currently supported by the airborne surveillance system.

Ground systems could also use register 18_{16} to $1C_{16}$, if available, to determine which registers are installed if those register are not included in register 17_{16}.

Register $1D_{16}$ is used to determine if Dataflash specific MSP is installed. Dataflash is an application allowing the transmission of registers to the ground only when they have changed, and, therefore, removing the need for periodic extraction of registers. Dataflash is not expected to be installed, however, some Mode S ground stations have been developed to take benefit of the dataflash application when available on aircraft.

Mode S ground stations can also use Mode S sub network version to filter old systems not correctly supporting EHS.

(ii) Basic Data

Example of a basic list of registers and parameters to use to support the declaration of registers and parameters supported by an EHS installation is provided in Table 2 below.

Table 2 - Example of basic list of EHS registers and parameters

Register number	***Assignment***	**Capability reporting in register 18_{16} to $1C_{16}$**	**parameters**	**EHS req**
40_{16}	Selected vertical intention	Reg. 19_{16} Bit 49	MCP/FCU Selected Altitude	Yes
			FMS Selected Altitude	No
			Barometric Pressure Setting	Yes
			MCP/FCU Mode bits	No
			Target altitude source bits	No
50_{16}	Track and turn report	Reg. 19_{16} Bit 33	Roll Angle	Yes
			True Track angle	Yes
			Ground speed	Yes
			Track Angle Rate	Yes
			True Airspeed	Yes
60_{16}	Heading and speed report	Reg. 19_{16} Bit 17	Magnetic Heading	Yes
			Indicated Airspeed	Yes
			Mach	Yes
			Barometric Altitude Rate	Yes
			Inertial Vertical Velocity	Yes

(3) Other data

Mode S ground stations can extract other data when available. It is, therefore, important that all data provided are verified.

The Table 3 provides more data to facilitate the declaration of other registers and parameters which may be supported and which may need to be added to the basic list provided above.

Table 3 - Example of extended list of Transponder registers and supported parameters

Register number	**Assignment**	**Capability reporting in register 18_{16} to $1C_{16}$**	**parameters**	**EHS req**
$0B_{16}$	Air/air information 1 (aircraft state)	Reg. 18_{16} Bit 46	True Air Speed	No
			heading	No
			True track angle	No
			Ground speed	No
$0C_{16}$	Air/air information 2 (aircraft intent)	Reg. 18_{16} Bit 45	Level Off Altitude	No
			Next Course	No

Register number	**Assignment**	**Capability reporting in register 18_{16} to $1C_{16}$**	**parameters**	**EHS req**
			Time to Next Waypoint	No
			Vertical Velocity	No
			Roll Angle	No
21_{16}	Aircraft and airline registration markings	Reg. 18_{16} Bit 24	Aircraft registration number	No
			ICAO airline registration marking	No
22_{16}	Antenna positions	Reg. 18_{16} Bit 23		No
25_{16}	Aircraft type	Reg. 18_{16} Bit 20		No
41_{16}	Next waypoint identifier	Reg. 19_{16} Bit 48	-	No
42_{16}	Next waypoint position	Reg. 19_{16} Bit 47	Waypoint latitude	No
			Waypoint Longitude	No
			Waypoint Crossing Altitude	No
43_{16}	Next waypoint information	Reg. 19_{16} Bit 46	Bearing to waypoint	No
			Time To Go	No
			Distance To Go	No
44_{16}	Meteorological routine air report	Reg. 19_{16} Bit 45	Wind Speed and Direction	No
			Average Static Pressure	No
			Turbulence	No
			Humidity	No
45_{16}	Meteorological hazard report	Reg. 19_{16} Bit 44	Turbulence	No
			Wind Shear	No
			Microburst	No
			Icing	No
			Wake vortex	No
			Static Air temperature	No
			Average Static Pressure	No
			Radio Height	No
48_{16}	VHF channel report	Reg. 19_{16} Bit 41	VHF1	No
			VHF2	No
			VHF3	No

Register number	Assignment	Capability reporting in register 18_{16} to $1C_{16}$	parameters	EHS req
51_{16}	Position report coarse	Reg. 19_{16} Bit 32	Latitude and Longitude and Pressure altitude	No
52_{16}	Position report fine	Reg. 19_{16} Bit 31	Latitude fine and Longitude Fine and Pressure altitude or GNSS Height	No
53_{16}	Air-referenced state vector	Reg. 19_{16} Bit 30	Magnetic Heading	No
			Indicated Airspeed	No
			Mach Number	No
			True Airspeed	No
			Altitude Rate	No
54_{16}	Waypoint 1	Reg. 19_{16} Bit 29	-	No
55_{16}	Waypoint 2	Reg. 19_{16} Bit 28	-	No
56_{16}	Waypoint 3	Reg. 19_{16} Bit 17	-	No
$E3_{16}$	Transponder type/part number	Reg. $1C_{16}$ Bit 54	-	No
$E4_{16}$	Transponder software revision number	Reg. $1C_{16}$ Bit 53	-	No
$E5_{16}$	ACAS unit part number	Reg. $1C_{16}$ Bit 52	-	No
$E6_{16}$	ACAS unit software revision number	Reg. $1C_{16}$ Bit 51	-	No
$F1_{16}$	Military applications	Reg. $1C_{16}$ Bit 40	-	No
$F2_{16}$	Military applications	Reg. $1C_{16}$ Bit 39	-	No

Note 1: When different fields are defined with their own status, each field will be listed in the table. In this case, it is possible to indicate the provision of the associated parameter by checking the value of the associated status bit.

Note 2: For more information about the content of the registers see Doc 9871 Edition 2 or above.

Note 3: It is recommended to provide registers $E3_{16}$, $E4_{16}$, $E5_{16}$ and $E6_{16}$.

(d) Existing Installed Transponders

A number of service bulletins have been issued to rectify some observed deficiencies and have already been addressed by the equipment manufacturers Therefore, the installed transponders should have all published corrective transponder equipment service bulletins (SB) relating to the correct operation of the elementary functionality embodied .

Appendix D — Differences between CS ACNS.D.ELS and JAA TGL 13 Rev1

To demonstrate compliance with CS ACNS Elementary Surveillance requirements, the following additional points need to be addressed for aircraft previously compliant with JAA TGL 13 Rev1:

(a) Verification that the Aircraft identification sent in Extended Squitter messages and in the Mode S replies are identical, (See CS ACNS.D.ELS. (b) (2));

(b) Verification that the pressure altitude provided in Extended Squitter messages and in Mode S replies if the installation sends Extended Squitter are identical (See CS ACNS.D.ELS. (b) (2));

(c) Other parameters provided by the airborne surveillance system are verified as correct and are correctly indicated as available. (See CS ACNS.D.ELS. (b) (1)).

Note. The tests of the other parameters transmitted by the system allow certification of aircraft not subject to full EHS mandate but capable of transmitting some of the parameters which can be used by the operational systems.

Appendix E — Differences between CS ACNS.D.EHS and EASA AMC 20-13

To demonstrate compliance with CS ACNS Enhanced Surveillance requirements, the following additional points need to be addressed for aircraft previously compliant with EASA AMC 20-13:

(a) All transmitted parameters are correct and are correctly indicated as available (see CS ACNS.D.EHS.015 (c)) ;

(b) Barometric pressure setting is provided (See CS ACNS.D.EHS.015 (a) (8) and (c)).

Appendix F — Example of Flight Manual Supplement for ELS/EHS

This Flight Manual is EASA approved under Approval Number P-EASA.xxxxx

Flight Manual [*or POH as appropriate*] Reference _______

(Company Name)

FLIGHT MANUAL SUPPLEMENT

Aircraft Model: ______

Serial Number: ____

SSR MODE S Elementary/Enhanced Surveillance

Modification Number __________

The limitations and information contained herein either supplement or, in the case of conflict, override those in the flight manual.

GENERAL

The installed transponder system is able to respond to interrogations in Modes A, C and S and is fully compliant with the requirements of CS ACNS.D.ELS/EHS (Mode S Elementary/Enhanced Surveillance). A detailed description of the transponder operation can be found in the ____________________, P/N __________________, Rev. ____ or subsequent revisions.

LIMITATIONS

None

EMERGENCY PROCEDURES

No change to Approved Aircraft Flight Manual

NORMAL/ ABNORMAL PROCEDURES

Normal/Abnormal transponder operating procedures are described in the ________________, P/N ____________________, Rev. _____ or subsequent revisions.

The procedure to change Aircraft Identification in flight is described in _________________________.

PERFORMANCE

No change to Approved Aircraft Flight Manual.

To be inserted in the flight manual and record sheet amended accordingly.

Page (__) of (__) **Authority/DOA Approval:______________________Date:____________**

Issue:________ **Signature:______________________________________**

Appendix G - Example of Flight Manual Supplement for ADS-B out

(*Aircraft Type*) Flight Manual [or POH as appropriate] Reference (*XXXX*)

(Company Name)

FLIGHT MANUAL SUPPLEMENT *(1)* ISSUE *(1)*

Aircraft Model: _______

Serial Number: ____

ADS-B Out

Modification Number ______

ADDITIONAL LIMITATIONS AND INFORMATION

The limitations and information contained herein either supplement or, in the case of conflict, override those in the flight manual.

GENERAL

The installed ADS-B out system is fully compliant with the requirements of CS ACNS.D.ADSB (1090 MHz Extended Squitter ADS-B Out). A detailed description of the system operation can be found in the ____________________, P/N __________________, Rev. ____ or subsequent revisions.

LIMITATIONS

None

EMERGENCY PROCEDURES

No change to Approved Aircraft Flight Manual

NORMAL/ ABNORMAL PROCEDURES

Normal/Abnormal operating procedures are described in the ________________, P/N ____________________, Rev. _____ or subsequent revisions.

The procedure to change Aircraft Identification in flight is described in __________________________.

PERFORMANCE

No change to Approved Aircraft Flight Manual

To be inserted in the flight manual and record sheet amended accordingly.

Page (__) of (__) **Authority/DOA Approval:________________________Date:_____________**

Issue:________ **Signature:____**

Appendix H – Guidance on 1090 MHz Extended Squitter ADS-B Out

Part 1 – ADS-B Out Data Parameters (AMC ACNS.D.ADSB.020(a))

Part 1 of this Appendix provides guidance to the aircraft integrator on the minimum ADS-B Out surveillance data requirements (Table 5 and associated Definitions).

In addition, guidance is given for the overall understanding of the ADS-B Out system, in support of equipment configuration and ADS-B Out data parameter testing, as appropriate. This includes the presentation of data encodings related to the so-called BDS registers (Table 4), as extracted from ED-102A. The content of the various BDS registers are loaded into the 56-bit ADS-B message (ME) field of the Mode S Downlink Format 17 (DF17, bits 33-88), in line with their respective transmission rates.

Table 5 below makes reference to the BDS registers that contain the various ADS-B Out data parameters. When Table 5 states Same source as for Mode S replies, reference is made to the requirement that the content of ADS-B broadcasts and Mode S replies that carry the same information need to come from the same source (CS ACNS.D.ADSB.025(b)).

The reference to the BDS registers is provided in order to facilitate a detailed understanding and traceability of ADS-B Out requirements at ADS-B transmit unit level, also in support of integration testing, as appropriate.

The relationship between the BDS registers and the ADS-B message Type Codes (first 5 bits in the 56-bit ADS-B message field) is thereby as shown in Table 4. The Type Code is used to differentiate between ADS-B message types (i.e. BDS registers). In addition, for Airborne and Surface Position Messages, the Type Code is used to encode the horizontal position integrity containment bounds (NIC). The Subtype Code is used to further differentiate between ADS-B messages of a certain type (e.g. Operational Status Message).

A number of service bulletins have been issued to rectify some observed deficiencies and have already been addressed by the equipment manufacturers. Therefore, the installed transponders should have all published corrective transponder equipment service bulletins (SB) relating to the correct operation of the ADS-B functionality embodied.

Table 4: BDS Register Overview

BDS Register	Type Code(s)	Subtype Code
05_{16} – Airborne Position Message	0, 9-18, 20-22	n/a
06_{16} – Surface Position Message	0, 5-8	n/a
08_{16} - Aircraft Identification and Category Message	1, 2, 3 or 4	n/a
09_{16} - Airborne Velocity Message Velocity over Ground (Normal/Supersonic)	19	1+2
61_{16} - Aircraft Status Message Emergency Status and Mode A Code	28	1
61_{16} - Aircraft Status Message ACAS RA Broadcast	28	2
62_{16} - Target State and Status Message	29	1
65_{16} – Aircraft Operational Status Message While Airborne	31	0
65_{16} – Aircraft Operational Status Message On the Surface	31	1

Note: Although BDS registers 07_{16} and $0A_{16}$ are not conveying ADS-B data items their implementation is needed to complement the ADS-B protocol.

Table 5: Minimum ADS-B Out Surveillance Data Transmission Requirements

Item	Parameter	Requirements	BDS Register	Remarks
1	Aircraft Identification	See Definition 1	08_{16}	Same source as for Mode S replies
2	Mode A Code	See Definition 2	61_{16}	Same source as for Mode S replies Broadcast suppressed for conspicuity code '1000'
3	ICAO 24-bit aircraft address	Transmit ICAO 24-bit aircraft address	All BDS (AA field of DF17, bits 9-32)	Unique ICAO 24 bit aircraft address needs to be assigned by the responsible authority
4a	Airborne Horizontal Position – Latitude and Longitude	See Definition 3	05_{16}	
4b	Airborne Horizontal Position Quality: NIC	See Definition 4 and 5	05_{16} Type Codes	Incl. NIC Supplements A (65_{16}) and B (05_{16})
4c	Horizontal Position Quality: NACp	See Definition 4 and 6	62_{16} and 65_{16}	
4d	Horizontal Position Quality: SIL	See Definition 4 and 7	62_{16} and 65_{16}	Incl. SIL Supplement.
4e	Horizontal Position Quality: SDA	See Definition 4 and 8	65_{16}	
5	Pressure Altitude	See Definition 9	05_{16}	Same source as for Mode S replies Data associated with 'NICbaro' integrity indicator
6	Special Position Identification (SPI)	Setting as per ED-73E §2.5	05_{16}	Same source as for Mode S replies
7a	Emergency Status	See Definition 10	61_{16} (subtype 1)	Same source as for Mode S replies (where defined for SSR)
7b	Emergency Indication	Setting as per ED-73E §2.5	05_{16}	Same source as for Mode S replies
8	1090 ES Version Number	To be set to 2 for ED-102A/DO-260B systems.	65_{16}	Value is fixed at the time the ADS-B transmit unit is manufactured.
9a	Airborne	See Definition 11	09_{16}	Same source as

Item	Parameter	Requirements	BDS Register	Remarks
	Horizontal Velocity (Ground Speed) - east/west and north/south		(subtypes 1and2)	for SSR EHS replies
9b	Horizontal Velocity Quality: NACv	See Definition 12	09_{16} (airborne) and 65_{16} (subtype 1, surface)	
10	Emitter Category	See Definition 13	08_{16}	
11	Vertical Rate	See Definition 14	09_{16} (subtypes 1and2)	Selected source is indicated in 09_{16} source indication
12a	Surface Horizontal Position – Latitude and Longitude	Source see AMC ACNS.D.ADSB.070 See Definition 3	06_{16}	Quality indicators NACp, SIL, SDA: same encodings as for airborne horizontal position
12b	Surface Horizontal Position Quality: NIC	See Definition 15	06_{16} Type Codes	Incl. NIC Supplements A and C (both 65_{16})
13	Heading/Ground Track	See Definition 16	06_{16}	Heading preferred source
14	Movement (surface ground speed)	See Definitions 11 and 12	06_{16}	NACv: same as for airborne ground velocity (see 9b)
15	Length/width of Aircraft	See Definition 17	65_{16} (subtype 1)	
16	GPS Antenna Offset	See Definition 18	65_{16} (subtype 1)	Lateral and longitudinal
17a	Geometric Altitude	See Definition 19	09_{16} (05_{16})	In 09_{16} reported as difference from Pressure Altitude
17b	Geometric Altitude Quality: GVA	See Definition 20	65_{16} (subtype 0)	

Definition 1: Aircraft Identification Data Sources

Aircraft Identification is provided to the ADS-B transmit unit so that the information is identical to the filed ICAO flight plan. This information may be provided from, amongst others:

A flight management system; or

A pilot control panel; or

For aircraft, which always operate with the same aircraft identification (e.g. using registration as the aircraft identification), it may be programmed into equipment at installation.

In case no ICAO flight plan is filed, the Aircraft Registration is provided to the ADS-B transmit unit.

