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

Advisory Circular

Subject: Airworthiness Approval of Automatic Dependent Surveillance - Broadcast (ADS-B) 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 of this Advisory Circular (AC).

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

b. 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.

c. This AC is primarily intended for installations compliant with the aircraft requirements of Title 14 of Code of Federal Regulations (14 CFR) 91.227. Airworthiness compliance will be evaluated based on the applicable intended function rule (e.g., 14 CFR 23.1301, 25.1301, 27.1301, 29.1301) recognizing that the intended function is to meet the equipment requirements in 14 CFR 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 the installation is in accordance with the criteria for ADS-B OUT in foreign non-radar airspace (e.g., 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 14 CFR 91.227 must follow all aspects of this AC or propose alternate means as appropriate to the Federal Aviation Administration (FAA).

1-2. Who This AC Applies To. 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. Where to Find This Advisory Circular. You can find this AC on the Federal Aviation Administration's (FAA's) websites, http://www.faa.gov/regulations_policies/advisory_circulars/ or http://rgl.faa.gov/.

1-4. Scope. 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 AC 20-149, Safety and Interoperability Requirements for Initial Domestic Flight Information Service-Broadcast. If Technical Standard Order, (TSO), 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 the 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. Appendix 5 provides a list of definitions that are specific to this

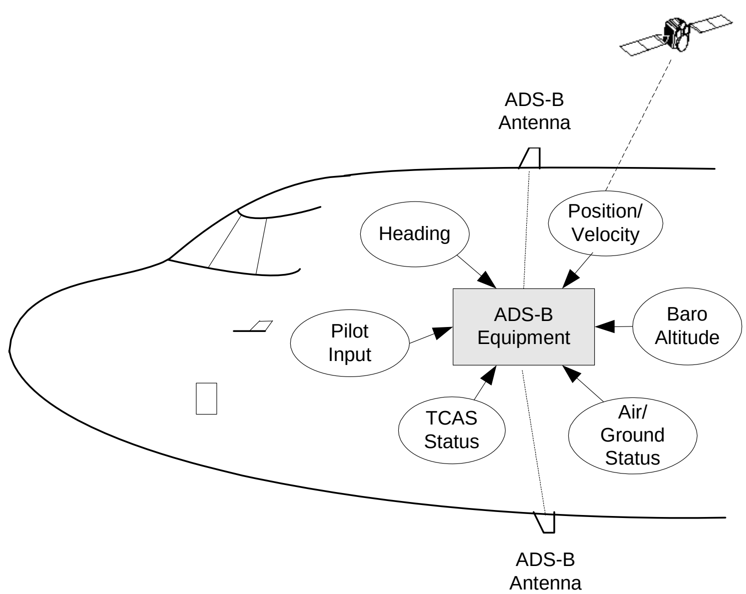
AC. Appendix 6 provides a list of acronyms that are used in the AC. The latest version of a document should be used where () follows its name. Appendix 7 provides a list of related documents.

1-5. Background.

a. 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 also receive these broadcasts and display the information to improve the pilot's situation awareness of other traffic.

b. 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 provides a functional overview of an aircraft ADS-B system.

Figure 1. Functional Overview of ADS-B OUT System.



Note: Heading is an optional interface. Traffic Alert and Collision Avoidance System (TCAS) status is only required for aircraft equipped with TCAS II.

c. ADS-B IN and ADS-B OUT. 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.

d. 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: 14 CFR 91.225 requires 1090ES in Class A airspace.

Chapter 2. The Approval Process & Necessary Documentation

2-1. ADS-B System Approval Process.

a. 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 equipment requirements of 14 CFR 91.227. Information on the STC and TC process can be found in the latest revisions of AC 21-40, *Guide for Obtaining a Supplemental Type Certificate* and Order 8110.4, *Type Certification*.

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

c. The ADS-B system is depicted in figure 1 and includes the ADS-B equipment, a position source, a barometric altitude source, an air-ground status source, a TCAS II source if the aircraft is equipped with TCAS II, an optional heading source, and all associated antennas and displays. Specifically list the components that make up the ADS-B system on the 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 system description in the Airplane Flight Manual (AFM), Rotorcraft Flight Manual (RFM), AFM Supplement (AFMS), or RFM supplement (RFMS). The flight manual must also indicate if that installation meets the equipment requirements of 14 CFR 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."**

a. Operating limitations. The flight manual should describe any operating limitations as specified by the equipment manufacturer or as a result of installation considerations.

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

(1) Describe any actions expected of the pilot.

(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, then the flight manual procedures must ensure conflicting information is not transmitted from the ADS-B system and transponder.

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

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

(5) Include guidance in the flight manual on when to enable the ADS-B system. The ADS-B 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 broadcasts, thus it is important for aircraft ADS-B OUT systems to continue to transmit on the airport surface. If the ADS-B function is embedded in a Mode S transponder, the flight manual, checklists, and any operator procedures manuals must be updated accordingly with ADS-B operations guidance.

> **Note:** Historically, transponders have been turned on by the flight crew 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 is operating during airport surface movement operations.

c. System Description. Describe the ADS-B OUT system and the interface with other systems on the aircraft in the flight manual.

2-3. Continuing Airworthiness Requirements.

a. 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.

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

c. 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. See 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.

d. 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.

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

(2) ADS-B source system components. While the installer may not have access to the specific source system ICAs 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 which 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 ICAs. If the installer determines that removal and replacement of the 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, their 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 log book entry for accomplishment of this test."

(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 System Installation Guidance

3-1. General Installation Guidance.

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

b. 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 utilize 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.

(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-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 Wide Area Augmentation System (WAAS),* TSO-C146, *Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS),* or TSO-C196, *Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation,* may set the SDA = 2 without further analysis. For installations in aircraft with more complex system architectures, a system safety assessment, as described below, is required to set the SDA. Installations with uncertified equipment must set SDA = 0.

(2) Conducting the system safety assessment. ADS-B systems using position sources not listed in paragraph 3-1b(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(), *Systems Design and Analysis,* AC 23.1309-1(), *System Safety Analysis and Assessment for Part 23 Airplanes*, SAE ARP 4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment, or* SAE ARP 4754a, *Certification Considerations for Highly-Integrated or Complex Aircraft Systems.*

Note: Although the direct effects to your aircraft of an ADS-B failure may be minor, the ADS-B information will be used by other ADS-B 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 system.

If the system contains different design assurance levels for hardware and software, then the worst case design assurance level should be used. For example, if the hardware assurance level is level C, and the software assurance level is B, the SDA would indicate that the system has been qualified commensurate with a Major failure condition. If the ADS-B system is integrated with a non-compliant GPS, the SDA must be set to 0.

(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, flight crew controls, heading instruments, or antennas. In contrast, the position source installation must be compliant with the guidance in this AC including design assurance considerations.

c. Position latency. Latency is the difference between the time a measurement is taken to determine the aircraft's geometric position and the time when that position measurement is transmitted by the aircraft's ADS-B equipment. Limiting the latency in ADS-B systems minimizes the errors in the reported position. TSO-C166b and TSO-C154c ADS-B equipment typically compensate for latency by extrapolating the position based on velocity information. All applicants must demonstrate compliance with the latency requirements in paragraph 3-1c(1). This can be done by equipping with a compliant architecture listed in paragraph 3-1c(2) or performing an analysis detailed in paragraph 3-1c(3). Latency terms are further defined in appendix 3 of this AC.

Note: To demonstrate compliance with 14 CFR 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 DO-260B, *Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance-Broadcast (ADS-B),* with Corrigendum 1 and DO-282B with corrigendum 1.

(1) Position latency requirements. There are two position latency requirements associated with ADS-B OUT.

(a) 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. In order to meet 14 CFR 91.227, the total latency must be less than or equal to 2.0 seconds.

(b) 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. In order to meet 14 CFR 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 by more 0.2 seconds (i.e. lead the aircraft position).

Note: RTCA Special Committee 186 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 14 CFR 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 appendix 3 of this AC.

(2) Compliant architecture. ADS-B systems which 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 meet the total latency and uncompensated latency requirements. Systems with a compliant architecture do not need to accomplish a position and velocity latency analysis.

(3) Position latency analysis. If you are installing an ADS-B system that does not have a compliant architecture described in paragraph 3-1c(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. Appendix 3 of this AC provides for an acceptable method to complete the latency analysis.

d. 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. 14 CFR 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.

(1) Compliant architecture. ADS-B equipment meeting the minimum performance requirements of TSO-C166b or TSO-C154c that are 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: *GNSS Sensor ARINC Characteristic 743A-5,* 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.

