



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

Advisory Circular

Subject: Airworthiness Approval of Airborne
Collision Avoidance Systems (ACAS)

Date: mm/dd/yyyy

AC No: 20-196

Initiated by: AIR-626C

Change:

This AC replaces AC 20-151C for installation of Traffic Alert and Collision Avoidance Systems (TCAS) II with hybrid surveillance. It also contains new material for installation of Airborne Collision Avoidance Systems Xa (ACAS Xa) developed under the FAA's NextGen program. Specifically, it provides acceptable means, but not the only means, for demonstrating compliance with title 14, Code of Federal Regulations (14 CFR) Parts 23 or 25 airworthiness regulations for initial and follow-on installations under the following Technical Standard Orders (TSOs):

- TSO-C119c, Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II with Optional Hybrid Surveillance, and
- TSO-C119d, Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II With Hybrid Surveillance, and
- TSO C119e, Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II with Hybrid Surveillance, and
- TSO-C219a, Airborne Collision Avoidance System (ACAS) Xa/Xo.

Air Traffic Control Radar Beacon System (ATCRBS) / Mode S transponder installation guidance is not addressed in this AC; refer to AC 20-194 for relevant information.

If you have suggestions for improving this AC, you may use the form at the end of this document.

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CHAPTER 1. GENERAL INFORMATION

1.1 Purpose.

- 1.1.1 This AC provides guidance for designing an acceptable installation for an Airborne Collision Avoidance System (ACAS) with hybrid surveillance compliant with TSO-C119c, TSO-C119d, TSO-C119e, or TSO-C219a. This AC covers design aspects, characteristics, mechanization, testing, interoperability, and system failures associated with ACAS. This guidance also focuses on the operational performance standards defined in technical documents developed by joint industry-government groups: RTCA Inc. Special Committee SC-147 and EUROCAE Working Group WG-75.
- 1.1.2 This AC is issued to describe an acceptable means, but not the only means, for demonstrating compliance with the appropriate airworthiness requirements. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the pertinent regulations.

1.2 Applicability.

- 1.2.1 The guidance provided in this AC is for manufacturers, modifiers, foreign regulatory authorities, and FAA engineers and their designees.
- 1.2.2 This is a guidance document. Its content is not legally binding in its own right and will not be relied upon by the Department as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with the guidance document is voluntary only. Nonconformity will not affect rights and obligations under existing statutes and regulations.
- 1.2.3 The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. Terms such as “should,” “may,” and “must” are used only in the sense of ensuring 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 as the basis for finding compliance.
- 1.2.4 The term “verify” is used to instruct the applicant to show or the FAA to find compliance. Methods of compliance may include, but are not limited to inspection, testing, review, analysis, reports, drawings, and documentation.
- 1.2.5 Where we use the phrase “the FAA will require” in this AC, it identifies the referenced compliance showing action as an inspection or test that the FAA has determined necessary for the applicant to make to determine compliance with the applicable airworthiness requirements for the ACAS installation under the FAA’s inspections and tests authority as provided in 14 CFR 21.33.

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- 1.2.6 This material does not change or create any additional regulatory requirements or authorize changes in or permit deviations from existing regulatory requirements.
- 1.2.7 This AC does not cover traffic symbology for cockpit display of traffic information (CDTI) in systems that integrate ACAS with Airborne Separation Applications System (ASAS) traffic symbology. Traffic symbology can be found in the applicable versions of RTCA/DO-185 and RTCA/DO-385. Guidance for airworthiness approvals of ADS-B Out and ADS-B In can be found in ACs 20-165() and 20-172() respectively. Guidance for airworthiness approvals of ATCRBS / Mode S transponders can be found in AC 20-194().
- 1.3 **Cancellation**
This AC cancels AC 20-151C Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders, dated July 21, 2017.
- 1.4 **Related Material**
See Appendix B for all materials related to this document.
- 1.5 **Definition of Key Terms.**
See Appendix C for definitions and acronyms that apply to this AC.

CHAPTER 2. SYSTEM DESCRIPTION

2.1 Airborne Collision Avoidance System (ACAS)

ACAS was developed as a safety-enhancing system to reduce the likelihood of midair collisions between aircraft. ACAS is a family of airborne devices that functions independently of the ground-based Air Traffic Control (ATC) system and provides collision avoidance for a broad spectrum of aircraft types. ACAS provides Traffic Advisories (TAs) that include aural and visual flightcrew alerting and indicate on a display the bearing, range, and altitude relative to ownship of nearby aircraft to assist the flightcrew in the visual acquisition of an intruder aircraft. ACAS also provides Resolution Advisories (RAs) that include aural and visual flightcrew alerting including recommend vertical maneuvers, or vertical maneuver restrictions that maintain or increase the vertical separation between aircraft to mitigate the risk of airborne collision. The intent of ACAS is to serve as a backup to visual collision avoidance, application of right-of-way rules, and air traffic separation service, referencing 14 CFR §§ 91.3, 91.111, 91.113, and 91.123. ACAS alone does not ensure safe separation in every case. ACAS does not alter nor diminish the responsibility or authority of a flightcrew to ensure a safe flight.

While other ACAS exist, when used in this AC, the term ACAS refers to Traffic Alert and Collision Avoidance System II (TCAS II) V7.1 with Hybrid Surveillance and Airborne Collision Avoidance System Xa systems unless otherwise specified.

2.1.1 TCAS II System

TCAS II systems covered by this AC comply with RTCA/DO-185B / EUROCAE/ED-143. TCAS II interrogates transponders in nearby aircraft and uses computer processing to identify and display potential and predicted collision threats along with maneuvering guidance for avoidance.

2.1.1.1 TCAS II with Hybrid Surveillance Description

TCAS II designed per TSO-C119d/e incorporates hybrid surveillance. TCAS II designed per TSO-C119c has an optional provision for hybrid surveillance. Hybrid surveillance allows TCAS II to use passive surveillance instead of active surveillance to track intruders that meet certain criteria and are not projected to be near-term collision threats. Passive surveillance is surveillance performed using Automatic Dependent Surveillance-Broadcast (ADS-B) information from other aircraft. Hybrid surveillance decreases Mode S interrogations and replies, thereby reducing 1030/1090 MHz frequency congestion. TCAS II with hybrid surveillance is standardized under RTCA/DO-185B / EUROCAE/ED-143 and RTCA/DO-300/DO-300A / EUROCAE ED-221/ED-221A. Unless otherwise stated, within this AC, the term TCAS II refers to a TCAS II Version 7.1 system with hybrid surveillance.

2.1.2 ACAS X System

The ACAS X system improves upon the TCAS II system by increasing safety margins, reducing nuisance alerts, and tuning and optimizing the surveillance and threat logic. ACAS X variants are tailored for different aircraft types or different flight missions, such as non-fixed wing aircraft, unmanned aircraft, or aircraft with lower performance capabilities. ACAS X variants have common design features, but have different hardware, surveillance, and threat logic. All ACAS X systems generate alerts and provide guidance maneuvers against other airborne traffic. Other ACAS X variants not covered by this AC include ACAS Xu, ACAS sXu, and ACAS Xr.

2.1.2.1 **ACAS Xa/Xo System**

ACAS Xa/Xo is an ACAS that complies with RTCA/DO-385A and EUROCAE/ED-256A. ACAS Xa generates vertical RAs only. The ACAS Xa/Xo system was specifically designed for transport category aircraft (type-certified under 14 CFR Part 25) and high-performance small category aircraft (type-certified under Title 14 CFR Part 23), such as commuter category or Certification Level 4 aircraft.¹ ACAS Xa/Xo includes hybrid surveillance.

There are two classes of equipment described in TSO-C219a: Class 1 and Class 2.

ACAS Xa, the TSO-C219a Class 1 system, incorporates enhanced surveillance and collision avoidance algorithms. ACAS Xa threat logic estimates risk based on the relative position and velocity of nearby aircraft and generates an RA when warranted by potential collision risk. ACAS Xa provides display symbols, control modes, operational procedures, and advisories that are almost identical to TCAS II with some small variations in aural annunciations. ACAS Xa is unchanged from TCAS II with respect to low altitude inhibits, handling of bearing-less and non-altitude reporting targets, and interaction with higher priority alerts (e.g., windshear, Terrain Awareness Warning System (TAWS), and stall). This allows aircraft with an existing TCAS II unit to be replaced with an ACAS Xa unit with minimal certification testing.

ACAS Xo, the TSO-C219a Class 2 system, is an ACAS Xa system that adds Designated No Alert (DNA) and/or Closely Spaced Parallel Runway

¹ Airplanes certified under 14 CFR 23 prior to Amendment 23-64 are certified as Normal, Utility, Acrobatic, or Commuter category airplanes. All airplanes certified under 14 CFR 23 at Amendment 23-64 are certified as Normal category airplanes and are differentiated by Certification Levels (1 through 4 depending on passenger seating capacity) and Performance Levels (low speed or high speed based on normal and maximum operating airspeeds and Mach numbers). Airplanes certified under 14 CFR 23 at Amendment 23-64 may or may not be certified to perform aerobatics. See 14 CFR 23.2005.

Operations down to 3000 feet (CSPO-3000) functions for certain operations. To perform their intended functions correctly, ACAS Xo system installations require the incorporation of an Airborne Surveillance and Separation Assurance Processor (ASSAP) from TSO-C195b or later approved revision meeting functionality 3.a. of TSO-C219a. Activation of the DNA feature allows the flightcrew to suppress all ACAS Xa RA alerts and guidance on a specific target. The flightcrew visually acquires the desired traffic before designating it as a DNA intruder. Activation of CSPO-3000 also designates a target and provides modified Traffic Advisory (TA) / Resolution Advisory (RA) alerting that is specifically tuned to support operations to parallel runways 3000 feet apart or greater and below 14,000 feet Mean Sea Level (MSL). CSPO-3000 will still provide TAs and RAs on blundering designated traffic.

CHAPTER 3. TCAS II AND ACAS XA/XO INSTALLATION CONSIDERATIONS

3.1 General

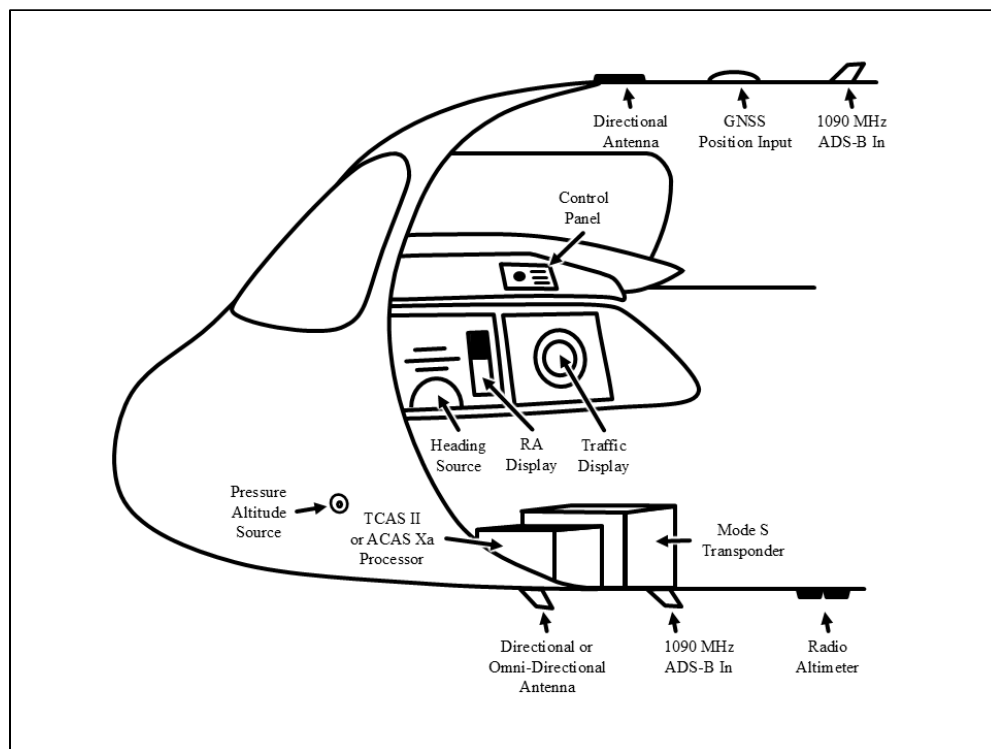
It is assumed that applicants using this AC to install ACAS on an aircraft are installing an ACAS that meet the TSOs referenced in §1.1.1 of this AC. The FAA will require the applicant to ensure the criteria are applicable to the installation in order to make a compliance determination to 14 CFR 25.1301 or equivalent 14 CFR Part 23 airworthiness rules. The information below provides the minimum performance and installation considerations for type certification.

3.1.1 System Overview

3.1.1.1 Minimum Equipment

Figure 3-1 provides an overview of the minimum ACAS.

Figure 3-1, Figure of Minimum ACAS



All ACAS covered by this AC, as a minimum, include:

- TCAS II Processor or ACAS Xa Processor
- Control Panel
- Traffic Display
- RA Display

- Top Directional Antenna
- Bottom Antenna: Directional or Omni-directional
- 1090 MHz ADS-B In
- Compatible Mode S ATC Transponder
- Pressure Altitude Source
- Position Source that incorporates Global Navigation Satellite System (GNSS)
- Radio Altimeter Source

In addition, ACAS Xa includes:

- Heading Source

In addition, ACAS Xo includes:

- Airborne Surveillance and Separation Assurance Processing (ASSAP)
- CDTI meeting RTCA/DO-317 or later version
- Control Panel to support DNA and/or CSPO-3000 applications

3.1.1.2 **Optional Equipment**

All ACAS covered by this AC may optionally include:

- Autopilot interface provisions with feedback annunciation of status
- Attitude Source

In addition, TCAS II may include:

- Heading Source

In addition, ACAS Xa may include:

- 978 MHz Universal Access Transceiver (UAT) ADS-B In

3.2 **Aircraft Operational Assumptions**

3.2.1 TCAS II and ACAS Xa Operational Assumptions

3.2.1.1 TCAS II and ACAS Xa are intended for fixed-wing normal, commuter, and transport category airplanes operating under 14 CFR Part 91, 121, 125, 129, and 135. Based on historical midair collision accident experience, equipage with an ACAS is required for certain aircraft by various operating rules, as outlined below.

3.2.1.2 The FAA rules for TCAS do not specifically reference TSO-C219a; however, for the purposes of air carrier operational and Reduced Vertical Separation Minimum (RVSM) compliance, the FAA considers ACAS Xa

systems equivalent to TCAS II, TSO-C119b (version 7.0) and later versions. Applicable U.S. regulations include 14 CFR §§ 91.180, 91.221, 91.706, 91.1045, 121.356, 125.224, 129.18, 135.180, and Part 91, Appendix G, Section 2.