Definition 2: Mode A Code

Refer to AMC1 ACNS.D.ELS.015 for general guidance.

When the ADS-B transmit unit receives a Mode A Code containing the Mode S conspicuity code (1000), the broadcast of Mode A code information is stopped.

Note: The broadcast of the Mode A Code is provided as a transitional feature, e.g. to aid operation of legacy ATC automation systems that use Mode A Code for Flight Plan correlation. Entry of the Mode A Code of 1000 will disable the transmission of the Mode A Code, and, hence, reduce the overall 1090 ES transmission rate.

Definition 3: Horizontal Position Information

The Mode S Extended Squitter position format uses the Compact Position Reporting (CPR) algorithm to encode latitude and longitude efficiently into messages. The resulting messages are compact in the sense that several higher order bits which are normally constant for long periods of time, are not transmitted in every message.

The CPR technique enables a receiving system to unambiguously determine the location of the aircraft, and, hence ,reconstruct the original information provided by the source. If required for integration testing purposes, detailed guidance on the CPR algorithm is provided in ED-102A/DO-260B.

A horizontal position data source provides position information for both the airborne and surface horizontal position data formats (i.e. registers 05_{16} or 06_{16}, respectively), accordingly encoded by the ADS-B transmit unit depending on the aircraft airborne/surface state.

Definition 4: Horizontal Position Quality – NIC and NACp

The encoding of the NIC and NACp horizontal position quality indicators should be directly derived from the corresponding integrity and accuracy information as being reported by the selected horizontal position source (refer also to CS ACNS.D.ADSB.025(c)).

In case a measurement integrity failure has been indicated by the selected horizontal position source (e.g. bit 11 of ARINC label 130 for ARINC 743A compliant sources), both the NIC and NACp quality indicators will be set to invalid (zero), regardless of the indicated integrity containment bound (e.g. HPL).

Definition 5: Airborne NIC Value

NIC is reported so that surveillance applications, such as by ATC or other aircraft, may determine whether the reported horizontal position has an acceptable level of measurement integrity for the intended use. (Note that the NIC parameter is closely associated with the SIL quality metric.)

The NIC (and SIL) values are associated with a possible failure condition of the position measurement function and the detection thereof. For most ADS-B applications, the NIC (and SIL) values are the key horizontal position quality metrics on which the horizontal position data is determined to be of sufficient quality for its intended use. The NIC value is encoded on the respective horizontal position integrity containment radius as provided by the source.

The NIC values, including the NIC Supplements values, are encoded for airborne position messages as follows (Rc is the horizontal position integrity containment bound, typically HPL/HIL for GNSS systems):

Table 6: Airborne NIC Encoding

NIC Value	**Radius of Containment (R_C)**	**Airborne**		
		Airborne Position TYPE Code	**NIC Supplement Codes**	
			A	**B**
0	R_C unknown or R_C ≥ 37 040 m (20 NM)	0, 18 or 22	0	0
1	R_C < 37 040 m (20 NM)	17	0	0
2	R_C < 14 816 m (8 NM)	16	0	0
3	R_C < 7 408 m (4 NM)	16	1	1
4	R_C < 3 704 m (2 NM)	15	0	0
5	R_C < 1 852 m (1 NM)	14	0	0
6	R_C < 1 111.2 m (0.6 NM)	13	1	1
	R_C < 926 m (0.5 NM)	13	0	0
	R_C < 555.6 m (0.3 NM)	13	0	1
7	R_C < 370.4 m (0.2 NM)	12	0	0
8	R_C < 185.2 m (0.1 NM)	11	0	0
9	R_C < 75 m	11	1	1
10	R_C < 25 m	10 or 21	0	0
11	R_C < 7.5 m	9 or 20	0	0

Note: The minimum NIC values required for the ADS-B-RAD application can be found in Table 20*, in Part 3 of Appendix A. They are met through the horizontal position source requirements defined in CS ACNS.D.ADSB.070.*

Definition 6: NACp

NACp specifies the 95 % radial accuracy of the aircraft's horizontal position information (latitude and longitude) derived from the position source's accuracy output, typically the HFOM metric from GNSS based sources.

Whereas the NIC value is associated with a possible failure condition of the position measurement function, the NACp value describes the nominal performance of the measurement function in terms of horizontal position accuracy as provided by the source.

The NACp value is encoded as follows:

Table 7: NACp Encoding

Coding	95% Horizontal Accuracy Bound
0	EPU ≥ 18 520 m (≥10 NM)
1	EPU < 18 520 m (10 NM)
2	EPU < 7 408 m (4 NM)
3	EPU < 3 704 m (2 NM)
4	EPU < 1852 m (1 NM)
5	EPU < 926 m (0.5 NM)
6	EPU < 555.6 m (0.3 NM)
7	EPU < 185.2 m (0.1 NM)
8	EPU < 92.6 m (0.05 NM)
9	EPU < 30 m
10	EPU < 10 m
11	EPU < 3 m

Note: The minimum NACp values required for the ADS-B-RAD application can be found in Table 20*, in Part 3 of Appendix A. This value is met through the horizontal position source requirements defined in CS ACNS.D.ADSB.070.*

The NACp encoding is the same for airborne position messages and surface position messages.

Definition 7: SIL

The encoding of the horizontal position source integrity level (SIL) is based on the probability of the reported horizontal position exceeding the radius of containment defined by the NIC, without alerting, assuming no avionics faults. The SIL value is set as follows:

Table 8: SIL Encoding

SIL value	Probability of Exceeding the NIC Containment Radius
0	Unknown or > 1×10^{-3} per flight hour or per sample
1	≤ 1×10^{-3} per flight hour or per sample
2	≤ 1×10^{-5} per flight hour or per sample
3	≤ 1×10^{-7} per flight hour or per sample

Note: The minimum SIL value required for the ADS-B-RAD application can be found in Table 20*, in Part 3 of Appendix A. This value is met through the horizontal position source requirements defined in CS ACNS.D.ADSB.070 (see also related AMC guidance).*

Whereas SIL assumes that there are no system integrity failures, the SIL should consider the effects of a faulted signal-in-space.

For horizontal position sources compliant with CS ACNS.D.ADSB.070, the probability of exceeding a NIC radius of containment without alerting is based on a per hour rate. Hence, the SIL Supplement should be set to 'zero'. If based on per sample, the SIL Supplement would be set to 'one'.

The SIL encoding is the same for airborne position messages and surface position messages.

Definition 8: SDA

The encoding of the system design assurance level (SDA) is based on the failure condition that the entire ADS-B Out system, with respect to the horizontal position data and associated quality indicators, is designed to support.

The SDA value is encoded as follows:

Table 9: SDA Encoding

SDA value	**Software & Hardware Design Assurance Level** (see Note 1)	**Corresponding System Integrity Level** (see Note 2)
0	N/A	> $1X10^{-3}$ per flight hour or unknown (No Safety Effect)
1	D	≤ $1X10^{-3}$ per flight hour (Probable)
2	C	≤ $1X10^{-5}$ per flight hour (Remote)
3	B	≤ $1X10^{-7}$ per flight hour (Extremely Remote)

Note 1: Software Design Assurance per EUROCAE ED-12C (RTCA DO-178C). Airborne Electronic Hardware Design Assurance per EUROCAE ED-80 (RTCA DO-254).

Note 2: In line with the ADS-B-RAD requirements, the minimum value required for the horizontal position source is SDA=2 ().

The SDA encoding is the same for airborne position messages and surface position messages.

Definition 9: Pressure Altitude Data Sources

Refer to AMC1 ACNS.D.ELS.015 for guidance.

The ADS-B NICbaro quality indicator is encoded as follows:

Table 10: NICbaro Encoding

Coding	Meaning
0	The barometric altitude is based on a Gillham coded input that has not been cross-checked against another source of pressure altitude.
1	The barometric altitude is either based on a Gillham code input that has been cross-checked against another source of pressure altitude and verified as being consistent, or is based on a non-Gillham coded source.

Definition 10: Emergency Status

The provision of the Emergency Status values that do not have a corresponding Mode A Code value (see **CS ACNS.D.ELS.**) denoting the other emergency conditions defined in 61_{16}, is optional. This applies to the decimal values 2, 3, 6 and 7 in Table 11.

Table 11: Emergency Status Encoding

Coding		**Meaning**
(Binary)	(Decimal)	
000	0	No Emergency
001	1	General Emergency
010	2	Lifeguard/medical Emergency
011	3	Minimum Fuel
100	4	No Communications
101	5	Unlawful Interference
110	6	Downed Aircraft
111	7	Reserved

Definition 11: Horizontal Velocity (Ground Velocity)

The horizontal velocity provides the rate at which an aircraft changes its horizontal position with a clearly stated direction.

Velocity data sources provide ground velocity vector information for both the airborne and surface velocity data transmit formats, allowing for the transmission of east/west and north/south velocity information (09_{16}), or velocity scalar (06_{16}, movement) and possibly ground track information[2] (06_{16}), respectively.

2. Refer to Definition 16.

In case of a failure of the provision of ground velocity data, the ADS-B transmit unit will broadcast airspeed (and heading) information instead (using subtypes 3 or 4 of register 09_{16}.

Definition 12: Horizontal Velocity Quality Indicator NACv

The NACv is an estimate of the accuracy of the horizontal geometric velocity data.

The NACv value is encoded as follows:

Table 12: NACv Encoding

Navigation Accuracy Category for Velocity NACv		
Coding		Horizontal Velocity Error (95%)
(Binary)	(Decimal)	
000	0	Unknown or $\geq$ 10 m/s
001	1	< 10 m/s
010	2	< 3 m/s
011	3	< 1 m/s
100	4	< 0.3 m/s

The NACv encoding is the same for airborne position messages and surface position messages.

Definition 13: Emitter Category

Emitter Category settings describe the size and performance of an aircraft, primarily expressed with respect to its maximum take-off weight.

The Emitter Category value is encoded as follows:

Table 13: Emitter Category Encoding

ADS-B Emitter Category Set "A"	
Coding	**Meaning**
0	No ADS-B Emitter Category Information
1	Light (< 7 031 kg (15 500 lbs))
2	Small (7 031 to 34 019 kg (15 500 to 75 000 lbs))
3	Large (34 019 to 136 078 kg (75 000 to 300 000 lbs))
4	High-Vortex Large (aircraft such as B-757)
5	Heavy (> 136 078 kg (300 000 lbs))
6	High Performance (> 49 m/s² (5g) acceleration and > 205 m/s (400 knots))
7	Rotorcraft

ADS-B Emitter Category Set "B"	
Coding	**Meaning**
0	No ADS-B Emitter Category Information
1	Glider / Sailplane
2	Lighter-than-Air
3	Parachutist / Skydiver
4	Ultralight / hang-glider / paraglider
5	Reserved
6	Unmanned Aerial Vehicle
7	Space / Trans-atmospheric vehicle

ADS-B Emitter Category Set "C"	
Coding	**Meaning**
0	No ADS-B Emitter Category Information
1	Surface Vehicle - Emergency Vehicle
2	Surface Vehicle - Service Vehicle
3	Point Obstacle (includes tethered balloons)
4	Cluster Obstacle
5	Line Obstacle
6 - 7	Reserved

ADS-B Emitter Category Set "D"	
Coding	**Meaning**
0	No ADS-B Emitter Category Information
1 - 7	Reserved

The ADS-B Emitter Category Sets A, B, C or D are identified by the Message Format TYPE Codes 4, 3, 2, and 1 respectively.

Note 1: A coding of '0' within an Emitter Category Set is not allowed.

Note 2: The Emitter Category codes 1 to 5 in category set A are intended to advise other aircraft of the transmitting aircraft's wake vortex characteristics, and not necessarily the transmitting aircraft's actual maximum take-off weight. In case of doubt, the next higher aircraft category code should be used

Definition 14: Vertical Rate

Vertical Rate is either the barometric or geometric rate at which the aircraft is climbing or descending, measured in feet per minute. The vertical rate is typically generated by an air data computer or GNSS position source, or equipment which blends barometric vertical rate with inertial vertical rate and/or GNSS vertical rate.

As the geometric vertical rate can be readily derived from the ADS-B Out position source, it is classified as a minimum requirement rather than an (effectively Mode S Enhanced Surveillance) conditional requirement.

Definition 15: Surface NIC Value

The Surface NIC value, including the NIC Supplement A and C values, is encoded as follows:

Table 14: Surface NIC Encoding

NIC Value	Radius of Containment (R_C)	Surface		
		Surface Position TYPE Code	NIC Supplement Codes	
			A	C
0	R_C unknown	0, 8	0	0
6	R_C < 1 111.2 m (0.6 NM)	8	0	1
	R_C < 555.6 m (0.3 NM)	8	1	0
7	R_C < 370.4 m (0.2 NM)	8	1	1
8	R_C < 185.2 m (0.1 NM)	7	0	0
9	R_C < 75m	7	1	0
10	R_C < 25m	6	0	0
11	R_C < 7.5m	5	0	0

Definition 16: Surface Heading/Ground Track

Aircraft Heading indicates the direction in which the nose of the aircraft is pointing. It should be used as the primary source and be expressed (in ME bit 54 in 65_{16}) as either true north (‘0’, preferred) or magnetic north (‘1’).

If an approved heading source is not available (or failed during operation), the Ground Track angle information from the selected ground velocity data source will be used instead by the ADS-B transmit unit for the determination of the direction of the horizontal velocity vector.

If the position source ground track is used and inaccurate below a certain ground speed, and the position source does not inhibit output of the ground track at these slower speeds, the installer should ensure that the ADS-B transmit unit has the capability to invalidate the ground track when the GNSS ground speed falls below a threshold specified by the position source manufacturer (e.g. 3.6 m/s (7 knots)).

Definition 17: Aircraft Length and Width

Aircraft Length and Width settings describe the aircraft dimensions by the width and length of a rectangle that is aligned parallel to the aircraft's heading. The aircraft's length is to be measured along its axis of symmetry (i.e. from nose to tail). The aircraft's width is to be measured from wing-tip to wing-tip.

The Aircraft Length and Width values are encoded as shown in Table 15 to be less than or equal to a respective upper bound length and width as expressed in the two right-side columns. The Length and Width Codes are based on a combined encoding of the actual length **and** width whereby the largest respective upper bound prevails. If the Aircraft or Vehicle is longer than 85 meters, or wider than 90 meters, then decimal Aircraft/Vehicle Length/Width Code 15 is used.

Table 15: Aircraft Length/Width Encoding

A/V - L/W Code (Decimal)	Length Code			Width Code	Upper-Bound Length and Width for Each Length/Width Code	
	'ME' Bit 21	'ME' Bit 22	'ME' Bit 23	'ME' Bit 24	Length (meters)	Width (meters)
0	0	0	0	0	No Data or Unknown	
1	0	0	0	1	15	23
2	0	0	1	0	25	28.5
3				1		34
4	0	1	0	0	35	33
5				1		38
6	0	1	1	0	45	39.5
7				1		45
8	1	0	0	0	55	45
9				1		52
10	1	0	1	0	65	59.5
11				1		67
12	1	1	0	0	75	72.5
13				1		80
14	1	1	1	0	85	80
15				1		90

Example: a powered glider with an overall length of 24 meters and wingspan of 50 meters would, normally, have a length code of '001'. However, since the wingspan exceeds 34 meters, it does not qualify for either Width subcategory of length category '001'. In line with its actual width, such an aircraft would be assigned a length code of '100' and width code of '1', meaning length less than 55 meters and width less than 52 meters.

Definition 18: GPS Antenna Offset (lateral and longitudinal)

GPS Antenna Offset information provides the position offset of the GNSS antenna used for the provision of horizontal position information.

Both a lateral distance of the GPS Antenna (from the longitudinal axis of the aircraft) and a longitudinal distance of the GPS Antenna (from the nose of the aircraft) are provided.

The accuracy of the information should be better than 2 meters, consistent with the data resolution.

