U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

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

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

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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.**

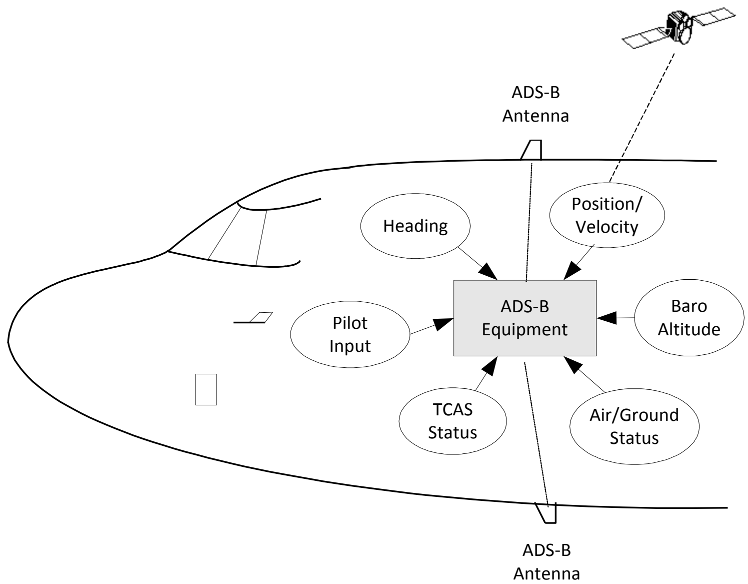
ADS-B is a next generation surveillance technology incorporating both air and ground aspects that provide air traffic control (ATC) with a more accurate picture of the aircraft’s three-dimensional position in the en route, terminal, approach, and surface environments. The aircraft provides the airborne 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 ADS-B Description.

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 System Description.

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 ADS-B OUT Equipment.

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.

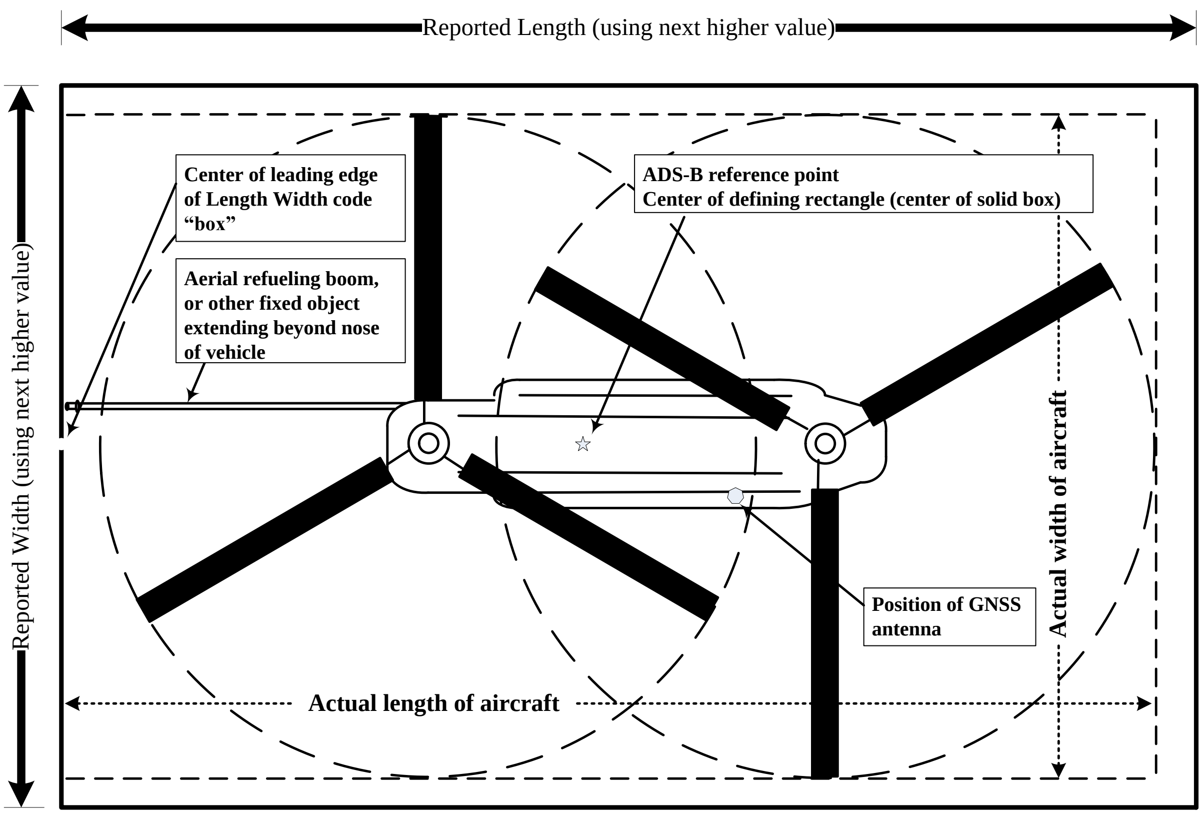
Note 2: The ICAO 24-bit address will have to be updated if the aircraft's registration number changes.

