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

Advisory Circular

Subject: Airworthiness Approval of Air Traffic Control Radar Beacon System (ATCRBS)/Mode S Transponders

Date: XX/XX/XX **AC No:** 20-194

Initiated by: AIR-626C **Change:**

1 **PURPOSE.**

The Federal Aviation Administration (FAA) is issuing this advisory circular (AC) to guide applicants seeking airworthiness approval for installations of Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) transponders certified to Technical Standard Order (TSO)-C112c or later, *Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*.

2 **APPLICABILITY.**The guidance provided in this AC is for manufacturers, modifiers, foreign regulatory authorities, FAA engineers and their designees, and applicants seeking a type certificate (TC), amended type certificate, or supplemental type certificate (STC) under title 14, Code of Federal Regulations (14 CFR) part 25 for initial approval and follow-on approvals of Mode S transponders. References to part 25 are appropriate when the transponder is installed on transport category airplanes. Although this AC is intended mainly for transponders installed on transport category airplanes, it provides useful guidance for 14 CFR parts 23, 27, and 29 installations if you refer to the equivalent ACs and sections of 14 CFR parts 23, 27, and 29. When seeking certification for a Mode S transponder installation in an aircraft certified under parts 23, 27, and 29, use the equivalent 14 CFR sections in the part applicable to the aircraft in which you are installing the transponder.

2.2 This is a guidance document. Its content is not legally binding in its own right and will not be relied upon by the FAA as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with the guidance document is voluntary only, although compliance with underlying legal requirements is not. Nonconformity will not affect rights and obligations under existing statutes and regulations.

2.3 The FAA will consider other means of demonstrating compliance with underlying legal requirements that an applicant may elect to present. Terms such as “should,” “may,” and “must” are used only in the sense of ensuring the applicability of this particular method of compliance when the acceptable method of compliance in this document is used. If the FAA becomes aware of circumstances in which following this AC would not result in compliance with the applicable regulations, the FAA may require additional substantiation or design changes as a basis for finding compliance.

2.4 This material does not change or create any additional regulatory requirements or authorize changes in or permit deviations from existing regulatory requirements.

3 CANCELLATION.

Advisory Circular 20-151C, *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders*, provided previous guidance for installation of both transponders and Traffic Alert and Collision Avoidance (TCAS II) systems. With the advent of the Airborne Collision Avoidance System X (ACAS X), the FAA is splitting the installation guidance into separate ACs for transponders and collision avoidance systems (TCAS II and ACAS Xa/Xo).

3.1 The FAA will cancel AC 20-151C upon issuance of both AC 20-194, Air Traffic Control Radar Beacon System (ATCRBS)/Mode S Transponders, and AC 20-196, Airworthiness Approval of Airborne Collision Avoidance Systems (ACAS).

4 RELATED MATERIAL.

See appendix A for a list of regulations and publications related to this AC.

5 DEFINITION OF KEY TERMS.

5.1 Air Traffic Control Radar Beacon System (ATCRBS). Secondary surveillance radar system with ground-based interrogators and airborne transponders capable of operation on Modes A and C.

5.2 Automatic Dependent Surveillance Broadcast (ADS-B) Out. A function on an aircraft or vehicle that automatically broadcasts its own aircraft's identity, state vector (horizontal and vertical position and velocity), associated quality and performance parameters (accuracy and integrity), and other information. Broadcast links include the 1090 MHz extended squitter and the Universal Access Transceiver broadcast on 978MHz.

5.3 Failure. Inability of a system, subsystem, unit, or part to perform within previously specified limits.

5.4 Mode A. Mode of operation that replies with one of 4096 possible selected codes when interrogated.

5.5 Mode C. Mode of operation that replies with aircraft altitude information when interrogated.

5.6 Mode S. Mode of operation that replies with a discrete address and other aircraft information when interrogated, including squittered information.

5.7 Squitter. Transmissions spontaneously generated by the transponder.

5.8 Transponder Register. A transponder data buffer containing different pieces of information. It has 56 bits which are divided into different fields. The definition of the transponder registers can be found in the International Civil Aviation Organization (ICAO) Doc 9871, Edition 2, and in RTCA/DO-181F, *Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*.

6 SCOPE.

6.1 ATCRBS/Mode S Transponders.

In this AC, we cover design aspects, characteristics, mechanization, testing, and the criticality of system failure cases for ATCRBS/Mode S transponders. Our guidance focuses on systems where technical documents developed by a joint air transport industry-government group (RTCA, Inc., Special Committee SC-209) define the operational performance standards.

6.2 Automatic Dependent Surveillance – Broadcast (ADS-B) Systems.

You can find guidance for airworthiness approvals of ADS-B Out and ADS-B In in Advisory Circulars 20-165(), *Airworthiness Approval of Automatic Dependent Surveillance - Broadcast OUT Systems,* and 20-172(), *Airworthiness Approval for ADS-B In Systems and Applications,* respectively.

Note: Where "()" is used, such as in AC 20-165(), use the latest published version.