The lateral and longitudinal GPS Antenna Offset values are encoded as follows:

Table 16: Lateral Axis GPS Antenna Offset Encoding

<table>
<tr><th colspan="3">'ME' Bit
(Message Bit)</th><th colspan="2" rowspan="3">Upper Bound of the
GPS Antenna Offset
Along Lateral (Pitch) Axis
Left or Right of Longitudinal (Roll) Axis</th></tr>
<tr><th>33
(65)</th><th>34
(66)</th><th>35
(67)</th></tr>
<tr><th rowspan="2">0 = left
1 = right</th><th colspan="2">Encoding</th></tr>
<tr><th>Bit 1</th><th>Bit 0</th><th>Direction</th><th>(meters)</th></tr>
<tr><td rowspan="4">0</td><td>0</td><td>0</td><td rowspan="4">LEFT</td><td>NO DATA</td></tr>
<tr><td>0</td><td>1</td><td>2</td></tr>
<tr><td>1</td><td>0</td><td>4</td></tr>
<tr><td>1</td><td>1</td><td>6</td></tr>
<tr><td rowspan="4">1</td><td>0</td><td>0</td><td rowspan="4">RIGHT</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>2</td></tr>
<tr><td>1</td><td>0</td><td>4</td></tr>
<tr><td>1</td><td>1</td><td>6</td></tr>
</table>

Supplementary Notes

Maximum distance left or right of aircraft longitudinal (roll) axis is 6 meters or 19.685 feet. If the distance is greater than 6 meters, then the encoding should be set to 6 meters.

The No Data case is indicated by encoding of 000 as above, while the ZERO offset case is represented by encoding of 100 as above.

The rounding should be performed to half of the resolution of the GPS antenna offset information, i.e. +/- 1 meter.

Table 17: Longitudinal Axis GPS Antenna Offset Encoding

'ME' Bit (Message Bit)					**Upper Bound of the GPS Antenna Offset Along Longitudinal (Roll) Axis Aft From Aircraft Nose**
36 (68)	**37** (69)	**38** (70)	**39** (71)	**40** (72)	
Encoding					
Bit 4	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**	**(meters)**
0	0	0	0	0	**NO DATA**
0	0	0	0	1	Position Offset Applied by Sensor *(see also Notes)*
0	0	0	1	0	2
0	0	0	1	1	4
0	0	1	0	0	6
*	*	*	*	*	***
1	1	1	1	1	60

Supplementary Notes:

If the distance is greater than 60 meters, the encoding should be set to 60 meters.

Position Offset Applied by the Sensor applies to future cases where the antenna offset is compensated by the horizontal position source to the centre of the rectangle describing the aircraft's length and width (refer to Definition 17).

The encoding of the values from decimal '2' (only bit 1 one set to '1') to '31' (all five bits set to '1') is as follows: encoded binary value = offset [m]) / 2 + 1 (e.g. an offset of 4 meters leads to a binary value of (4/2 + 1 = 3), i.e. Bits 0-1 equal '1' and Bits 2-4 equal '0').

Definition 19: Geometric Altitude

The geometric altitude is a measure of the aircraft's height above a geometric reference and is provided by a GNSS-based position source.

Both within 05_{16} and 09_{16}, Geometric Altitude is provided as height above ellipsoid (HAE) in accordance with the WGS 84 coordinate system (AMC1 ACNS.D.ADSB.085(b)).

Definition 20: Geometric altitude quality indicator information (GVA)

The GVA parameter expresses the actual performance of the geometric altitude data source as valid at the time of applicability of the measurement.

The GVA value is encoded as follows:

Table 18: GVA Encoding

GVA Encoding (decimal)	**95% Accuracy** (meters)
0	Unknown or > 150 meters
1	≤ 150 meters
2	≤ 45 meters
3	Reserved

Appendix H

Part 2 – ADS-B Out Surveillance Data Parameters (AMC1 ACNS.D.ADSB.020(b))

Table 19 below makes reference to the BDS register(s) that contain the various ADS-B Out surveillance data parameters. When Table 19 states Same source as for Mode S replies, reference is made to the requirement that the content of ADS-B broadcasts and Mode S replies that carry the same information and need to come from the same source (CS ACNS.D.ADSB.025(b)).

Guidance on the content of the various BDS registers and their relationship with the ADS-B message Type Codes is provided in Table 4 in part 1 of Appendix A.

Table 19: ADS-B-ADD Surveillance Data Transmission Requirements

Item	Parameter	Requirements	BDS Register	Remarks
1	Selected Altitude	See Definition 21.	62_{16}	Same source as for Mode S replies
2	Barometric Pressure Setting		62_{16}	
3a	ACAS Operational	See Definition 22.	62_{16} and 65_{16}	
3b	Resolution Advisory (RA)		61_{16} (subtype 2)	

Definition 21: Selected Altitude/Barometric Pressure Setting

Refer to **AMC1 ACNS.D.EHS.** (c) (1 and (c) (3) for detailed guidance.

Definition 22: ACAS Operational /Resolution Advisory (RA)

Refer to **AMC1 ACNS.D.ELS.015** (f) for detailed guidance.

The data is populated from ACAS II systems if installed on the aircraft. Both parameters should be preset to 'zero' if an ACAS II system is not installed (refer to ADS-B transmit unit manufacturer instructions).

Appendix H

Part 3 – ADS-B Out Minimum Horizontal Position and Velocity Data Requirements

Table 20 provides a summary of the minimum horizontal position data requirements as specified in the defining ADS-B-RAD Safety and Performance Requirements/Interoperability document (ED-161).

Table 20: Minimum Horizontal Position and Velocity Data Quality Requirements

Quality Parameter	Requirement
Position Accuracy (NACp)	NACp<=185.2 m (0.1NM) (i.e. NACp>=7) for both 3 NM and 5 NM separation
Position Integrity Containment Radius (NIC)	3 NM Sep: NIC<=1 111.2 m (0.6 NM) (i.e. NIC>=6) 5 NM Sep: NIC<=1 852 m (1 NM) (i.e. NIC>=5)
Source Integrity Level (SIL)	SIL=3: 10^{-7}/flight-hour
System Design Assurance (SDA)	SDA=2: 10^{-5}/flight-hour - allowable probability level REMOTE (MAJOR failure condition, LEVEL C software and design assurance level)
Velocity Accuracy (NACv)	NACv<=10 m/s (i.e. NACv>=1)

Note 1: The requirement of NACp<=0.1NM in support of 3NM separation is based on the arguments produced in Annex B to ED-161 (ADS-B-RAD Safety and Performance Requirements*/Interoperability Requirements Document).*

Note 2: The SDA encoding of '2' (10-5/fight-hour) applies to individual components of the ADS-B Out system, i.e. 10-5/fight-hour for the ADS-B transmit unit and 10-5/flight-hour for the horizontal position and velocity source.

Note 3: ADS-B transmit units interfaced with a GNSS position source that is compliant with CS ACNS.D.ADSB.070 (and the related AMC guidance) should preset the SIL Supplement to 'zero'.

Note 4: If set as fixed value, NACv should be always 'one'. For quality indications that are dynamically provided by the velocity source, NACv should be 'one' or 'two'. There is currently no established guidance on establishing a NACv performance of 'three' or better.

This should be verified through appropriate tests, as follows. With respect to NIC and NACp testing, the ADS-B Out system installer should check for satellite shielding and masking effects if the stated performance is not achieved.

(a) Airborne & Surface NIC:

During testing under nominal GNSS satellite constellation and visibility conditions, the transmitted NIC value should be a minimum of 'six'.

(b) NACp:

During testing under nominal GNSS satellite constellation and visibility conditions, the transmitted NACp value should be a minimum of 'eight'

In order to validate the correctness of the transmitted horizontal position, the aircraft should be positioned on a known location.

(c) SIL:

SIL is typically a static (unchanging) value and may be set at the time of installation if a single type of position source is integrated with the ADS-B transmit unit. SIL should be set based on design data from the position source equipment manufacturer. Installations which derive SIL from GNSS position sources compliant with CS ACNS.D.ADSB.070 should set the SIL to 'three'.

ADS-B transmit units interfaced with a GNSS position source that is compliant with CS ACNS.D.ADSB.070 (and the related AMC guidance) should pre-set the SIL Supplement to 'zero'.

(d) NACv:

If set as fixed value, NACv should be always 'one'. For quality indications that are dynamically provided by the velocity source, NACv should be 'one' or 'two'.

It is noted that there is currently no established guidance on establishing a NACv performance of 'three' or better.

Appendix H.

Part 4 – ADS-B Out Integrity and Continuity Requirements

CS ACNS.D.ADSB.100 and CS ACNS.D.ADSB.105 summarise, per data parameter, the integrity and continuity probability levels applicable to the ADS-B Out system.

In the first place, the ADS-B Out System installed in the aircraft needs to deliver data that satisfy the ADS-B-RAD airborne domain system safety and performance requirements in line with Section 3.4 of the ADS-B-RAD Safety and Performance Requirements/Interoperability standard ED-161.

As, for the purpose of framing the ADS-B-RAD operational safety assessment, the ADS-B-RAD airborne domain only comprises the horizontal position data source and the ADS-B transmit unit, including the interconnecting avionics, the data sources providing surveillance information other than horizontal position and velocity are assumed to operate as within today's SSR environment. Hence, in line with CS ACNS.D.ADSB.080, the related Mode S Elementary and Enhanced Surveillance requirements apply.

It is noted that the respective Mode S Elementary and Enhanced Surveillance requirements have to be understood within their given context, in particular taking into account applicable procedural mitigation means (e.g. as currently performed by means of the ICAO required controller-pilot verification procedure for pressure altitude reporting).

The ADS-B Out data parameters other than the ones addressed in the preceding paragraphs, need to satisfy comparable ADS-B-RAD requirements.

The specified integrity levels are required to adequately protect against the corruption of ADS-B Out surveillance data causing false or misleading information to be transmitted.

Although the direct effects to an aircraft of an ADS-B Out failure may be minor, the ADS-B Out information will be used by ATC and other ADS-B equipped aircraft, thus provisions that would allow for a reduction in failure probabilities and design assurance level, do not apply to the ADS-B Out system.

Appendix H

Part 5 – GNSS Position and Velocity Source Qualification

This part 5 of Appendix H provides guidance to GNSS equipment manufacturers on how to establish a qualification for these ADS-B specific requirements, i.e. beyond the demonstration of compliance to ETSO requirements. In the following, as appropriate, reference is made to the respective:

- ETSO material: ETSO-C129a (JTSO-C129a), ETSO-C196a, ETSO-C145()/146()
- EUROCAE/RTCA MOPS material: ED-72A, DO-208, DO-229D, DO-316 as well as DO-235B; and
- FAA AC material (AC 20-138C).

Note: ETSO-C145 refers to RTCA DO-229A, ETSO-C146 refers to RTCA DO-229B, ETSO-C145c/146c refers to RTCA DO-229D, and ETSO-C145()/146() refers to any of those revisions.

In addition to the ETSO minimum requirements, the requirements of this part need to be demonstrated unless this has been demonstrated as a declared non-ETSO function. It is expected that the required compliance demonstration is supplied by the position and velocity source manufacturer through a Declaration of Design and Performance (DDP), or an equivalent document.

(a) Horizontal Position Integrity (HPL)

Horizontal Position Integrity — AMC1 ACNS.D.ADSB.070(a).1.2(a)

Applicability: ETSO-C129a (JTSO-C129a)

GNSS equipment manufacturers should provide substantiation data showing that the equipment outputs latitude and longitude information that is referenced to the WGS-84 coordinate system.

GNSS equipment manufacturers should provide substantiation data showing that the equipment outputs a 10^{-7}/hr Horizontal Protection Limit (HPL, or equivalent) based on the RAIM algorithm meeting the ETSO-C129a (JTSO-C129a) Class A1, A2, B1, B2, C1, or C2 RAIM requirements.

Applicability: ETSO-C145()/146()

SBAS equipment certified under any revision of ETSO-C145 or ETSO-C146 is required to have several modes of operation depending on the availability of augmentation. For example, when operating in an augmented mode intended for LPV approach guidance, the position source may determine HPL based on a lateral error versus a horizontal error and an exposure time based on the duration of the approach versus flight hour (refer to Appendix J to RTCA DO229D for details).

If the position source outputs the HPL on lateral error and approach exposure time, it is possible that the ADS-B transmit function would need to inflate the HPL by 3% in approach modes to ensure the integrity is appropriately bounded.

GNSS equipment manufacturers should provide information data to determine if the integrity output needs to be scaled (i.e., by applying an inflation factor). The same considerations apply to GBAS differentially-corrected position sources when in approach mode.

Integrity Fault – Time to Alert — AMC ACNS.D.ADSB.070(a).1.2(b)

Applicability: ETSO-C129a (JTSO-C129a)

For the horizontal position sources compliant with AMC ACNS.D.ADSB.070, it should to be demonstrated, that a non-isolated GNSS satellite fault detected by the position source is properly passed to the ADS-B transmit unit within the allowable time to alert of 10 seconds, at any time.

With reference to the mode dependent time to alert in Table 3-5 of EUROCAE ED-72A section 3.2.1 (Table 2-1 of RTCA DO-208 Section 2.2.1.13.1), GNSS equipment manufacturers should provide information describing the equipment integrity fault output latency, along with interface instructions and/or any limitations for meeting the 10-second latency requirement of AMC1 ACNS.D.ADSB.070(a).1.2(b).

Note 1: The latency of reporting nominal ADS-B Quality Indicator changes, such as in response to changing GNSS satellite constellations or due to switching between position sources, is bounded by CS ACNS.D.ADSB.070(a).1.2(c) as well.

Note 2: ED-72A allows a provision to extend the Time to Alarm up to 30 seconds during en route phases of flight while for terminal and Non-Precision Approach the 10-second limit is applicable. For ADS-B Out, a time to alert of 10 seconds applies to any phases of flight.

Mode Output — AMC1 ACNS.D.ADSB.070(a).1.3

Applicability: ETSO-C129a (JTSO-C129a), ETSO-C196a, ETSO-C145()/146()

GNSS equipment manufacturers should provide instructions describing any equipment modes affecting the interpretation of horizontal position integrity output and how the position source outputs the mode indication.

As the minimum horizontal position integrity containment bound provided by non-augmented, as well as some specific augmented GNSS source, equipment is limited to 0.1 NM by design, the GNSS equipment manufacturer should present substantiation data whether the HPL output is limited or not, and provide proper instructions for the ADS-B Out system integration. If the GNSS source equipment does not limit the HPL, although it should do so by design, the ADS-B transmit unit limits the encoded NIC value to be equal to or less than 'eight'.

(b) Horizontal Position Accuracy (HFOM) — AMC ACNS.D.ADSB.070(a).1.2(d)

Applicability: ETSO-C129a, ETSO-C145, and ETSO-C146

Note 1: Compliance with RTCA/DO-229D is required by ETSO-C145c-C146c. ETSO-C145/-C146 may be acceptable by applications of a positive deviation.

Note 2: If in the following, reference is made in the qualification tests described in DO-229D, the equivalent material in DO-316 applies as well.

GNSS equipment manufacturers should provide substantiation data showing the equipment computes and outputs HFOM. The following criteria for an acceptable horizontal position output and its associated HFOM accuracy metric are recommended to be applied:

(1) The horizontal position output should be calculated using the general least squares position solution of DO-229D Appendix J.1 (or any mathematically equivalent linear combination of range measurements). There is no restriction on the choice of the weight matrix W including non-weighted solutions; the use of the LNAV/VNAV, LP, LPV approach weight ($w_i = 1/\sigma_i^2$) is optional.

(2) The horizontal position accuracy should be tested using the procedure of DO-229D Section 2.5.8.3. The σ_i^2 used to compute the variance d^2_{major} should be greater or equal to the ones listed in DO-229D Appendix J when the equipment uses SBAS-provided integrity and greater or equal to the ones listed as an acceptable means for FDE-provided integrity in section DO-229D 2.1.2.2.2.2 when the equipment does not use SBAS-provided integrity. A fixed sigma of 33.3 m is considered a sufficient over-bound when using FDE-provided integrity. For equipment that uses SBAS-provided integrity, testing only in the highest mode attainable for its declared Operational Class as specified in the test itself is acceptable.

(3) The accuracy metric should be greater or equal to 1.96 sqrt($d^2_{east} + d^2_{north}$) or 2.45 d_{major} where d_{major}, d_{east}, and d_{north} are computed using the same σ_i employed during the horizontal accuracy test procedure. General certification substantiation data that the equipment meets this requirement is sufficient; no specific test is required.

Note 1: The scaling factors for the horizontal position accuracy metrics were rounded to 2 decimal places; there is no intention to prohibit the use of a more accurate number.

Note 2: The horizontal position accuracy metrics listed above are the standard metrics used to provide a minimum of 95 % containment (varying from 95 % to approximately 98.5 % for the horizontal metrics) under the assumption that a Gaussian distribution with a sigma of σ_i over- bounds the error of the range measurements. The use of a general least squares position solution (or mathematically equivalent) results in a joint Gaussian distribution for the *components (North, East, Up) of the position error. Any accuracy metric that can be mathematically demonstrated to provide a minimum 95 % containment in the position domain under the Gaussian assumption is also acceptable.*

(c) Horizontal Position Latency — AMC1 ACNS.D.ADSB.070(a).1.2(e)

Time of Measurement to Time of Applicability

Applicability: ETSO-C129a (JTSO-C129a)

The intent of this qualification is to ensure that position and related quality indicator information are related to the same time of applicability in a consistent manner.