(2) Integrity metric latency analysis. If you are installing an ADS-B system without a compliant architecture 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.

e. System design assurance (SDA) and source integrity level (SIL) latency. 14 CFR 91.227 requires changes in the SDA or SIL be broadcast within 10 seconds. Changes in the SDA or SIL will typically only occur 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 non-compliant GPS, the SDA and SIL must be set to 0.

f. Populating message elements. 14 CFR 91.227 lists parameters that must be populated (i.e. not a null value) for operation in airspace defined by 14 CFR 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.

a. Equipment eligibility. ADS-B equipment must meet the requirements specified in TSO-C166b or TSO-C154c.

b. Installation guidance.

(1) UAT systems with Mode S transponders. Do not install a UAT ADS-B OUT system which has the capability to transmit a random 24-bit address in an aircraft which 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.

(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) Stand alone 1090ES transmitters. RTCA/DO-260B, paragraph 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 14 CFR 91.227.

(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 a random address feature. If dual ADS-B OUT systems of the same link are installed (e.g., to increase dispatch reliability), the installation must preclude operation of both systems simultaneously.

Note: 1: We recommend that you do not install both 1090ES and UAT ADS-B OUT capability on the same aircraft.

Note: 2: Installation of dual 1090ES and UAT ADS-B IN capability is acceptable and encouraged.

c. Configuration of associated parameters. The following paragraphs provide additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in appendix 1.

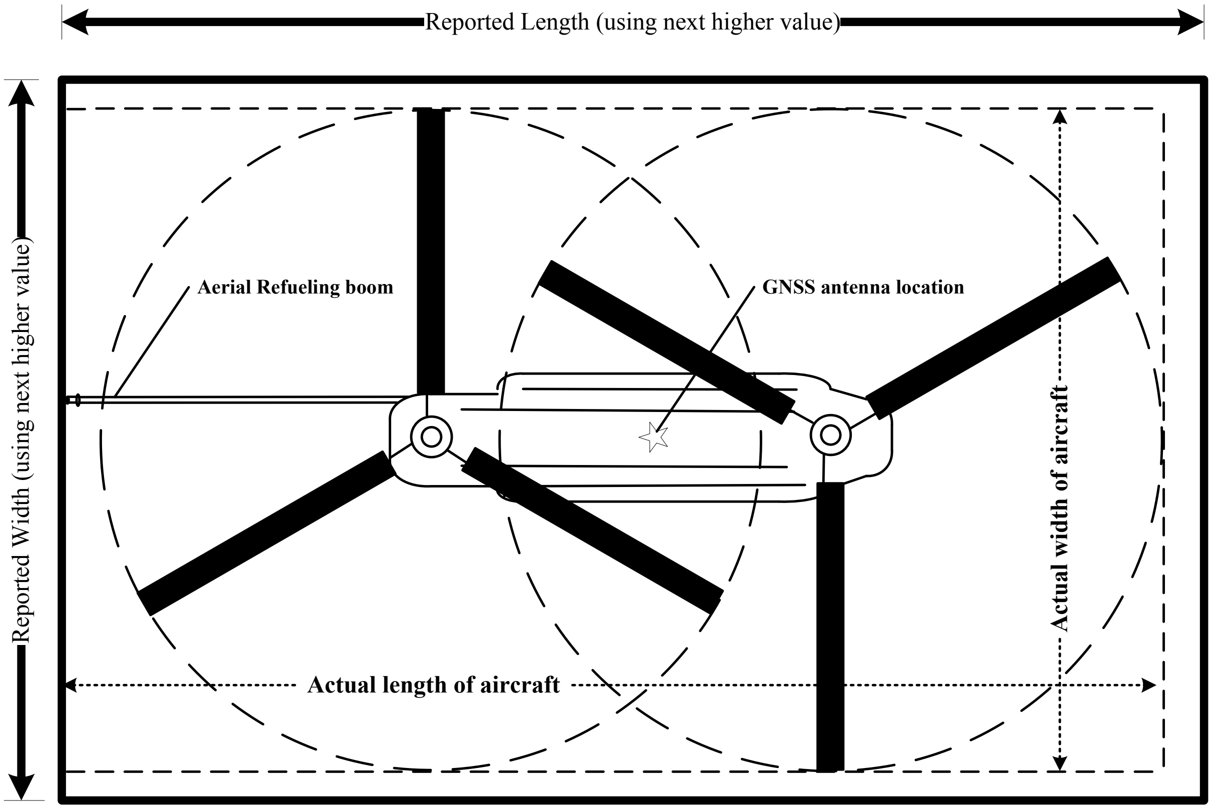
(1) International Civil Aviation Organization (ICAO) 24-bit address. You must set the ICAO 24-bit address during installation in accordance with the ADS-B equipment manufacturer's instructions. For U.S. civil aircraft, the ICAO 24-bit address is established as a function of the aircraft's registration 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 paragraph 3-7.b.(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.

(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 14 CFR 91.227. The length and width code chosen should be the smallest value that encompasses the entire aircraft. For example, the length and width code for a helicopter with a refueling boom would include the rotor blades or any other fixed object that extends from the fuselage, see figure 2.

Figure 2. Example of Aircraft Length and Width Code Determination.



(3) ADS-B IN capability. This parameter must be configured to indicate if the aircraft has an ADS-B IN system installed. 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.

(4) Emitter category. Table 1, Emitter Category, provides guidance on setting the emitter category.

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 pounds	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 pounds	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 pounds	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 Airplane ≥ 300,000 pounds	Any airplane with a maximum takeoff weight equal to or above 300,000 pounds.
Highly Maneuverable > 5 G and > 400 TAS	Any airplane, regardless of weight, which 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.
UAV	Any unmanned aerial vehicle or unmanned aircraft system regardless of weight.
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.

3-3. Position Source.

a. Equipment eligibility. 14 CFR 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 appendix 2 minimum performance requirements. Compliance with the appendix 2 requirements may be documented in the position source manufacturer's installation instructions.

Note: Not all GNSS position sources will provide the same availability. See appendix 2 for more information on GNSS availability. The FAA recommends TSO-C145 or TSO-C146 position sources that meet the appendix 2 requirements to maximize availability and ensure access to the airspace identified in 14 CFR 91.227 after January 1, 2020.

b. Installation guidance.

(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 20-138C, *Airworthiness Approval of Positioning and Navigation Systems.*

(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 which demonstrates that 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) 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 appendix 2.

Note: If a position source is unable to provide 14 CFR 91.227 accuracy and integrity values, it will not qualify the aircraft to operate in airspace defined by 14 CFR 91.225 after January 1, 2020.

(4) Position source selection. If multiple position sources 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 flight crew 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, and accuracy metrics, and integrity metrics.

(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 without providing any navigation information to other on-board systems. As addressed in appendix 2, an integrated GNSS position source should still meet the requirements of TSO-C145, TSO-C146, or

TSO-C196.

(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 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.

c. Configuration of associated parameters. The following paragraphs provide additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in appendix 1.

(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.

(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 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, see paragraph 3-5c for additional information on interfacing heading.

(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 which derive SIL from GNSS position sources compliant with any revision of TSO-C129, TSO-C145, TSO-C146, or TSO-C196 which 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 non-compliant GPS, SIL must be set to 0.

(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.

(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, while HPL values significantly smaller than 0.1 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 un-augmented 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 un-augmented 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 which limits the NIC ≤ 8. See appendix 2, paragraph 4.f for additional information on HPL considerations.

(6) Navigation Accuracy Category for Position (NAC_P). The ADS-B equipment must set the NAC_P based on the real time 95% 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).

(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.

(a) A $NAC_V = 1$ (< 10 m/s) may be permanently set at installation for GNSS equipment passing the tests identified in appendix 2, or may be set dynamically from velocity accuracy output of a position source qualified in accordance with the appendix 2 guidance.

(b) A $NAC_V = 2$ (< 3 m/s) may be set dynamically from velocity accuracy output of a position source qualified in accordance with the appendix 2 guidance. Do not permanently pre-set a $NAC_V = 2$ at installation, even if the position source has passed the tests identified in appendix 2.

(c) 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.

(8) Geometric Altitude. Ensure that 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 that 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 reported geometric accuracy to be exceeded.

(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."

(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 that 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.

a. Equipment eligibility.

(1) Utilize barometric altitude from a barometric altimeter meeting the minimum performance requirements of:

(a) TSO-C10, *Altimeter, Pressure Actuated, Sensitive Type*, (any revision) or

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

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

b. Installation guidance.