- 3.2.1.3 This AC provides guidance for TCAS II and ACAS Xa installations on transport category aircraft (type-certified under 14 CFR Part 25) and high-performance small category aircraft (type-certified under Title 14 CFR Part 23), such as commuter category or Certification Level 4 aircraft. Airborne Collision Avoidance System X for Rotorcraft (ACAS Xr) is a more suitable collision avoidance system for rotorcraft and other aircraft with rotorcraft-like flight characteristics. ACAS Xr provides collision avoidance in both the vertical and horizontal directions. ACAS Xr may also provide increased safety margins for fixed wing aircraft with climb and/or descent rates below the TCAS II / ACAS Xa design assumptions. TCAS II and ACAS Xa may be installed on helicopters and other lower-performing aircraft on a case-by-case basis, though consideration should be given to the installation of ACAS Xr.

3.2.2 ACAS Xo Operational Assumptions

The ACAS Xo options on an ACAS Xa platform are additional features intended for fixed-wing normal, commuter, and transport category airplanes to either eliminate alerts or desensitize alerting for certain airspace procedures where standard ACAS Xa alerting does not meet operational requirements.

3.3 **Aircraft Performance Considerations**

The following are the assumed set of aircraft performance criteria when using the method provided by this AC. This section may also be used to develop automatic response functions for an RA.

3.3.1 Vertical Rate Performance

For initial climb and descent actions, TCAS II and ACAS Xa were designed with an assumed aircraft sustained climb and descent rate capability of 1500 feet per minute, a response time within 5 seconds, and an instantaneous vertical acceleration of 0.25 times the force of gravity (G). For increase climb and descent actions, the design assumptions were a climb and descent rate capability of 2500 feet per minute, a response time within 2.5 seconds, and an instantaneous vertical acceleration of 0.33 G. Lower performing aircraft reduce safety margins as predicted by risk ratios produced by modeling and simulation analysis. However, studies show that ACAS systems still provide a safety benefit for aircraft with reduced climb and descent rate capability.

3.3.2 Lower Performing Aircraft

- 3.3.2.1 TCAS II and ACAS Xa were not designed to operate with RAs inhibited for long periods of time. The intention of an ACAS installation is to have

RAs available to the maximum extent possible while airborne. Generally, the FAA will not find it acceptable to prescribe flight procedures that require the pilot to manually switch to the TA-ONLY mode during portions of the flight where the desired performance cannot be achieved.

- 3.3.2.2 Assessment of rotorcraft performance to comply with RA-generated climb rates is acceptable for this purpose if it is based on the use of minimum specification engine power. For twin-engine rotorcraft, the FAA generally does not consider it acceptable to base climb performance on time limited one-engine inoperative (OEI) power levels.
- 3.3.2.3 Climb performance based on time limited all-engines operating (AEO) power level is acceptable provided the power level is approved for 5 minutes or more of continuous use, e.g. AEO takeoff power. The FAA does not generally consider it acceptable for the rotorcraft to rely on entering an autorotation to achieve the required RA generated descent rate.
- 3.3.2.4 TCAS II includes the capability to set climb inhibits. However, studies have shown that climb inhibits can increase the risk ratios of the system more often than decreasing them. For that reason, climb inhibits were not included in ACAS Xa. For a similar reason, the FAA does not recommend incorporating climb inhibits in a TCAS II installation. Any use of climb inhibits should be carefully studied to ensure that they are providing a safety benefit relative to not implementing the climb inhibits.

3.4 Surveillance Equipment Performance on the Aircraft

3.4.1 Mode S Transponder

Verify the ACAS integrates with a Mode S transponder. Verify the Mode S transponder meets TSO-C112c or later for TCAS II installations or TSO-C112d or later for ACAS Xa. Transponder markings that contain the ID Code of ‘a’ signify that the transponder has been verified for ACAS Compatibility as prescribed in TSO-C112d/e/f.

3.4.2 ADS-B In

- 3.4.2.1 Verify the ACAS integrates with a 1090 MHz ADS-B In receiver that meets RTCA/DO-260B/C, Class A1, A2, or A3; the ADS-B receive requirements of RTCA/DO-300/A; or the ADS-B receive requirements of RTCA/DO-385A.
- 3.4.2.2 Class A0 receivers are not considered acceptable since they do not provide adequate power or range for the ACAS hybrid surveillance capability.
- 3.4.2.3 If the installation includes the capability to receive ADS-B messages on the Universal Access Transceiver (UAT) 978 MHz frequency directly from the intruder aircraft (dual-link ADS-B In) rather than through

Automatic Dependent Surveillance-Rebroadcast (ADS-R), verify the ADS-B receiver meets the requirements of RTCA/DO-282B or later version. See AC 20-172B, or later revision, for ADS-B In installation considerations.

Note: ACAS hybrid surveillance uses ADS-B Out signals directly from aircraft transmitters. While ADS-R and TIS-B may be displayed on the CDTI, hybrid surveillance does not use information from ground stations.

3.5 Antenna Installation Considerations

The antennas are critical components of the ACAS, in which protocol messages are sent and received. Proper installation enables ACAS performance and ensures non-interference with other aircraft systems.

3.5.1 Structural Analysis

Submit a structural analysis to the FAA for all new antenna installations that show compliance with the applicable regulations of 14 CFR Part 23 or 25.

3.5.2 Active Surveillance Antenna Installation Considerations

Verify the ACAS-equipped aircraft has a top directional antenna and a bottom omnidirectional antenna or both top and bottom directional antennas. Use Chapter 3, Installed Equipment, of RTCA/DO-185B or RTCA/DO-385A for further antenna installation guidance and other installation guidance material.

3.5.2.1 Directional Antenna

3.5.2.1.1 For an aircraft installation, locate the ACAS directional antenna on the top, forward fuselage as close to the centerline as possible. For certain installations, such as helicopters, it may be difficult to install in a location where there is a big enough ground plane; therefore, the FAA will require the applicant to demonstrate antenna patterns consistent with § 3.4.3.5 of RTCA/DO-185B or RTCA/DO-385A to ensure sufficient intruder detection range to meet the ACAS alerting timelines. If the ACAS has more than one directional antenna, locate the second antenna in a similar manner on the lower fuselage.

3.5.2.1.2 Mount the ACAS antennas on the aircraft with at least 20 decibel (dB) isolation from other L-band antennas.

3.5.2.1.3 Since the antenna diameter may be large, some structural considerations may be necessary, and a centerline offset resulting in an angular offset of up to 5 degrees is acceptable.

3.5.2.1.4 If the antenna height is more than approximately 1-inch, anti-icing provisions may be necessary. RTCA/DO-185B and RTCA/DO-385A provide antenna selection and performance criteria.

- 3.5.2.1.5 For propeller-driven aircraft, investigate the location and performance of the directional antenna for minimum blockage and ensure that the propellers do not interfere with system operation.

3.5.2.2 Omni-Directional Antenna

If an omni-directional antenna is used, mount the ACAS omni-directional antenna on the bottom of the aircraft fuselage as close to the centerline as possible with at least 20 dB isolation from other L-band antennas.

3.5.2.3 Shared Antenna with ADS-B Out

When the installation uses a shared antenna for ADS-B and ACAS, the active surveillance location, interference issues, and structural issues guidance of this section apply.

3.6 Global Navigation Satellite System (GNSS) Data Information

All GNSS information supplied to the ACAS should come from the same position source.

3.6.1 GNSS Horizontal Position Information

Verify the GNSS meets the requirements for Class Beta equipment defined in TSO-C145 (any revision), or equipment meeting TSO-C196 (any revision) and is installed in accordance with AC 20-138D, Change 2 or later revision.

Note: Class Gamma equipment meeting TSO-C146 (any revision) uses a TSO-C145 (any revision) sensor and is acceptable for horizontal position information.

3.6.2 GNSS Vertical Position Information - Geometric Altitude

If the GNSS is used as a back-up for the altitude for vertical position information, it is acceptable for the GNSS vertical position information to meet the requirements in TSO-C145d, TSO-C196, or later versions. If the GNSS uses barometric aiding to enhance the availability of fault detection and exclusion, verify that it meets the requirements in RTCA/DO-229E, Appendix G.

3.6.3 GNSS Velocity – Geometric Velocity

Verify the GNSS position source meets the minimum velocity accuracy requirement prescribed by the installation. GNSS position sources do not have to pass velocity accuracy tests to receive TSO authorization. One means to verify this performance is to ensure the GNSS source passes the velocity accuracy tests prescribed in AC 20-138D, or later revisions, that support a Navigation Accuracy Category for Velocity (NAC_v) of at least 1. Typically, the GNSS source equipment manufacturer will accomplish these GNSS tests.

3.7 Pressure Altitude and Radio Altimeter Vertical Position Source

3.7.1 Pressure Altitude Information

Verify the pressure altitude data is the same data the associated Mode S transponder transmits. RTCA/DO-185B or RTCA/DO-385A § 3.2.8, as applicable, specify the accuracy of the altitude data. Show that the resolution of the altimetry source is compatible with the ACAS. Use the altitude source with the finest quantization available; ACAS typically requires resolution in increments of 10 feet or less to provide intended separation. Also provide information to indicate when the pressure altitude information is invalid.

3.7.2 Altitude Alerter

For some TCAS II installations, the current clearance altitude from the altitude alerter may be used to enable TCAS II to select RAs that are more consistent with the aircraft's altitude clearance once it resolves the immediate collision threat. This does not apply to ACAS Xa installations.

3.7.3 Radio Altitude Information

Verify the radio altitude source operates at a minimum up to 2350 ft above ground level (AGL). Provide information to indicate when the radio altitude information is invalid.

3.8 Aircraft Attitude Source

The system may provide aircraft pitch and roll attitude to assist with stabilization of the directional antenna function to assure surveillance and to ensure normal aircraft maneuvers do not affect traffic display data. If the ACAS uses attitude information, provide an indication when the attitude data are invalid.

3.9 Aircraft Heading Source

The FAA recommends providing heading to TCAS II as this data is needed to validate the bearing. The TCAS II system will skip the bearing validation step if heading is not available, but this increases the probability that a target will be displayed that is not truly present. Heading is a minimum requirement for ACAS Xa. ACAS Xa uses heading for validation and uses the heading data as part of the tracking algorithm. While ACAS Xa will function without heading data, the performance of the system is degraded.

For any ACAS integration that includes heading, provide information to indicate when the heading data becomes invalid.

3.10 Air/Ground (A/G) State

- 3.10.1 The A/G state provides information on whether the aircraft is on the ground or in the air. Typically, fixed-wing aircraft use weight-on-wheels switches to detect when the landing gear is compressed and use redundant switches on each gear to prevent false alerts. More complex systems incorporate aircraft dynamics (airspeed, ground speed, Mach number, and attitude) for validation of the air/ground state input.
- 3.10.2 Verify the proper performance of the sensors that support the A/G state for the ACAS logic. Perform tests on the ground and in the air to ensure proper installation. See [Chapter 6](#) for testing guidance.

3.11 Pilot Controls

3.11.1 TCAS II and ACAS Xa Pilot Controls

Verify proper operation of the following pilot controls:

- Mode control allows selection of TA/RA mode.
- Mode control allows selection of TA-ONLY mode.
- Means for selecting standby.
- Means of initiating a self-test.

If installed, verify proper operation of the following pilot controls:

- Display mode selection allows simultaneous operation of display of traffic within selected “Above” and “Below” altitude bands.
- Display mode selection allows simultaneous display of traffic information and other data on the displays (such as weather or terrain).
- Display mode selection allows actual flight level (FL) or relative altitude of traffic.
- Display mode selection allows traffic information on displays.

Note: AC 20-172(), *Airworthiness Approval for ADS-B In Systems and Applications*, provides guidance addressing integration of controls for ACAS and ADS-B In installations.

3.11.2 ACAS Xo Additional Pilot Control Considerations

For an ACAS Xo installation, verify proper operation of the following pilot controls where applicable:

- ACAS Xo mode selection allows only one of the two modes, DNA mode or CSPO-3000 mode, to be enabled at a time.
- ACAS Xo only allows one designated aircraft at a time.
- ACAS Xo allows a previously designated aircraft to be undesignated.

- A means to disable the ACAS Xo mode to return to ACAS Xa normal mode.

3.12 **Autopilot/Flight Control System Integration**

- 3.12.1 As technology progresses in understanding human and functional design, applicants are increasingly requesting automation of the human interface. Because ACAS directs the pilots to follow certain commands such as CLIMB, INCREASE CLIMB, DESCEND, etc., automation of the commands has been implemented into the aircraft design. The FAA has accepted such designs based on the use of EUROCAE/ED-224 and FAA Issue Papers. However, the designer should provide analysis and Human Factors (HF) studies for these designs to ensure there are no strategies that may adversely affect pilot interaction with the autopilot and its response to the RA.
- 3.12.2 Using EUROCAE/ED-224 for integration of the autopilot (AP) system and auto throttle system is an acceptable means of compliance for ACAS autopilot integration.
- 3.12.3 The system should include the ability to disable the auto-response to RAs, without suppressing RAs, while allowing the AP to remain engaged.
- 3.12.4 For rotorcraft applications, the applicant will need to work with the appropriate Aircraft Certification Branch (ACB) to develop a Method of Compliance Issue Paper to address issues associated with autopilot coupling.

3.13 **ACAS Traffic Symbolology and Display Information**

All ACAS have traffic and RA displays. Color depiction and traffic symbolology of different traffic are largely similar on all platforms; however, RA display information may differ due to differences in pilot guidance. ACAS Xa equipment may optionally display TAs for aircraft that are not validated with a transponder reply using an option referred to as ADS-B Only TA-Only (AOTO). Installations with AOTO have additional requirements pertaining to the display of non-validated TAs.

Note 1: For AOTO installations, the ACAS Xa system generates TAs against ADS-B only or ADS-R only targets. These TAs do not progress into RAs.

Note 2: When AOTO is not implemented, ADS-B targets that would have generated an AOTO alert are displayed as other or proximate traffic as appropriate, and will not progress to a TA or RA.

3.13.1 ACAS Traffic Symbolology

- 3.13.1.1 Verify the traffic symbols comply with RTCA/DO-185A/B or RTCA/DO-385A, as applicable. Verify the traffic symbols also comply with the appropriate version of RTCA/DO-317.
- 3.13.1.2 If new symbolology is used, contact the appropriate FAA ACB early in the development cycle. Consider human factors policy and use of appropriate

human factors test and evaluation methods. See CHAPTER 6 for testing and evaluation. The use of new ACAS symbology will necessitate testing throughout the flight envelope to determine accuracy, over/under shoot tendencies, flight technical error, and potential confusion resulting from the proposed symbology.