6.3 Mode S Elementary Surveillance (ELS) and Enhanced Surveillance (EHS).

For guidance on Mode S Elementary Surveillance (ELS) and Enhanced Surveillance (EHS), refer to European Union Aviation Safety Agency (EASA) *Certification Specification and Acceptable Means of Compliance – Airborne Communication Navigation and Surveillance,* CS-ACNS, Issue 5, subpart D, sections 2 and 3.

7 ATCRBS/MODE S TRANSPONDER SYSTEM.

7.1 System Components.

7.1.1 ATCRBS/Mode S Transponder.

7.1.1.1 An ATCRBS/Mode S transponder is an enhancement to the ATCRBS transponder, designed for interoperability and compatibility with ATCRBS. Each aircraft equipped with a Mode S transponder is assigned a unique ICAO aircraft address, ensuring distinct identification for each aircraft.

7.1.1.2 You may install an ATCRBS/Mode S transponder independently or as part of an ACAS. ACAS-equipped aircraft use Mode S to coordinate

resolution maneuvers. This ensures the Resolution Advisory (RA) displayed in one ACAS-equipped aircraft is compatible with the maneuver displayed in the other ACAS-equipped aircraft.

Note: As used in this AC, the term Airborne Collision Avoidance System, and the acronym ACAS, collectively includes the following systems that interface with a Mode S transponder to provide RAs: Traffic Alert and Collision Avoidance System (TCAS) II, ACAS Xa, ACAS Xu, and ACAS Xr.

7.1.2 Pilot Controls.

To meet the regulatory requirements and TSO-C112c/d/e/f minimum performance requirements cited below, the system must:

- Provide a means to select the assigned Mode A code, per § 91.215.
- Provide a means to initiate the transponder "IDENT" function, also referred to as Special Position Identification (SPI), per RTCA/DO-181D/E/F § 2.2.4.1.3.
- Provide a means to deactivate pressure altitude (Mode C) reporting, per § 91.217.
- Provide a means to put the transponder in standby, per RTCA/DO-181D/E/F § 2.1.7.c.

Note 1: AC 20-196() and AC 20-172() provide guidance addressing integration of controls for ACAS and ADS-B In installations.

Note 2: Title 14 CFR §§ 91.215, 121.345, and 135.143 require transponder equipment meeting the performance and environmental requirements of the appropriate TSO-C112 class for certain operations or, in certain cases, allow the use of transponder equipment meeting the performance and environmental requirements of the appropriate TSO-C112 class as a compliance option. The minimum performance standards specified by the applicable revision of the TSO used for compliance and its associated minimum operational performance specification requirements are therefore, by extension, compliance requirements for the applicable operating rules.

Note 3: Additional guidance can be found in AC 20-175().

7.1.3 Antennas.

7.1.3.1 **Diversity.**

To meet the international standard specified in ICAO Annex 10 Volume IV § 2.1.5.3, an ATCRBS/Mode S transponder installed on an aircraft with gross mass in excess of 5,700 kg or with a maximum cruising true airspeed capability in excess of 463 km/h (250 kt) must operate with antenna diversity, with one antenna on the top and the other on the bottom of the aircraft's fuselage. Additionally, ICAO Annex 10

Volume IV § 4.3.11.1 requires a transponder used with an ACAS to have antenna diversity.

7.1.3.2 **Location.**

7.1.3.2.1 To meet the international standard specified in ICAO Annex 10 Volume IV § 3.1.2.10.4.5, the total two-way transmission difference in mean reply delay between the two antenna channels (including the differential delay caused by transponder-to-antenna cables and the horizontal distance along the aircraft center line between the two antennas) must not exceed 0.13 microseconds.

7.1.3.2.2 The horizontal distance between the top and bottom antennas should be less than 25 ft (ICAO Annex 10 Volume IV § 3.1.2.10.4.2.1).

7.1.3.2.3 To meet the international standard specified in ICAO Annex 10 Volume IV § 3.1.2.10.4.2, the antennas must be mounted as near as possible to the aircraft's fuselage centerline, minimizing any obstructions in the horizontal plane.

7.1.3.3 **Transponder to Antenna Cables.**

The Radio Frequency (RF) losses in the transponder-to-antenna cables need to comply with the limits specified by the manufacturer. To meet RTCA/DO-181D/E/F § 2.2.3.2 (a minimum performance standard for a TSO-C112c/d/e/f transponder), the RF peak power must be between 21 and 27 dBW.

Note: Aircraft that operate at altitudes not exceeding 15,000 feet and that have a normal cruising speed less than 175 knots may have a power between 18.5 dBW and 27 dBW.

7.1.3.4 **Certification.**

The antenna(s) used in the installation must be certified to TSO-C112c or later to ensure that the following requirements from RTCA/DO-181D/E/F are met:

- The voltage standing wave ratio produced by the antenna, when terminated in a 50-ohm transmission line, does not exceed 1.5:1 across the 1030 to 1090 MHz frequency band.
- The antenna is vertically polarized.
- The antenna gain is not less than the gain of a matched quarter-wave stub minus 3 decibels (dB) over 90 percent of a coverage volume from 0 to 360 degrees in azimuth and from 5 to 30 degrees above the ground plane when installed at the center of a1.2-meter diameter (or larger) flat circular ground plane.