(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.

(2) 14 CFR 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 14 CFR part 91 appendix G, *Operations in Reduced Vertical Separation Minimum (RVSM)*, accuracy, that resolution and accuracy should be reflected in the ADS-B message.

(3) If a secondary altitude source is utilized 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 that the altitude source remains the same for both the transponder and ADS-B.

c. Configuration of associated parameters. The following paragraphs provide additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in appendix 1.

(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.

(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 which 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.

a. 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.

b. Installation guidance.

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

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

c. 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 Status Source.

a. Equipment eligibility. TCAS II systems should comply with TSO-C119a, *Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment*, or subsequent, 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.

b. Installation guidance.

(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 that the "TCAS installed and operational" and the "TCAS traffic status" parameters indicate the real-time status of the TCAS II.

(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 utilize 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. See AC 20-151A for more information on hybrid surveillance.

(3) 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.

c. Configuration of associated parameters. The following paragraphs provide additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in appendix 1.

(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.

(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.

a. Equipment eligibility. There are no unique equipment requirements.

b. Installation guidance.

(1) System status. The installation must have a method to display system operational status to the flight crew, which is consistent with the overall flight deck design philosophy. The system must display flight crew 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 available to the flight crew.

(a) ADS-B device failure. If the ADS-B equipment is unable to transmit ADS-B messages, the system provides an appropriate annunciation to the flight crew.

(b) 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 then 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. TSO-C166b and TSO-C154c require this condition to be annunciated. 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 either an AFM or Pilot's Guide, which 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.

(2) Turning off ADS-B. 14 CFR 91.225 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 (i.e. Standby or Off). If this architecture is used, specify the impact in the flight manual or pilot's guide, (e.g., loss of ADS-B, transponder and TCAS functionality). Locate the ADS-B on/off controls to prevent inadvertent actuation.

(3) Anonymity feature. 14 CFR 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 14 CFR 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 utilizing the anonymity feature:

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

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

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

(d) 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 DO-282()) call sign based solely on pilot selection of the 1200 Mode 3/A code.

(e) 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.

(f) Describe the ramifications of selecting the anonymity features in the flight manual or Pilot's Guide. Ramifications 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.

c. Configuration of associated parameters. The following paragraphs provide additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in appendix 1.

(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 flight crew. When the ADS-B equipment is initially 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 which existed prior to the ADS-B equipment being powered off, or to the aircraft registration number. See paragraph 3-7b(3) 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.

(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 (i.e. Mode 3/A codes 7500, 7600, and 7700). See paragraph 3-7c(5) for information on single point of entry of the emergency status.

(3) IDENT. The installation must provide a means for the pilot to enter the IDENT feature. See paragraph 3-7c(5) for information on single point of entry of the IDENT.

(4) Mode 3/A code. The installation must provide a means for the pilot to enter the Mode 3/A code. See paragraph 3-7c(5) for information on single point of entry of the Mode 3/A code.

(5) Single point of entry. Aircraft equipped with a 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 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:

(a) 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 flight crew, and enables the flight crew to detect and correct errors that do occur. Evaluate the system interface design to ensure that dual entry of the emergency status, IDENT, and Mode 3/A code does not introduce significant additional workload, particularly when communicating an aircraft emergency. See paragraph 4-1e(4) for additional information on the human factors evaluation.

(b) 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 1×10^{-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 1×10^{-5} per flight hour. The analysis must consider the potential of all pilot errors.

3-8. ADS-B Antenna Interface. 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.

a. Equipment eligibility. ADS-B antennas must meet requirements defined in the ADS-B equipment manufacturer's installation manual.

b. Installation guidance.

(1) Utilizing an existing antenna. When utilizing 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.

(2) Installing a new shared transponder/ADS-B antenna. Follow the transponder antenna installation guidance in AC 20-151A.

(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 utilize the existing transponder antenna, use the following guidance:

(a) 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.

(b) 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 20dB 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.

(c) Transmit power. Transmit power will be verified during ground test.

(d) Structural analysis. You must submit a structural analysis of new antenna installations to show compliance with the applicable regulations.

(4) Antenna diplexers. Diplexers manufactured in accordance with TSO-C154b or TSO-C154c may be installed so that 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.

(5) Single antenna. Single antenna systems must utilize a bottom mounted antenna.

c. Configuration of associated parameters. The following paragraphs provide additional guidance on setting key ADS-B OUT parameters. Definitions for each of the following associated parameters are included in appendix 1.

(1) GNSS antenna offset and position offset applied (POA). Although not required to comply with 14 CFR 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. If the ADS-B equipment is interfaced to multiple GNSS position sources that utilize 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.

(2) Single antenna bit. For aircraft using a single antenna, this parameter should be set to True.

d. 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 which 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 paragraph 3-3 and 3-4, as applicable.

a. 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:

(1) Hybrid vertical rate source. Vertical rate may be taken from a hybrid system which filters barometric vertical rate with an Inertial Reference Unit (IRU) vertical rate and GNSS vertical rate, provided the 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 (e.g., TSO-C106). Hybrid vertical rate could come from a Flight Management System (FMS), Air Data and Inertial Reference System (ADIRS), or an IRU. ADS-B equipment should transmit hybrid vertical rate solutions as barometric vertical rates.

(2) Blended vertical rate source. Vertical rate may be taken from a blended system which 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 (e.g., TSO-C106). Blended vertical rate could come from a FMS, ADIRS, or an IRU. ADS-B equipment should transmit blended vertical rate solutions as barometric vertical rates.

(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*. 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.

(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 appendix 2. Do not interface GNSS vertical velocity if the equipment has not been qualified in accordance with appendix 2.

(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.

(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.

b. 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.

c. Configuration of associated parameters. The following paragraphs provide additional guidance on setting key ADS-B OUT parameters.

(1) Vertical rate. Interface vertical rate from one or more of the sources listed 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.

(2) Vertical rate source. The source bit for vertical rate should be coded as barometric when utilizing 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.

a. The length and width code is required by 14 CFR 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.

b. For aircraft with retractable landing gear, the air-ground status determination is typically provided through a landing gear weight-on-wheels 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 Weight-on-Wheels (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.

c. TSO-C112d, *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.

a. Optional Parameters. If operations are planned in a country that requires parameters not mandated in the US, such as selected heading and selected altitude, follow the ADS-B equipment manufacturer's installation guidance to interface those parameters. The FAA will cooperate with foreign regulators to ensure compliance with their requirements.

Chapter 4. Test & Evaluation

4-1. Ground Test.

a. Systems interface testing. Verify that the installed ADS-B equipment meets its intended function and transmits the appropriate information from each of the interfaced systems (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.

b. System latency. Latency is addressed through analysis rather than testing. See paragraph 3-1.

c. Rule compliance. Ensure the ADS-B system meets the requirements of 14 CFR 91.227.

(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 14 CFR 91.227 (c)(1) requirements, listed in table 2.

Table 2. Accuracy and Integrity Requirements

NIC ≥ 7	R_c < 370.4 m (0.2 nm)
NAC_P ≥ 8	EPU < 92.6 m (0.05 nm)
NAC_V ≥ 1	< 10 m/s
SIL ≥ 3	≤ $1x10^{-7}$ per hour or sample
SDA ≥ 2	≤ $1x10^{-5}$ per hour

(2) Parameters. Ensure all 14 CFR 91.227(d) parameters are properly populated and transmitted.

(3) Position accuracy. Position the aircraft on a surveyed location and validate the position transmitted from the ADS-B system. Ensure that 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. Reference appendix 1 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) 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.

d. 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), 14 CFR 25.1353 (a) and (b), 14 CFR 25.1431 (a) and (c), 14 CFR 27.1301, 14 CFR 27.1309, 14 CFR 29.1353 (a) and (b), 14 CFR 29.1431 (a) and (b) as appropriate. Accomplish EMI/EMC testing to ensure that the ADS-B equipment does not provide an interference source on other installed systems on the aircraft. Additionally, ensure that 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.

e. Human machine interface. Evaluate the flight crew 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 flight deck design characteristics (such as access to controls, sunlight readability, night lighting, etc.) as well as the airplane environment, such as vibrations.

(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 pilot to see and interpret it. Ensure the pilots have a clear, unobstructed, and undistorted view of the displayed information. 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.

(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 flight deck, 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 (e.g., trackballs) as these can be susceptible to unintended mode selection resulting from their location in the flight deck (e.g., proximity to a foot rest or adjacent to a temporary stowage area).