- 3.13.1.3 For AOTO installations, verify that acceptable differentiation is provided so that the traffic can be easily recognized as a different type of traffic that will not progress into an RA if the ownship continues its path towards the intruder.

3.13.2 Traffic Display

- 3.13.2.1 The primary purpose of the traffic display is to aid the flightcrew in the out-the-window visual acquisition of transponder and/or ADS-B equipped aircraft. It depicts the relative position (range, bearing, and altitude) of transponder and ADS-B equipped aircraft. A secondary purpose of the traffic display is to give the flightcrew confidence in proper system operation and time to prepare to maneuver the aircraft if the ACAS issues an RA.

- 3.13.2.2 Verify the traffic information on the traffic display meets RTCA/DO-185B, RTCA/DO-385A, and/or the appropriate version of RTCA/DO-317, as applicable.

- 3.13.2.3 Verify the traffic display is installed in accordance with manufacturer's installation instructions.

3.13.2.3.1 Multi-Function Display Mode

- 3.13.2.3.2 When the “pop-up” mode is enabled, verify there is a visual indicator/label to distinguish that the display is in a mode that is displaying traffic information.

- 3.13.2.3.3 When the traffic information is not selected for display, verify the RA display and aural indication are displayed in the flight deck when the RA is issued to indicate to the flightcrew that TAs and RAs are still operational.

3.13.2.4 **ACAS Xo DNA and CSPO-3000 Display**

Activation of the DNA feature allows the flightcrew to suppress all ACAS Xa alerts and guidance on a specific target. Activation of the CSPO-3000 feature desensitizes the ACAS logic for closely spaced parallel approach operations down to 3000 feet runway spacing and provides TAs and RAs on blundering designated traffic. Perform tests in CHAPTER 6 to verify the implemented ACAS Xo mode(s) performance in-flight.

3.13.2.5 TA Display Information

3.13.2.5.1 TAs indicate on a display the bearing, range, and altitude of nearby aircraft relative to ownship to assist the flightcrew in the visual acquisition. TA symbols are amber and indicate the relative positions of intruding aircraft that are approximately 20 - 48 seconds from the closest point of approach (CPA), depending on the altitude, and may a short time later require a RA. It will also include an amber text on a display such as “Traffic”. TA visual annunciations should remain on until the ACAS criteria for a TA is no longer met.

3.13.2.5.2 Verify the text corresponds with the aural annunciation and is amber in color.

Note: The nomenclature “advisory” notwithstanding, the FAA considers that TAs generally require immediate flightcrew awareness and subsequent flightcrew response. In accordance with 14 CFR 25.1322, this corresponds to a Caution level alert, which must be amber or yellow in color.

3.13.2.6 RA Display Information

3.13.2.6.1 The purpose of the RA display is to indicate the recommended vertical maneuvers, or vertical maneuver restrictions that maintain or increase the vertical separation between aircraft to mitigate the risk of airborne collision. An RA display for each pilot indicates the appropriate vertical maneuver to avoid a threat. The RA display provides the pilot with information on the vertical speed and optionally pitch angle to fly to avoid a threat. The RA display may be integrated with the two primary stand-alone VSI on the flight deck, be integrated into the Primary Flight Display (PFD), or be incorporated into a head-up display (HUD). Refer to RTCA/DO-185B or RTCA/DO-385A, as applicable, for descriptions and requirements for the various resolution advisory display implementations.

3.13.2.6.2 Verify, for each RA aural annunciation, there is a corresponding text or visual indication that is red in color.

Note: The nomenclature “advisory” notwithstanding, the FAA considers that RAs generally require immediate flightcrew awareness and immediate flightcrew response. In accordance with 14 CFR 25.1322, this corresponds to a Warning level alert, which must be red in color.

3.13.3 ACAS Visual and Aural Annunciations

For new installations (not previously installed with ACAS), if ownship transponder status is determined to be in standby or failed during airborne operation, an aural and visual annunciation to the crew is required. The FAA considers that this condition generally requires immediate flightcrew awareness and subsequent flightcrew response (to attempt to restore proper operation). As such, this annunciation should be a caution

alert. It could be provided by a centralized crew alerting system. For ACAS designed for installation on aircraft that will not have a centralized crew alerting system capable of annunciating this condition, the ACAS should provide an aural annunciation upon detection of this condition.

- Verify the suite of annunciations found in RTCA/DO-185B or RTCA/DO-385A are installed.
- Verify messages are phrased as a positive action (for example, use “LEVEL OFF” rather than “DON’T CLIMB”).
- Verify ACAS generates aural annunciations when the TA and/or the first RA of an encounter is displayed and each time a subsequent change in the resolution advisory is displayed (strengthened, weakened, or reversed).
- Verify that there is a “Clear of Conflict” when the RA is cleared.
- Verify for each aural annunciation that there is a corresponding text or visual annunciation.
- Verify there is a visual annunciation of the ACAS fail and ACAS standby states.

3.13.4 ACAS Aural Annunciation Inhibit

- Verify that ACAS inhibits TA aural annunciations below 400 ft AGL while descending and below 600 ft AGL while climbing.
- When aural annunciations are inhibited by the ACAS, verify ACAS automatically switches to TA-ONLY mode. The FAA would not generally consider ACAS to be designed to minimize crew errors that could create additional hazards (as required by 14 CFR 25.1309(c)) if ACAS can be in TA/RA mode while aural annunciations are inhibited.
- If installed, verify TA and RA annunciations are inhibited against the designated aircraft when ACAS X or DNA is activated.

Note: TA-ONLY mode only on the ground does not produce any aural annunciations. The operations manual may state: “Below approximately 1000 feet when the TA/RA mode is selected on the transponder panel, TA-ONLY mode is enabled automatically. All ACAS voice annunciations are inhibited below 500 feet Radio Altitude.”

3.14 **Traffic Information Prioritization**

Verify the proper prioritization of alerts among the various alerts that may be generated while the ACAS is operating.

The aural cautions and warnings should be prioritized at the aircraft level. Warnings for hazards that pose an immediate threat to continued safe flight of the aircraft, such as Stall, Overspeed, Reactive Windshear, or TAWS “Pull-up”, etc., should be of a higher priority than an RA. The ACAS is designed to revert, as configured, to TA-ONLY when another higher priority alert is active and all ACAS aural annunciations are suppressed. Demonstrate prioritization in a simulator or on the aircraft.

3.15 ACAS Communication of RA Information

Provide documentation that tests were conducted in accordance with § 6.5.6 of this AC for new and first of model installations or previously conducted under TSO-C219a or TSO-C119c/d/e.

CHAPTER 4. SYSTEM SAFETY CONSIDERATIONS

4.1 System Safety Assessment (SSA)

- 4.1.1 Conduct a safety assessment for the ACAS installation. It should include an overview of the system, consideration of the design, failure classifications, failure condition, any assumptions, failure modes, common mode failures, and Fault Tree Analysis (FTA), if required.
- 4.1.2 The following information provides a path for meeting the safety objectives for certification.

4.2 Quantitative Safety Analysis

The need for quantitative safety analysis (such as FTA) will depend on the aircraft type, application, and failure condition. Refer to AC 23.1309-1E and AC 25.1309-1B, as applicable to the aircraft category in which the ACAS equipment is being installed, when performing the System Safety Assessment for the ACAS installation on aircraft.

4.3 Failure Classifications and Failure Conditions

- 4.3.1 Failure classifications help designers develop appropriate aircraft architectures to mitigate potential hazards. The classification of the failure condition does not depend on whether the system or function is required by any specific regulation. Regardless of the types of assessment used, classify failure conditions with consideration of all relevant factors:

- crew workload,
- automatic system checks,
- system performance,
- system reliability,
- operating environment,
- interfaces, and
- any required action of the flightcrew or maintenance personnel.

- 4.3.2 Ensure the ACAS design installation addresses the following four critical failure conditions in the SSA:
 1. Annunciated Loss of System Function,
 2. Unannunciated Incorrect RA,
 3. Unannunciated Missing RA, and
 4. False RA.

- 4.3.3 Unannunciated failures of the ACAS equipment, its associated transponder, sensors, or displays that could generate an incorrect or false RA, or result in a missing RA, must be improbable. Design the ACAS to prevent incorrect RAs, missing RAs (including late issuance of an RA, i.e. not within nominal timing parameters for the ACAS logic declaring and posting an RA), and false RAs, as defined in APPENDIX C, § C.1.

Use the following information for the safety analysis.

4.3.4 Failure Classifications and Conditions

4.3.4.1 Loss of System Function

- 4.3.4.1.1 Consistent with TSO-C219a failure condition classifications, which reflect accident experience with TCAS II-equipped aircraft, the FAA considers annunciated or detected loss of the system to perform its intended function to be a minor failure condition.

Note: Consistent with TSO-C219a, the FAA considers that loss of function does not include unannunciated loss or degradation of capability to generate an RA. Unannunciated loss or degradation of capability to generate an RA is an unannunciated failure that may result in a missing RA or incorrect RA.

- 4.3.4.1.2 An acceptable software and airborne electronic hardware (AEH) life cycle process for software and AEH that may contribute to the annunciated or detected loss of the system is to develop the software and AEH to at least DAL D as defined in RTCA/DO-178B/C (for software) and RTCA/DO-254 (for AEH) or later approved revisions.

- 4.3.4.1.3 In order to verify compliance to 14 CFR §§ 25.1309 and 23.2510, the FAA will require applicants to show that the failure of the installed system does not negatively impact any essential or critical user system to which it interfaces. This can be demonstrated through an aircraft level functional hazard assessment.

4.3.4.2 Missing and Incorrect RA

- 4.3.4.2.1 Consistent with TSO-C219a failure condition classifications, which reflect accident experience with TCAS II-equipped aircraft, the FAA considers an unannunciated failure that could generate an incorrect RA or result in a missing RA to be a hazardous failure condition. (The FAA no longer uses the term “severe-major” since AC 25.1309-1B was issued on September 3, 2024, and 14 CFR 25.1309 was amended to Amendment 25-152 on September 26, 2024.)

Note: Although this failure of the system is associated with a "hazardous" condition, the FAA accepts higher hardware probabilities on a case-by-case basis. The FAA assumes that this criterion can be met with a single system. The FAA still expects a fault tree analysis to be included in the

safety analysis to ensure the ACAS hardware and its dependent systems are at a level commensurate with this failure criterion. This criterion does not apply to the assessment of the required software and AEH DAL level. TSO-C219a and this AC define a missing RA as an RA that does not occur, or that occurs later than the collision alerting system logic indicated is necessary, when a threat is present. An acceptable probability of a missing RA due to an unannounced failure of the hardware is no greater than 5.0×10^{-4} per flight hour.

4.3.4.2.2 TSO-C219a and this AC define an incorrect RA as an RA occurring when a threat is present, but, because of the failure of the function, commands a maneuver that reduces separation from the threat. An acceptable probability of an incorrect RA aural and visual alert due to an unannounced failure of the hardware is no greater than 5.0×10^{-4} per flight hour.

4.3.4.2.3 In consideration of the hazardous failure condition classification of unannounced failures that result in a missing (including on another aircraft in an encounter) or incorrect RA, an acceptable software and AEH life cycle process for software and AEH that may contribute to a missing or incorrect RA is to develop the software or AEH to DAL B as defined in RTCA/DO-178B/C (for software) and RTCA/DO-254 (for AEH) or later approved revisions.

4.3.4.3 False RA

4.3.4.3.1 TSO-C219a and this AC, which reflect accident experience with TCAS II-equipped aircraft, define a false RA as an RA that is not warranted by an actual threat, caused by a system malfunction. A false RA is considered an unannounced failure. Consistent with TSO-C219a failure condition classifications, the FAA considers failures that could generate a false RA to be a major failure condition.

4.3.4.3.2 An acceptable probability of a false RA aural and visual alert due to failures of the hardware is no greater than 5.0×10^{-4} per flight hour.

4.3.4.3.3 An acceptable software and AEH life cycle process for software and AEH that may contribute to a false RA, but not to a missing or incorrect RA, is to develop the software and AEH to DAL C as defined in RTCA/DO-178B/C (for software) and RTCA/DO-254 (for AEH) or later approved revisions.

4.3.4.4 Summary of ACAS DAL

To help ease the burden of determining software and AEH DAL for components associated with the failure conditions above, table 4-1 below represents some typical acceptable software and hardware DAL for components used on the ACAS at their minimum acceptable DAL.

Table 4-1 AEH DAL

Component	Function	Minimum Acceptable Software/AEH DAL
Controller	Controls ON/OFF	DAL C
Transponder	Supports RA Coordination	DAL C
Surveillance Module	Surveillance Function	DAL B
Threat Module	TA and RA Function	DAL B
Audio System	Aural Annunciations	DAL C, if applicable
Vertical Guidance Display	RA Vertical Alerting and Guidance Information	DAL B
Traffic Display	Surveillance Display	DAL C
Antenna	Sends and Receives Data	DAL C, if applicable
Monitor	Monitors Surveillance Function	DAL B

4.4 Common Mode Failures

The FAA may examine whether any common mode failures exist for the system, and if potential common mode failures appear to exist, will examine whether or not an adequate common mode analysis has been performed. An acceptable fault tree analysis and/or common mode analysis reflects any dependencies and identifies when partitioning is necessary for failures that may contribute to a hazard or unsafe operating condition. Issues may include common use of sensor types, antenna, algorithms, and similar or identical types of microprocessors.

4.5 ACAS Alerting

- 4.5.1 For new installations of ACAS (aircraft does not have an approved ACAS installation), verify the following caution alert conditions are annunciated in yellow/amber (as specified by § 2.2.6.6.1 of RTCA/DO-185B / DO-385A) in the primary field of view: An ACAS failure due to the following reasons is considered a caution level alert:

- Pressure altitude failure.

- Radio Altimeter or other AGL Altitude Source failure.
- Transponder failure.

It is recommended that these annunciations are interfaced with the aircraft's master caution and warning system.

Note 1: Past accident experience² has shown that loss of ACAS RA functionality requires flightcrew awareness (amber annunciation) and may require subsequent flightcrew response. This response includes checking for proper ACAS settings and operation as well as Mode S transponder settings and operation.

- 4.5.2 Verify compliance with appropriate regulations such as 14 CFR §§ 25.1302, 25.1309(c), and 25.1322 for flightcrew alerting.

Note 2: Guidance for compliance with 14 CFR §§ 25.1302 and 25.1322 is contained in AC 25.1302-1, *Installed Systems and Equipment for Use by the Flightcrew*, and AC 25.1322-1, *Flightcrew Alerting*.

4.6 Verifying and Validating ACAS Software

Equipment produced under a TSO has obtained FAA concurrence that the software and/or AEH for the equipment was developed in accordance with RTCA/DO-178B/C and RTCA/DO-254 levels that are specified in the TSO. Subsequent installations of the same ACAS equipment on other aircraft types do not require any additional verification if the software and the interfaces have not changed.