Based on the particular receiver design, GNSS equipment manufacturers should use a manufacturer-defined test, and/or analysis to determine the latency between the time satellite measurements are collated for processing and the time the equipment calculates a filtered (impulse response) position solution. The equipment should meet a 500-millisecond time of measurement to time of applicability requirement and account for the impulse response of the position solution.

Note: Whilst CS ACNS.D.ADSB does not establish requirements on the time of measurement, the above qualification has been incorporated to ensure consistency with FAA AC 20-165A.

Time of Applicability to Time of Output

Applicability: ETSO-C129a (JTSO-C129a)

The GNSS equipment manufacturer should document the position source latency from time of applicability to time of position output. If this latency exceeds 0.4 seconds, it may not support the 1.5-second total ADS-B transmission latency at the aircraft level (refer also to AMC1 ACNS.D.ADSB.115).

Time Mark

Applicability: ETSO-C129a (JTSO-C129a), ETSO-C196a, ETSO-C145()/C146()

If the use of the time mark to reduce latency is implemented in the ADS-B Out system, GNSS equipment manufacturers should provide installation instructions describing how the time mark relates to the time of applicability of the position, velocity, and related quality indicator information.

(d) Horizontal Velocity Accuracy — AMC1 ACNS.D.ADSB.070(a).1.2(f)

Environmental Noise Test Conditions:

Applicability: ETSO-C129a, ETSO-C145( )/C146( ) (JTSO-C145/C146)

For equipment that was not required to meet the environmental noise standard prescribed by DO-235B, the velocity tests in AC 20-138B, Appendix 4 use environmental noise test conditions that may cause the equipment to stop functioning, i.e. to lose satellite acquisition and tracking capability that causes the equipment to stop outputting velocity. Whilst this contributes to an ADS-B availability issue for operators, this loss of function will not prevent the equipment from being used as an ADS-B velocity input, provided:

(1) the equipment does not output misleading velocity information at or after the onset of the triggering interference levels; and

Note: A method to accomplish this is first running the test at the higher noise level to ensure there is no misleading velocity information at loss of function before running the complete test at the lower noise level.

(2) the equipment manufacturer should state that the equipment meets the noise requirements in DO-235B.

If the above conditions are met, the velocity tests in Appendix 4 of AC 20-138B (see below for NACv=1 and NACv=2 cases) can be run using an interference level that does not cause the equipment to lose acquisition and tracking.

ADS-B Out system installations intending to support NACv = 1:

Applicability: ETSO-C129a (JTSO-C129a), ETSO-C196a, ETSO-C145()/146()

The GNSS equipment manufacturer should perform the velocity tests in Appendix 4 of AC 20-138B associated with NACv = 1 to substantiate the equipment's velocity output.

The GNSS equipment manufacturer should indicate that the equipment satisfies the requirements for NACv =1 in the instructions for the ADS-B integration.

ADS-B Out system installations intending to support NACv = 2:

Applicability: ETSO-C129a (JTSO-C129a), ETSO-C196a, ETSO-C145()/146()

The GNSS equipment manufacturer should substantiate that the equipment dynamically outputs HFOMv and VFOMv and perform the velocity tests in AC 20-138C Appendix 4 associated with NACv = 1 and NACv = 2 to substantiate the equipment's velocity output.

The GNSS equipment manufacturer should indicate that the equipment satisfies the requirements for NACv = 2 in the instructions for ADS-B Out system integration.

Track Angle Validity:

Applicability: ETSO-C129a (JTSO-C129a), ETSO-C196a, ETSO-C145()/146()

Using test and/or analysis for substantiation data, GNSS manufacturers should provide instructions for the ADS-B Out system integrator indicating when the track angle 95 % accuracy, when derived from north/east velocity, exceeds plus/minus 'eight' degrees. It is acceptable for the instructions to state that the track angle does not meet the required accuracy below a specified speed.

Note 1: Track Angle Validity is only an issue at taxiing speeds. Thereby, only along-track acceleration (0.58g) and jerk (0.25g/sec) are assumed to apply.

Note 2: Use should be made of the test environment specified in Appendix 4 of AC 20-138B. The interference levels used to demonstrate velocity accuracy compliance can be used for true track angle validity testing as well.

(e) Geometric Altitude Accuracy (VFOM) — AMC ACNS.D.ADSB.085

Applicability: ETSO-C129a (JTSO-C129a), ETSO-C196a, ETSO-C145()/146()

GNSS equipment manufacturers should provide substantiation data showing if and how the equipment computes and outputs VFOM. If VFOM is output, the following criteria for an acceptable HAE-referenced geometric altitude output and its associated VFOM accuracy metric are recommended to be applied:

(1) The HAE output should be calculated using the general least squares position solution of DO-229D Appendix J.1 (or any mathematically equivalent linear combination of range measurements). There is no restriction on the choice of the weight matrix W including non-weighted solutions; the use of the LNAV/VNAV, LP, LPV approach weight ($w_i = 1/\sigma_i^2$) is optional.

(2) The HAE accuracy should be tested using the procedure of DO-229D Section 2.5.8.3. The σ_i^2 used to compute the variance d_U^2 should be greater or equal to the ones listed in DO-229D Appendix J when the equipment uses SBAS-provided integrity and greater or equal to the ones listed as an acceptable means for FDE-

provided integrity in section 2.1.2.2.2.2 when the equipment does not use SBAS-provided integrity. A fixed sigma of 33.3 m is considered a sufficient over-bound when using FDE-provided integrity. For equipment that uses SBAS-provided integrity, testing only in the highest mode attainable for its declared Operational Class as specified in the test itself is acceptable.

(3) The accuracy metric should be greater or equal to 1.96 d_U where d_U is computed using the same σ_i employed during the HAE accuracy test procedure. General certification substantiation data that the equipment meets this requirement is sufficient; no specific test is required.

For GPS equipment that outputs altitude references other than HAE whilst the overall ADS-B Out System meets AMC1 ACNS.D.ADSB.085(b), an equivalent data accuracy should be demonstrated.

Note 1: The scaling factors for the vertical position accuracy metrics were rounded to 2 decimal places; there is no intention to prohibit the use of a more accurate number.

Note 2: The vertical position accuracy metrics listed above are the standard metrics used to provide a minimum of 95 % containment (varying from 95 % to approximately 98.5 % for the vertical metrics) under the assumption that a Gaussian distribution with a sigma of σ_i over- bounds the error of the range measurements. The use of a general least squares position solution (or mathematically equivalent) results in a single Gaussian distribution for the components (North, East, Up) of the position error. Any accuracy metric that can be mathematically demonstrated to provide a minimum 95 % containment in the position domain under the Gaussian assumption is also acceptable.

Appendix H

Part 6 – Compliance Matrix BDS Register Fields

This part of Appendix H lists compliance matrices of the BDS register fields transmitted by the 1090 ES ADS-B transmit unit, with respect to the population of the 1090 ES data fields with data from approved sources (CS ACNS.D.ADSB.025(a) applies).

Omitted in the tables are fields containing the subtype codes (for these, refer to Part 1 of this Appendix) and reserved fields.

Reference to ADS-B Out item numbers is made in line with Part 1 of this Appendix respectively. Reference to Definitions is made in line with Part 1 of this Appendix.

Within the requirements (Req't) column, 'M' expresses a mandatory requirement, i.e. the respective fields are populated with data from approved sources. 'O' expresses an optional requirement, 'NA' expresses non-applicability and 'C' expresses a conditional requirement (requirement is mandatory provided that the condition expressed in the remark column is met).

In addition to the 1090 ES data fields (as specified by the respective 'ME' Bits conveyed within the downlink format DF 17), the 3-bit 'Capability (CA)' field, also conveyed within downlink format DF 17, should be populated for all below registers as follows:

DF 17 – CA Field

DF 17 bits	Field	Req't	Remark
6-8	Capability	M	Refer to ICAO Annex 10, Volume IV, section 3.1.2.5.2.2.1.

Register 05_{16} – Airborne Position Message

ME Bits	Field	Req't	Remark
6-7	Surveillance Status	M	= '0', no condition information = '1', Item 7a, Definition 10 = '2', Mode A code change = '3', Item 6
8	NIC Supplement-B	M	Item 4b, Definition 4 and 5
9-20	Altitude	M	Item 5, Definition 9
21	Time (T)	M	"GNSS time mark coupled" ('0' no, '1' yes), Item 4a, Definition 3
22	CPR Format (F)	M	Compact Position Reporting (CPR) format type ('0' even, '1' odd) , Item 4a, Definition 3
23-39	CPR Encoded Latitude	M	Item 4a, Definition 3
40-56	CPR Encoded Longitude	M	

Register 06_{16} – Surface Position Message

ME Bits	Field	Req't	Remark
6-12	Movement	M	Item 14, Definitions 11 and 12
13	Heading/Ground Track Status	M	Item 13, Definition 15
14-20	Heading/Ground Track	M	
21	Time (T)	M	'GNSS time mark coupled' ('0' no, '1' yes), Item 4a, Definition 3
22	CPR Format (F)	M	Compact Position Reporting (CPR) format type ('0' even, '1' odd) , Item 4a, Definition 3
23-39	CPR Encoded Latitude	M	Item 4a, Definition 3
40-56	CPR Encoded Longitude	M	

Register 08_{16} - Aircraft Identification and Category Message

ME Bits	Field	Req't	Remark
6-8	ADS-B Emitter Category	M	Item 10, Definition 13
9-56	Identification Characters #1-#8	M	6 bits per character, Item 1, Definition 1

Register 09_{16} - Airborne Velocity Message - Velocity over Ground (Subtypes 1and2, Normal/Supersonic)

ME Bits	Field	Req't	Remark
6-8	Subtype	M	'0' normal, '1' supersonic
9	Intent Change Flag	O	Mode S protocol support, indication of new information in GICB registers 40_{16} to 42_{16}
11-13	NAC_V	M	Item 9b, Definition 12
14	E/W Direction Bit	M	Item 9a, Definition 11
15-24	E/W Velocity	M	
25	N/S Direction Bit	M	
26-35	N/S Velocity	M	
36	Vertical Rate Source	M	Item 11, Definition 14
37	Vertical Rate Sign	M	
38-46	Vertical Rate	M	
49	Difference from Barometric Altitude Sign	M	Item 17a, Definition 19
50-56	Difference from Barometric Altitude	M	

Register 09_{16} - Airborne Velocity Message - Airspeed (Subtypes 3 and 4, Normal/Supersonic)

ME Bits	Field	Req't	Remark
6-8	Subtype	M	'0' normal, '1' supersonic
9	Intent Change Flag	O	Mode S protocol support, indication of new information in GICB registers 40_{16} to 42_{16}
11-13	NAC_V	O	Item 9b, Definition 12
14	Heading Status Bit	O	Item 9a, Definition 11
15-24	Heading	O	
25	Airspeed Type	O	
26-35	Airspeed	O	
36	Vertical Rate Source	M	Item 11, Definition 14
37	Vertical Rate Sign	M	
38-46	Vertical Rate	M	
49	Difference from Barometric Altitude Sign	M	Item 17a, Definition 19
50-56	Difference from Barometric Altitude	M	

Register 61_{16} - Aircraft Status Message - Emergency Status and Mode A Code

ME Bits	Field	Req't	Remark
6-8	Subtype	M	='1'
9-11	Emergency/Priority Status	M	Mandatory codes: '0', '1', '4' and '5', Item 7a, Definition 10
12-24	Mode A Code	M	Item 2, Definition 2

Register 61_{16} - Aircraft Status Message - ACAS RA Broadcast

ME Bits	Field	Req't	Remark
5-8	Subtype	M	='2'
9-22	Active Resolution Advisories	M	Item 20b, Definition 22
23-26	RACs Record	M	
27	RA Terminated	M	
28	Multiple Threat Encounter	M	
29-30	Threat Type Indicator	M	
31-56	Threat Identity Data	M	

Register 62_{16} - Target State and Status Message

ME Bits	**Field**	**Req’t**	**Remark**
6-7	Subtype	M	= ‘1’
8	SIL Supplement	M	Item 4d, Definition 4 and 7
9	Selected Altitude Type	C	Where available in a suitable format Item 18, Definition 21
10-20	MCP/FCU Selected Altitude ***or*** FMS Selected Altitude	C	
21-29	Barometric Pressure Setting	C	Where available in a suitable format Minus 800 millibars.
30	Selected Heading Status	O	not required by Commission Regulation (EU) No 1207/2011
31	Selected Heading Sign	O	
32-39	Selected Heading	O	
40-43	Navigation Accuracy Category Position (NAC_P)	M	Item 4c, Definition 4 and 6
44	Navigation Integrity Category Baro	M	Item 5, Definition 9
45-46	Source Integrity Level	M	Item 4d, Definition 4 and 7
47	Status of MCP/FCU Mode Bits	M	Item 18, Definition 21
48	Autopilot Engaged	O	
49	VNAV Mode Engaged	O	
50	Altitude Hold Mode	O	
52	Approach Mode	O	
53	TCAS Operational	M	Item 20a, Definition 22
54	LNAV Mode Engaged	O	Item 18, Definition 21

Register 65_{16} – Aircraft Operational Status Message - While Airborne

ME Bits	Field	Req't	Remark
6-8	Subtype	M	= '0' (Airborne)
9-10	Airborne Capability Class Subtype	M	= '0,0'
11	TCAS Operational	M	Item 20a, Definition 22
12	1090 ES IN	O	not required by EU Regulation No 1207/2011
15	Air Referenced Velocity Report Capability	M	= '0', if aircraft is not capable of sending Airborne Velocity, Subtype 3 or 4 = '1', if yes
16	Target State Report Capability	M	= '1'
17-18	Trajectory Change Report Capability	M	= '0'
19	UAT IN	O	not required by EU Regulation No 1207/2011
25-26	Airborne Operational Mode Subtype	M	= '0,0'
27	TCAS RA Active	M	Item 20b, Definition 22
28	IDENT Switch Active	M	Item 6
30	Single Antenna Flag	M	= '0', see CS-ACNS.D.ADSB.040
31-32	System Design Assurance	M	Item 4e, Definition 4 & 8
41-43	MOPS Version Number	M	= '2'
44	NIC Supplement-A	M	Item 4b, Definition 4 & 5
45-48	NACP	M	Item 4c, Definition 4 & 6
49-50	GVA	M	Item 17b, Definition 20
51-52	Source Integrity Level	M	Item 4d, Definition 4 & 7
53	NICBaro	M	Item 5, Definition 9
54	Horizontal Reference Direction (HRD)	O	'0' true north, '1' magnetic north (Airborne Velocity, subtype 3 & 4)
55	SIL Supplement	M	Item 4d, Definition 4 & 7

Register 65_{16} – Aircraft Operational Status Message - On the Surface

ME Bits	Field	Req't	Remark
6-8	Subtype	M	= '1' (Surface)
9-10	Surface Capability Class Subtype	M	= '0,0'
12	1090 ES IN	O	not required by Commission Regulation (EU) No 1207/2011
15	B2 Low	NA	not applicable (targeting at class B2 equipment, e.g. ground vehicles)
16	UAT IN	O	not required by Commission Regulation (EU) No 1207/2011
17-19	NACv	M	Item 9b, Definition 12
20	NIC Supplement C	M	Item 12b, Definition 15
21-24	Length/Width Codes	M	Item 15, Definition 17
25-26	Surface Operational Mode Subtype	M	= '0,0'
27	TCAS RA Active	M	Item 20b, Definition 22
28	IDENT Switch Active	M	Item 6
30	Single Antenna Flag	M	= '0', see CS ACNS.D.ADSB.040
31-32	System Design Assurance	M	Item 4e, Definition 4 and 8
33-40	GPS Antenna Offset	M	Item 16, Definition 18
41-43	MOPS Version Number	M	= '2'
44	NIC Supplement-A	M	Item 12b, Definition 15
45-48	NAC_P	M	Item 4c, Definition 4 and 6
51-52	Source Integrity Level	M	Item 4d, Definition 4 and 7
53	Track Angle/Heading	M	Item 9a, Definition 11
54	Horizontal Reference Direction (HRD)	M	'0' true north, '1' magnetic north Item 13, Definition 15
55	SIL Supplement	M	Item 4d, Definition 4 and 7

Appendix I — On-the-ground status Test and Validation Guidance for Aeroplanes

The ADS-B Out system installer should verify that the air-ground status inputs (or algorithms) are functioning properly and that the ADS-B Out system transmits the appropriate airborne messages or surface messages based on the On-the-ground status. This can be accomplished with simulated inputs to the appropriate sensors or accomplished in conjunction with the flight test.