(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, AC 27.1322, and AC 29.1322 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 flight crew 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) 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 flight crew, and enable the flight crew to detect and correct errors that do occur. System interface design must also be evaluated to ensure that dual entry of the Mode 3/A code, IDENT, and emergency status does not introduce significant additional workload, particularly when communicating an aircraft emergency. Evaluations should consider pilot-detected and undetected error rates, pilot workload, as well as training times. See paragraph 3-7c(5) for additional information on transponder and ADS-B system single point of entry.

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

f. 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 that replies to the Mode A/C and ATCRBS / Mode S all-call interrogations are inhibited on the ground.

g. 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, then ensure both the transponder and ADS-B system both 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.

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

i. 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.

j. 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

k. Transmit power. Transmit power testing must be accomplished if a new antenna has been installed, an existing antenna has been relocated, if 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.

(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

(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

l. TCAS. If a TCAS II system is installed on the aircraft, ensure that 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.

m. Transponder all-call inhibit. When ADS-B functionality resides in a Mode S transponder, conduct a test which demonstrates 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.

n. 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.

a. Mutual interference. During all phases of flight, demonstrate that there is no mutual interference with any other aircraft system. Have all installed systems operating during the flight test.

b. Other system performance. Demonstrate the proper performance of any previously installed aircraft system(s) 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 system, and does not require a unique test for ADS-B.

c. 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 that the same Mode 3/A code, IDENT, and emergency codes are transmitted from both systems.

4-3. In-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 drop outs 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. If you have flight test data from a previous STC or TC which established this compatibility, you do not need to re-accomplish the flight test.

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.

a. Preflight coordination.

(1) Data retrieval. At least 48 hours prior to the flight, notify the FAA by e-mailing 9-avs-air-130flttest@FAA.gov that you require data from the flight test to support post flight analysis. Include contact information for your ACO point of contact, aircraft registration number or applicable call sign, 24-bit address, expected date, location and approximate time of the flight.

(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.

b. 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 paragraph 4-3b(3) thru (7) below may be flown in any order.

(1) Location of flight. The flight may be accomplished in any airspace that has FAA ADS-B ground station coverage. See the following web site for information on existing ADS-B coverage in the National Air Space (NAS):
http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/enroute/surveillance_broadcast/coverage/

(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.

(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) 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 provides 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

Configuration	Altitude Range AGL	Speed Range	Bank Angle
Part 23 Aircraft			
Configuration	**Altitude Range AGL**	**Speed Range**	**Bank Angle**
Takeoff	3000-5000	1.4 V_S	30^0
Approach or Landing	2000-7000	1.4 V_S	30^0
Cruise	7000-10000	1.5 V_S to 1.8 V_S	30^0
Part 25 Aircraft			
Configuration	**Altitude Range**	**Speed Range**	**Bank Angle**
Takeoff	3000-5000	V_2 + 20 kts	30^0
Approach or Landing	2000-7000	V_{APP} + 20 kts	30^0
Cruise	7000-10000	1.5 V_S to 1.8 V_S	30^0
Part 27 Rotorcraft			
Configuration	**Altitude Range**	**Speed Range**	**Bank Angle**
Landing	1000-3000	V_Y + 10 kts	30^0
Cruise	2000-5000	0.8 V_{NE} or 0.8 V_H	30^0
Part 29 Rotorcraft			
Configuration	**Altitude Range**	**Speed Range**	**Bank Angle**
Landing	1000-3000	V_Y + 10 kts	30^0
Cruise	2000-10000	0.8 V_{NE} or 0.8 V_H	30^0

(5) Climbs/descents. Verify the ADS-B system performs properly during climbs and descents. Table 6 provides a suggested rate at which climbs should be made during the test flight. Table 7 provides a suggested rate 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.
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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_Y	V_{MO} - 10 kts	0.8 V_{NE} or 0.8 V_H	0.8 V_{NE} or 0.8 V_H

Table 7. Decent 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

(6) Position accuracy. Utilizing a known waypoint, fly a north/south course that crosses the defined waypoint followed by an east/west course that crosses the same defined way point.

c. Post-flight data retrieval. Within 48 hours of completing the STC or TC flight test against the FAA ground stations, email: amc-ajw-sbsm@faa.gov, to request flight data from your flight. You must include your Type Inspection Authorization, name and email address of your ACO project engineer, aircraft registration number or applicable call sign, 24-bit address, date, location and time of the flight.

d. Post-flight data analysis. You must accomplish a post flight data analysis to ensure that 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 from 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:

(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 where unaugmented GNSS solutions drop below the NIC and NACp 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, then 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 NACv=0, and status messages transmit NACp=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, then the applicant must establish root cause and provide a solution prior to granting installation approval. Demonstrate that you meet all 14 CFR 91.227 (c)(1) requirements, listed in table 8, accuracy and integrity requirements during flight.

Table 8. Accuracy and Integrity Requirements During Flight

Ensure NIC ≥ 7 throughout the flight.	R_c <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	$\leq 1\text{x}10^{7}$
Ensure SDA ≥ 2 throughout the flight	$\leq 1\text{x}10^{-5}$

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(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.

(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) 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.

(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.

(6) Validity checks. The FAA plans to utilize 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 an enhanced validity status is provided in the flight test data, then 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 14 CFR 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 paragraph 4-3 apply to initial STC/TC applications. Flight test data from a similar installation, covered under a previous STC, may be used in-lieu-of a new flight test if the following conditions can be confirmed through the documentation of the previous STC:

a. The position source must be identical to that of the other STC documentation. Equipment families that use the same baseline design may make a case for equivalence.

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

c. 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 STC. Aircraft with data concentrators will have to re-accomplish the flight test, even if the equipment is identical.

d. The air-data interface to the ADS-B equipment must be identical to that of the previous 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 that broadcast of simulated altitude information does not cause interference with ATC or ADS-B IN applications.

e. The heading interface to the ADS-B equipment (if applicable) must be identical to that of the previous 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.

f. The TCAS interface to the ADS-B equipment must be identical to that of the previous STC. The TCAS equipment may be different, only the interface to the ADS-B equipment needs to be identical.

Appendix 1. Message Elements Descriptions

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

2. Message Elements.

a. 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 14 CFR 91.227.

b. 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.

c. 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 14 CFR 91.227.

d. 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 14 CFR 91.227 except when using the TSO-C154c anonymity feature.

e. 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 14 CFR 91.227.

f. 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 14 CFR 91.227.

g. 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 WGS-84 ellipsoid (HAE). Geometric altitude is required to be transmitted by 14 CFR 91.227.

h. Geometric vertical accuracy (GVA). The GVA indicates the 95% accuracy of the reported vertical position (geometric altitude) within an associated allowance.

i. GNSS antenna offset and position offset applied.

(1) The GNSS antenna offset indicates the longitudinal distance between the nose of the aircraft and the GNSS antenna and the lateral distance between the longitudinal center line of the aircraft and the GNSS antenna.

(2) The position offset applied 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. See RTCA/DO-242A, *Min Aviation System Performance Standards for ADS-B,* change 1, paragraph 2.1.2.5 and figure 2-1 for a depiction of the ADS-B position reference point.

j. 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.

k. 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 in order to transmit complete velocity information.

l. 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 in order to transmit complete velocity information.

m. 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 14 CFR 91.227.

n. ICAO 24-bit address. 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 the 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 14 CFR 91.227 except when using the TSO-C154c anonymity feature.

o. IFR capability. This parameter existed in TSO-C166a and TSO-C154b compliant equipment, however it was removed from TSO-C166b and TSO-C154c equipment.

p. IDENT. 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 controllers screen. IDENT is required to be transmitted by 14 CFR 91.227.

q. 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 World Geodetic System 1984 (WGS-84) ellipsoid. Latitude and longitude are required to be transmitted by 14 CFR 91.227.

r. 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 14 CFR 91.227.

s. 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 - 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 14 CFR 91.227.

t. 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% probability that the reported information is correct within an associated allowance. A minimum NAC_P value of eight must be transmitted to operate in airspace defined in 14 CFR 91.225. Table 9 provides the applicable NAC_P values.

Table 9. 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

u. 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 14 CFR 91.227.

v. Navigation Integrity Category (NIC). The NIC parameter specifies a position integrity containment radius. NIC is reported so that 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 horizontal protection level (HPL) from the GNSS. A minimum NIC value of seven must be transmitted to operate in airspace defined in 14 CFR 91.225. Table 10 provides the applicable NIC values.