7.1.4 Mutual Suppression.

The mutual suppression system is intended to prevent interference from and towards other similar frequency band equipment (reference ARINC 735B-2, attachment 8). To meet the international standard specified in ICAO Annex 10 Volume IV § 4.3.11.1, a Mode S transponder used in conjunction with an ACAS must support a mutual suppression interface capability. Follow the transponder equipment manufacturer's guidance on interfacing the transponder equipment to the mutual suppression system.

7.2 **Airworthiness Considerations.**

7.2.1 Certification Program.

This AC will guide your installation of ATCRBS/Mode S transponder systems. Installations include the transponder, antennas, and control panel. These components are all certified initially as a single installed system with a defined configuration. For any change to the defined configuration, the FAA will require either a new initial approval or a follow-on approval. The degree of system integration needed to perform these functions is extensive and, as a result, you may expect the FAA to require you to obtain airworthiness approval through the type certification or supplemental type certification process.

7.2.2 Certification Plan.

Develop a comprehensive certification plan, which should include how you will comply with the applicable certification requirements, the substantiating data, necessary tests, a system description, and an estimated time schedule. A well-developed certification plan will be of significant value both to you (the applicant) and the appropriate FAA certification branch.

7.2.3 Equipment Compatibility.

AC 20-196() includes tests to demonstrate compatibility with ACAS.

7.2.4 ATCRBS/Mode S Transponder Aircraft System Interfaces.

7.2.4.1 **Pressure Altitude**.

7.2.4.1.1 In accordance with 14 CFR 91.217, the transmitted pressure altitude must correspond within 125 feet (on a 95 percent probability basis) of the indicated or calibrated datum of the altimeter normally used to maintain flight altitude, with that altimeter referenced to 29.92 inches of mercury for altitudes from sea level to the maximum operating altitude of the aircraft. Aircraft equipped with an ACAS have additional altimeter requirements to comply with ACAS operating rules (refer to AC 20-196() for more details).

7.2.4.1.2 To support compliance with pressure altitude reporting requirements of § 91.215, the FAA considers pressure altitude information that meets the requirements of TSO-C10b or later, *Pressure Altimeter System*, or TSO-

C106a or later, *Air Data Computer*, an acceptable source of pressure altitude.

7.2.4.1.3 ICAO Annex 6 Part I § 6.20.3 requires that airplanes used for international commercial air transport be equipped with a data source that provides pressure altitude information with a resolution of 25 ft or better. This requirement implies that airplanes used for international commercial air transport may not use Gillham encoding, since that method can only provide altitude with a resolution of 100 ft. The FAA recommends that installers avoid the use of Gillham encoding wherever possible.

7.2.4.2 **ICAO Aircraft Address**.

7.2.4.2.1 The ICAO aircraft address is a unique, internationally recognized identifier assigned to each aircraft. This address is a 24-bit binary code, which is normally represented in hexadecimal format (and sometimes in octal or decimal format). The ICAO aircraft address is used to distinguish one aircraft from another in Air Traffic Control (ATC) systems, ADS-B In systems, and ACAS.

7.2.4.2.2 Obtain the ICAO aircraft address for the Mode S transponder from the appropriate airworthiness authority of the country in which the aircraft is registered. For U.S. registered aircraft, obtain the ICAO aircraft address by looking up the N-number at https://registry.faa.gov/aircraftinquiry/Search/NNumberInquiry and note the "Mode S Code" provided in hexadecimal and octal formats. Alternatively, the ICAO aircraft address can be obtained from the FAA Aircraft Registration Branch, PO Box 25504, Oklahoma City, OK 73125; or by phone at (405) 954-3116.

7.2.4.2.3 Two aircraft reporting identical ICAO aircraft addresses can have adverse impacts to ATC and to the operation of other aircraft's ADS-B In and ACAS. Therefore, it is essential to operate with the correct ICAO aircraft address. It is crucial to update the ICAO aircraft address to correspond with any new registration number.

7.2.4.3 **Transponder Ground Detection.**

7.2.4.3.1 When the aircraft is on the ground, the ATCRBS/Mode S transponder is inhibited from replying to any Mode A, Mode C, and Mode S-only all-call interrogations. Typically, a landing gear weight-on-wheels switch provides acceptable air/ground status determination.

7.2.4.3.2 Installations that provide a means to automatically determine air/ground status based on inputs from other aircraft sensors may be acceptable if you can demonstrate that use of those inputs results in accurate determination of the air/ground status.

7.2.4.3.3 Fixed-wing aircraft without an automatic means of detecting air/ground status will use an internal algorithm to determine air/ground status. For these implementations, the FAA recommends integration of equipment compliant with TSO-C112f because the air/ground determination algorithm is greatly improved from previous revisions of TSO-C112.

7.2.4.3.4 The transponder unit will override an on-the-ground status if ground speed, airspeed, or radar altimeter altitude exceed the given thresholds. Therefore, the FAA recommends providing these inputs to the unit.

7.2.4.3.5 The FAA does not consider manual selection of the air/ground status acceptable because the potential for human error introduces an unacceptably high likelihood of incorrect air/ground status reporting, potentially leading to adverse system-level effects.