The following tests provide guidance to the aircraft integrator for the verification of the ADS-B Out system installation, as appropriate. Separate cases are presented depending on the need to validate the status within the ADS-B transmit unit.

(a) Directly determined On-the-ground status being validated outside the ADS-B transmit function:

Modern aircraft with integrated avionics suites commonly contain sophisticated algorithms for determining the On-the-ground status based on multiple aircraft sensors. These algorithms are customised to the airframe and designed to overcome individual sensor failures. These algorithms are an acceptable means to determine the On-the-ground status and do not require additional validation.

(b) Validation of directly determined On-the-ground status not being validated outside the ADS-B transmit function:

If ground speed **or** airspeed is larger than the aeroplane's typical rotation speed, then the On-the-ground status is (changed to) airborne and the airborne position message is broadcast irrespective of the directly determined On-the-ground status (i.e. as indicated to the ADS-B transmit function).

(c) Indirectly determined On-the-ground status validation within the ADS-B transmit unit:

If an aircraft is not equipped with a means, such as a weight-on-wheels switch, to determine whether it is airborne or on the ground, then the following tests should be performed to determine whether to broadcast the Airborne or Surface Position Messages.

(1) If the aircraft's radio height (RH) parameter is available, and RH is less than 15 m (50 feet), and at least ground speed (GS) or airspeed (AS) is available, and the GS or the AS are less than 51 m/s (100 knots), then that aircraft broadcasts the surface position message.

If all three parameters are available, the decision to broadcast the Airborne or Surface Position Messages is determined by the logical AND of all three parameters.

(2) If radio height (RH) is not available, and if the aircraft's ground speed (GS) and airspeed (AS) are available, and GS<26 m/s (50 knots) and AS<26 m/s (50 knots), then that aircraft broadcasts the surface position message.

Otherwise, the aircraft broadcasts the Airborne Position Message.

On-the-ground status Test and Validation Guidance for Helicopters, Lighter-than-Air Vehicles and Fixed-under-Carriage Aeroplanes

Installations intended for this category that are unable to provide a compliant direct or indirect ground status detection function, should only broadcast the Airborne Position Message. In addition, the "CA" capability field in downlink format DF 17 should be set accordingly.

Appendix J — Comparison between EASA CS ACNS.D.ADSB and FAA AC 20-165A Requirements

CS ACNS.D.ADSB Reference	Comparison
CS ACNS.D.ADSB.001 Applicability	CS refers to Commission Regulation (EU) No 1207/2011, AC to FAA 14 CFR § 91.227.
CS ACNS.D.ADSB.010 ADS-B Out System Installation	CS addresses 1090 ES as the only ADS-B Out data link, AC UAT as well.
CS ACNS.D.ADSB.020 ADS-B Out Data Parameters	Parameters required by CS, optional for AC: GPS Antenna Offset. Parameters required by CS where available in suitable format, optional for AC: Vertical Rate and Selected Altitude. Parameters required by CS where available in suitable , not addressed by AC: Barometric Pressure Setting. Parameters not required by CS, required by AC: ADS-B In Capability. Parameters not addressed by CS, optional for AC: Selected Heading. All other parameters are required by both the CS and AC.
CS ACNS.D.ADSB.025 Provision of Data	No difference.
CS ACNS.D.ADSB.030 ADS-B Transmit Unit Installation	No difference.
CS ACNS.D.ADSB.040 Antenna Diversity	CS requires antenna diversity (as applicable to Commission Regulation (EU) No 1207/2011 aircraft). Within AC, single bottom-mounted antenna installations are allowed for ETSO-C166b classes A1S and B1S.
CS ACNS.D.ADSB.050 Transmit Power	No difference.
CS ACNS.D.ADSB.055 Simultaneous Operation of ADS-B Transmit Units	No difference.
CS ACNS.D.ADSB.060 On-the-ground Status Determination	No difference.
CS ACNS.D.ADSB.070 Horizontal Position and Velocity Data Sources	No difference overall. However, CS specifies ETSO-C129a as a minimum requirement (in line with Commission Regulation (EU) No 1207/2011).
CS ACNS.D.ADSB.080 Other Data Sources	No difference, as applicable to the common data parameters (see also 'CS ACNS.D.ADSB.020').

CS ACNS.D.ADSB Reference	**Comparison**
CS ACNS.D.ADSB.085 Geometric Altitude	No difference.
CS ACNS.D.ADSB.090 Flight Deck Interface	No difference.
CS ACNS.D.ADSB.100 Integrity	No difference, however, CS details requirements per data parameter.
CS ACNS.D.ADSB.105 Continuity	No requirement expressed in AC.
CS ACNS.D.ADSB.110 Horizontal Position and Velocity Data Refresh Rate	No difference.
CS ACNS.D.ADSB.115 Horizontal Position and Velocity Total Latency	CS uses time of applicability as a reference, AC time of measurement. In line with the AC recommendation that the difference between the two references should be less than or equal to 500ms, the total latency requirements are effectively the same (CS: 1.5s, AC 2.0s).
CS ACNS.D.ADSB.120 Horizontal Position Uncompensated Latency	No difference.
AMC1 ACNS.D.ADSB.010(b) Flight Test	AC requires a flight test, for any set of component part numbers of the ADS-B Out system on a given aircraft type.

Subpart E — Others

SECTION 1 – TERRAIN AWARENESS AND WARNING SYSTEM (TAWS)

GM1 ACNS.E.TAWS.001 Applicability

CS ACNS.TAWS airworthiness requirements are not suitable to allow the use of TAWS for navigation or for mitigation of navigation system failures.

AMC1 ACNS.E.TAWS.005 TAWS equipment approval

The Class A or Class B TAWS equipment should be approved in accordance with ETSO-C151b.

AMC1 ACNS.E.TAWS.010 Required functions

Note: An example of an acceptable TAWS installation is provided at Appendix 2.

(a) For the voice call out a predetermined altitude of 150 m (500 ft.) has been found acceptable. However, another altitude may be allowed when a call-out at 150 m (500 ft.) would interfere with other operations.

(b) For Class B equipment the predetermined altitude voice callout is based upon barometric height above runway elevation.

Note: The nearest runway elevation may be used for this purpose.

(c) TAWS equipment may compute Barometric Altitude Rate using an Instantaneous Vertical Speed Indicator (IVSI) or an inertial smoothed vertical speed indicator. An alternative means, with demonstrated equal or better accuracy, may be used in lieu of barometric altitude rate (accuracy specified in ETSO-C10b, Altimeter, Pressure Actuated, Sensitive Type, or later revisions) and/or altimeter altitude (accuracy specified in ETSO-2C87 (Low range radio altimeters) - or later revisions) to meet the warning requirements described in RTCA Document No. DO-161A. In addition, ETSO-C106 for Air Data Computers may be used as an alternative means of compliance with this provision.

(d) An interface with the accident data recording system to record alerts from the TAWS and to record, where practicable, when FLTA or PDA is inhibited.

Note 1: It is not necessary to be able to distinguish between the Basic GPWS and the new FLTA and/or PDA alerts from the recording. The voice recorder will be used for this purpose.

Note 2: Where the data recorded by the Flight Data Recorder is modified, the document which presents the information necessary to retrieve and convert the stored data into engineering units, will need to be amended by the operator.

AMC 2 ACNS.E.TAWS.010 Required functions

In case of descent the TAWS should provide an automatic call out when descending through a predefined altitude (typically 150 m (500 ft) above terrain or above the elevation of nearest runway).

For a Class B TAWS in order to compensate for the lack of 'excessive closure rate to terrain' function the predefined altitude should be 500ft.

AMC1 ACNS.E.TAWS.015 FLTA function requirements

(a) The TAWS lateral search area should be less than the protected area defined by ICAO PANS OPS 8168, volume 2 to prevent nuisance alerts.

Note: The required obstacle (terrain) clearance (ROC) have been used to define the minimum requirements for obstacle/terrain clearance (RTC) appropriate to the FLTA function

(b) As an alternate to the stepped down reduction from the terminal to approach phase in CS ACNS.E.TAWS.015 Table 1 , a linear reduction of the RTC as the aeroplane comes closer to the nearest runway is allowed, providing the requirements of CS ACNS.E.TAWS.015 Table 1 are met.

(c) During the visual segment of a normal instrument approach (typically about 1850 m (1 NM) from the runway threshold), the RTC should be defined/reduced to minimise nuisance alerts.

(d) The RTC values can be reduced slightly for descending flight conditions to accommodate the dynamic conditions and pilot response times.

(e) The FLTA search volume should vary as a function of phase of flight, distance from runway, and the required terrain clearance.

GM1 ACNS.E.TAWS.020 PDA function requirements

The purpose of the PDA alert is to increase pilot's awareness. Therefore 'significantly below' means the point below the profile where the pilot would normally initiate a Go Around (e.g. for ILS this would correspond to 1 dot deviation).

AMC1 ACNS.E.TAWS.025 Class A TAWS inhibition

(a) An automatic inhibit capability is acceptable if it uses the information of the TAWS as a failure monitoring function.

(b) If an automatic inhibition is provided and it automatically inhibits the FLTA alerts, PDA alerts and terrain display then the manual inhibit may be designed to only inhibit aural and visual alerts.

(c) A separate guarded control should be provided to inhibit GPWS alerts based on flaps being other than the landing configuration.

AMC1 ACNS.E.TAWS.030 Terrain information display

(a) Terrain data should be displayed in the normal field of view. Terrain that is more than 600 m (2000 ft.) below the aeroplane's elevation need not be depicted.

(b) If terrain alerting information is displayed on a weather radar, an Electronic Flight Instrument System display, or other compatible display system available on the flight deck, then the TAWS information should be displayed in a manner consistent with other information (e.g. range, colour coding, symbology).

(c) When Auto-range switching is provided, an auto-ranging display should be designed so that it is evident to the flight crew that the range has been automatically selected. The range selected for auto-ranging should clearly depict the threat on the display. Manual reversion to a selected range should be simple.

AMC1 ACNS.E.TAWS.035 Aural and visual alerts

(a) The testing of the TAWS system integration within the aircraft should address the provision of the alerts listed in Table 1 below. In addition to this minimum set, other implemented optional voice alerts should be tested.

Alert Condition	Caution	Warning
Ground proximity Altitude Loss after Take-off Class A & Class B equipment	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural message **Aural Alert** 'Don't Sink' and 'Too Low Terrain'	**Visual Alert** None required **Aural Alert** None Required
Ground Proximity Envelope 1 (Not in Landing Configuration) Class A equipment	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural message **Aural Alert** 'Too Low Terrain' and 'Too Low Gear'	**Visual Alert** None required **Aural Alert** None Required
Ground Proximity Envelope 2 Insufficient Terrain Clearance (Landing and Go around configuration) Class A equipment	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural message **Aural Alert** 'Too Low Terrain' and 'Too Low Flaps'	**Visual Alert** None required **Aural Alert** None Required
Ground Proximity Envelope 4C Insufficient Terrain Clearance (Take-off configuration) Class A equipment	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural message **Aural Alert** 'Too Low Terrain'	**Visual Alert** None required **Aural Alert** None Required
Ground Proximity Excessive Glide Slope Deviation Class A equipment	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural message **Aural Alert** 'Glide Slope'	**Visual Alert** None required **Aural Alert** None Required
Ground Proximity	**Visual Alert** None Required	**Visual Alert** None required

Alert Condition	Caution	Warning
Advisory Voice Call Out Class A & Class B equipment	**Aural Alert** 'Five Hundred'	**Aural Alert** None Required
Reduced Required Terrain Clearance Class A & Class B equipment	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural message **Aural Alert** Minimum selectable Voice Alerts: 'Caution, Terrain; Caution, Terrain' and 'Terrain Ahead; Terrain Ahead'	**Visual Alert** Red text message that is obvious, concise and must be consistent with the Aural message **Aural Alert** Minimum selectable Voice Alerts: 'Caution, Terrain; Terrain; Pull-Up, Pull-Up' and 'Terrain Ahead, Pull-Up; Terrain Ahead, Pull-Up'
Imminent Impact with Terrain Class A & Class B equipment	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural message **Aural Alert** Minimum selectable Voice Alerts: 'Caution, Terrain; Caution, Terrain' and 'Terrain Ahead; Terrain Ahead'	**Visual Alert** Red text message that is obvious, concise and must be consistent with the Aural message **Aural Alert** Minimum selectable Voice Alerts: 'Caution, Terrain; Terrain; Pull-Up, Pull-Up' and 'Terrain Ahead, Pull-Up; Terrain Ahead, Pull-Up'
Premature Descent Alert (PDA) Class A & Class B equipment	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural message **Aural Alert** 'Too Low Terrain'	**Visual Alert** None required **Aural Alert** None Required
Ground Proximity Envelope 1, 2 or 3 Excessive Descent Rate Class A & Class B equipment	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural message **Aural Alert** 'Sink Rate'	**Visual Alert** Red text message that is obvious, concise and must be consistent with the Aural message **Aural Alert** ' Pull-Up'
Ground Proximity Excessive Closure Rate (Flaps not in Landing Configuration) Class A equipment	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural message **Aural Alert** 'Terrain- Terrain'	**Visual Alert** Red text message that is obvious, concise and must be consistent with the Aural message **Aural Alert** ' Pull-Up'
Ground Proximity Excessive Closure Rate (Landing	**Visual Alert** Amber text message that is obvious, concise, and must be consistent with the Aural	**Visual Alert** None required **Aural Alert** ' Pull-Up' - for gear up

Alert Condition	Caution	Warning
Configuration) Class A equipment	message **Aural Alert** 'Terrain- Terrain'	None required - for gear down

TABLE 1: Visual and aural alerts

(b) If a two tone sweep ('Whoop Whoop') is used then the complete cycle of the two tone sweeps plus annunciation may be extended from '1.4' to '2' seconds.

(c) Note: GPWS alerting thresholds may be adjusted or modified to be more compatible with the FLTA alerting functions and to minimize GPWS nuisance alerts.

(d) Parameters such as airspeed, groundspeed barometric altitude rate should be included in the logic that determines basic GPWS alerting time.

(e) GPWS alerting thresholds may be adjusted or modified to be more compatible with the FLTA alerting functions and to minimize GPWS nuisance alerts.

(f) Consideration should be given to presenting voice announcements at a pre-set level via headsets when they are in use.

AMC1 ACNS.E.TAWS.055 Terrain and airport information

Terrain data used for the generation of the TAWS terrain database should be compliant with EUROCAE ED-98 () – User Requirements for Terrain and Obstacle Data. Similarly airport and runway data terrain used for the generation of the TAWS airport database should be compliant with EUROCAE ED-77 () – Standards for Aeronautical Information. Generation of the TAWS terrain database and of the TAWS airport database should be compliant with EUROCAE ED-76 () – Standards for Processing Aeronautical Information.

Note: Other technologies could be considered to provide the required terrain and airport information.

The manufacturer of the TAWS system should present the development and methodology used to validate and verify the terrain and airport information and, if relevant, obstacle information in compliance with EUROCAE ED-76/RTCA DO-200A.

AMC1 ACNS.E.TAWS.060 Positioning information

(a) The TAWS positioning information can be generated internally to the TAWS (e.g. GPS receiver) or acquired by interfacing to other installed avionics on the aeroplane (e.g. FMS).

(1) For Class A TAWS an RNAV system may be used as an aeroplane horizontal position sensor provided that:

- it has been approved for navigation in accordance with ETSO-C115() or ETSO-C129a or ETSO-C145() or ETSO-C146() or ETSO-C196a; or
- it satisfies FAA AC 20-138 or FAA AC 20-130A.

(2) For Class A and B TAWS a GNSS sensor may be used as an aeroplane horizontal position sensor provided that it is compliant with ETSO-C196 or ETSO-C145.

Note: For TAWS relying on GNSS sensor, the TAWS design should consider the use of other horizontal position sensors to ensure TAWS availability in case of GNSS failures

(3) Equipment that uses a GNSS internal to the TAWS for horizontal position information, and that are capable of detecting a positional error that exceeds the appropriate alarm limit for the particular phase of flight in accordance with ED-72A is considered acceptable.