Table 10. NIC Values

NIC	Containment Radius
0	Unknown
1	R_C < 37.04 km (20nm)
2	R_C < 14.816 km (8nm)
3	R_C < 7.408 km (4nm)
4	R_C < 3.704 km (2nm)
5	R_C < 1852 m (1nm)
6	R_C < 1111.2 m (0.6nm)
	R_C < 926 m (0.5nm)
	R_C < 555.6 m (0.3nm)
7	R_C < 370.4 m (0.2nm)
8	R_C < 185.2 m (0.1nm)
9	R_C < 75 m
10	R_C < 25 m
11	R_C < 7.5 m

w. 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.

x. 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 World Geodetic System 1984 (WGS-84) ellipsoid. Latitude and longitude is required to be transmitted by 14 CFR 91.227.

y. Receiving ATC services. 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, however it was removed from TSO-C166b and TSO-C154c equipment.

z. Single antenna bit. Indicates if the ADS-B equipment is transmitting through a single antenna.

aa. 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 un-annunciated faults in the avionics system, the SIL must consider the effects of a faulted Signal-In-Space (SIS), if a signal-in-space is used by the position source. A minimum SIL value of three must be transmitted to operate in airspace defined in 14 CFR 91.225. Table 11 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 11. SIL Values, Probability of Exceeding the NIC Containment Radius.

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

bb. 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 12.

Table 12. Source Integrity Level Supplement

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

cc. System Design Assurance (SDA). The SDA parameter defines the failure condition that the ADS-B system is designed to support as defined in table 13. 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. Since 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, *System Design and Analysis*, AC 23.1309-1(), *System Safety Analysis and Assessment for Part 23 Airplanes*, and AC 29-2, *Certification of Transport Category Rotorcraft (Changes 1-3 incorporated)*. The SDA includes the position source, ADS-B equipment, and any intermediary devices that process the position data. 14 CFR 91.227 requires a SDA of 2 or 3 as defined in table 13.

Table 13. 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
3	Hazardous	$\leq 1x10^{-7}$ Per Hour	B
2	Major	$\leq 1x10^{-5}$ Per Hour	C
1	Minor	$\leq 1x10^{-3}$ Per Hour	D
0	Unknown/ No safety effect	$> 1x10^{-3}$ Per Hour or Unknown	N/A

Note: 1: Software design assurance per RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification,* or equivalent. Airborne electronic hardware design assurance per 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 other ADS-B 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 system.

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

dd. 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 14 CFR 91.227.

ee. 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 14 CFR 91.227 if the aircraft is TCAS II equipped.

ff. 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.

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

hh. 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 two 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 two or higher is required by 14 CFR 91.227.

Appendix 2. Identifying and Qualifying ADS-B Position Sources

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 that the installer can properly interface the position source to the ADS-B system. Position source suppliers must ensure that any supplied data is incorporated into the article design, and changes to any documented characteristics result in a change to the part number.

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. All references in this AC to TSO-C129, TSO-C145, TSO-C146, and TSO-C196 refer to any revision of the TSO.

3. General Guidance for all Position Sources. All ADS-B position sources should provide the following outputs.

a. 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. 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.

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

d. 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 TSO authorization or design approval. This output must describe the vertical position accuracy with 95% probability under fault-free conditions.

e. Position integrity (horizontal). The position source must have a horizontal position integrity output qualified during the system's TSO authorization 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 which describes the region assured to contain the indicated horizontal position with at least 99.99999% probability under fault-free avionics conditions. Position sources which degrade from a 99.99999% probability to a 99.999% probability (e.g., a tightly-coupled inertial/GNSS system after the loss of GNSS) can still be installed, however they won't meet 14 CFR 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.

(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.

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

(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.

f. 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).

g. Signal-in-space 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.

h. Velocity accuracy. The position source should have a velocity accuracy output that was qualified in conjunction with the system's TSO authorization or design approval. In lieu 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 20-138C, Appendix 4. The position source manufacturer may propose a test method for non GNSS sources or an alternate test for GNSS sources during the TSO authorization or design approval.

i. Design assurance. The position source must support a major or greater failure effect. This includes software compliant with RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification,* 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, paragraph 1.6 applies. Because the broadcast position can be used by any other ADS-B 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 system. The overall probability of a position source malfunction causing a position to be output which exceeds the output integrity radius must be less than $1x10^{-5}$ per hour.

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

k. 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.

l. 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 system, and not just the position source, the following position source latency targets are only guidelines. Position source uncompensated latency should be less than 200ms, compensated latency should be less than 500ms, and total latency should be less than 700ms.

Note: 1: System latency requirements are described in paragraph 3-1 of this AC.

Note: 2: This paragraph addresses position latency only.

m. 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. See TSO-C145, TSO-C146, or TSO-C196 for additional information on the integrity time-to-alert.

n. 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.

o. Availability. 14 CFR 91.225 and 91.227 do not define an availability requirement, however it is a significant operational factor when selecting the position source, (see table 14, Estimated GNSS availabilities minimum threshold constellation).

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.

a. 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 Technical Standard Order Authorization (TSOA) for the aforementioned TSOs require no additional qualification for the position output.

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

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

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

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO are defined in DO-229C, *Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment,* section 2.1.2.6.

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO are defined in DO-229C sections 2.1.4.8 & 2.1.5.8.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO are defined in DO-229 D 2.1.2.6.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO are defined in DO-229D sections 2.1.4.8 & 2.1.5.8.

(7) TSO C196/196a. Means of compliance for this TSO are defined in DO-316, *Minimum Operational Performance Standards (MOPS) for Global Positioning System/Aircraft Based Augmentation System Airborne Equipment,* section 2.1.2.6.

b. Position source latency. GNSS position source manufacturer must provide position source latency information.

(1) TSO C129. Means of compliance for this TSO requires 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 two second ADS-B transmission latency at the aircraft level.

(2) TSO C129a. Means of compliance for this TSO requires 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 two second ADS-B transmission latency at the aircraft level.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO are defined in DO-229C section 2.1.2.6.2.

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO are defined in DO-229C sections 2.1.2.6.2 and 2.1.5.8.2.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO are defined in DO-229 D 2.1.2.6.2.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO are defined in DO-229D sections 2.1.2.6.2 and 2.1.5.8.2.

(7) TSO C196/196a. Means of compliance for this TSO are defined in DO-316 section 2.1.2.6.2.

c. Availability.

(1) Analysis has shown the following estimated availability for GPS receivers meeting the minimum TSO performance standards, (see table 14), assuming the minimum threshold GPS satellite constellation. The availability improves when the GPS constellation is full of operational satellites.

(2) The FAA plans to integrate back up surveillance systems with ADS-B, including SSR and Wide Area Multilateration, to mitigate the impact of loss of GNSS performance due to 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 availability determination system to assist operators in determining surveillance availability for ADS-B prior to flight. This tool will consider 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 and the required performance for the separation standard in use along the route of flight.

Table 14. 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%

d. Horizontal position integrity. GNSS position sources must have a horizontal position integrity (e.g., HIL or HPL) output qualified during the system's TSO authorization or design approval to determine NIC.

(1) TSO C129. The requirements outlined for Class A, B, and C equipment provides horizontal integrity through RAIM algorithms under DO-208, *Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)*, change 1 section 2.2.1.13. But there is no requirement to compute or output HPL. To properly comply with the ADS-B requirements, additional means of compliance for this TSO requires 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 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 DO-208 change 1 Appendix F provides an acceptable HPL.

(2) TSO C129a. The requirements outlined for Class A, B, and C equipment provides horizontal integrity through RAIM algorithms under DO-208 change 1 section 2.2.1.13. But there is no requirement to compute or output HPL. To properly comply with the ADS-B requirements, additional means of compliance for this TSO requires 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 Advisory Circular recommends an 8 second time to alert. The protection level value is acceptable as an HPL if the equipment performs the test in 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 DO-208 change 1 Appendix F provides an acceptable HPL.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO are defined in 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 DO-229C section 2.1.1.13.1.

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO are defined in 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 DO-229C section 2.1.1.13.1.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO are defined in DO-229D sections 2.1.2.6, 2.1.2.2.2, and 2.1.3.2.2. Related requirements can be found in DO-229D sections 2.1.1.4 and 2.1.4.9.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO are defined in 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 DO-229D sections 2.1.1.4 and 2.1.4.9.

(7) TSO C196/196a. Means of compliance for this TSO are defined in DO-316 section 2.1.2.6, 2.1.2.2.2, and 2.1.3.2.

e. Position integrity (probability). GNSS position source manufacturer must provide information describing the basis for the probability of exceeding the horizontal integrity containment radius.