7.2.4.4 **Elementary and Enhanced Surveillance.**

ELS and EHS are capabilities required for many aircraft flying in Europe. Refer to Commission Implementing Regulation (EU) No 2023/1770 and amendments. Refer to Certification Specifications and CS-ACNS, Issue 5, for applicable certification specifications, acceptable means of compliance, and guidance material.

7.2.5 Failure Conditions System Safety Assessment and Design Assurance.

7.2.5.1 TSO-C112f classifies failures of transponder functioning resulting in any of the following unannunciated failures as a major failure condition:

- Lack of responses to valid interrogations to a degree sufficient to create the potential for a missing RA, as defined in TSO-C219, *Airborne Collision Avoidance System (ACAS) Xa/Xo*, on the other aircraft's ACAS in an encounter;
- Replies sent with incorrect timing;
- Replies sent with an incorrect altitude; or
- Transmission of incorrect information to a connected ACAS.

Note: TSO-C219a, *Airborne Collision Avoidance System (ACAS) Xa/Xo,* contains the same definition of a missing RA as TSO-C219.

7.2.5.2 Regulatory requirements codified at 14 CFR 25.1309(b)(3) at amendment 25-152, which became effective on September 26, 2024, provide that the airplane systems must be designed so that each occurrence of a major failure condition is remote. For other product classes (14 CFR part 23, *Normal Category Airplanes*; 14 CFR part 27, *Normal Category Rotorcraft*; and 14 CFR part 29, *Transport Category Rotorcraft*), the regulations applicable to the product class (14 CFR § 23.1309(c)) prior to amendment 23-64, § 23.2510(c) at amendment 23-64 or later, § 27.1309(b)(2), and § 29.1309(b)(2)) require major failure conditions to

be remote for small airplanes (14 CFR part 23) or improbable for rotorcraft (14 CFR parts 27 and 29).

7.2.5.3 In accordance with the above regulations as applicable to the product class and consistent with the failure classification of the transponder, the FAA will require installers to show that unannunciated failures of the installed transponder as listed above are remote or improbable. You can do this by using the methods described in the following documents:

- AC 23.1309-1E, *System Safety Analysis and Assessment for Part 23 Airplanes* (for Part 23 airplanes certified before Amendment 23-64);
- AC 25.1309-1B, S*ystem Design and Analysis* (for transport category airplanes);
- AC 27-1B, *Certification of Normal Category Rotorcraft*; or
- AC 29-2C, *Certification of Transport Category Rotorcraft; or*
- PS-ASW-27-15, *Safety Continuum for Part 27 Normal Category Rotorcraft Systems and Equipment.*

7.2.5.4 A functional hazard assessment, a failure modes and effects analysis, and a quantitative probability analysis of the transponder, displays, and sensors (including altitude information sources) will normally be necessary to show that the system design is compliant with the following:

- Failure of the installed system to perform its intended function from a reliability and availability perspective occurs no more than 1.0 $x10^{-3}$ times per flight hour.
- Transmitting misleading range or altitude information occurs no more than 1.0 $x10^{-5}$ times per flight hour.

7.2.5.5 Transponders used with an ACAS system need to be evaluated for additional failure conditions listed in AC 20-196().

7.2.6 Installation Considerations.

7.2.6.1 **Aircraft Systems Information Security Protection (ASISP).**

The applicant should provide information security review and mitigation strategies for any installation that could potentially have aircraft information security vulnerabilities due to the use of non-trusted connectivity. RTCA DO-326A, *Airworthiness Security Process Specification*, and DO-356A, *Airworthiness Security Methods and Considerations*, provide acceptable methodologies for aircraft information security assessment and protection.

7.2.6.2 **Multiple Transponders Simultaneous Transmissions.**

To support compliance with 14 CFR §§ 23.2500, 25.1301, 27.1301, and 29.1301, as applicable, an acceptable installation has a limitation prohibiting simultaneous operation of two or more transponders if

multiple transponders are installed. Simultaneous transmissions from multiple transponders on the same aircraft may result in garbled signals and will likely be unusable by ATC or ACAS.

7.2.7 Structural Analysis.

Per the guidance in AC 43.13-2B, *Acceptable Methods, Techniques, and Practices – Aircraft Alterations,* chapter 3, analyze the structural effects of an antenna installation on the mounting structure. Submit a structural analysis of the antenna installations to the FAA.

7.2.8 Failures.

Regulatory provisions codified in 14 CFR §§ 23.2600, 23.2605(c), 25.1302, 25.1309(c), 25.1322, 27.1309(c), 27.1322, 29.1309(c), and 29.1322 contain requirements for flightcrew alerting. For purposes of compliance with § 25.1322(b), accident experience has shown that loss of ATCRBS/Mode S transponder functionality requires immediate flightcrew awareness and subsequent flightcrew response. This response includes checking for proper transponder settings and operation. Therefore, in acceptable new installations of ATCRBS/Mode S transponders, to meet Section 25.1322 requirements for a caution level alert, the system annunciates both a transponder failure and the transponder in standby mode in yellow/amber in the pilot's primary field of view and includes timely attention-getting cues through aural or tactile indications. The FAA further recommends interfacing these alerts with the aircraft's master caution and warning system. Additionally, the FAA recommends providing an indication when the transmission of pressure altitude is inhibited.