4.7 Hybrid Surveillance Failure Reporting

- 4.7.1 To ensure that latent failures do not exist in airborne ACAS units for extended periods of time, verify that the system annunciates failures of hybrid surveillance for maintenance actions, or verify there is a periodic scheduled maintenance task to check hybrid surveillance functionality. The following provides guidance for monitoring the ACAS against latent failures.

Note: RTCA/DO-300A § 2.2.10 and RTCA/DO-385A § 2.2.7.2.9, Monitoring Requirements, provides a means for annunciation or recording of failures of ownship latitude, longitude, and/or ground speed inputs. A failure of any of these inputs will not cause the ACAS to fail, but it will disable the hybrid surveillance functionality.

- 4.7.2 For aircraft without a centralized crew alerting system and/or an onboard maintenance computer, add a scheduled maintenance task to the aircraft's maintenance program to check for the presence of any existing or past failures of hybrid surveillance and to

² In particular, see Appendix A, section A.4 of this AC.

ensure hybrid surveillance is functional. Take corrective action as specified by the ACAS manufacturer.

- 4.7.3 For aircraft equipped with an onboard maintenance computer interfaced with ACAS, add a scheduled maintenance task to the aircraft's maintenance program to check for the presence of any existing or past failures of hybrid surveillance. Take appropriate corrective action, such as that specified by the ACAS manufacturer.

CHAPTER 5. INTEROPERABILITY**5.1 Interoperability Demonstration**

- 5.1.1 ACAS installations are designed and intended to interoperate with each other to perform the collision avoidance function. As such, demonstration of interoperability of an ACAS installation is essential to showing compliance with airworthiness rules that require equipment to be suitable for its intended function, such as 14 CFR 25.1301(a)(1). Therefore, to show compliance with those rules, the FAA will require demonstration of interoperability of ACAS installations. Accordingly, this chapter provides an acceptable means of demonstrating essential aspects of interoperability to support compliance with applicable suitability-for-intended-function airworthiness rules.
- 5.1.2 The main objectives of this chapter are to ensure the compatibility of critical interfaces to the ACAS and to ensure that the installation of the ACAS does not degrade the operation of existing ACAS.
- 5.1.3 These equipment compatibility tests are only necessary for initial approval.
Note: Equipment that conforms to RTCA/DO-185B with RTCA/DO-300A, or RTCA/DO-385A meets the interoperability requirements as prescribed in RTCA/DO-382.

5.2 ACAS to ACAS System Interoperability

Unless this is performed as part of the TSO process, the initial approval of an ACAS system shows that the ACAS system communicates with a dissimilar ACAS system. This may be with another manufacturer's approved ACAS system or with a primarily different ACAS system that has no common hardware or software modules required for the ACAS function. Include an ACAS-to-ACAS coordination demonstration or equivalent in your evaluation.

5.3 ACAS and Mode S Transponder Interoperability

For the initial approval of a new pairing of an ACAS system and a Mode S transponder, submit evidence to show that this pairing has passed interoperability testing. The same part numbers as those seeking certification are to be used for this testing; revised parts of the same type are not sufficient for showing interoperability unless it can be shown that the revisions have no effect on interoperability. These may be bench tests based upon the applicable ACAS Minimum Operational Performance Standards (MOPS), bench tests based upon the applicable Mode S MOPS, or a test run on the aircraft.

Choose one of the following subsections of this AC (§§ 5.3.1, 5.3.2, 5.3.3, 5.3.4, or 5.3.5) for this testing.

Note: Any ACAS or transponder being tested in §§ 5.3.1 – 5.3.5 below has previously passed all of the interoperability bench tests in its applicable ACAS or transponder MOPS as a part of the TSO process. The testing specified by § 5.3 of this AC ensures that the ACAS and transponder seeking certification (actual physical equipment) pass these tests when run together as a pair.

5.3.1 DO-185B Based Interoperability Tests

For a TCAS II based system, conduct all the following RTCA/DO-185B tests, using the actual TCAS II unit and Mode S transponder seeking certification.

When paired with a DO-181E transponder, run the following tests as described in these sections of RTCA/DO-185B:

- § 2.4.2.2.3.1
- § 2.4.2.2.3.2
- § 2.4.2.2.4.1
- § 2.4.2.2.4.2.1 (only scenarios A, B, C, and H)
- § 2.4.2.2.4.2.5
- § 2.4.2.2.4.2.6
- § 2.4.2.2.4.2.8 (only scenario C, part a)
- § 2.4.2.2.5

When paired with a DO-181F transponder, run the same tests as above except:

- Omit (do not run) RTCA DO-385A § 2.4.2.2.3.1 (Ground Control of Sensitivity Level), and
- Replace § 2.4.2.2.4.2.6 (Transponder/TCAS Throughput) with § 2.4.2.4.3.5 in RTCA/DO-385A.

Note: The § 2.4.2.4.3.5 DO-385A test is required even though a DO-185B unit is being tested. The DO-185B / DO-181F transponder pairing will fail § 2.4.2.2.4.2.6 because with the DO-181F transponder, the messages will not always reach the TCAS II unit in the order they are input to the transponder. The DO-181F transponder is required to prioritize the incoming coordination interrogations on the interface bus, potentially making the order on the bus different from the order they are input to the transponder.

For either transponder pairing, additionally run the test in § D.4 of this AC.

5.3.2 DO-385A Based Interoperability Tests

For an ACAS Xa based system, conduct all the following RTCA/DO-385A tests, using the actual ACAS Xa unit and Mode S transponder seeking certification.

When paired with *either* a DO-181E or DO-181F transponder, run the following tests as described in these sections of RTCA/DO-385A:

- § 2.4.2.3.1

- § 2.4.2.3.2
- § 2.4.2.4.1 (only scenario A)
- § 2.4.2.4.2
- § 2.4.2.4.3.1 (only scenarios A, B, C, and H)
- § 2.4.2.4.3.3
- § 2.4.2.4.3.5
- § 2.4.2.4.3.8
- § 2.4.2.5 (only scenarios A or B and D)
- § 2.4.2.6

For either transponder pairing, additionally run the test in § D.4 of this AC.

5.3.3 DO-181E Based Interoperability Tests

For an ACAS paired with a DO-181E based transponder, conduct all the testing in § D.1 of this AC, using the actual ACAS unit and Mode S transponder seeking certification. Additionally, run the test in § D.4 of this AC and either § 2.4.2.2.4.1 from RTCA/DO-185B (for TCAS II) or § 2.4.2.4.2 from RTCA/DO-385A (for ACAS Xa).

5.3.4 DO-181F Based Interoperability Tests

For an ACAS paired with a DO-181F based transponder, conduct all the testing in § D.2 of this AC, using the actual ACAS unit and Mode S transponder seeking certification. Additionally, run the test in § D.4 of this AC and either § 2.4.2.2.4.1 from RTCA/DO-185B (for TCAS II) or § 2.4.2.4.2 from RTCA/DO-385A (for ACAS Xa).

5.3.5 Aircraft Based/Test Bench Interoperability Tests

The tests defined in §§ D.3 and D.4 of this AC can be performed on an aircraft or on a test bench. They are acceptable for pairings of an ACAS unit with a transponder when both the ACAS unit and the transponder have previously been tested according to the procedures in §§ 5.3.1 - 5.3.4 of this AC (but not necessarily in the pairing being considered). The tests in this section may also be acceptable for pairings with subsequent revisions to an ACAS or transponder that has been previously tested according to the procedures in §§ 5.3.1 - 5.3.4 of this AC.

Two test units may be necessary for testing – one to interact with the transponder and one to interact with the ACAS. See CHAPTER 6 for guidance on ground-based testing of the system.

CHAPTER 6. TEST AND EVALUATION (INITIAL AND FOLLOW-ON APPROVALS)

6.1 General

- 6.1.1 This chapter provides acceptable test and evaluation methods for both initial and follow-on approvals for ACAS installations. Initial approvals are intended for new ACAS designs, new aircraft type design installations, or unique changes in the ACAS design that would significantly impact the type design of the aircraft and therefore be subject to extensive flight testing for system design evaluation. The FAA expects initial approvals to include ACAS-to-ACAS flight testing. Follow-on approvals are for changes that do not significantly impact the design but are necessary to ensure proper installation and operation.
- 6.1.2 The level of flight test required to validate a particular ACAS design and installation will depend on the type of aircraft, aircraft system architecture, and credit given from previously certified installations, simulations, and ground testing. Work with the local Aircraft Certification Branch (ACB) to determine if a flight test is required. Evaluate the actual requirement for a flight test for each installation. Credit may be taken for performance flight testing specified in this AC that may have been conducted as part of the Technical Standard Order Authorization (TSOA) if the aircraft installation used to obtain TSOA is similar in performance to the installation of the make and model that is under review for certification. Flight testing of an ACAS for follow-on approvals (previously approved ACAS equipment installed in a different aircraft type or change to the defined configuration of a previously approved system installation) may be necessary to verify that the design and installation perform their intended functions under the expected operating conditions.
- 6.1.3 For the purposes of this AC, initial approval testing for an ACAS will lead to an airworthiness approval through the type certification (TC), amended type certification (ATC), or supplemental type certification (STC) processes. Follow-on installations are based on existing airworthiness approvals and would be amendments to the STC or type design changes to existing TC or amended TC. This section provides guidance for the first of type/model and follow-on ACAS installations. These tests are applicable for all classes of airplanes and rotorcraft. Unless otherwise agreed to by the FAA, the FAA expects the following inspections and tests to be completed for both initial and follow-on approval installations.

6.2 Create a Test Plan

- 6.2.1 Provide a test plan that includes adequate testing to perform this verification.
- 6.2.2 For initial approvals, acceptable test plans will generally include a combination of HF evaluations, ground tests, basic flight tests, and flight tests involving planned encounters with another ACAS-equipped aircraft.

- 6.2.3 For follow-on installations, an acceptable test plan will generally include ground testing to verify proper installation with the different interfaces and human factors compliance inspections. The certification policy for follow-on approvals (STC or amended STC) of ACAS units is that it is not necessary to do flight tests if the appropriate testing is performed on the ground to certify that the system has been correctly installed and that any new interfaces operate correctly with the installed system.
- 6.2.4 If upgrading an existing approved ACAS installation to a newer ACAS version (i.e., TCAS II V7.0 to V7.1 or from TCAS II to ACAS Xa), and the higher version installation is only a software change to the traffic computer, then applicants will not need to conduct additional certification flight tests to obtain a follow-on STC, amended STC, or an amended TC. The appropriate aircraft ground tests of § 6.4 are sufficient to ensure that the newer ACAS version is operating properly. However, if the upgrade involves changes other than software (such as the addition of an ACAS Xo interface), the FAA will evaluate the changes to determine what level of flight testing (if any) will be required.
- 6.2.5 For initial approvals, where there is a new type design aircraft with a previously approved/modified ACAS installation, the testing may not need to include the extensive ground testing and encounter testing as for a new ACAS model. For these installations, some ground testing, HF compliance, and some basic flight testing with one or two encounter tests to verify proper installation integration and HF against the RA and TA functions may be sufficient. For these types of installations, applicants should propose and provide rationale for the extent of ground test, HF compliance, and flight test they consider adequate to show compliance for the installation. The rest of this chapter lists and explains the minimum elements of the test plan.

6.3 **Conformity Inspection**

For certification testing, perform the conformity inspection, list all electronic systems onboard the aircraft, including part numbers and software versions, in the type inspection authorization report. Verify the ACAS installation conformity in accordance with installation instructions, including location of controls, displays, and annunciators.

6.4 **HF Airworthiness Compliance Inspection and On-Ground Testing**

CAUTION: When ground testing the ACAS system, it is necessary to take precautions to prevent being a source of interference to ATC or other ACAS aircraft operating in the area. 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 on the transponder antenna (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, radiated testing can be used, provided that the altitude reported by the traffic system via Mode C, Mode S, and ADS-B all provide altitude at ground level.

6.4.1 HF- General Arrangement, Access, Performance, and Visibility of Information

- 6.4.1.1 Testing and evaluation in this section are appropriate for initial and follow-on testing.
- 6.4.1.2 Conduct a human factors/pilot/flight test pilot evaluation of the controls, displays, circuit breakers, placards, and annunciators for the ACAS. Many of these tests will provide the most reliable results if they are conducted on-board the test aircraft. Some tests may require further evaluation in an engineering simulator cabin, flight test simulator, or certified flight deck/control station display arrangement. The evaluation should include the following:
- 6.4.1.3 Consider relevant HF design and evaluation guidance in the following publications:
- “Human Factors Considerations in the Design and Evaluation of Flight Deck Displays and Controls” (DOT/FAA/TC-16/56)
 - AC 25-11B
 - AC 25.1302-1
 - AC 25.1322-1
- 6.4.1.4 Aural Annunciations**
- 6.4.1.4.1 After aircraft power-up, verify the ACAS passes all checks, including self-test functions, and is ready for operation. The result of the test should be heard through the aural speakers. Verify that the use of the TEST function does not change the audio level; if it does, then an evaluation of the audio should be accomplished through a ground test with the aircraft in air-mode or as part of the flight test. If the installation has a different aural level on ground and in air, an evaluation in both cases should be made.
- 6.4.1.4.2 Evaluate a subset of aural annunciations found in § 3.13.3 of this AC. Check volume levels and intelligibility for acceptability for both low and high flight deck noise levels from the flight deck speakers and/or headsets, as applicable.
- 6.4.1.5 ACAS Mode Selections**
- Evaluate any ACAS status changes which could result from ACAS mode selections. Evaluate ACAS standby and TA-ONLY mode annunciations and verify proper coloring, text, legibility, and location.
- 6.4.1.6 Controls, Displays, and Inhibits**