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 <u>Equipment Eligibility.</u>

§ 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 <u>Installation Guidance.</u>

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 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**.

3.3.3.1 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 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** 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.

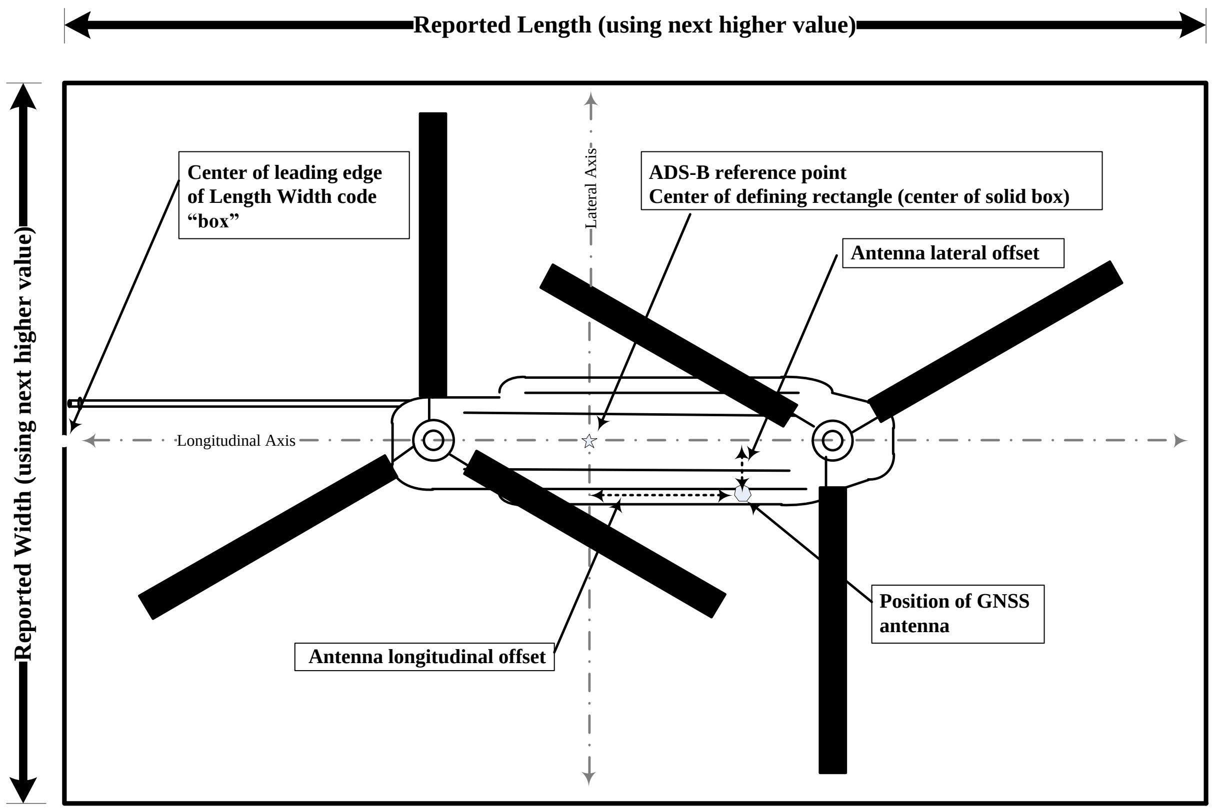
3.8.4.2 If the ADS-B equipment is interfaced to multiple GNSS position sources that use GNSS antennas in different locations on the aircraft, the installation must have provisions to ensure the appropriate GNSS antenna offset is being transmitted when the ADS-B equipment switches from one position source 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 $\geq$ 7	Rc < 370.4 m (0.2 nm)
$NAC_P \geq 8$	EPU < 92.6 m (0.05 nm)
$NAC_V \geq 1$	< 10 m/s
SIL $\geq$ 3	$\leq 1\text{x}10^{-7}$ per-hour or per sample
SDA $\geq$ 2	$\leq 1\text{x}10^{-5}$ 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 ≥ 8 throughout the flight.	EPU <92.6 m (0.05 nm)
Ensure NAC_V ≥ 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 Source Integrity Level (SIL).

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 Source Integrity Level Supplement (SIL_{SUPP}).

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 System Design Assurance (SDA).

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 1×10^{-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 <u>Position Integrity Limits.</u>

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 <u>Vertical Position Accuracy.</u>

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 Tightly-Coupled GNSS/IRS Outputs.

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 Horizontal Velocity Accuracy.

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

B.5.3 GNSS Performance.

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 1×10^{-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 1×10^{-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 1×10^{-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 1×10^{-7}. The integrity limit for fault-free (rare normal) case is 1×10^{-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 1×10^{-7} basis to the fault free 1×10^{-5} basis, the position source needs to indicate this change to the ADS-B equipment. We recommend the position source use a 1×10^{-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 1×10^{-5} to 1×10^{-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 <u>Minor Changes to Position Source Type Design.</u>

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	> $1x10^{-3}$ or unknown
1	≤ $1x10^{-3}$
2	≤ $1x10^{-5}$
3	≤ $1x10^{-7}$

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.

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