Note 1: AC 25.1302-1, *Installed Systems and Equipment for Use by the Flightcrew*, and AC 25.1322-1, *Flightcrew Alerting*, contain guidance for compliance with 14 CFR §§ 25.1302 and 25.1322.

Note 2: For the purposes of this subsection, we consider a new installation of an ATCRBS/Mode S transponder as one that occurs in:

- An aircraft that does not currently have one fitted; or
- A new aircraft, i.e., one that has not received a type certificate.

8 TEST AND EVALUATION.

8.1 General.

Conducting tests and evaluation in accordance with this chapter will ensure the design and installation perform their intended functions under the expected operating conditions and that there are no adverse interactions between the transponder and existing aircraft systems.

8.2 Create a Test Plan.

Provide a test plan that includes adequate testing to perform the requisite verification of design and installation. This test plan will generally require a combination of

ground tests and basic flight tests. The rest of this chapter lists and explains the minimum elements the FAA will normally require to find the test plan acceptable in accordance with its authority under 14 CFR § 21.33.

8.2.1 Basic Ground Tests.

CAUTION: When ground testing the transponder system, it is necessary to take precautions to prevent being a source of interference to ATC or other aircraft operating in the area with ACAS and/or ADS-B In. False ACAS and/or ADS-B In indications of "intruder aircraft" could result in unnecessary ATC communications or ACAS induced aircraft maneuvers. Conduct such testing in coordination with ATC and use antenna shielding (transmission absorption covers or caps) to prevent the system from transmitting test data that could generate false intruder information whenever possible. As an alternative to the use of antenna shielding, you can use radiated testing provided that the altitude reported by the transponder system (via Mode C, Mode S, and ADS-B) is at ground level. Ground testing should include the following:

8.2.1.1 Ensure the ICAO aircraft address is correct. Additionally, ensure the system reports Flight ID, Mode A code, and Mode C altitude data correctly.

8.2.1.2 Ensure that the transponder transmits an SPI pulse in Mode A responses for 18 ±1 seconds when you activate the IDENT switch.

8.2.1.3 Ensure that you have connected the air/ground inputs properly by placing the aircraft in the ground state and verifying that there are no replies to Mode A, Mode C, and Mode S-only all-call interrogations, and that the transponder does not transmit any acquisition squitters. Simulate an airborne state and ensure that the transponder replies to Mode A, Mode C, and Mode S-only all-call interrogations and that it transmits acquisition squitters.

8.2.1.4 Ensure that the system properly annunciates a transponder failure and transponder in the standby mode in yellow/amber in the pilot's primary field of view along with an aural or tactile indication. If implemented, verify that an indication is provided when the transmission of pressure altitude is inhibited.

8.2.1.5 Conduct the pressure altitude correspondence test described in AC 43-6D*, Altitude Reporting Equipment and Transponder System Maintenance and Inspection Practices,* paragraph 9.4.

8.2.1.6 Ensure diversity isolation (power level difference between transponder "On" antenna squitters and "Off" antenna squitters) is greater than or equal to 20 dB. The Auto Test screen generally displays diversity isolation. To ensure >=20 dB dynamic range, it is necessary to run the test within 50 feet (15 meters) of the transponder antenna you are testing.

8.2.1.7 For aircraft with an ACAS, ensure that you have completed the interoperability testing from AC 20-196().

8.2.1.8 Ensure the frequency of the transponder is 1090 MHz (± frequency tolerance as specified by the equipment manufacturer).

8.2.1.9 Ensure that the RF peak power is between 21 and 27 dBW (aircraft that operate at altitudes not exceeding 15,000 feet and that have a normal cruising speed less than 175 knots may have a power between 18.5 dBW and 27 dBW).

8.2.1.10 Ensure that altitude reporting is suppressed when disabled via the control.

8.2.1.11 Ensure that the maximum airspeed reported in DF=0 replies is appropriate for the aircraft or that the system reports "No maximum airspeed available."

8.2.1.12 Place the transponder on standby. Return the transponder to normal operation and ensure that the transponder can reply within 5 seconds.

8.2.1.13 For transponders with ELS capability (letter l in the transponder capability declaration), ensure that the system correctly reports the data outlined in CS-ACNS, Issue 5, AMC1 ACNS.D.ELS.015.

8.2.1.14 For transponders with EHS capability (letter n in the transponder capability declaration), ensure that the system correctly reports the data outlined in CS-ACNS, Issue 5, AMC1 ACNS.D.EHS.015.

8.2.2 Basic Flight Test.

You can use the test described in paragraphs 8.2.2.1 through 8.2.2.9 to obtain the certification of an ATCRBS/Mode S transponder installation. The test primarily ensures that the installed antenna(s) is compatible with the ATCRBS/Mode S transponder and provides an adequate response to ground radar interrogations during normal aircraft maneuvers.

8.2.2.1 **Applicability.**

This test is intended for a Mode S transponder installation in an aircraft that does not have a previously approved ATCRBS transponder installation, or that uses a bottom mounted antenna location that differs significantly from that used by a previously approved ATCRBS transponder antenna. If you are upgrading a previously installed and certified transponder, you do not necessarily need to conduct flight testing to obtain approval for the upgrade. You should conduct a careful examination of the proposed transponder upgrade and consult with your FAA certification branch to determine if flight testing is necessary and appropriate. 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.