- 6.4.1.6.1 Evaluate pilot controls, display information, and inhibits found in §§ 3.11 and 3.13 of this AC.
- 6.4.1.6.2 Evaluate the ACAS installation for satisfactory identification, legibility, accessibility, unambiguity, attention-getting characteristics (as applicable), and visibility during both day and night conditions.
- 6.4.1.6.3 When observable on the ground, verify the performance of the ACAS traffic display by observing any available area traffic.
- 6.4.1.6.4 Check the installation instructions to verify when the ACAS unit automatically switches to TA-ONLY mode and back to TA/RA mode of operation. Typically, this occurs when stall, TAWS, or windshear alerts are generated.
- 6.4.1.6.5 Enable operation of other installed systems to check any anomalies, disruptions, or clutter that may affect the operation of the ACAS or vice versa.
- Check interference with step overs or overlays on the display from windshear, TAWS, or Helicopter TAWS (HTAWS), or aural/tactile annunciations from Overspeed or Stall.
 - Check electromagnetic interference (EMI), especially for C-band and L-band operations. ACAS operates under L-band frequencies. Radio Altimeters and 5G Wireless Telecommunications operate under C-band frequencies. ACAS uses the radio altimeter for CLIMB inhibits and other desensitization near the ground.
- 6.4.1.6.6 Check the controls to verify no inadvertent pilot actions would disengage the ACAS or inhibit the ACAS without notification. Pay close attention to line select keys, touch screens, touch pads, or cursor-controlled trackballs, as these can be susceptible to unintended mode selection resulting from their location in the flight deck (for example, proximity to a footrest or adjacent to a temporary stowage area).
- 6.4.1.7 Follow-on Approvals**
- For follow-on approvals, re-evaluate any previously installed aircraft systems that required changes because of the ACAS installation (for example: electronic flight instrument system (EFIS), Flight Director (FD), PFD, navigation displays (ND), stand-alone VSI, interface etc.). Conduct a change impact analysis to look at the before/after performance of the system and clearly document the pass/fail criteria for the evaluation. A third-party installer may perform this analysis.
- 6.4.1.8 ACAS Alerting, Failure Alerting, and Alert Prioritization**

- 6.4.1.8.1 Acceptable alerting and alert priorities are found in §§ 3.13.3, 3.14, and 4.5 of this AC. Alert prioritization may also be found in the manufacturer's installation manual.
- 6.4.1.8.2 Verify that when the transponder is in standby mode or failed, the appropriate ACAS annunciation occurs (standby or failed) as described in § 4.5 of this AC.
- 6.4.1.8.3 If connected, verify that the altitude alerter is installed per manufacturer's installation instructions.
- 6.4.1.8.4 Check the installation instructions to find when the ACAS automatically switches from TA/RA mode to TA-ONLY mode. Verify there is an annunciation of the TA-ONLY mode and/or that RAs are unavailable. Typically, this occurs when a stall, TAWS, or windshear alerts are generated.
- 6.4.1.8.5 Simulate failures of individual sensors, including surveillance sources, position sources, and any combination of failures deemed necessary. Determine that the resulting system failure state agrees with the predicted results.
- 6.4.1.8.6 Evaluate failure modes in § 4.5 of this AC.

6.4.2 Interoperability Testing, If Conducted

Verify proper interoperability of the Mode S transponder with the ACAS. Acceptable test methods are in CHAPTER 5 of this AC. Further testing may also be found in the manufacturer's installation manual.

6.4.3 Bearing Accuracy/Directional Antenna Performance

- 6.4.3.1 This test is typically conducted for new ACAS model approvals, a new antenna placement or antenna type with an existing ACAS, or a new type design aircraft model that has not been approved with an ACAS installation. For this test, verify the active Mode S or C interrogation response is used. Demonstrate the bearing estimation accuracy of the ACAS system as installed in the aircraft, using any of the following techniques:
 - Measure the bearing accuracy using a calibrated directional antenna range that allows precise echo controlled, far field, angle-of-arrival measurements at or slightly above zero degrees elevation and over 360 degrees in azimuth.
 - Measure the bearing accuracy using a fixed transponder or ACAS test equipment location while rotating the test aircraft on a compass rose while measuring the bearing angles at 30-degree intervals.

- Measure the bearing using the airplane's fixed position and move the transponder (refer to § 6.4 for CAUTION statement on testing).

6.4.3.2 The manual readout of the bearing estimate directly from a plan position display on the traffic advisory display may be used. Alternatively, use an automatic recording of the bearing estimates or read them from a special test display. A maximum error of ± 15 degrees in azimuth is acceptable; however, larger errors are acceptable around the tail (for example, within ± 45 degrees of the tail) when that area is not visible from the flight deck. In this case, aircraft structure may interfere with the signal path.

6.4.3.3 If there is a second directional antenna on the aircraft, repeat tests in this section; and if installed on the bottom, include allowances for landing gear and other obstructions.

6.4.4 GNSS Disable Feature

Verify the ACAS functions are still operational when the GNSS is disabled, when the ACAS is in either the TA/RA mode or the TA-ONLY mode and Mode S transponder is operating simultaneously.

6.5 **ACAS Flight Tests**

The following provides general information to be considered when conducting flight testing with ACAS equipment. Note that these are not typically required for follow-on installations of a similar aircraft type (fixed wing, helicopter, etc.). To ensure the FAA finds the applicant's test plan acceptable, the FAA recommends coordinating with the certification authority to determine which (if any) of the flight tests need to occur.

6.5.1 Test Safety Considerations

6.5.1.1 All encounters are recommended to be flown in day Visual Meteorological Conditions (VMC).

6.5.1.2 Before any cooperative flight tests at any altitude involving the ACAS-equipped aircraft and another aircraft, fly both aircraft in close proximity to ensure matched altimetry readouts. Fly these checks at the speeds and altitudes that are normally used for these tests. Any differences are recommended to be noted and accounted for as part of the test.

6.5.1.3 Both aircraft are recommended to remain in continuous radio communication with each other.

6.5.1.4 At least one aircraft is recommended to remain in visual contact with the other during each encounter.

- 6.5.1.5 Procedures for loss of visual contact are recommended to be developed and briefed to all pilots before the flight.
- 6.5.1.6 Procedures for early termination and to abort testing are recommended to be developed and briefed to all pilots before the flight.
- 6.5.1.7 During head-on encounters, the two aircraft are recommended to fly offset tracks. Use appropriate reference as cues when performing this test. For example, use opposite sides of a ground cue, e.g. north-south roads as reference in remote areas.
- 6.5.1.8 Overtaking and converging encounter profiles should include a lateral offset and vertical offset.
- 6.5.1.9 Suspend flight testing whenever the potential for an unplanned encounter with proximate/nearby traffic arises.
- 6.5.1.10 For RA autopilot testing, ensure there are procedural mitigations if the aircraft does not respond to the RA command or if the RA command is latent or incorrect.
- 6.5.1.11 Verify altimeter correlation between the encounter aircraft and the ACAS aircraft.

6.5.2 ATC Coordination Considerations

When conducting flight testing of the ACAS for certification approval, the applicant is responsible for preventing the ACAS from being a source of interference to ATC or other ACAS-equipped aircraft operating in the area. For example, using a fixed transponder to simulate an intruder aircraft can cause transmission of data that produces false targets for the ground ATC surveillance systems, airborne ACAS-equipped aircraft, and/or ADS-B In systems. These false indications of “intruder aircraft” could result in unnecessary ATC communications and possibly in ACAS induced aircraft maneuvers. Therefore, conduct such testing in coordination with ATC. When conducting such tests, add a note in the test procedures, which states:

“Note: The conduct of this test requires cooperation with ATC controllers. Coordination with ATC is important before the flight test for any necessary approval of the flight and agreement with the flight test procedures. During the flight test, the test crew will need to communicate with the controller monitoring the aircraft and reporting transponder performance data.”

6.5.3 Follow-on ACAS approvals on New Aircraft Types or Models

- 6.5.3.1 Use of this section assumes a previous approval of an existing ACAS design.

6.5.3.2 Follow-on flight test applicants may demonstrate operation by observing proximate traffic and conducting at least one TA and RA. Aircraft should meet the minimum aircraft performance assumed by the appropriate ACAS installation. Confirm that the appropriate aural annunciations occur correctly with the TA and RA. These follow-on flight tests will demonstrate that the RA and TA alerts are appropriate for the installation, operation, and flightcrew procedures. For these encounter sets, follow-on applicants may use:

- Planned encounters with an intruder aircraft operating a transponder.
- Mode C or Mode S transponders installed at a fixed ground location, reporting an appropriate test altitude. The traffic for this test is generated using suitable test equipment. (See statement in §6.5.2).
- Aircraft targets of opportunity.

Note: 14 CFR 91.111(a) states that no person may operate an aircraft so close to another aircraft as to create a collision hazard. In view of this regulation, the FAA does not consider intentional encounters with aircraft targets of opportunity for the purpose of generating TAs or RAs appropriate. To ensure compliance with 91.111(a), intentional generation of TAs and/or RAs may only be done on planned encounters with another aircraft whose crew are planned and briefed as participants in the test, or on encounters with ground-based transponders. Targets of opportunity may be used for other evaluations of the system, such as the evaluation of the traffic display range.

6.5.3.3 Some follow-on ACAS approvals may need further flight testing due to changes in the installation or performance assumptions from the existing ACAS approved design, such as a new flight deck display, controls, or avionics platform installation. To ensure FAA acceptability of their flight test plan, applicants should coordinate with the ACB to determine which (if any) of the flight tests need to occur from the encounter flight testing set forth in § 6.5.6 of this AC.

6.5.4 First of Model ACAS Installation Approvals

An acceptable test program for a first of model ACAS installation approval entails demonstrating the system by flying the test aircraft using the flight test encounters in § 6.5.6 and evaluating the performance using § 6.5.6.1. Installations with ACAS Xo DNA and CSPO-3000 features will also include demonstration of the system using encounters described in § 6.5.6.2. Performing these tests provides assurance of performance of the equipment's intended function and proper function when installed under their respective TSOs and applicable airworthiness rules such as 14 CFR §§ 25.1301(a)(4) and 25.1309(a) (and comparable Part 23 rules); and is consistent with RTCA/DO-385A, RTCA/DO-185A/B, and RTCA/DO-300 (as modified by Change 1 and Change 2) or RTCA/DO-300A (as modified by Change 1), as appropriate. To ensure that these tests produce valid results, the FAA expects the intruder aircraft to have a previously

approved transponder installation capable of Mode A, Mode C, Mode S, and ADS-B. These tests are also used to expose the installed ACAS to a reasonable number of carefully controlled encounters that are likely to occur in service. The ACAS and/or aircraft manufacturer will propose the encounter speeds, altitudes, and geometries based on the aircraft model under test. For initial approval of an ACAS, it is crucial that these installation tests are conducted. Previous installation tests have revealed installation flaws, pairing issues, and antenna mechanization problems that were not detected during bench tests.

6.5.5 ACAS In-Flight Display and Performance Flight Testing

- 6.5.5.1 Testing and evaluation in this section are appropriate for initial approvals.
- 6.5.5.2 During all phases of flight, observe and record any mutual interference of the ACAS with any other aircraft systems.
- 6.5.5.3 Demonstrate that traffic information remains valid and usable when the aircraft is pitched both ± 15 degrees and rolled approximately ± 30 degrees during normal maneuvers by observing area traffic in the traffic advisory display or use other normal pitch and roll characteristics to verify the system can track aircraft without any issues on the display.
- 6.5.5.4 Evaluate the effective surveillance range of the traffic display, including target azimuth reasonableness and track stability. Use targets of opportunity; however, as required by 14 CFR 91.111(a), ensure the test aircraft does not operate so close to another aircraft as to create a collision hazard.
- 6.5.5.5 Determine that any configuration discretely (changes in logic or function with aircraft configuration, altitude, or speed) associated with the ACAS logic, including inhibits of climb RAs, operate properly unless it has been demonstrated during ground tests.
- 6.5.5.6 Perform the additional flight tests in § 3.4.4 of RTCA/DO-185B, in § 3.4.4 of RTCA/DO-385A, and in §§ 3.2 and 3.3 of RTCA/DO-300A, as applicable, unless previously accomplished under TSO-C119c/d/e, TSO-C219a, or any of their later approved revisions. There is no need to test against ADS-B Versions 0 and 1.
- 6.5.5.7 If the system can perform any RA autopilot maneuvers, evaluate the interaction of this automation with nominal and off-nominal flight plan execution, approach, and landing automation, and any other non-traffic related automation. The applicant will be responsible for developing pass/fail criteria and proper automation performance/response with FAA concurrence. Review the encounter set in § 6.5.6 of this AC to determine which ones to use for the RA autopilot maneuvers.

- 6.5.5.8 If any selectable ACAS modes could not be demonstrated during the ground test, evaluate the remaining selectable ACAS modes during in-flight testing. Demonstrate that each selectable ACAS mode performs its intended function, and that the operating mode is clearly and uniquely annunciated.

6.5.6 Planned Encounter Flight Tests

These tests are appropriate for initial flight testing. A modified set may be used for follow-on flight-testing demonstrations. The goal of the encounters is to generate RAs and/or TAs, as appropriate. Conduct some of the testing at 3,000 feet over calm water or over terrain, wherever the environment is conducive to evaluating multi-path protection:

- Intruder overtaking ACAS aircraft (from the aft quadrants)
- ACAS aircraft overtaking intruder (from the aft quadrants)
- Head-on with both low and high closure speeds (consider varying closure speeds with 80 knot intruders to 130 - 140 knot intruders in class G and E airspace)
- Horizontal converging with passes both behind and ahead of the intruder
- Crossing where both ACAS aircraft and intruder conduct climbs and descents though the other aircraft's path

The FAA considers an encounter set acceptable if it is constructed to allow for the following alerting and guidance progression:

- a. Intruder begins sufficiently far in range such that no alerting and guidance is initially displayed or annunciated
- b. TA is issued
- c. RA is issued

6.5.6.1 What to Evaluate for Planned Encounter Tests

- Evaluate both TAs and RAs. Each encounter should be long enough that the ACAS under test generates a TA, followed by an RA.
- Evaluate the TA-ONLY mode during planned encounters.
- Evaluate a mix of intruder transponder modes (A/C and S with ADS-B). Include aircraft that do not report altitude and aircraft that do not report bearing.
- Evaluate with another ACAS to test coordination. Make sure that the messages are from each intruder transponder mode.
- Verify correct air-to-air coordination between the test ACAS and another manufacturer's previously approved, dissimilar ACAS.
- Evaluate the effect of electrical transients (bus transfer) during encounters, ensuring that the ACAS does not experience adverse

effects, that electrical transients do not result in generation of any false TAs or RAs, and that normal ACAS functions and displays are restored within 3 seconds.

- Evaluate the traffic display, RA display, guidance bands, alerts, aural annunciations, and any other HF interfaces.

6.5.7 ACAS Xo CSPO-3000 Flight Demonstrations

6.5.7.1 Objective

Verify the CSPO-3000 feature performs its intended function of providing modified, desensitized alerting logic for closely spaced parallel runway operations without excessively increasing crew workload.

6.5.7.2 Test Procedure

Use an engineering simulator cab or certified flight simulator to demonstrate this performance before verification in-flight.

Perform an approach with vertical guidance using automated flight control systems (if available) to achieve a stabilized flight profile. Conduct the demonstration at an airport with parallel approaches featuring a minimum runway centerline separation of 3,000 ft.

While on approach:

1. Designate a specific aircraft and enable the CSPO-3000 function.
2. Verify the system provides a clear indication that CSPO-3000 is active.
3. Verify the system distinguishes the target aircraft from all other aircraft on the traffic display.