(4) Vertical position for TAWS may come from a barometric source such as an altimeter or an air data computer, or from a geometric source, such as GNSS provided that:

- the barometric altitude equipment is approved in accordance with ETSO-C106 Air data computer or ETSO-C10b Altimeter, Pressure Actuated, Sensitive Type;
- the radio altimeter equipment is approved in accordance with ETSO-2C87 Low-Range Radio Altimeter;
- the vertical velocity equipment is compliant with ETSO-C8 Vertical Velocity Instruments or ETSO-C105 Air Data Computer;
- the GNSS equipment is approved in accordance with:
  - ETSO-C129a, Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS); or
  - ETSO-C145, Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite Based Augmentation System; or
  - ETSO-C146, Stand-Alone Airborne Navigation Equipment Using the Global Positioning System Augmented by the Satellite Based Augmentation System.

Note: TAWS should mitigate potential vertical positioning source inaccuracies by appropriate blending of available vertical position information.

(b) When the GPS alert limit is activated, the GPS computed position is considered unsuitable for TAWS, and a TAWS unsuitability indication should be given.

(c) Geometric altitude should be enabled if the system has the facility.

AMC1 ACNS.E.TAWS.075 Prioritisation schemes

TAWS prioritisation schemes should be compliant with the content of Table 2:

Priority	Description	Alert Level	Comments
1	Reactive Windshear Warning	W	
2	Sink Rate Pull-Up Warning	W	Continuous
3	Excessive Closure Pull-Up Warning	W	Continuous
4	RTC Terrain Warning	W	
5	V1 Callout	A	
6	Engine Fail Callout	W	
7	FLTA Pull-Up Warning	W	Continuous
8	PWS Warning	W	
9	RTC Terrain Caution	C	Continuous
10	Minimums	A	
11	FLTA Caution	C	7 s period

12	Too Low Terrain	C	
13	PDA ‘Too Low Terrain’ Caution	C	
14	Altitude Callouts	A	
15	Too Low Gear	C	
16	Too Low Flaps	C	
17	Sink Rate	C	
18	Don’t Sink	C	
19	Glideslope	C	3 s period
20	PWS Caution	C	
21	Approaching Minimums	A	
22	Bank Angle	C	
23	Reactive Windshear Caution	C	
Mode 6	TCAS RA (‘Climb’, ‘Descent’, etc)	W	continuous
Mode 6	TCAS TA (‘Traffic, Traffic’)	C	Continuous

Table 2: Alert Prioritization Scheme

Note 1: These alerts can occur simultaneously with TAWS voice callout alerts.

Note 2: W= Warning, C= Caution, A= Advisory.

TAWS internal priority alerting scheme should be compliant with the content of Table 3 below

Priority	**Description**
1	Sink Rate Pull-Up Warning
2	Terrain Awareness Pull-Up warning
3	Terrain Awareness Caution
4	PDA ‘Too Low Terrain’ Caution
5	Altitude Callouts ‘500’
6	Sink Rate
7	Don’t Sink (Mode 3)

TABLE3: TAWS Internal Alert Prioritization Scheme

AMC1 ACNS.E.TAWS.080 Pop-up mode

For dual displays installations, when an automatic pop-up mode is provided, the pop-up function should be inhibited if terrain is already presented on at least one display.

If TAWS and the Predictive Windshear System share the same display and an automatic pop-up function is employed, the display priorities indicated in Table 4 are recommended:

Priority	Description
Highest	Terrain Awareness Warning
↕	Predictive Windshear Warning
	Terrain Awareness Caution
	Predictive Windshear Caution
	Normal Terrain Display
Lowest	Weather Radar Display

TABLE 4: Alert display priorities

If the TAWS system provides alerting for obstacle threats, the priority for warning and cautions should be the same as those for terrain.

APPENDIX A: TAWS INSTALLATIONS TESTING GUIDANCE MATERIAL

General Testing:

(a) Most of the testing of a TAWS installation can be achieved by ground testing that verifies system operation, interfaces between affected aeroplane systems, correct warning prioritisation, and freedom from unwanted interaction or interference.

(b) The use of the TAWS as an integrated part of the aeroplane flight deck should be demonstrated. The TAWS should be shown to be compatible with the operation of the installed navigation systems, the airborne collision and avoidance system (ACAS), the windshear warning system, and the weather radar.

(c) The tests should evaluate the effects of sensor failure on TAWS operation.

(d) Flight testing should be carried out to evaluate overall operation, compatibility of TAWS with warning systems, navigation systems, and displays, freedom from unwanted interference, and to assess, during adverse flight conditions, instrument visibility, display intelligibility, sound levels and intelligibility of voice announcements, and the effects of electrical transients.

(e) Adequate flight testing to evaluate the terrain display can be conducted while verifying all the other required TAWS functions. Emphasis could be placed on showing compliance with CS ACNS.E.TAWS requirements during normal aeroplane manoeuvres for all phases of flight. Pop-up and auto-ranging features could be evaluated if applicable. Sustained turns could be performed, to evaluate for example symbol stability, flicker, jitter, display update rate, readability, the use of colour to depict relative elevation data, caution and warning alerts, and overall suitability of the display.

GPWS Testing:

(a) Flight testing to verify the proper operation of Basic GPWS functions can be conducted in any area where the terrain elevation is known to the flight crew. The following information provides an example of guidance for conducting flight tests to verify the proper operation of each GPWS function.

(1) Excessive *Rate of Descent.* Descents toward near level terrain are recommended if they provide the best results and ease of correlation with designed Mode 1 envelopes. This test verifies the operation of barometric altitude (and the corresponding computation of barometric altitude rate) and radio altitude.

(2) Excessive *Closure Rate To Terrain*. It is recommended that one level test run at an altitude between 150 m (500 ft.) and 300 m (1000 ft.) above the terrain elevation be conducted. This test will verify the proper installation of the radio altimeter.

(3) *Negative Climb Rate or Altitude Loss After take-off.* If it is adequate this test can be conducted immediately after take-off before climbing above 700 AGL or above runway elevation. This test verifies the proper operation of barometric altitude, barometric altitude rate and radio altitude.

(4) *Flight Into Terrain When Not In Landing Configuration.* If it is adequate this test can be conducted while *on* a visual approach to a suitable runway. This test verifies the proper installation of barometric altitude, barometric altitude rate and radio altitude as well as the gear and flap sensor inputs to TAWS.

(5) *Excessive Downward Deviation from an ILS Glideslope.* This test should be conducted during an ILS approach. This test will verify the proper operation of the ILS Glideslope input to TAWS.

(6) *Voice Callout 'Five Hundred ft.* This test should be conducted during an approach to a suitable runway in order to verify the proper operation of barometric altitude and/or radio altitude.

(7) Go-*around*. This test can be performed to confirm that nuisance alerts do not occur during normal go-around manoeuvres.

FLTA Testing:

(a) Flight testing to verify the proper operation of the FLTA function can be conducted in an area where the terrain elevation for the test runs is known within approximately 90 m (300 ft.). Two test runs can be performed:

(1) In level flight at approximately 150 m (500 ft) above the terrain of interest.

(2) While descending toward the terrain of interest.

(b) In each test case, the terrain display, the aural and visual alerts, the navigation source input, and the terrain data base can each be evaluated if necessary. Confirmation that the specific terrain cells do generate the required alert can also be evaluated if necessary.

Note: To conduct the test as described, the chosen terrain could be for example at least 28 Km (15 NM) away from the nearest airport. If this is not practical, the fly-over altitude will have to be lowered, for example to 90 m (300 ft.) or less above the terrain in order to generate a TAWS alert.

PDA Testing:

(a) Flight testing to verify the proper operation of the PDA function can be conducted in any airport area within an adequate distance of the nearest runway for example, 18.5 Km (10 NM). The aeroplane should be configured for landing at an adequate height for example, 450 m (1500 ft.) AGL, along the final approach segment of the runway at an adequate distance from the runway, for example, 18.5 Km (10 NM).

(b) At a suitable point, a normal flight path angle descent, for example, three degrees can be initiated and maintained until the PDA alert occurs. This test may exercise also, if necessary the 500 ft. voice callout.

The adequacy of the PDA aural alert should be verified during this test. If necessary, this test could verify the adequacy of the airport data base, the navigation source input and the barometric and/or radio altitude inputs to TAWS.

Note: The area in the vicinity of the runway selected for this test should be relatively free from terrain and obstacles to preclude activation of the FLTA function. Approximately level terrain along the final approach segment will exercise the PDA function.

(c) Flight tests should be conducted to verify that conditions at 300 m (1000 ft) AGL within 18.5 – 28 Km (10 -15 NM) of the nearest airport the TAWS system does not generate alerts.

APPENDIX B: EXAMPLE OF AN ACCEPTABLE TAWS INSTALLATION

An example of an acceptable installation is a single approved TAWS comprising the following components or inputs:

(a) A single terrain awareness and warning computer.

(b) A single radio altimeter sensor.

(c) A single air data system.

(d) An ILS/GBAS/SBAS/MLS/MMR receiver for Class A TAWS only.

(e) An interface with the landing gear and flaps.

(f) A roll attitude sensor.

(g) An accurate source of aeroplane position e.g. Flight Management System (FMS), or a Global Positioning System (GPS) or both.

(h) Where operations are reliant on the use of QFE, an adequate means of determining the altitude should be provided.

(i) A terrain data base covering the expected region of normal operations, together with a means of updating the stored data and to check its validity (by effective date and geographical region).

(j) A terrain awareness display.

(k) A loudspeaker for voice announcements.

(l) Consideration should be given to presenting voice announcements via headsets at a preset level particularly where active noise-reducing or noise cancelling headsets are used.

(m) Indication of TAWS and sensor failures.

(n) Indication that the TAWS is operating in Basic GPWS mode only.

(o) A means to initiate the TAWS self-test function on the ground.

(p) An interface with the flight recording system to record TAWS alerts and inhibition of FLTA or PDA functions.

(q) Indication to the flight crew where geographical regions of operation or other factors which adversely affect system performance to the extent that the TAWS may be potentially misleading and should not be relied up. If this indication is not practicable, a flight crew procedure may be used to determine whether the navigation system accuracy is acceptable for continued use of the TAWS.

(r) A means for the flight crew to inhibit the FLTA and PDA functions together with appropriate annunciation of the inhibited condition.

(s) A display with a means for the flight crew to select or deselect the terrain information. An automatic pop-up mode may be used with a simple means to deselect the terrain information after an automatic pop-up.

Appendix 3 — Background information for Terrain Awareness and Warning System (TAWS)

(a) General

This appendix provides additional references, background information, and guidance for maintenance testing, as appropriate to TAWS installations.

(b) Related References

(1) EASA

(i) ETSO-C151b Terrain Awareness and Warning System (TAWS) dated 18/12/2007

(ii) ETSO-C92c Ground Proximity Warning, Glide Slope Deviation Alerting Equipment dated 24/10/2003

(iii) ETSO-C10b Aircraft Altimeter, Pressure Actuated, Sensitive Type dated 24/10/2003

(iv) ETSO-2C87 Low Range Radio Altimeters dated 24/10/2003

(v) ETSO-C106 Air Data Computer dated 24/10/2003

(vi) ETSO –C115b Airborne Area Navigation Equipment using Multi-Sensor Inputs dated 24/10/2003

(vii) ETSO-C129a Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS) dated 24/10/2003

(viii) ETSO-C145 Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS) dated 24/10/2003 – ETSO-C145c Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite Based Augmentation System (SBAS) dated 21/12/2010

(ix) ETSO–C146 Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS) dated 24/10/2003 – ETSO-C146c Stand-Alone Airborne Navigation Equipment Using the Global Positioning System Augmented by the Satellite Based Augmentation System (SBAS) dated 21/12/2010

(x) ETSO-C196a Airborne Supplemental navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation dated 05/07/2012

(xi) ETSO-C105 Optional Display Equipment for Weather and Ground Mapping Radar Indicators dated 24/10/2003

(2) ICAO

Doc 8168 Aircraft Operations Procedures for Air Navigation Services Fifth edition – 2006 Volume II Construction of Visual and Instrument Flight Procedures

(3) EUROCAE

(i) ED-98 () User requirements for Terrain and Obstacle Data (any edition - last edition B dated September 2012)

(ii) ED-76 Standards for processing aeronautical data dated October 1998 (identical to RTCA DO-200A)

(4) RTCA

DO-161A Minimum Performance Standards-Airborne Ground Proximity Warning Equipment dated 27/05/1976

SECTION 2 – REDUCED VERTICAL SEPARATION MINIMUM (RVSM)

AMC1 ACNS.E.RVSM.001 Applicability

Previous airworthiness certification against JAA TGL6 is an acceptable means of compliance for the RVSM system.

AMC1 ACNS.E.RVSM.005 RVSM system

(a) When Static Source Error Corrections (SSEC) are required they should be embedded within the altimetry system.

Note: The design aim for SSEC is to correct for the residual static source error, compatible with the RVSM performance requirements.

(b) For RVSM systems with SSEC, an equivalent SSEC should be applied to the altitude control signal.

AMC1 ACNS.E.RVSM.010 Required functions

The signal representing the altitude alerting system may be used either directly, or combined with other sensor signals. The signal may be an altitude deviation signal, relative to the selected altitude, or a suitable absolute altitude signal.

AMC1 ACNS.E.RVSM.030 RVSM system performance requirement

If the design and characteristics of the aircraft and its altimetry system are such that the performance requirements are not satisfied by the location and geometry of the static sources alone, then suitable Static Source Error Corrections should be applied automatically within the altimetry system.

AMC1 ACNS.E.RVSM.035 Altimetry system accuracy

To demonstrate the compliance with ASE performances the following steps should be performed:

(a) Group determination:

(1) Aircraft should have been constructed to a nominally identical design and be approved on the same Type Certificate (TC). Aircraft modified to a TC amendment, or by a Supplemental TC may be considered as part of the same group providing that all height keeping performance characteristics as described in the following paragraphs remain the same.

(2) The static system of each aircraft should be nominally identical. The Static Source Error and any applied SSE Corrections should be the same for all aircraft of the group. Differences affecting factors that contribute to the Static Source Error (see Appendix A, Table 1), that effect RVSM performances and accuracy should be demonstrated as negligible.

(3) The operational flight envelope should be the same.

(4) The avionics units installed on each aircraft to meet the minimum RVSM performance requirements should demonstrate equivalent height keeping system performance in relation to; altitude control, altitude reporting and the interface to the altimetry system sensors. Altimetry system integrity should be the same with equivalent reliability, degradation and failure rates.

If an airframe does not meet the conditions above to qualify as a member of a Group, or is presented as an individual airframe for approval, then it will be considered as a non-group aircraft for the purposes of RVSM approval.

(b) RVSM Flight envelopes boundaries (Full and Basic)

The RVSM full flight envelope boundaries should be defined based on the RVSM airspace and aircraft or group aircraft characteristics as summarised in Table 1.

The RVSM basic envelope boundaries are similar to the ones of the full flight envelope, however, the upper Mach boundary may be lower than the one of the full flight envelope but not be less than the Long Range Cruise Mach Number plus 0.04 Mach, unless limited by available cruise thrust, buffet or other flight limitations. This reduction in upper Mach value would typically apply to cases where airspeeds could be limited to the range of airspeeds over which the aircraft can reasonably be expected to operate most frequently.

Condition	Lower Boundary is defined by	Upper Boundary is defined by
Flight Level	FL 290	The lower of : • FL 410 • Aircraft maximum certified altitude • Altitude limited by: cruise thrust; buffet; other aircraft flight limitations
Mach or Speed	The lower of: • Maximum endurance (holding speed) • Manoeuvre speed	The lower of : • MMO/VMO • Speed limited by cruise thrust; buffet; other aircraft flight limitations
Gross Weight	• The lowest gross weight compatible with operations in RVSM airspace	• The highest gross weight compatible with operations in RVSM airspace

TABLE 1 - Full RVSM envelope boundaries

(c) Test performance results presentation:

The test performance results may be presented on a single chart if the RVSM flight envelope is plotted using W/δ (weight divided by atmospheric pressure ratio) versus Mach number.

Note: This is due to the relationship between W/δ and the fundamental aerodynamic variables M and lift coefficient as shown below.

$W/\delta = 1481.4 C_L M^2 S_{Ref}$, where:

δ = ambient pressure at flight altitude divided by sea level standard pressure of 1013.25 hPa

W/δ = Weight over Atmospheric Pressure Ratio

C_L = Lift Coefficient

M = Mach number

S_{Ref} = Reference Wing Area

Since δ is a fixed value for a given altitude, weight can be obtained for a given condition by simply multiplying the W/δ value by δ. Furthermore, over the RVSM altitude range, it is a good approximation to assume that position error is uniquely related to Mach number and W/δ for a given aircraft.

(d) Error budget

The demonstration of compliance with the RVSM performance criteria should include a justification of the contribution of all significant errors to the ASE (Error Budget). Appendix A provides guidance supporting the development of such justification.