8.2.2.2 **Authorization.**

Follow your standard process for requesting flight test authorization; there are no unique flight test authorization requirements for transponder flight tests.

8.2.2.3 **ATC Coordination.**

Follow normal flight test procedures for coordinating with ATC. There is no specific requirement to coordinate the flight test in advance with ATC because FAA systems log and store flight data for later retrieval and analysis.

8.2.2.4 **Mutual Interference.**

During all phases of flight, determine if there is any mutual interference with any other aircraft system. Have all installed systems, including the weather radar, operating during at least a portion of the flight test.

8.2.2.5 **Mode A Codes.**

Only use Mode A codes assigned by ATC (or use code 1200 if appropriate per the FAA Aeronautical Information Manual). You do not need to test emergency codes (i.e. 7400, 7500, 7600, and 7700) in flight and should not radiate them for testing purposes.

8.2.2.6 **Location of Flight.**

There is no specific location restriction for this type of test plan within the U.S. National Airspace System. There is no specified distance that the aircraft must be from an FAA ground station. You will evaluate transmitted power through ground testing instead of demonstrating a minimum air-to-ground reception distance.

8.2.2.7 **Flight Profile.**

Fly at an altitude of at least 10,000 ft (or 90 percent of the certificated altitude for the aircraft if less than 10,000 ft). Fly level on a constant heading for at least 30 minutes. Perform a minimum of two left and two right 360-degree turns. The bank angles of the turns should be approximately 30 degrees (or the maximum appropriate for the aircraft). A “Figure 8” pattern is an acceptable means of conducting this profile.

8.2.2.8 **Data Retrieval.**

You can request flight test data from the FAA for testing a first-of-kind installed transponder system. The FAA prefers that system integration teams request flight test data for first-of-kind transponder system after completion of the flight. First-of-kind systems are those that are part of a TC, STC, or Approved Model List effort.

Request flight test data from the FAA after completion of the flight by emailing 9-avs-air-130flttest@FAA.gov and indicating that you require data to support first-of-kind testing of a new transponder system. Upon initial contact, the FAA will provide a flight test data request sheet. When contacting the FAA for flight test data, the FAA recommends you copy any certifying officials you may be working with within the Certification Branch, Military Certification Branch, Flight Standards District Office, or Flight Inspection District Office. The FAA can usually provide flight test data to the requester within two weeks.

8.2.2.9 **Post-Flight Data Analysis.**

Following a flight test, conduct a post-flight data analysis to ensure the aircraft is transmitting accurate information. Ensure all data associated with the track is consistent. The post-flight data analysis should reveal if there were any unexpected data dropouts. Look for any instances of two or more consecutive missed detections from a radar that should have the aircraft in its coverage volume. Investigate any instances of missed detections further by checking detection of nearby radars if available, analyzing possible antenna blockages, etc. and document your findings. For assistance determining FAA radar coverage volume or any other questions pertaining to flight testing analysis, email 9-avs-air-130flttest@FAA.gov.

9 FLIGHT MANUAL.

Regulations codified at 14 CFR §§ 23.2620, 25.1581, 27.1581, and 29.1581 require the applicant to provide an Airplane Flight Manual (AFM), Rotorcraft Flight Manual (RFM), AFM Supplement, or RFM Supplement with normal, non-normal, and emergency procedures as appropriate, as well as other information necessary for safe operation of the aircraft due to design, operating, or handling characteristics of the transponder, including expected flightcrew actions. In evaluating compliance with the rules cited earlier in this paragraph, the FAA will consider whether the flight manual provided by the applicant contains sufficient information according to the following guidelines:

9.1 Operating Limitations.

Describe any operating limitations necessary for safe operation of the aircraft due to design, installation, or operating characteristics of the transponder.

9.2 Operating Procedures.

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

9.2.2 Describe any actions expected from the pilot to properly operate the transponder.

9.2.3 Describe how to enter the Mode A code and aircraft identification into the transponder, how to operate the transponder's IDENT function, and how to activate and deactivate the transponder's emergency status.

9.2.4 Describe any transponder displays and provide instructions to the pilot on how to respond to any error conditions.

9.2.5 Describe transponder indications of an equipment failure (see Section 7.2.8) and any associated flightcrew procedures to consider in response to loss of the transponder.

9.2.6 Include guidance to enable the transponder system (turned ON) per 14 CFR § 91.215(c). The FAA recommends that flightcrews keep the transponder enabled with altitude reporting throughout the flight (i.e., from completion of the before starting engines or pushback checklist until the shutdown checklist).

9.3 **System Description.**

Describe the transponder system components and the interface with other systems on the aircraft. If multiple altimeter sources are interfaced to the transponder, describe the source selection mechanism and any related indication.

10 CONTINUED OPERATIONAL SAFETY.

10.1 Transponder Equipment.

10.1.1 Follow the transponder equipment manufacturer's guidance for periodic inspection and maintenance of the transponder system. 14 CFR §§ 23.1529, 25.1529, 27.1529, 29.1529, and 25.1729 require applicants to provide Instructions for Continued Airworthiness (ICA) to address any maintenance requirements to maintain the transponder equipment.