6.5.7.3 Success Criteria

The CSPO-3000 function:

- Does not result in excessive workload increases for the flightcrew during the designation of a target aircraft.
- Provides clear and unambiguous indications of CSPO-3000 status and target designation.

6.5.8 ACAS Xo DNA Flight Demonstrations

6.5.8.1 Objective

Verify the DNA feature performs its intended function of alert suppression on a designated target aircraft without inducing traffic mode confusion or excessively increasing crew workload.

6.5.8.2 Test Procedure

Use an engineering simulator cab or certified flight simulator to demonstrate this performance before verification in-flight.

Perform a hand flown visual approach for the demonstration.

While performing the approach:

1. Visually acquire an aircraft within 6 NM laterally and then designate the aircraft for the DNA function using defined operational procedures.
 - Verify the system provides a clear indication DNA is active.
 - Verify the traffic display distinguishes the target aircraft from all other aircraft on the traffic display.
 - Verify DNA suppresses all RA and TA alerting for the designated target.
 - Verify DNA function can be manually disabled by the flightcrew.
2. Re-enable DNA on a designated target aircraft and verify the DNA function automatically:
 - i. Suspends when a non-designated threat aircraft enters the alerting area.
 - ii. Un-designates the target aircraft if lateral separation exceeds 6 NM.

6.5.8.3 Success Criteria

The DNA function:

- Does not result in excessive workload increases for the flightcrew.
- Provides clear and unambiguous indications of DNA status and target designation and transitions back to standard protection.
- Un-designates the target aircraft when a divergence exceeds 6 NM.
- Suspends alert suppression when a multiple threat encounter occurs.

CHAPTER 7. FLIGHT MANUAL (SUPPLEMENT)

7.1 Content of Flight Manual (FM)/FM Supplement (FMS)/Pilot Operating Handbook (POH)

The airworthiness rules of 14 CFR Parts 23 and 25, as applicable to the aircraft type in which the ACAS is installed, require applicants to provide a flight manual with normal, non-normal, and emergency procedures as appropriate, and other information necessary for safe operation because of design, operating, or handling characteristics. For an ACAS installation, an acceptable FM/FMS/POH provides the appropriate ACAS limitations and procedures (including those listed in §§ 7.2 through 7.3 of this AC as applicable to the installation), and a comprehensive description of all normal and abnormal modes of ACAS operation, including expected flightcrew actions.

7.2 FM/FMS/POH Operating Procedures

Include procedures for RAs and TAs based on the guidance contained in AC 90-120 or later revision. Also include guidance for responding to any other advisories or guidance that may be generated by the ACAS.

7.2.1 RA Autopilot Feature

RA autopilot maneuvering, if implemented, may be implemented differently on each aircraft type. Each will depend on the type of autopilot coupled with the RA. Manufacturers should provide procedures for the flightcrew after the auto RA has completed its function, covering both the condition where the flightcrew receives a “Clear of Conflict” message and when no “Clear of Conflict” message is received.

7.2.2 ACAS Xo Features

Procedures covering the use of the DNA and/or CSPO-3000 features should be included.

7.3 Rotorcraft and Lower Performing Aircraft

ACAS developed under RTCA/DO-185B and RTCA/DO-385A were not designed for rotorcraft or lower performing aircraft installations, so the ACAS operating envelope may not suit all aircraft. An acceptable FM/FMS/POH will include any ACAS operating limitations or procedures needed for rotorcraft or lower performing aircraft.

CHAPTER 8. CONTINUED OPERATIONAL SAFETY**8.1 General**

- 8.1.1 Notwithstanding the operational assumptions of § 3.2 of this AC and the fact that ACAS are supplemental systems, ACAS is required equipment by various operating rules, which have evolved as a response to midair collision accident history (see Appendix A, § A.4 of this AC for additional information).
- 8.1.2 ACAS are required by applicable airworthiness rules to be of a kind and design appropriate to their intended function; to function properly or as intended when installed; to perform their intended functions appropriately to the airworthiness rules applicable to the class of aircraft in which installed (e.g., compare 14 CFR § 23.2500(a), with § 25.1309(a)); and to possess an appropriate level of fail-safe design in accordance with §§ 25.1309 or 23.2510, as applicable to the class of aircraft in which installed.
- 8.1.3 Accordingly, the FAA’s intent for safety impact evaluation of in-service malfunctions, defects, and failures of ACAS is for design approval holders and the FAA to fully consider the nature of the malfunction, defect, or failure against the failure condition classification requirements of the appropriate revision of TSO-C119 or TSO-C219a, as applicable, and the system safety guidance in [Chapter 4](#) of this AC.
- 8.1.4 For the reasons cited above, the FAA does not consider it appropriate to conclude that an in-service malfunction, defect, or failure of an ACAS is not an unsafe condition solely based on ACAS being a supplemental system, flightcrew requirements to see and avoid, and/or availability of ATC services. See-and-avoid requirements and availability of ATC services may be considered as factors when performing an appropriate safety risk assessment, but those factors notwithstanding, ACAS are required to maintain compliance with the above-cited airworthiness rules applicable to the aircraft in which they are installed, and design approval holders should develop corrective actions for identified non-compliances to those rules.
- 8.1.5 For the same reasons, the FAA also does not consider it appropriate to conclude that an in-service ACAS malfunction, defect, or failure is not an unsafe condition based on the claim that loss of ACAS is a “minor failure condition”. Loss of ACAS is minor only if the loss of function is adequately annunciated, affording the flightcrew awareness that the ACAS is no longer providing collision avoidance protection and enabling them to increase their see-and-avoid vigilance accordingly if proper system operation cannot be restored. Consult [Chapter 4](#) of this AC for system safety considerations for ACAS.

8.2 **Antenna**

- 8.2.1 Verify the Instructions for Continued Airworthiness includes instructions to maintain the antenna housing and/or radome to ensure performance of the ACAS, or a means to identify when the antenna housing/radome is no longer capable of meeting the performance requirements for ACAS operation as specified in the alerting and guidance requirements of RTCA/DO-185B or RTCA/DO-385A.
- 8.2.2 Repairs on ACAS antennas, except for cosmetic repairs, are not recommended. Some repaired antennas exhibit gain measurements up to 10 dB below specifications, which would not meet the TSO requirements. The FAA recommends replacing damaged or defective antennas with new or properly refurbished antennas.

APPENDIX A. HISTORICAL INFORMATION ON TCAS AND ACAS X**A.1 Early TCAS**

Since 1955, the airline industry has been working with the Air Transport Association of America (ATA), now known as Airlines for America (A4A), toward a collision avoidance system. It was not until the mid-1970s, however, that research centered on using signals from ATCRBS airborne transponders as the cooperative element of a collision avoidance system. This technical approach allows a collision avoidance capability on the flight deck, which is independent of the ground system. In 1981, the Federal Aviation Administration (FAA) announced the decision to implement an aircraft collision avoidance concept called the Traffic Alert and Collision Avoidance System (TCAS). TCAS development focused on beacon-based collision avoidance systems and air-to-air discrete address communications techniques utilizing Mode S airborne transponder message formats.

A short time later, prototypes of TCAS II were installed on two Piedmont Airlines Boeing 727 aircraft and were flown on regularly scheduled flights. Although the displays were located outside the view of the flightcrew and seen only by trained observers, these tests did provide valuable information on the frequency and circumstances of alerts and their potential for interaction with the ATC system. In a follow-on Phase II program, a later version of TCAS II was installed on a single Piedmont Airlines Boeing 727, and the system was certified in April 1986 and then subsequently approved for operational evaluation in early 1987. Since the equipment was not developed to full standards, the system was only operated in visual meteorological conditions. Although the flightcrew operated the system, the evaluation was conducted primarily to collect data and to compare observations and responses of the flightcrew with those of other observers.

Later versions of TCAS II were installed and approved on United Airlines and Northwest Airlines airplanes in early 1988. This limited installation program operated TCAS II units approved for operation as full-time systems in both visual and instrument meteorological conditions on three different aircraft types. The operational evaluation programs continued through 1988 to validate the operational suitability of the systems.

A.2 Subsequent TCAS Developments

During the early 1990s, an operational evaluation known as the TCAS Transition Program collected and analyzed data on the performance and use of TCAS II in both the U.S. National Airspace System and in other airspace worldwide. As a result of these analyses, changes to TCAS II were developed, tested, and implemented in the early to mid-1990s. These changes, collectively known as TCAS II V7.0, were implemented by industry in the late 1990s. In response to the 2002 Ueberlingen mid-air collision, TCAS II V7.1 was implemented in 2009. This change improved reversal logic and changed the Adjust Vertical Speed, Adjust (AVSA) RA to a Level Off with a single vertical rate target (0 fpm). TCAS II V7.1 complies with the International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARP) for ACAS II.

While developing corrective action for the operational problems addressed by TCAS II V7.1, the FAA, along with industry representatives, decided to develop performance standards for TCAS II hybrid surveillance. Hybrid surveillance is used to minimize 1030/1090 MHz spectrum utilization by reducing interrogation rates for non-threatening traffic that can be tracked passively. That work resulted in the creation of RTCA/DO-300, Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance.

Investigation of operational problems reported after the introduction of TCAS II units incorporating hybrid surveillance resulted in changes to TCAS II V7.1. Those changes were invoked by TSO-C119e. Change 2 to RTCA/DO-300 and Change 1 to RTCA/DO-300A also incorporated these changes for TCAS II hybrid surveillance units designed to TSO-C119c and C119d, respectively.

As a result of a 2006 midair collision in Brazil, the FAA determined that a need exists to strengthen crew alerting for loss of TCAS functionality. Consistent with 14 CFR §§ 25.1302, 25.1309(c), and 25.1322, we have incorporated those changes into this AC.

A.3 Failure Condition Classifications and System Reliability

TSO-C119e classified failure of the TCAS II to provide a reliable traffic alert and collision avoidance function as a Hazardous/Severe-Major failure condition. However, revisions of the TCAS II ACs before AC 20-151C only provided guidance for “incorrect RAs”, defined in the AC as an “RA occurring when a threat is present, but, because of a failure of the installed TCAS II, Mode S transponder, or associated sensors, *commands a maneuver that reduces separation to the threat.*” AC 20-151B, *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders* (March 18, 2014), at Appendix E, § 1(m) (emphasis added). In some cases, this resulted in design approval holders and ACB engineers incorrectly classifying failure to provide RA when a threat is present, or late provision of an RA, as simple loss of function and therefore minor.

The FAA considers failure to provide an RA (or late provision of an RA) when a threat is present, without annunciation of loss of TCAS II functionality, to also be a Hazardous failure of the function defined in paragraph 3.a of TSO-C119e / TSO-C219/a (i.e., provide a reliable traffic alert and collision avoidance function). The FAA determined the DAL would need to meet this level of hazard. (Note that since publication of AC 25.1309-1B and revision of 14 CFR 25.1309 to Amendment 25-152 in 2024, the FAA no longer uses the term “severe major”.)

AC 20-151C originally clarified TCAS II failure classification and system safety assessment considerations by adding reference to a “Missing RA,” defined as “an RA that does not occur, or that occurs later than the ACAS logic indicates is necessary, when a threat is present,” which is a Hazardous failure condition. System Safety Considerations in [Chapter 4](#) of this AC contains one acceptable, but not the only, means of compliance for addressing missing RAs.

ACAS system reliability does not need to be as robust as is typically the minimum acceptable for most other aircraft systems, because the flightcrew is still responsible for

see-and-avoid and ATC services are also commonly available. Because the system relies on a single transponder for input information and cost for hardware redundancy would burden the industry, the FAA accepts a lower integrity of the hardware. Typically for Hazardous failure conditions, the FAA expects the failure rate to be 1×10^{-7} per flight hour. In the case of transport, commuter class 3, and normal category Certification Level 3 aircraft, the acceptable failure rate for an ACAS is up to 5.0×10^{-4} per flight hour. This accounts for use of a single transponder and radio altimeter issues. Practically, this allows a single ACAS unit to be installed on an aircraft rather than requiring two systems. The primary concerns for the system are latent and unannunciated failures. It is assumed that the unannunciated and latent failures are more likely to be introduced in software or in the AEH rather than from the architecture of the hardware. Therefore, the DAL of the system, where the failure condition resulting in an unannunciated, missing, or incorrect RA is most likely to occur, should be developed to Level B of RTCA/DO-178C.

A.4 Accident History Related to the Development and Evolution of TCAS

This section provides links to online information on significant historical accidents that have played a role in the development and evolution of TCAS. This section does not provide a detailed narrative of those events but rather enables interested readers to conduct further research into accidents that have influenced the development of TCAS by providing easy access to relevant information. The intent of providing links to this information is to capture historical lessons learned related to TCAS, in order to preserve key safety objectives for the system and facilitate its continued refinement.

Pacific Southwest Airlines (PSA) Flight 182 Boeing 727 collision with a Cessna 172, near San Diego, September 25, 1978; and Aeromexico Flight 498 McDonnell Douglas DC-9 collision with a Piper-28-181, near Los Angeles, August 31, 1986: Detailed information is available at the FAA's Lessons Learned from Transport Airplane Accidents website at: <https://lessonslearned.faa.gov/>. NTSB reports are available at <https://www.nts.gov/investigations/AccidentReports/Reports/AAR7905.pdf> and <https://www.nts.gov/investigations/AccidentReports/Reports/AAR8707.pdf>.

DHL Flight 611, a Boeing 757 collision with Bashkirian Airlines Flight 2937, a Tupolev Tu-154 midair collision, near Überlingen, Germany, on July 1, 2002: Further information is available at the Aviation Safety Network website at: <https://aviation-safety.net/database/record.php?id=20020701-1> (for the Boeing 757), and <https://aviation-safety.net/database/record.php?id=20020701-0> (for the Tu-154). The final report of the German Federal Bureau of Aircraft Accidents Investigation (BFU) is also available, in English, at: <http://www.bfu-web.de>, file number AX001-1-2/02.

GOL Linhas Aéreas Flight 1907 Boeing 737-800 collision with an Embraer Legacy 600, near Peixoto Azevedo, MT, Brazil, on September 29, 2006: Further information is available at the Aviation Safety Network website at: <https://aviation-safety.net/database/record.php?id=20060929-0> (for the Boeing 737-800), and <https://aviation-safety.net/database/record.php?id=20060929-1> (for the Embraer Legacy 600).