Note: A trade-off may be made between the various error sources which contribute to ASE (e.g.: in the case of an aircraft group approval, the smaller the mean of the group and the more stringent the avionics standard, the larger the available allowance for the SSE variations). The ASE performance demonstration should consider this ASE trade off.

(e) ASE Flight Calibration Methods

Where flight calibrations are used to quantify or verify altimetry system performance they should be accomplished by any of the following methods. Flight calibrations should be performed only when appropriate ground checks have been completed. Uncertainties in application of the method will need to be assessed and taken into account in the data package.

(1) Precision tracking radar in conjunction with pressure calibration of atmosphere at test altitude.

(2) Trailing cone.

(3) Pacer aircraft.

(4) Any other method acceptable to the competent authority

Note: When using pacer aircraft, the pacer aircraft will need to be calibrated directly to a known standard. It is not acceptable to calibrate a pacer aircraft by another pacer aircraft.

(f) Compliance Demonstration for Groups of Aircraft.

Because of the statistical nature of the performance requirements, the demonstration of the compliance may vary considerably from group to group and therefore for a group aircraft the following process should be applied:

(1) The mean and airframe-to-airframe variability of ASE should be established, based on flight test calibration of the accuracy for a number of aircraft. Where analytical methods are available, it may be possible to enhance the flight test data base and to track subsequent changes in the mean and variability based on geometric inspections and bench test, or any other method acceptable to the responsible authority. In the case of derivative aircraft it may be possible to use data from the parent as part of the data base, providing adequate provision is made for the changes that may contribute to difference in ASE characteristics.

Note: This is particularly important when a derivative involves changes to the airframe structure that may alter the SSE characteristics.

(2) An assessment of the aircraft-to-aircraft variability of each error source should be made. The error assessment may take various forms as appropriate to the nature and magnitude of the source and the type of data available. It may be acceptable to use specification values to represent three standard deviations for smaller error sources; however a more comprehensive assessment may be required for those sources that contribute a greater proportion of the overall error.

Note: This assessment is particularly important for airframe error sources where specification values of ASE contribution may not have been previously established.

(3) In many cases, one or more of the major ASE error sources will be aerodynamic in nature, such as variations in the airframe surface contour in the vicinity of the static pressure source. If evaluation of these errors is based on geometric measurements, substantiation should be provided that the methodology used is adequate to ensure compliance.

(4) An error budget should be established to ensure that the RVSM performance criteria are met.

Note: the worst condition experienced in flight may differ for each criterion and therefore the component error values may also differ.

(5) In showing compliance with the overall criteria, the component error sources should be combined appropriately. In most cases this will involve the algebraic summation of the mean components of the errors, root-sum-square (rss) combination of the variable components of the errors, and summation of the rss value with the absolute value of the overall mean. Care should be taken that only variable component error sources that are independent of each other are combined by rss.

(6) A statistical study based on a representative sample of measured data should provide sufficient confidence that each individual aircraft in the group would have an ASE contained within ±60m (±200 ft).

Note :It is accepted that if any aircraft is identified as having an error exceeding ±60m (±200 ft) then it should receive corrective action.

(g) Compliance Demonstration for a Non Groups Aircraft.

For non-group aircraft, the following data should be established:

(1) Flight test calibration of the aircraft to establish its ASE or SSE over the RVSM envelope should be conducted. The flight test calibration should be performed at points in the flight envelope(s) as agreed by the responsible authority using one of the methods identified in (e) above.

(2) Calibration of the avionics used in the flight test as required may be conducted for establishing residual SSE. The number of test points should be agreed by the responsible authority. Since the purpose of the flight test is to determine the residual SSE, specially calibrated altimetry equipment may be used.

(3) The installed altimetry avionics equipment specification should identify the largest allowable errors.

GM1 ACNS.E.RVSM.035 Altimetry System Accuracy

For group aircraft; to evaluate a system against the ASE performance, it is necessary to quantify the mean and three standard deviation values for ASE expressed as ASE_{mean} and ASE_{3SD}. To do this, it is necessary to take into account the different ways in which variations in ASE can arise. The factors that affect ASE are:

(a) Unit to unit variability of avionics equipment.

(b) Effect of environmental operating conditions on avionics equipment.

(c) Airframe to airframe variability of static source error.

(d) Effect of flight operating conditions on static source error.

Note : Assessment of ASE, whether based on measured or predicted data will need to consider item a to d above. The effect of item d as a variable can be eliminated by evaluating ASE at the most adverse flight condition in an RVSM flight envelope.

Appendix A provides two examples of methods to establish and monitor static source errors.

APPENDIX A - ALTIMETRY SYSTEM ERROR COMPONENTS

1 Introduction

The purpose of this appendix is to provide guidance to help ensure that all the potential error sources are identified and included in the Altimetry System Error budget.

2 Objective of ASE Budget

The purpose of the ASE budget is to demonstrate that the allocation of tolerances amongst the various parts of the altimetry system is consistent with the overall statistical ASE performance requirements. These individual tolerances within the ASE budget also form the basis of the procedures, defined in the airworthiness approval data package, which will be used to demonstrate that aircraft satisfy the RVSM criteria.

It is necessary to ensure that the budget takes account of all contributory components of ASE.

For group approval it is necessary to ensure either that the budget assesses the combined effect of the component errors in a way that is statistically realistic, or that the worst case specification values are used.

3 Altimetry System Error

3.1 Breakdown

Figure 1 shows the breakdown of total ASE into its main components, with each error block representing the error associated with one of the functions needed to generate a display of pressure altitude. This breakdown encompasses all altimetry system errors that can occur, although different system architectures may combine the components in slightly different ways.

(a) The 'Actual Altitude' is the pressure altitude corresponding to the undisturbed ambient pressure.

(b) The 'Static Source Error' is the difference between the undisturbed ambient pressure and the pressure within the static port, at the input end of the static pressure line.

(c) The 'Static Line Error' is the difference in pressure along the length of the line.

(d) The 'Pressure Measurement and Conversion Error' is the error associated with the processes of sensing the pneumatic input seen by the avionics, and converting the resulting pressure signal into altitude. As drawn, Figure 2-1 represents a self-sensing altimeter system in which the pressure measurement and altitude conversion functions would not normally be separable. In an air data computer system the two functions would be separate, and SSEC would probably then be applied before pressure altitude (Hp) was calculated.

(e) The 'Perfect SSEC' would be that correction that compensated exactly for the SSE actually present at any time. If such a correction could be applied, then the resulting value of Hp calculated by the system would differ from the actual altitude only by the static line error plus the pressure measurement and conversion error. In general this cannot be achieved, so although the 'Actual SSEC' can be expected to reduce the effect of SSE, it will do so imperfectly.

(f) The 'Residual Static Source Error' is applicable only in systems applying an avionic SSEC. It is the difference between the SSE and the correction actually applied. The corrected value of Hp will therefore differ from actual pressure altitude by the sum of static line error, pressure measurement and conversion error, and residual SSE.

(g) The error between Hp and displayed altitude is the sum of the baro-correction error and the display error. Figure 2-1 represents their sequence for a self-sensing altimeter system. Air data computer systems can implement baro-correction in a number of ways that would modify slightly this part of the block diagram, but the errors would still be associated with either the baro-correction function or the display function. The only exception is that those systems that can be switched to operate the display directly from the Hp signal can eliminate baro-correction error where standard ground pressure setting is used, as in RVSM operations.

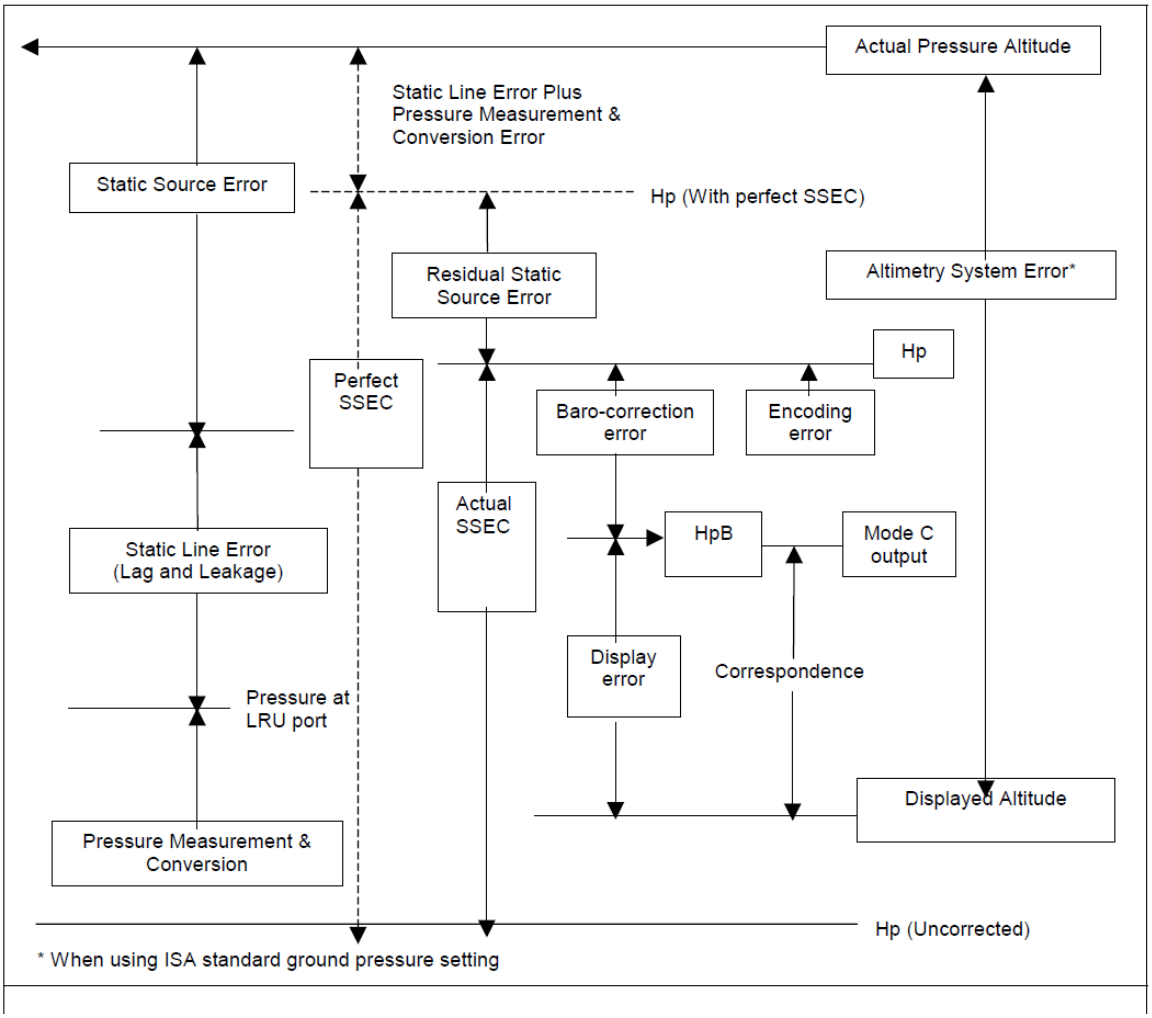


FIGURE 1 - Altimetry system errors

3.2 Components

Each of the system errors presented in Figure 1 and described in (c)(1) is discussed below in greater detail.

3.2.1 Static Source Error

The component parts of SSE are presented in Table 1, with the factors that control their magnitude.

(a) The reference SSE is the best estimate of actual SSE, for a single aircraft or an aircraft group, obtained from flight calibration measurements. It is variable with operating condition, characteristically reduced to a family of W/δ curves that are functions of Mach.

It includes the effect of any aerodynamic compensation that may have been incorporated in the design. Once determined, the reference SSE is fixed for the single aircraft or group, although it may be revised when considering subsequent data.

(b) The test techniques used to derive the reference SSE will have some measurement of uncertainty associated with them, even though known instrumentation errors will normally be eliminated from the data. For trailing-cone measurements the uncertainty arises from limitations on pressure measurement accuracy, calibration of the trailing-cone installation, and variability in installations where more than one are used. Once the reference SSE has been determined, the actual measurement error is fixed, but as it is unknown it can only be handled within the ASE budget as an estimated uncertainty.

(c) The airframe variability and probe/port variability components arise from differences between the individual airframe and probe/port, and the example(s) of airframe and probe port used to derive the reference SSE.

3.2.2 Residual Static Source Error

(a) The components and factors are presented in Table 1. Residual SSE is made up of those error components which make actual SSE different from the reference value, components 2, 3, and 4 from Table 1, plus the amount by which the actual SSEC differs from the value that would correct the reference value exactly, components 2(a), (b) and(c) from Table 2.

(b) There will generally be a difference between the SSEC that would exactly compensate the reference SSE, and the SSEC that the avionics is designed to apply. This arises from practical avionics design limitations. The resulting error component 2(a) will therefore be fixed, for a particular flight condition, for the single aircraft or group. Additional variable errors 2(b) and 2(c) arise from those factors that cause a particular set of avionics to apply an actual SSEC that differs from its design value.

(c) The relationship between perfect SSEC, reference SSEC, design SSEC and actual SSEC is illustrated in Figure 2, for the case where static line errors and pressure measurements and conversion errors are taken as zero.

(d) Factors that create variability of SSE relative to the reference characteristic should be accounted for twice. First, as noted for the SSE itself in Table 2, and secondly for its effect on the corruption of SSEC as in factor 2(a)(i) of Table 2. Similarly the static pressure measurement error should be accounted for in two separate ways. The main effect will be by way of the 'pressure measurement and conversion' component, but a secondary effect will be by way of factor 2(a)(ii) of Table 2.

Factors	Error Components
Airframe Effects Operating Condition (Speed, altitude, angle of attack, sideslip) Geometry: Size and shape of airframe; Location of static sources; Variations of surface contour near the sources; Variations in fit of nearby doors, skin panels or other items.	1) Reference SSE values from flight calibration measurements. 2) Uncertainty of flight calibration measurements.
Probe/Port Effects Operating Condition (Speed, altitude, angle of attack, sideslip) Geometry: Shape of probe/port; Manufacturing variations; Installation variations.	3) Airframe to airframe variability. 4) Probe/port to probe/port variability.

TABLE 1 - Static source error

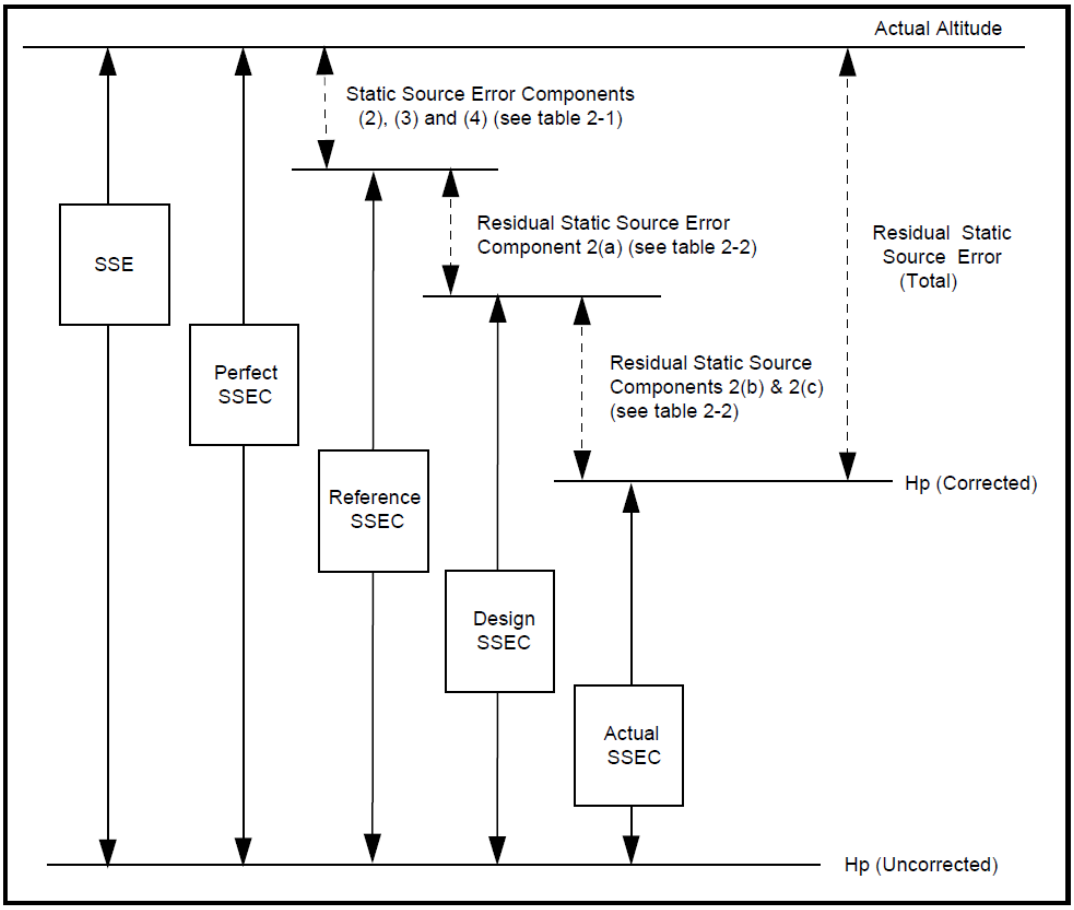
(Cause: Aerodynamic Disturbance to Free-Stream Conditions)

Factors	Error Components
(1) As for Static Source Error PLUS	1) Error Components (*2*), (*3*), and (*4*) from table 2-1 PLUS
(2) Source of input data for SSEC function	2(a) Approximation in fitting design SSEC to flight calibration reference SSE.
(a) Where SSEC is a function of Mach:	
(i) P_S sensing: difference in SSEC from reference SSE.	2(b) Effect of production variability (sensors and avionics) on achieving design SSEC.
(ii) P_S measurement: pressure transduction error.	
(iii) P_T errors: mainly pressure transduction error.	2(c) Effect of operating environment (sensors and avionics) on achieving design SSEC.
(b) Where SSEC is a function of angle of attack:	
(i) geometric effects on alpha:	
- sensor tolerances;	
- installation tolerances;	
- local surface variations.	
(ii) measurement error:	
- angle transducer accuracy.	
(3) Implementation of SSEC function	
(a) Calculation of SSEC from input data;	
(b) Combination of SSEC with uncorrected height.	