(1) TSO C129. Means of compliance for TSO-C129 are defined in DO-208 change 1 section 2.2.1.13.1 referring to Table 2-1.

(2) TSO C129a. Means of compliance for TSO-C129a are defined in DO-208 change 1 section 2.2.1.13.1 referring to Table 2-1.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO are defined in 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 DO-229D Appendix U Section 4. FDE requirements can be found in 2.1.2.2.2.2.2.

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO are defined in 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 DO-229D Appendix U Section 4. FDE requirements can be found in section 2.1.2.2.2.2.2.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO are defined in 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 DO-229D Appendix U Section 4. FDE requirements can be found in section 2.1.2.2.2.2.2.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO are defined in 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 DO-229D Appendix U Section 4. FDE requirements can be found in section 2.1.2.2.2.2.2.

(7) TSO C196/196a. Means of compliance for this TSO are defined in DO-316 section 2.1.2.2.2.2. For additional guidance on an acceptable scaling method, GNSS manufacturers can refer to DO-316 Appendix U Section 4.

f. 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. ARINC characteristic 743A-5, *GNSS Sensor*, dated May, 2009, compliant receivers 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.

(1) TSO C129. The requirements in 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 requires 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 14 CFR 91.227.

(2) TSO C129a. The requirements in 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 requires 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 Advisory Circular.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO are defined in DO-229C sections 2.1.1.13, and 2.1.2.2.2.2.1 through 2.1.2.2.2.2.4.

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO are defined in 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.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO are defined in DO-229D sections 2.1.1.13, and 2.1.2.2.2.2.1 through 2.1.2.2.2.2.4.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO are defined in 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.

(7) TSO C196/196a. Means of compliance for this TSO are defined in DO-316 sections 2.1.1.11, and 2.1.2.2.2.1 through 2.1.2.2.2.4.

g. Position integrity limits. The 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 nautical mile (nm). While 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 un-augmented 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:

(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 0.1nm, 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.

(a) TSO C129. Means of compliance for this TSO requires GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration.

(b) TSO C129a. Means of compliance for this TSO requires GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration.

(c) TSO C196/196a. Means of compliance for this TSO requires GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration.

(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.

(a) TSO C145/146 Rev a Class 1. Means of compliance for this TSO requires GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration.

(b) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO requires 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 (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 (reference 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.

(c) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO requires GNSS manufacturers to present substantiation data whether HPL is limited or not, and provide proper installation instructions for the ADS-B integration.

(d) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO requires 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 (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 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.

h. Horizontal Position accuracy. GNSS position sources should provide a HFOM output which was demonstrated during the position source's design approval or during an installation approval. GNSS certified under TSO-C145b/c, C146b/c, or all revisions of TSO-C196 are required to provide the HFOM output. TSO-C129, TSO-C145a, and TSO-C146a does not contain a horizontal position accuracy output requirement, however all equipment must provide a HFOM output in order 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 DO-229D Section 2.1.2.6 and 2.1.2.6.2).

(1) TSO C129. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data showing the equipment computes and outputs HFOM. See the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-11 for an acceptable HFOM test.

(2) TSO C129a. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data showing the equipment computes and outputs HFOM. See the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-11 for an acceptable HFOM test.

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

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data based on the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-11 for an acceptable HFOM test.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO are defined in DO-229D section 2.1.2.6 (also see section 1.7.1 and Appendix H of DO-229D).

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO are defined in DO-229D section 2.1.2.6 (also see section 1.7.1 and Appendix H of DO-229D).

(7) TSO C196/196a. Means of compliance for this TSO are defined in DO-316 section 2.1.2.6 (also see section 1.7.1 and Appendix H of DO-316).

i. 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 (i.e. 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 the geoid (HAG) instead of height above the ellipsoid (HAE). The position source manufacturer must provide data on whether the position source outputs HAE or HAG.

(1) TSO C129. Means of compliance for this TSO requires GNSS manufacturers to provide data to substantiate the output of HAE. The data produced to substantiate vertical position accuracy per the test described in the latest revision of AC 20-138 appendix 4, paragraph 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.

(2) TSO C129a. Means of compliance for this TSO requires GNSS manufacturers to provide data to substantiate the output of HAE. The data produced to substantiate vertical position accuracy per the test described in the latest revision of AC 20-138 appendix 4, paragraph 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.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data showing the equipment outputs HAE. The data produced to substantiate vertical position accuracy per the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10 is sufficient.

(4) TSO C145/146 Rev a Class 2/3. For Class 2 equipment, the means of compliance for this requires GNSS manufacturers to provide substantiation data showing the equipment outputs HAE. The data produced to substantiate vertical position accuracy per the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10 is sufficient. Class 3 equipment complies with the ADS-B geometric altitude requirement per DO-229C section 2.1.5.8.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data showing the equipment outputs HAE. The data produced to substantiate vertical position accuracy per the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10 is sufficient.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data showing the equipment outputs HAE. The data produced to substantiate vertical position accuracy per the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10 is sufficient.

(7) TSO C196/196a. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data showing the equipment outputs HAE. The data produced to substantiate vertical position accuracy per the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10 is sufficient.

j. 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.

(1) TSO C129. Means of compliance is described in 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.

(2) TSO C129a. Means of compliance is described in 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 section (a)(5)(v) respectively.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO are defined in DO-229C section 2.1.2.6.1.

(4) TSO C145/146 Rev a Class 2. Means of compliance for this TSO are defined in DO-229C section 2.1.2.6.1 and 2.1.5.8.1.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO are defined in DO-229D section 2.1.2.6.1.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO are defined in DO-229D sections 2.1.2.6.1 and 2.1.5.8.1.

(7) TSO C196/196a. Means of compliance for this TSO are defined in DO-316 section 2.1.2.6.1.

k. 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 DO-229D Section 2.1.2.6 and 2.1.2.6.2).

(1) TSO C129. Means of compliance for this TSO requires GNSS manufacturers to perform the velocity test in the latest revision of AC 20-138, Appendix 4 and provide information substantiating the data is output.

(2) TSO C129a. Means of compliance for this TSO requires GNSS manufacturers to perform the velocity test in the latest revision of AC 20-138, Appendix 4 and provide information substantiating the data is output.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO are defined in DO-229C section 2.1.2.6 along with the test defined in the latest revision of AC 20-138 Appendix 4.

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO are defined requirements are defined in DO-229C section 2.1.2.6 along with the test defined in the latest revision of AC 20-138 Appendix 4.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO are defined in 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 paragraph 4.n of this appendix (Horizontal Velocity Accuracy) and the associated velocity accuracy tests.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO are defined in 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 paragraph 4.n of this appendix (Horizontal Velocity Accuracy) and the associated velocity accuracy tests.

(7) TSO C196/196a. Means of compliance for this TSO are defined in 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 paragraph 4.n of this appendix (Horizontal Velocity Accuracy) and the associated velocity accuracy tests.

Note: The velocity test found in the latest revision AC 20-138 is also defined in section 2.3.6.4 of DO-316.

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

(1) TSO C129. Means of compliance for this TSO requires GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (i.e., in a groundspeed format versus north/east velocity format) and the protocols used.

(2) TSO C129a. Means of compliance for this TSO requires GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (i.e., in a groundspeed format versus north/east velocity format) and the protocols used.

(3) TSO C145/146 Rev a Class 1. The Gamma equipment requirements outlined in 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 DO-229D, Appendix H. Additional means of compliance for TSO-C145/146 Rev a Class 1 requires GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (i.e., in a groundspeed format versus north/east velocity format) and the protocols used.

(4) TSO C145/146 Rev a Class 2/3. The Gamma equipment requirements outlined in 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 DO-229C, Appendix H. Additional means of compliance for TSO-C145/146 Rev a Class 2/3 requires GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (i.e., in a groundspeed format versus north/east velocity format) and the protocols used.

(5) TSO C145/146 Rev b/c Class 1. Gamma-1 equipment requirements outlined in 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 DO-229D, Appendix H. Additional means of compliance for TSO-C145/146 Rev b/c Class 1 requires GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (i.e., in a groundspeed format versus north/east velocity format) and the protocols used.

(6) TSO C145/146 Rev b/c Class 2/3. Gamma-2 and Gamma-3 equipment requirements outlined in 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 DO-229D, Appendix H. Additional means of compliance for TSO-C145/146 Rev b/c Class 2/3 requires GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (i.e., in a groundspeed format versus north/east velocity format) and the protocols used.