A.5 ACAS Xa

A new family of systems called Airborne Collision Avoidance System X (ACAS X) was developed to replace TCAS II (reference RTCA/DO-337, Future CAS). Its development was not motivated by safety or specific operational issues, but rather by the need to evolve collision avoidance to continue to be effective in changing airspace, as well as to extend its use to new entrants. The first ACAS X system developed, ACAS Xa, builds on the TCAS II V7.1 hybrid surveillance platform with the same voice annunciations and pilot procedures, adds versatility to the platform to allow other types of aircraft installations, corrects issues with excessive nuisance alerts, improves spectrum saturation, and is compatible with ADS-B system applications.

The improvements lie principally in the surveillance systems and the threat logic. Surveillance includes ADS-B information not used by TCAS threat logic. Threat logic replaces the rule-based algorithms and strict thresholds of TCAS with a Markov Decision Process-optimized table computed in advance and implemented as a lookup table aboard the avionics.

The benefits of ACAS Xa lie in both improved safety and operational acceptability. As there is some tradeoff among those factors in design, the goal is to balance a reduction in collision risk with reductions in various operational metrics, especially to minimize the number of alerts.

The FAA published TSO-C219, *ACAS Xa/Xo*, on February 28, 2020. It superseded FAA TSO-C119e, applicable to TCAS II. The FAA decided to supersede TSO-C119e with TSO-C219, since ACAS Xa improves safety and performance while reducing nuisance alerts compared to all versions of TCAS II. The FAA has decided not to support new applications of TCAS II 7.1 systems under TSO-C119e, and in accordance with the provisions of TSO-C219, stopped accepting new applications for TSO-C119e equipment authorizations after March 30, 2022. In addition to the safety and performance benefits that ACAS Xa brings, ACAS Xa was designed to mitigate the 1030/1090 MHz frequency congestion concerns in the U.S. and Europe.

Based on the results of ACAS Xa operational trials in Europe using TSO-C219 equipment, EASA determined it would not accept TSO-C219 equipment for compliance with its ACAS operating rules. The FAA subsequently issued TSO-C219a on December 1, 2023, which canceled TSO-C219. The FAA anticipates that TSO-C219a equipment will be the initial entry-into-service version of ACAS Xa. At the time of publication of this AC, EASA has issued Notice of Proposed Amendment (NPA) No. 2023-04, proposing to allow use of TSO-C219a ACAS Xa equipment for compliance with its rules.

ACAS Xa is intended for transport category airplanes. It uses ADS-B in combination with active surveillance. RA alerts and pilot displays are essentially unchanged from TCAS.

ACAS Xo may be incorporated with Xa avionics. It enables crew designation of a displayed target aircraft for adapted alerting thresholds to support operations where standard ACAS Xa alerting does not meet operational needs. One example would be to suppress RAs against a designated target, such as when a pair of aircraft are

intentionally flying in close proximity. Another example would be to enable a variation of threat logic to be used only for a designated target, with logic tailored to a specific operation type.

APPENDIX B. RELATED DOCUMENTS**B.1 Current Regulatory References**

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.

- Part 5, Safety Management Systems.
- Part 15, Administrative Claims Under Federal Tort Claims Act.
- Part 23, § 23.2250, Design and Construction Principles; §23.2260, Materials and Processes; §23.2500, Airplane Level Systems Requirements; §23.2505, Function and Installation; §23.2510, Equipment, Systems, and Installations; §23.2515, Electrical and Electronic System Lightning Protection; §23.2520, High-Intensity Radiated Fields (HIRF) Protection; §23.2535, Safety Equipment; §23.2540, Flight in Icing Conditions (if applicable); §23.2600, Flightcrew Interface; §23.2605, Installation and Operation; §23.2610, Instrument Markings, Control Markings, and Placards; §23.2615, Flight, Navigation, and Powerplant Instruments; §23.2620, Airplane Flight Manual; Appendix A.
- Part 25, § 25.301, Loads; §25.303, Factor of Safety; §25.305, Strength and Deformation; §25.561, General; §25.603, Materials; §25.609, Protection of Structure; §25.629, Aeroelastic Stability Requirements; §25.777, Cockpit Controls; §25.869, Fire Protection: Systems; §25.899, Electrical Bonding and Protection Against Static Electricity; §25.1301, Function and Installation; §25.1302, Installed Systems and Equipment for Use by Flightcrew; §25.1303, Flight and Navigation Instruments; §25.1307, Miscellaneous Equipment; §25.1309, Equipment, Systems, and Installations; §25.1310, Power Source Capacity and Distribution; §25.1316, Electrical and Electronic System Lightning Protection; §25.1317, High Intensity Radiated Fields (HIRF) Protection; §25.1321, Arrangement and Visibility; §25.1322, Flightcrew Alerting; §25.1331, Instruments Using a Power Supply; §25.1333, Instrument Systems; §25.1351, General; §25.1353, Electrical Equipment and Installations; §25.1355, Distribution System; §25.1357, Circuit Protective Devices; §25.1363, Electrical System Tests; §25.1381, Instrument Lights; §25.1419, Ice Protection; §25.1431, Electronic Equipment; §25.1529, Instructions for Continued Airworthiness; §25.1543, Instrument Markings: General; §25.1581, General; §25.1583, Operating Limits; §25.1585, Operating Procedures; §25.1587, Performance Information.
- Part 35, § 135.180, Traffic Alert and Collision Avoidance System.
- Part 87, Subpart D, § 87.18(b), §87.39.
- Part 91, § 91.3, Responsibility and Authority of the Pilot in Command; §91.111, Operating Near Other Aircraft; §91.113(b), General; §91.123; Compliance with ATC Clearances and Instructions; §91.180, Operations Within Airspace Designated as Reduced Vertical Separation Minimum Airspace; §91.181(b), Course to be Flown; §91.213, Inoperative Instruments and Equipment; §91.221, Traffic Alert and Collision Avoidance System Equipment and Use; §91.706 Operations Within

Airspace Designed as Reduced Vertical Separation Minimum Airspace; §91.1045, Additional Equipment Requirements; Appendix G, Section 2.

- Part 121, § 121.356, Collision Avoidance System.
- Part 125, § 125.224, Collision Avoidance System.
- Part 129, § 129.18, Collision Avoidance System.
- 47 CFR Part 300, Manual of Regulations and Procedures for Federal Radio Frequency Management.

B.2 Federal Aviation Administration (FAA) Advisory Material References

Applicants can find a current list of Advisory Circulars (ACs) on the FAA online Dynamic Regulatory System (DRS) at <http://drs.faa.gov>.

- AC 20-109B, *Service Difficulty Reporting System (Air Operator/Air Agency/General Aviation/Unmanned Aircraft Systems)*, dated 11/01/2023.
- AC 20-115D, *Airborne Software Development Assurance Using EUROCAE ED-12() and RTCA/DO-178()*, (July 21, 2017).
- AC 20-138D, *Airworthiness Approval of Positioning and Navigation Systems* (March 28, 2014).
- AC 20-141B, *Airworthiness and Operational Approval of Digital Flight Data Recorder Systems* (Aug. 17, 2010).
- AC 20-152A, *Design Assurance for Airborne Electronic Hardware* (Oct. 7, 2022).
- AC 20-151C, *Airworthiness Approval of TCAS II, Versions 7.0 & 7.1 and Associated Mode S Transponders* (July 21, 2017).
- AC 20-172B, *Airworthiness Approval for ADS-B In Systems and Applications* (May 20, 2015).
- AC 20-175, *Controls for Flight Deck Systems* (Dec. 8, 2011).
- AC 20-181, *Airworthiness Approval of Attitude Heading Reference System* (April 14, 2014).
- AC 21-16G, *RTCA Document DO-160 Versions D, E, F and G, “Environmental Conditions and Test Procedures for Airborne Equipment”* (June 22, 2011).
- AC 21-40A, *Application for Obtaining a Supplemental Type Certificate* (Sept. 27, 2007).
- AC 21-50, *Installation of TSOA Articles and [Letter of Design Approval] Appliances* (Feb. 28, 2011).
- AC 23-17C, *Systems and Equipment Guide for Certification of Part 23 Airplanes and Airships* (Nov. 17. 2011).
- AC 23-23, *Standardization Guide for Integrated Cockpits in Part 23* (Sept. 30, 2004).

- AC 23.1309-1E, *System Safety Analysis and Assessment for Part 23 Airplanes* (Nov. 17, 2011).
- AC 23.1311-1C, *Installation of Electronic Displays in Part 23 Airplanes* (Nov. 17, 2011).
- AC 25-11B, *Electronic Flight Displays* (Oct. 7, 2014).
- AC 25.1302-1, *Installed Systems and Equipment for Use by the Flightcrew* (May 3, 2013).
- AC 25.1309-1B, *System Design and Analysis* (Sept. 3, 2024).
- AC 25.1322-1, *Flightcrew Alerting* (Dec. 13, 2010).
- AC 25.1329-1C, *Approval of Flight Guidance Systems* (May 24, 2016).
- AC 90-48E, *Pilot's Role in Collision Avoidance* (Oct. 20, 2022).
- AC 90-120, *Operational Use of Airborne Collision Avoidance Systems* (Nov. 20, 2024).

B.3 FAA Technical Standard Order (TSO) References

A current list of TSOs can be found on the FAA's online DRS at <http://drs.faa.gov>. The TSO Index of Articles can be found at the same site.

- TSO-C10c, *Pressure Altimeter System* (Oct. 13, 2016).
- TSO-C88b, *Automatic Pressure Altitude Reporting Code-Generating Equipment* (Feb. 6, 2007).
- TSO-C106a, *Air Data Computer* (Oct. 16, 2020).
- TSO-C112f, *Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment* (March 10, 2023).
- TSO-C113b, *Airborne Multipurpose Electronic Displays* (Sept. 17, 2018).
- TSO-C119e, *Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II with Hybrid Surveillance* (June 30, 2016) (Historical).
- TSO-C145e, *Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite Based Augmentation System* (May 5, 2017).
- TSO-C165b, *Electronic Map Display Equipment for Graphical Depiction of Aircraft Position (Own-Ship)* (Nov. 28, 2018).
- TSO C195c, *Avionics Supporting Automatic Dependent Surveillance – Broadcast (ADS B) Aircraft Surveillance Applications (ASA)* (June 15, 2023).
- TSO-C196b, *Airborne Supplemental Navigation Sensors for Global Positioning System Equipment using Aircraft-Based Augmentation* (Dec. 20, 2013).
- TSO-C198, *Automatic Flight Guidance and Control System (AFGCS) Equipment* (June 2, 2011).

- TSO-C201, *Attitude Heading Reference System* (July 26, 2012).
- TSO-C219a, *Airborne Collision Avoidance System (ACAS) Xa/Xo* (Dec. 1, 2023).

B.4 Industry Material References

B.4.1 RTCA, Inc. Documents

Order RTCA, Inc. documents online at www.rtca.org.

- RTCA DO-178C, *Software Considerations in Airborne Systems and Equipment Certification* (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). RTCA DO-185B, *Minimum Operational Performance Standards for TCAS II* (June 19, 2008), including Change 1 (July 1, 2009) and Change 2 (March 20, 2013).
- RTCA DO-229F, *Minimum Operational Performance Standards for Global Positioning System/Satellite-Based Augmentation System Airborne Equipment* (June 11, 2020).
- RTCA DO-254, *Design Assurance Guidance for Airborne Electronic Hardware* (April 9, 2000).
- RTCA DO-260C, *Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Services-Broadcast (TIS-B)* (Dec. 17, 2020), including Change 1 (Jan. 25, 2022).
- RTCA DO-300A, *Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System (TCAS II) Hybrid Surveillance* (March 20, 2013), including Change 1 (Dec. 15, 2015).
- RTCA DO-317B, *Minimum Operational Performance Standards for Aircraft Surveillance Applications* (June 17, 2014).
- RTCA DO-317C, *Minimum Operational Performance Standards for Aircraft Surveillance Applications (ASA) System* (June 11, 2020).
- RTCA DO-325, *Minimum Operational Performance Standards for Automatic Flight Guidance and Control System and Equipment* (Dec. 8, 2010).
- RTCA DO-334, *Minimum Operational Performance Standards Attitude Heading and Reference Systems* (March 21, 2012).
- RTCA DO-337, *Recommendations for Future Collision Avoidance Systems* (March 21, 2012).
- RTCA DO-382, *Minimum Aviation System Performance Standards (MASPS) for Interoperability of Airborne Collision Avoidance Systems (CAS)* (Sept. 10, 2020).

- RTCA DO-385A, *Minimum Operational Performance Standards for Airborne Collision Avoidance System X (ACAS X) (ACAS Xa and ACAS Xo)*, Volumes I and II (June 22, 2023).

B.4.2 SAE International

Order SAE documents from SAE International online at www.sae.org.

- ARP 926B, *Fault/Failure Analysis Procedure* (June 11, 1997).
- ARP 1834A, *Fault/Failure Analysis for Digital Systems and Equipment* (June 1, 1997).
- ARP 4102/7, *Electronic Displays* (July 1, 1988).
- ARP 4102/8A, *Flight Deck Head-Up Displays* (Nov. 1, 1998).
- ARP 4754B, *Guidelines for Development of Civil Aircraft and Systems* (Dec. 20, 2023).
- ARP 4761A, *Guidelines for Conducting the Safety Assessment Process on Civil Aircraft, Systems, and Equipment* (Dec. 20, 2023).

B.4.3 Aeronautical Radio, Inc. (ARINC)

ARINC 735(), *Mark 2 Traffic Alert and Collision Avoidance System (TCAS)* is related to this AC. Publications are available online at <https://aviation-ia.sae-itc.com/product-categories/arinc-standards>.

B.4.4 International Civil Aviation Organization (ICAO)

Airborne Collision Avoidance System (ACAS) Manual document 9863, Third Edition (2021) is related to this AC. Publications are available from ICAO online at <http://www.icao.int>.

APPENDIX C. DEFINITIONS AND ACRONYMS**C.1 Definitions**

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

- C.1.1 Active Surveillance - Using ACAS interrogations and subsequent replies to update or acquire an ACAS track.
- C.1.2 Advisory - An alert for conditions that require flightcrew awareness and may require subsequent flightcrew response for collision avoidance.
- C.1.3 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.
- C.1.4 Alert - Indication (aural or visual) meant to attract the attention of and identify to the flightcrew information relevant to collision avoidance.
- C.1.5 Automatic Dependent Surveillance Broadcast (ADS-B) - 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 (1090ES) and the universal access transceiver (UAT) broadcast on 978 MHz.
- C.1.6 Coast - Condition which occurs when ACAS does not receive a reply to an interrogation from an intruder for which it has established a track, resulting in the logic continuing the track based on previous track characteristics.
- C.1.7 Collision Avoidance - A function used to provide alerts to indicate the need to take immediate action by generating a recommended maneuver to limit the risk of collision with all threats.
- C.1.8 Corrective Resolution Advisory - Advises the pilot to either deviate from the current vertical rate, such as CLIMB when the aircraft is level. (A “Maintain Rate RA” is classified as a corrective RA solely to provide a green fly-to arc or zone on a vertical speed indicator.)
- C.1.9 Discrete - Separate, complete, and distinct signal.
- C.1.10 Failure - Inability of a system, subsystem, unit, or part to perform within previously specified limits.
- C.1.11 False Resolution Advisory - RA caused by a false track or ACAS malfunction; i.e. when no actual threat aircraft is present in the ACAS alerting envelope.