TABLE 2 - Residual static source error: (aircraft with avionic SSEC)

(Cause: Difference between the SSEC actually applied and the actual SSE)

FIGURE 2-2 SSE/SSEC RELATIONSHIPS FOR ASE WHERE STATIC LINE, PRESSURE MEASUREMENT AND CONVERSION ERRORS ARE ZERO



3.2.3 Static Line Error

Static line errors arise from leaks and pneumatic lags. In level cruise these can be made negligible for a system that is correctly designed and correctly installed.

3.2.4 Pressure Measurement and Conversion Error

(a) The functional elements are static pressure sensing, which may be mechanical, electromechanical or solid-state, and the conversion of pressure signal to pressure altitude.

(b) The error components are:

(i) calibration uncertainty;

(ii) nominal design performance;

(iii) unit to unit manufacturing variations; and

(iv) effect of operating environment.

(c) The equipment specification is normally taken to cover the combined effect of the error components. If the value of pressure measurements and conversion error used in the error budget is the worst case specification value, then it is not necessary to assess the above components separately. However, calibration uncertainty, nominal design performance and effect of operating environment can all contribute to bias errors within the equipment tolerance. Therefore, if it is desired to take statistical account of the likely spread of errors within the tolerance band, then it will be necessary to assess their likely interaction for the particular hardware design under consideration.

(d) It is particularly important to ensure that the specified environmental performance is adequate for the intended application.

3.2.5 Baro-Setting Error

This is the difference between the value displayed and the value applied within the system. For RVSM operation the value displayed should always be the International Standard Atmosphere ground pressure, but setting mistakes, although part of TVE, are not components of ASE.

(a) The components of Baro-Setting Error are:

(i) resolution of setting knob/display;

(ii) sensing of displayed value; and

(iii) application of sensed value.

(b) The applicability of these factors and the way that they combine depend on the particular system architecture.

(c) For systems in which the display is remote from the pressure measurement function there may be elements of the sensing and/or application or sensed value error components which arise from the need to transmit and receive the setting between the two locations.

3.2.6 Display Error

The cause is imperfect conversion from altitude signal to display.

The components are:

(a) conversion of display input signal;

(b) graticule/format accuracy, and

(c) readability.

Note: In self-sensing altimeters the first of these would normally be separate from the pressure measurement and conversion error.

APPENDIX B — EXAMPLES OF METHODS TO ESTABLISH AND MONITOR STATIC SOURCE ERRORS (Group aircraft only)

1 Introduction

Two examples showing the method establish and monitor static source errors are presented below.

2 Example 1

One process for showing compliance with RVSM criteria is shown in Figure 1. Figure 1 illustrates how those flight test calibrations and geometric inspections will be performed on a given number of aircraft. The flight calibrations and inspections will continue until a correlation between the two is established. Geometric tolerances and SSEC will be established to satisfy RVSM criteria. For aircraft being manufactured, every Nth aircraft will be inspected in detail and every Mth aircraft will be flight test calibrated, where 'N' and 'M' are determined by the aircraft constructor and agreed to by the competent authority.

The data generated by 'N' inspections and 'M' flight calibrations can be used to track the mean and three standard deviation values to ensure continued compliance of the model with the criteria of CS ACNS.E.RVSM.035.

As additional data are acquired, they should be reviewed to determine if it is appropriate to change the values of N and M as indicated by the quality of the results obtained.

There are various ways in which the flight test and inspection data might be used to establish the correlation. The example shown in Figure 2 is a process in which each of the error sources for several aeroplanes is evaluated based on bench tests, inspections and analysis. Correlation between these evaluations and the actual flight test results would be used to substantiate the method.

The method illustrated in Figures 1 and 2 is appropriate for new models since it does not rely on any pre-existing data base for the group.

3 Example 2

Figure 3 illustrates that flight test calibrations should be performed on a given number of aircraft and consistency rules for air data information between all concerned systems verified. Geometric tolerances and SSEC should be established to satisfy the criteria. A correlation should be established between the design tolerances and the consistency rules. For aircraft being manufactured, air data information for all aircraft should be checked for consistency in cruise conditions and every Mth aircraft should be calibrated, where M is determined by the manufacturer and agreed to by the responsible authority. The data generated by the M flight calibrations should be used to track the mean and three standard deviation values to ensure continued compliance of the group with the criteria of CS ACNS.E.RVSM.035.

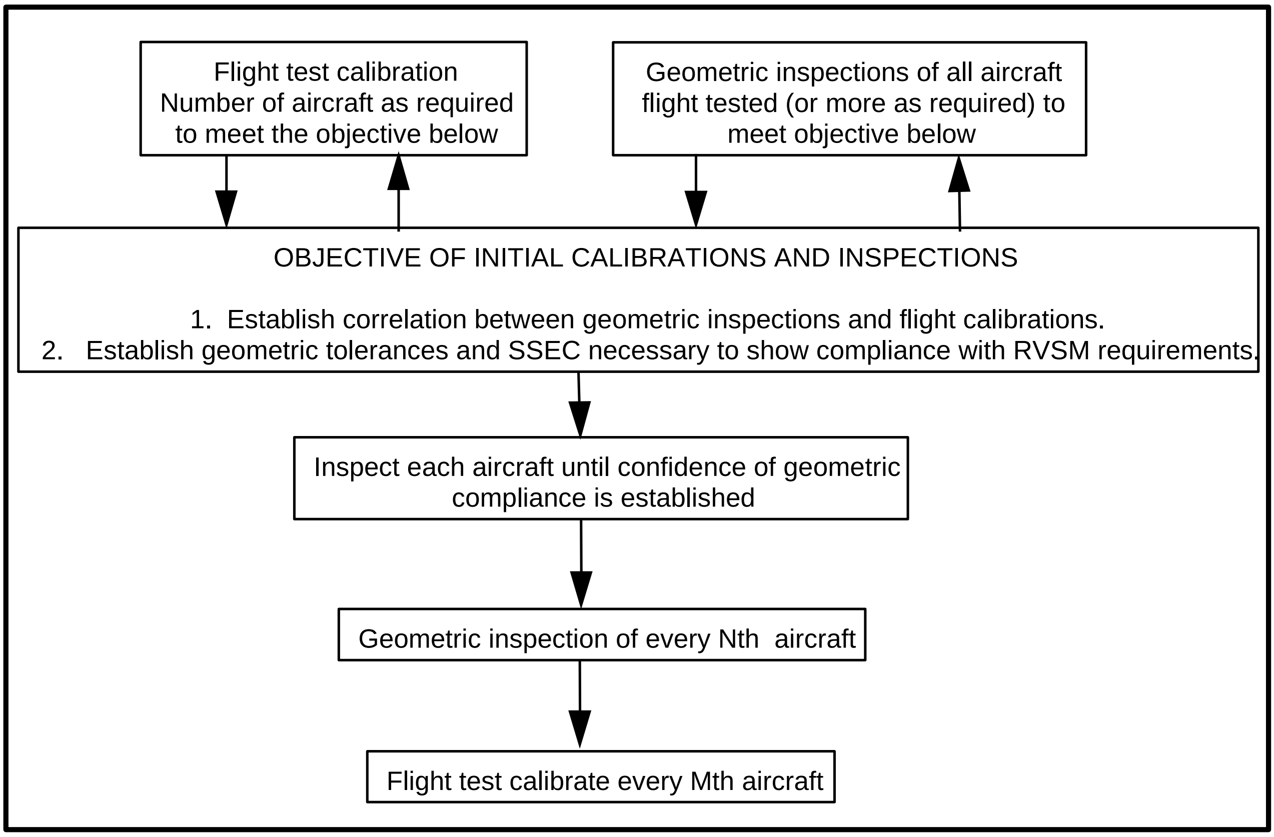


Figure 1 - Process for showing initial and continued compliance of airframe static pressure systems

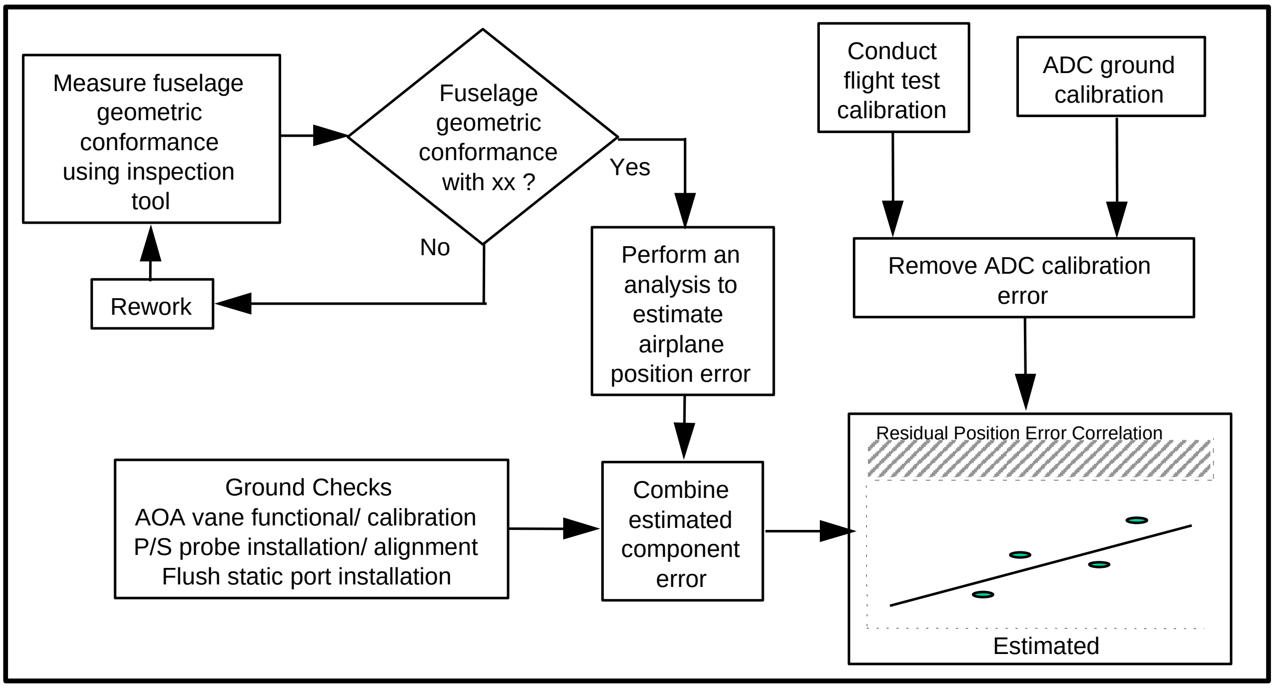


Figure 2 - Compliance demonstration ground - to flight test correlation process example

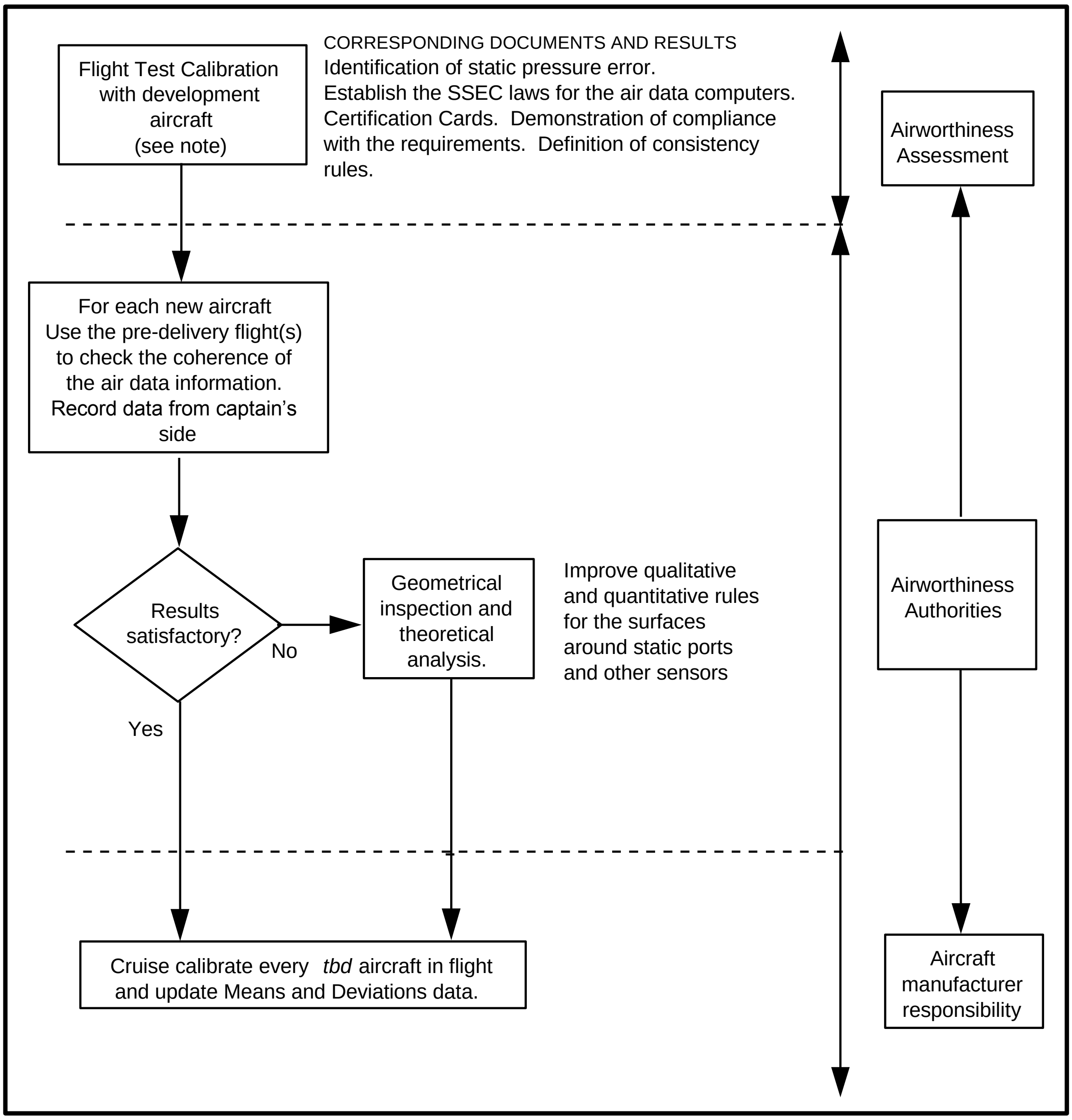


Figure 3 - Process for showing initial and continued compliance of airframe static pressure systems for new model aircraft.

Note : The flight test installation chosen to get the calibration data will need to have an accuracy compatible with the level of performance to be demonstrated and an analysis of this accuracy will need to be provided. Any possible degradation of this accuracy will need to be monitored and corrected during the flight test period.