10.1.2 Transponders must comply with the operational requirements of 14 CFR §§ 91.215, 91.217, and 91.413, and the transponder system tests and inspections listed in 14 CFR Part 43, Appendix F.

Note: For detailed information on maintenance and inspection practices for transponder systems, consult AC 43-6().

10.2 Altimetry Systems and Altitude Reporting Equipment.

Altitude reporting equipment connected to the transponder system must comply with all applicable test and inspection requirements in 14 CFR §§ 91.217, 91.411, and part 43, Appendix E, as applicable.

Note: For detailed information on maintenance and inspection practices for altitude reporting equipment, consult AC 43-6().

10.3 Maintenance and Design Changes to Interfacing Components.

The transponder system interfaces with multiple external components, such as altimetry sources and EHS 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 the overall transponder system maintains continued satisfactory performance.

10.3.1 Maintenance of the Transponder System.

Include in the ICA how to accomplish a complete functional check of the system and how to ensure an acceptable transponder system installation, to comply with 14 CFR part 23, appendix G § 23.3(b)(4), part 25, appendix H § 25.3(b)(4), part 27, appendix A § 27.3(b)(4), or part 29, appendix A § 29.3(b)(4).

10.3.2 Transponder Source System Components.

The installer may not have access to the specific source system ICA to incorporate changes into those specific documents. However, to ensure compliance with 14 CFR § 91.227, the FAA will require the installer to perform an analysis of the source systems to determine what maintenance actions on those source systems would require a functional test of the transponder system to verify that the system is operating properly. For systems providing a dedicated input to the transponder system that you cannot verify by other means, you should test those systems as part of the transponder system as a whole. Once the installer identifies the required maintenance actions, the installer should provide recommended language for the operator to include in their ICA. If the installer determines that removal and replacement of the altimetry system requires a full functional check of the transponder system because the operator cannot verify the pressure altitude input to the transponder by other means, the instructions to the operator should indicate this.

10.3.3 Design Changes to Interfacing Components.

Ensuring continued airworthiness of the transponder system following upgrades of interfacing components could be problematic if the installer of the transponder 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 transponder system. To avoid this problem, follow the guidance in AC 21.101-1B, *Establishing the Certification Basis of Changed Aeronautical Products,* section 3.1. As part of its continued operational safety responsibilities, the FAA expects the transponder system installer to have and use a process to update the ICA following design changes to each interfacing system that ensures continued airworthiness of the transponder system.

11 AC FEEDBACK FORM

For your convenience, the AC Feedback Form is the last page of this AC. Note any deficiencies found, clarifications needed, or suggested improvements regarding the contents of this AC on the Feedback Form.

Daniel J. Elgas
Aviation Safety
Director, Policy and Standards Division, Aircraft Certification Service

Appendix A. Related Material

A.1 TITLE 14, CODE OF FEDERAL REGULATIONS (14 CFR).

The following 14 CFR regulations are related to this AC. You can download the full text of these regulations from the Federal Register website at www.eCFR.gov.

- Section 25.301 Loads.
- Section 25.303 Factor of Safety.
- Section 25.305 Strength and Deformation.
- Section 25.561 General.
- Section 25.603 Materials.
- Section 25.609 Protection of Structure.
- Section 25.869 Fire Protection: Systems.
- Section 25.1301 Function and Installation.
- Section 25.1302 Installed Systems and Equipment for Use by the Flightcrew.
- Section 25.1309 Equipment, Systems, and Installations.
- Section 25.1316 System Lightning Protection.
- Section 25.1317 High-intensity Radiated Field (HIRF) Protection.
- Section 25.1321 Arrangement and Visibility.
- Section 25.1322 Flightcrew Alerting.
- Section 25.1331 Instruments Using a Power Supply.
- Section 25.1333 Instrument Systems.
- Section 25.1351 Electrical Systems and Equipment: General.
- Section 25.1353 Electrical Equipment and Installations.
- Section 25.1357 Circuit Protective Devices.
- Section 25.1381 Instrument Lights.
- Section 25.1431 Electronic Equipment.
- Section 25.1581 Airplane Flight Manual: General.
- Section 25.1585 Operating Procedures.

Note: 14 CFR Part 23 underwent a major amendment through a 2016 final rule (Amendment 23-64). Prior to amendment, rules in Part 23 were numerically aligned with the corresponding rules in Parts 25, 27, and 29. After amendment, most rules are no longer so aligned. However, the final rule implementing the Part 23 amendments provides a cross-reference table identifying Part 23 numbering pre- and post-amendment. See *Revision of Airworthiness Standards for Normal, Utility, Acrobatic, and Commuter Category Airplanes*, Docket No. FAA-2015-1621, 81 FR 96572 (Dec. 30, 2016) (reference Appendix 1 to the Preamble—Former to New Regulations Cross-Reference Table).

A.2 FAA ADVISORY CIRCULARS.

The following ACs are related to the guidance in this AC. Unless otherwise noted, use the latest version of each AC referenced in this document; they are available on the FAA website at http://www.faa.gov/regulations_policies/advisory_circulars/ and on the FAA https://drs.faa.gov/browse (DRS).