(7) TSO C196/196a. Means of compliance for this TSO requires GNSS manufacturers to provide information in the installation instructions describing how the velocity is output (i.e., in a groundspeed 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 DO-316 Appendix H.

m. Time of Applicability. The GNSS equipment must output a time of applicability.

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

(1) TSO C129. Means of compliance for this TSO requires 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 time of measurement to time of applicability requirement and account for the impulse response of the position solution.

(2) TSO C129a. Means of compliance for this TSO requires 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.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO are defined in DO-229C sections 2.1.2.6 and 2.1.2.6.2.

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO are defined in DO-229C sections 2.1.2.6, 2.1.2.6.2, and 2.1.5.8.2.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO are defined in DO-229D sections 2.1.2.6 and 2.1.2.6.2.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO are defined in DO-229D sections 2.1.2.6, 2.1.2.6.2, and 2.1.5.8.2.

(7) TSO C196/196a. Means of compliance for this TSO are defined in DO-316 sections 2.1.2.6 and 2.1.2.6.2.

n. 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.

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

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

(3) NAC_V. = 3 or 4. No standard for performance has been developed to support NACV = 3 or 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.

(4) TSO C129. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data based on the NACv =1 and NACv = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration. See AC 20-138() appendix 4, paragraph A4-2.d(3) for additional guidance relative to using the noise environment in DO-235B for the velocity tests.

(5) TSO C129a. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data based on the NACv =1 and NACv = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration. See AC 20-138() appendix 4, paragraph A4-2.d(3) for additional guidance relative to using the noise environment in DO-235B for the velocity tests.

(6) TSO C145/146 Rev a Class 1. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data based on the NACv =1 and NACv = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration.

(7) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data based on the NACv =1 and NACv = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration.

(8) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data based on the NACv =1 and NACv = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration.

(9) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data based on the NACv =1 and NACv = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration.

(10) TSO-C196/196a. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data based on the NACv =1 and NACv = 2 test as appropriate and document the NAC_V in the installation instructions for the ADS-B integration.

o. Vertical position accuracy. The GNSS should output vertical position accuracy. The vertical accuracy should specify a 95% 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.

(1) TSO C129. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10.

(2) TSO C129a. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10.

(4) TSO C145/146 Rev a Class 2. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in the latest revision of AC 20-138 appendix 4, paragraph A4-10.

(7) TSO C196/196a. Means of compliance for this TSO requires GNSS manufacturers to provide substantiation data along with the VFOM output based on the test described in the latest revision of AC 20-138 appendix 4 paragraph A4-10.

p. 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.

(1) TSO C129. Means of compliance for this TSO requires 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 (See Integrity Limit, paragraph 4.g, of this appendix).

(2) TSO C129a. Means of compliance for this TSO requires 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 (See Integrity Limit, paragraph 4.g, of this appendix).

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO requires 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 (See Integrity Limit, paragraph 4.g, of this appendix).

(4) TSO C145/146 Rev a Class 2. Means of compliance for this TSO requires 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 (See Integrity Limit, paragraph 4.g, of this appendix).

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO requires 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 (See Integrity Limit, paragraph 4.g, of this appendix).

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO requires 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 (See Integrity Limit, paragraph 4.g, of this appendix).

(7) TSO C196/196a. Means of compliance for this TSO requires 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 (See Integrity Limit, paragraph 4.g, of this appendix).

q. 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. Reference 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% 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 (i.e., 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.

(1) TSO C129. This is not applicable to this TSO as no HPL scaling is applied.

(2) TSO C129a. This is not applicable to this TSO as no HPL scaling is applied.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO are defined in DO-229C sections 2.1.1.13.1 and 2.1.3.2.2.

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO are defined in DO-229C sections 2.1.1.13.1, 2.1.3.2.2, 2.1.4.2.2, and 2.1.5.2.2.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO are defined in DO-229D sections 2.1.1.13.1 and 2.1.3.2.2.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO are defined in DO-229D sections 2.1.1.13.1, 2.1.3.2.2, 2.1.4.2.2, and 2.1.5.2.2.

(7) TSO C196/196a. This is not applicable to this TSO as no HPL scaling is applied.

r. 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, then the position source manufacturer must provide information on velocity limitations for GNSS track angle.

Note: 1: The interference levels used to demonstrate velocity accuracy compliance can be used for track angle validity as well.

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

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

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

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

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

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO requires GNSS manufacturers to use the test environment and guidance defined in the latest revision of AC 20-138, appendix 4 paragraph 4-12. It is recommended that manufacturers use DO-229D, Appendix H for outputting track angle (ARINC 743 all revisions label 103) for those using ARINC 429 characteristics.

(7) TSO C196/196a. Means of compliance for this TSO requires GNSS manufacturers, using test or analysis to use the test environment and guidance defined in the latest revision of AC 20-138, appendix 4 paragraph 4-12. It is recommended that manufacturers use DO-316, Appendix H for outputting track angle (ARINC 743 all revisions label 103) for those using ARINC 429 characteristics.

s. 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.

(1) TSO C129. Means of compliance for this TSO requires GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

(2) TSO C129a. Means of compliance for this TSO requires GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO requires GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO requires GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO requires GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO requires GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

(7) TSO C196/196a. Means of compliance for this TSO requires GNSS manufacturers to provide installation instructions describing how the time mark relates to the position, velocity, FOM, and time of applicability.

t. Signal-in-space 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 1×10^{-3}. GNSS equipment provides the appropriate SIS error detection.

(1) TSO C129. Means of compliance for this TSO is defined in DO-208 change 1 Section 2.2.1.13.1 referring to Table 2-1 (see 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 their RAIM algorithm includes pseudorange step detection per TSO-C129a section (a)(3)(xv) 5.

(2) TSO C129a. Means of compliance is defined in DO-208 change 1 section 2.2.1.13.1 referring to Table 2-1 (see Table 2-1 Note D) and TSO-C129a section (a)(3)(xv)5.

(3) TSO C145/146 Rev a Class 1. Means of compliance for this TSO is defined in DO-229C 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 Signal in Space (SIS) includes health monitoring/fault information which is why these general signal processing requirements are included.

(4) TSO C145/146 Rev a Class 2/3. Means of compliance for this TSO is defined in DO-229C 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.

(5) TSO C145/146 Rev b/c Class 1. Means of compliance for this TSO is defined in DO-229C 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.

(6) TSO C145/146 Rev b/c Class 2/3. Means of compliance for this TSO is defined in DO-229C 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.

(7) TSO C196/196a. Means of compliance for this TSO are defined in DO-316 sections 2.1.1.2, 2.1.1.3, and 2.1.2.2.2.2.

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.

a. 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. Address the horizontal velocity accuracy.

c. 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.

d. Install the GNSS sensor(s) in accordance with AC 20-138(), *Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment.*

e. 14 CFR 91.227 requires a SIL = 3, which means the probability of exceeding the NIC containment radius should be less than $1x10^{-7}$ per hour or per sample. The tightly-coupled GNSS/IRS system should transmit the integrity quality metric on a "per-hour" basis. After loss of GNSS or GNSS RAIM, the hybrid system should report the integrity containment radius of $1x10^{-7}$ probability on a per sample basis rather than on a per hour basis. Doing so would allow the GNSS/IRS system to transmit at a probability of $1x10^{-7}$ for a longer period of time.

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

(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, then the position source must indicate this change to the ADS-B equipment (i.e. SIL Supplement).

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

f. 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:

(1) If inertial coasting will meet 14 CFR 91.227 requirements, such as $NAC_P = 8$, NIC = 7, SIL = 3, and SDA = 2.

(2) Estimated length of time following a loss of GNSS for which inertial coasting is expected to meet the 14 CFR 91.227 requirements. The estimate should assume the system met minimum 14 CFR 91.227 requirements just prior to the loss of GNSS or GNSS RAIM. This estimate will be helpful to operators in developing a means to assure that the system can meet

14 CFR 91.227 requirements during predicted GNSS degradations.

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 14 CFR 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 14 CFR 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 14 CFR 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.

a. Distance Measuring Equipment (DME/DME).

(1) The DME/DME 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.*

(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.

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

(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.

(5) Reasonableness Checks. The DME/DME system must incorporate reasonableness checking. Reference AC 90-100A for additional information on reasonableness checks.

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

c. Inertial Navigation System/Inertial Reference Unit (INS)/(IRU) Loosely Coupled with DME or GNSS.

(1) The GNSS equipment or DME equipment must meet the requirements in this appendix.

(2) Loosely coupled INS/IRU equipment must meet 14 CFR part 121, appendix G.

(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, see paragraph 3 of this appendix. Velocity accuracy may be qualified and set statically. Update the position accuracy and position integrity metrics dynamically.

(4) 14 CFR 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 prior to the loss of GNSS, must continue to be bounded.

(a) 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, then 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) 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, then the position source must relay this change to the ADS-B equipment.

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 14 CFR 91.227. Future revisions of this AC will address new position source technology when it becomes available.

Appendix 3. Latency Analysis

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

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 the ADS-B equipment. Use the following guidelines to determine latency for each component:

a. 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 Time-Of-Measurement (TOM) and end when the position is output from the position source.

(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 per 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.

(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.

(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 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.

(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.

b. 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. 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 100ms.

d. 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 hertz position source can introduce 1 second of total latency. This 1 second must be included in the total latency calculation.

3. Equipment latency budget. There are no individual component latency requirements; however we recommend the following guidelines:

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

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

b. 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 100ms. (Reference RTCA/DO-260B, appendix U).

c. 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 100ms of uncompensated latency. TSO-C166b or TSO-C154c are required by 14 CFR 91.225.

4. General Latency Issues.

a. Recommendations for reducing latency.

(1) Directly connect the position source to the ADS-B equipment.

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

(3) Use a position source that provides position updates at greater than 1Hz.

(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).

b. 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. 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 to 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.

d. Compensating for interface latency in unsynchronized systems. It is acceptable to install ADS-B equipment which 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 which 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.

e. Overcompensating. It is possible for compensation algorithms to “over compensate” 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 200ms. (Reference RTCA/DO-260B, appendix U).

f. Extrapolation during loss of position data. TSO-C166b equipment compliant with RTCA/DO-260B, paragraphs 2.2.3.2.3.7.4 and 2.2.3.2.3.8.4, allows extrapolation of the position for up to two 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 per TSO-C166b.

g. 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. In order 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.

h. 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.

(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 area navigation (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 14 CFR 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 DO-260B with Corrigendum 1 and DO-282B with corrigendum 1.

(2) Transmit time-of-applicability. The transmit time is the time which 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.

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

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 15 is considered a compliant architecture.

Table 15. Latency Analysis Example

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

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 4. Definitions

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

a. Automatic Dependent Surveillance Broadcast (ADS-B). ADS-B is an advanced surveillance technology where ADS-B OUT equipped aircraft share position, altitude, velocity, and other information with ATC and other appropriately equipped aircraft.

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

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

d. 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.

e. 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.

f. Flight Information System - Broadcast (FIS-B). FIS-B is a ground broadcast service provided over the UAT data link. The FAA FIS-B system provides pilots and flight crews of properly equipped aircraft with a cockpit display of certain aviation weather and aeronautical information.

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

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

i. Global Navigation Satellite System (GNSS). The generic term for a satellite navigation system, such as the Global Positioning System (GPS), that provides autonomous worldwide geo-spatial positioning and may include local or regional augmentations.

j. Global Positioning System (GPS). GPS is 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 *GPS Standard Positioning System Performance Standard, 4th edition* available at http://pnt.gov/public/docs/2008/spsps2008.pdf.

k. GNSS time of applicability. The time that the position output from the GNSS sensor is applicable.

l. GNSS Time of Measurement (TOM). TOM for GNSS sources is the time when the last GNSS signal used to determine the position arrives at the aircraft GNSS antenna.

m. 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% probability under fault-free conditions at the time of applicability.

n. Horizontal Protection Level Fault Detection (HPL_{FD}). 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. It 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.

o. Horizontal Protection Level Fault Free (HPL_{FF}). Fault Free horizontal protection level. See RTCA/DO-229D appendix R.

p. 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.

q. 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 (e.g., 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.

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

s. Selective Availability (SA). A protection technique employed by the Department of Defense which degraded GPS accuracy. Selective availability was discontinued on May 1, 2000.

t. 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 which provides position, velocity, and other information on traffic which is detected by a secondary surveillance radar, but is not transmitting an ADS-B position.

u. 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).

v. Uncompensated latency. Any latency in the ADS-B system which 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.

w. Wide Area Augmentation System (WAAS). The U.S. implementation of SBAS.

Appendix 5. Acronyms

1. Acronyms.

Acronym	Definition
14 CFR	Title 14 of the Code of Federal Regulations
AC	Advisory Circular
ACO	Aircraft Certification Office
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
EMC	Electro Magnetic Compatibility
EMI	Electromagnetic Interference
EPU	Estimated Position Uncertainty
FAA	Federal Aviation Administration
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

Acronym	Definition
kts	Knots
LPV	Localizer Performance with Vertical Guidance
m/s	Meters per second
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
R_c	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 II	Traffic Alert and Collision Avoidance System
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	VHF 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

Acronym	Definition
V_2	Takeoff safety speed
WAAS	Wide Area Augmentation System
WGS-84	World Geodetic System 1984

Appendix 6 Related Documents

1. 14 CFR. Title 14 of the Code of Federal Regulations (14CFR) can be obtained at www. access.gpo.gov. Select "Access," then "Online bookstore." Then select "Aviation," then "Code of Federal Regulations."

2. Advisory Circulars. Order copies of Advisory Circulars 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/.

a. AC 20-131(), *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders*

b. AC 20-138(), *Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment*

c. AC 20-151(), *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) Version 7.0 & 7.1 and Associated Mode S Transponders*

d. AC 20-172(), *Airworthiness Approval for ADS-B IN Systems and Applications*

e. AC 21-40(), *Guide for Obtaining a Supplemental Type Certificate*

f. AC 23.1309-1(), *System Safety Analysis and Assessment for Part 23 Airplanes*

g. AC 25.1309-1(), *System Design and Analysis*

h. AC 27-1(), *Certification of Normal Category Rotorcraft*

i. AC 29-2(), *Certification of Transport Category Rotorcraft*

j. AC 43-6(), *Altitude Reporting Equipment and Transponder System Maintenance and Inspection Practices*

3. TSO. You can find a current list of technical standard orders on the FAA Internet website at www.airweb.faa.gov/rgl. You will also find the TSO Index of Articles at the same site.

a. TSO-C5, *Direction Instrument, Non-Magnetic (Gyroscopically Stabilized)*

b. TSO-C6, *Direction Instrument, Magnetic (Gyroscopically Stabilized)*

c. TSO-C8(), *Vertical Velocity Instruments*

d. TSO-C10(), *Altimeter, Pressure Actuated, Sensitive Type*

e. TSO-C66(), *Distance Measuring Equipment (DME) Operating Within the Radio Frequency Range of 960-1215 Megahertz*

f. TSO-88(), *Automatic Pressure Altitude Reporting Code-Generating Equipment*

g. TSO-C106(), *Air Data Computer*

h. TSO-C112(), *Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*

i. TSO-C119(), *Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment*

j. TSO-C129(), *Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)*

k. TSO-C145(), *Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)*

l. TSO-C146(), *Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)*

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

n. 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)*

o. TSO-C196(), *Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation*

4. RTCA, Inc. 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.

a. RTCA DO-160D, E, F or G *Environmental Conditions and Test Procedures For Airborne Equipment*

b. RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*

c. RTCA/DO-208 change 1, *Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)*

d. RTCA/DO-229D, *Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment*

e. DO-242A change 1 *Min Aviation System Performance Standards for ADS-B*

f. RTCA/DO-254*, Design Assurance Guidance for Airborne Electronic Hardware*

g. RTCA/DO-260B, *Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance-Broadcast (ADS-B*) corrigendum 1

h. RTCA/DO-300, *Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance*

i. RTCA/DO-316, *Minimum Operational Performance Standards (MOPS) for Global Positioning System/Aircraft Based Augmentation System Airborne Equipment*

5. FAA Orders. FAA order 8110.44C Change 1 incorporated *Type Certification*, can be found at the FAA Regulatory and Guidance Library website: http://rgl.faa.gov/.

6. ARINC, Inc. Documents. ARINC document *GNSS Sensor ARINC Characteristic 743A-5* can be obtained from ARINC Incorporated, 2551 Riva Rd., Annapolis, MD, 21401. Telephone +1 800-633-6882, fax +1 410-956-5465. You can also get copies from their website, www.arinc.com.

7. SAE International. 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.

a. SAE ARP 4754A, *Certification Considerations for Highly-Integrated or Complex Aircraft Systems*

b. SAE ARP-4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*

8. European Aviation Safety Agency. Copies of EASA document 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*, can be obtained from the European Aviation Safety Agency, Postfach 10 12 53, D-50452 Cologne, Germany.