- AC 20-115D, Airborne Software Development Assurance Using EUROCAE ED-12( ) and RTCA DO-178( ).
- AC 20-151C, Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders.
- AC 20-165B, Airworthiness Approval of Automatic Dependent Surveillance - Broadcast OUT Systems.
- AC 20-172B, Airworthiness Approval for ADS-B In Systems and Applications.
- AC 20-175, Controls for Flight Deck Systems.
- AC 20-196, Airworthiness Approval of Airborne Collision Avoidance Systems (ACAS) with Automatic Dependent Surveillance-Broadcast (ADS-B)/Hybrid Surveillance[placeholder].
- AC 21.101-1B, Establishing the Certification Basis of Changed Aeronautical Products.
- AC 23.1309-1E, System Safety Analysis and Assessment for Part 23 Airplanes (for Part 23 airplanes certified before Amendment 23-64).
- AC 25-11B, Electronic Flight Displays.
- AC 25.1302-1, Installed Systems and Equipment for Use by the Flightcrew.
- AC 25.1309-1B, System Design and Analysis.
- AC 25.1322-1, Flightcrew Alerting.
- AC 25.1329-1C, Approval of Flight Guidance Systems.
- AC 27-1B, Certification of Normal Category Rotorcraft.

- AC 29-2C, Certification of Transport Category Rotorcraft.
- AC 43-6D, Altitude Reporting Equipment and Transponder System Maintenance and Inspection Practices.
- AC 43.13-2B, Acceptable Methods, Techniques, and Practices – Aircraft Alterations.
- AC 90-120, Operational Use of Airborne Collision Avoidance Systems.

A.3 FAA TECHNICAL STANDARD ORDERS.

The following TSOs are relevant to this AC. You will find a current list of TSOs on https://drs.faa.gov/browse. You can also find a database of TSO authorizations for production of TSO articles on DRS at https://drs.faa.gov/browse/TSOI/doctypeDetails.

- TSO-C10, Pressure Altimeter System.
- TSO-C88b, Automatic Pressure Altitude Reporting Code-Generating Equipment.
- TSO-C106a, Air Data Computer.
- TSO-C112f, Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment.
- TSO-C119e, Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II With Hybrid Surveillance Functionality.
- TSO-C219a, Airborne Collision Avoidance System (ACAS) Xa/Xo.

A.4 RTCA.

The following RTCA (formerly Radio Technical Commission for Aeronautics) documents are related to the guidance in this AC. If the document is revised after publication of this AC, you should verify that the FAA accepts the subsequent revision or update as an acceptable form of guidance. These documents can be ordered online at https://www.rtca.org/.

- RTCA/DO-160G, Environmental Conditions and Test Procedures for Airborne Equipment (Dec. 12, 2010).
- RTCA/DO-178C, Software Considerations in Airborne Systems and Equipment Certifications (Dec. 13, 2011).
- RTCA/DO-181F, Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment (Dec. 17, 2020); including Change 1 (Jan. 25, 2022).
- RTCA/DO-185B, Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance Systems II (TCAS II) (June 19, 2008); including Change 1 (July 1, 2009), and Change 2 (March 20, 2013).

- RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware.
- RTCA/DO-300A, Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance)March 20, 2013); including Change 1 (Dec. 15, 2015).
- RTCA/DO-385A, Minimum Operational Performance Standards for Airborne Collision Avoidance System X (ACAS X) (ACAS Xa and ACAS Xo) (June 22, 2023).

A.5 SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) INTERNATIONAL.

The following SAE Aerospace Recommended Practice (ARP) documents are related to the guidance in this AC. Unless otherwise specified, use the latest FAA-accepted revision for guidance. If the document is revised after publication of this AC, you should verify that the FAA accepts the subsequent revision or update as an acceptable form of guidance. The documents are available online at https://www.sae.org/.

- ARP 926C, Fault/Failure Analysis Procedure (Feb. 14, 2018).
- ARP 1834B, Fault/Failure Analysis for Digital Systems and Equipment (Feb. 14, 2018).
- ARP 4102/7, Electronic Displays (July 10, 2007).
- ARP 4102/8A, Flight Deck Head-Up Displays (July 10, 2007).
- ARP 4754B, Guidelines for Development of Civil Aircraft and Systems (Dec. 20, 2023).
- ARP 4761A, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment (Dec. 20, 2023).

A.6 AERONAUTICAL RADIO, INC. (ARINC).

The following ARINC publications are relevant to this AC. Publications are available online at https://aviation-ia.sae-itc.com/product-categories/aeec-material.

- ARINC 718A-4, Mark 4 Air Traffic Control Transponder (ATCRBS/MODE S).

A.7 INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO).

The following ICAO publications are relevant to this AC. Publications are available online at https://www.icao.int/.

- Document 9871, Technical Provisions for Mode S Services and Extended Squitter, Second Edition (2012).

- Document 9924, Aeronautical Surveillance Manual, Second Edition (2017).

A.8 **EASA.**

The following certification specification (CS) document, relevant to this AC, can be obtained online at https://www.easa.europa.eu/.

- Issue 5, EASA Certification Specification and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance (CS-ACNS) (April 24, 2024).