- C.1.12 Hybrid Surveillance - Combined use of active and validated ADS-B passive surveillance to update an ACAS track.
- C.1.13 Incorrect Resolution Advisory - RA occurring when a threat is present, but, because of a failure of the installed ACAS, Mode S transponder, or associated sensors, commands a maneuver that reduces separation to the threat or increases collision risk with the ground.
- C.1.14 Intruder - A transponder- or ADS-B-equipped aircraft within the surveillance range of the ACAS for which the ACAS has an established track.
- C.1.15 Missing Resolution Advisory - An RA that does not occur, or that occurs later than the ACAS logic indicates is necessary, when a threat is present, with no indication to the flightcrew that the system is unable to generate an RA. A missing RA may occur on ownship, the other aircraft, or both during an encounter.
- C.1.16 Mode A - A type of ATCRBS transmission which requests (via Mode A interrogations) or reports (via Mode A replies) aircraft identity information.
- C.1.17 Mode C - A type of ATCRBS transmission which requests (via Mode C interrogations) or reports (via Mode C replies) aircraft altitude information.
- C.1.18 Mode S - A type of secondary surveillance radar transmission which contains a unique ICAO 24-bit aircraft address, thus allowing interrogations to be addressed to individual aircraft. Mode S transmissions can be short (56 bits) or long (112 bits), with long transmissions containing a 56-bit “message” field.
- C.1.19 Other Traffic - Aircraft more than ± 1200 feet vertical or 6 nautical miles (NM) from own aircraft that are neither involved in a TA or RA with ownship.
- C.1.20 Passive Surveillance - The use of ADS-B messages to update an ACAS track.
- C.1.21 Preventive Resolution Advisory - A resolution advisory that instructs a pilot to avoid certain deviations from the current vertical rate (for example, a Do Not Climb RA when the aircraft is level).
- C.1.22 Proximate Traffic - Aircraft within 6 NM in range and within $\pm 1,200$ feet vertically from own aircraft, but does not meet the ACAS thresholds of a TA or RA.
- C.1.23 Resolution Advisory (RA) - Aural voice and display given to the pilot recommending a vertical maneuver, or in some cases no maneuver, to either increase or maintain the existing vertical separation relative to an intruding aircraft, in order to avoid a collision with the intruding aircraft.
- C.1.24 Resolution Advisory Display - A display depicting vertical speeds and/or pitch to “fly to” or avoid to comply with an active ACAS RA.

- C.1.25 Sense - A direction that an RA may take relative to the existing flight path of own aircraft.
- C.1.26 Threat - An intruder that satisfies the threat detection logic and thus requires an RA.
- C.1.27 Track - Estimated position and velocity of a single aircraft based on surveillance data reports.
- C.1.28 Traffic - Aircraft capable of being tracked and displayed by an ACAS-equipped aircraft.
- C.1.29 Traffic Advisory (TA) - Aural voice and display information given to the pilot pertaining to the presence or position of another aircraft in the immediate vicinity. The information contains no suggested maneuver.
- C.1.30 Traffic Display – Shows the horizontal position and altitude of traffic relative to the ACAS equipped aircraft.

C.2 **Acronyms**

- | | | |
|--------|-----------------------|---|
| C.2.1 | <u>14 CFR</u> | Title 14 of the Code of Federal Regulations |
| C.2.2 | <u>AC</u> | Advisory Circular |
| C.2.3 | <u>ACAS</u> | Airborne Collision Avoidance System |
| C.2.4 | <u>ACAS X</u> | Family of ACAS systems using risk ratios (as opposed to directly encoded algorithms) to determine the threat of other traffic and what measures might be taken to avoid a collision |
| C.2.5 | <u>ACAS Xa</u> | ACAS X variant used for fixed wing aircraft |
| C.2.6 | <u>ACAS Xo</u> | ACAS X variant used for “operations” |
| C.2.7 | <u>ACB</u>
Office) | Aircraft Certification Branch (formerly ACO, Aircraft Certification |
| C.2.8 | <u>ADS-B</u> | Automatic Dependent Surveillance – Broadcast |
| C.2.9 | <u>AEH</u> | Aircraft Electronic Hardware |
| C.2.10 | <u>AFM</u> | Airplane Flight Manual |
| C.2.11 | <u>AFMS</u> | Airplane Flight Manual Supplement |
| C.2.12 | <u>AGL</u> | Above Ground Level |
| C.2.13 | <u>AOTO</u> | ADS-B Only TA-ONLY |

C.2.14	<u>AP</u>	Autopilot
C.2.15	<u>ATC</u>	Air Traffic Control
C.2.16	<u>ATCRBS</u>	Air Traffic Control Radar Beacon System
C.2.17	<u>CDTI</u>	Cockpit Display of Traffic Information
C.2.18	<u>CPA</u>	Closest Point of Approach
C.2.19	<u>CSPO-3000</u>	Closely Spaced Parallel Runway Operations down to 3000 feet
C.2.20	<u>DAL</u>	Development Assurance Level or Design Assurance Level
C.2.21	<u>dB</u>	Decibel
C.2.22	<u>DNA</u>	Designated No Alert
C.2.23	<u>FAA</u>	Federal Aviation Administration
C.2.24	<u>FD</u>	Flight Director
C.2.25	<u>FM</u>	Flight Manual
C.2.26	<u>FMS</u>	Flight Manual Supplement
C.2.27	<u>fpm</u>	Feet Per Minute
C.2.28	<u>FTA</u>	Fault Tree Analysis
C.2.29	<u>GHz</u>	Gigahertz
C.2.30	<u>GPS</u>	Global Positioning System
C.2.31	<u>GPWS/TAWS</u> System	Ground Proximity Warning System/Terrain Awareness Warning
C.2.32	<u>HF</u>	Human Factors
C.2.33	<u>HUD</u>	Head-up Display
C.2.34	<u>ICAO</u>	International Civil Aviation Organization
C.2.35	<u>MHz</u>	Megahertz
C.2.36	<u>MOPS</u>	Minimum Operational Performance Standards
C.2.37	<u>MSL</u>	Mean Sea Level

C.2.38	<u>NM</u>	Nautical Mile
C.2.39	<u>POH</u>	Pilot Operating Handbook
C.2.40	<u>RA</u>	Resolution Advisory
C.2.41	<u>RVSM</u>	Reduced Vertical Separation Minimum
C.2.42	<u>RWC</u>	Remain Well Clear
C.2.43	<u>SSA</u>	System Safety Assessment
C.2.44	<u>STC</u>	Supplemental Type Certificate
C.2.45	<u>TA</u>	Traffic Advisory
C.2.46	<u>TC</u>	Type Certificate
C.2.47	<u>TCAS</u>	Traffic Alert and Collision Avoidance System
C.2.48	<u>TSO</u>	Technical Standard Order
C.2.49	<u>TSOA</u>	Technical Standard Order Authorization
C.2.50	<u>VSI</u>	Vertical Speed Indicator

APPENDIX D. TRANSPONDER INTEROPERABILITY TESTING**D.1 Tests using a DO-181E Transponder**

The following tests are derived from those contained in RTCA/DO-181E.

D.1.1 Procedure #30: Sensitivity Level Operation

This test verifies that the transponder (1) accepts incoming UF=20, 21 interrogations containing a Sensitivity Level Command Message and passes all necessary information (IIS and SLC subfields) to the ACAS unit, and (2) receives sensitivity level information from the ACAS unit and correctly reports this information in outgoing DF=0, 16 replies.

1. Command the ACAS into “TA/RA” mode via a control interface. Simulate ownship as airborne (radio altitude invalid) with a pressure altitude of 15,000 ft.

Interrogate the transponder with a UF=0 and a UF=16 non-acquisition interrogation.

Show that the transponder correctly reports the ACAS status (RI=3) and sensitivity level (SL=6 for TCAS II, SL=3 for ACAS Xa) in the DF=0 and DF=16 replies.

2. Interrogate the transponder with a UF=20 interrogation containing a Sensitivity Level Command Message (ADS1=0, ADS2=5, and TMS=0) with IIS=1 and SLC=4.

Show that the IIS and SLC subfields are correctly output on the transponder/ACAS interface.

3. Interrogate the transponder with a UF=21 interrogation containing a Sensitivity Level Command Message with IIS=15 and SLC=5.

Show that the IIS and SLC subfields are correctly output on the transponder/ACAS interface.

4. Send a sensitivity level=4 to the transponder via the transponder/ACAS interface. Interrogate the transponder with a UF=0 and a UF=16 non-acquisition interrogation.

Show that the transponder correctly reports the ACAS status (RI=3) and sensitivity level (SL=4 for TCAS II, SL=3 for ACAS Xa) in the DF=0 and DF=16 replies.

D.1.2 Procedure #31: Transmission of RA Report to Mode S Sensor

This test verifies that the transponder correctly (1) receives RA information from the ACAS unit, (2) indicates to the ground (DR field in DF=4, 5, 20, and 21 replies) that it has information awaiting downlink, (3) transmits this information in DF=20, 21 replies, (4) retains RA information for 18 ± 1 seconds following the end of the RA, and (5) properly indicates the end of the RA via the RA Terminated indicator.

Note: The tests refer to a “TCAS bit” in the DR field of DF=4, 5, 20, and 21 replies. The TCAS bit is interpreted herein as bit 12 of the 5-bit (bits 9 – 13) DR field. That is,

if DR=2, 3, 6, or 7, then the “TCAS bit” is set, and the transponder is therefore indicating that it has ACAS information available.

1. ARA=0 and RAC=0:

Ensure ownship ICAO address is greater than 0x111111. Power up the system. Command the ACAS into “TA/RA” mode via a control interface. Simulate ownship as airborne (radio altitude invalid) with a pressure altitude of 15,000 ft. Verify no RA is being generated. Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the ‘TCAS bit’ in the DR field is not set in the DF=4, 5, 20, and 21 replies.

2. ARA≠0 and RAC≠0:

Simulate a TCAS II equipped intruder with the following parameters:

- Distance from Ownship: ≤ 0.70 nautical miles
- Pressure Altitude: 14,800 ft
- Relative Bearing: 0 degrees
- ICAO Address: 0x111111
- CA: 6 (Air state unknown)
- FS: 2 (Alert, airborne)
- SL: 6
- RI: 3 (RA-capable)

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=1, CHC=0, HRC=0, and VSB=14.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the ‘TCAS bit’ in the DR field is set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19.

Show that the ‘TCAS bit’ in the DR field is set in the DF=20 and 21 replies.

Show that the RA report fields are correctly reported in the DF=20 and 21 replies as listed below:

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
‘11000010000000’	‘1000’	0	0	1	0x111111

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
'1000100000'	0	1	'1000'	0	0	0	1	0x111111	0	0

Stop simulating the intruder.

Interrogate the transponder once per second for the next 30 seconds with a UF=4 interrogation with RR=19.

Show that for 18 ± 1 seconds after the end of the RA, the 'TCAS bit' in the DR field in the reply remains set, and that the RA report fields are correctly reported in the DF=20 replies as listed below.

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
'11000010000000'	'1000'	1	0	1	0x111111

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
'1000100000'	0	1	'1000'	1	0	0	1	0x111111	0	0

Show that after 18 ± 1 seconds, the 'TCAS bit' in the DR field in the reply is not set and that the RA report fields are correctly reported in the DF=20 replies as listed below.

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
0	0	0	0	0	0

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
0	0	1	0	0	0	0	0	0	0	0

3. ARA $\neq$ 0 and RAC=0:

Simulate a Mode C intruder with the following parameters:

- Distance from Ownship: 0.0625 nautical miles to 0.25 nautical miles
- Pressure Altitude: 15,200 ft
- Relative Bearing: 0 degrees

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the ‘TCAS bit’ in the DR field is set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19.

Show that the ‘TCAS bit’ in the DR field is set in the DF=20 and 21 replies.

Show that the RA report fields are correctly reported in the DF=20 and 21 replies as listed below:

TCAS II:

ARA (bits 41-54)	RAC (55-58)	RAT (59)	MTE (60)	TTI (61-62)	TIDA (63-75)	TIDR (76-82)	TIDB (83-88)
‘11100010000000’	0	0	0	2	‘1101000000000’	*	**

* Not equal to 0 and equal to the value provided by the ACAS on the transponder/ACAS interface.

** Equal to the value provided by the ACAS on the transponder/ACAS interface.

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TIDA (63-73)	TIDR (74-80)	TIDB (81-86)	DSI (87)	SPI (88)
‘1010100000’	0	1	0	0	0	0	0	‘00010100011’	*	**	0	0

* Not equal to 0 and equal to the value provided by the ACAS on the transponder/ACAS interface.

** Equal to the value provided by the ACAS on the transponder/ACAS interface.

Stop simulating the intruder.

Interrogate the transponder once per second for the next 30 seconds with a UF=4 interrogation with RR=19.

Show that for 18 ± 1 seconds after the end of the RA, the ‘TCAS bit’ in the DR field in the reply remains set, and that the RA report fields are correctly reported in the DF=20 replies listed below:

TCAS II:

ARA (bits 41-54)	RAC (55-58)	RAT (59)	MTE (60)	TTI (61-62)	TIDA (63-75)	TIDR (76-82)	TIDB (83-88)
'11100010000000'	0	1	0	2	'1101000000000'	*	**

* Not equal to 0 and equal to the value provided by the ACAS on the transponder/ACAS interface.

** Equal to the value provided by the ACAS on the transponder/ACAS interface.

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TIDA (63-73)	TIDR (74-80)	TIDB (81-86)	DSI (87)	SPI (88)
'1010100000'	0	1	0	1	0	0	0	'00010100011'	*	**	0	0

* Not equal to 0 and equal to the value provided by the ACAS on the transponder/ACAS interface.

** Equal to the value provided by the ACAS on the transponder/ACAS interface.

Show that after 18 ± 1 seconds, the 'TCAS bit' in the DR field in the reply is not set and the RA report fields are correctly reported in the DF=20 replies listed below.

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
0	0	0	0	0	0

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
0	0	1	0	0	0	0	0	0	0	0

4. ARA=0 and RAC≠0:

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=1, CHC=0, HRC=0, and VSB=14. Repeat this interrogation one second later.

Show that RAC='1000' in the transponder DF=16 reply to the second UF=16 interrogation.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the 'TCAS bit' in the DR field is not set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19.

Show that the ‘TCAS bit’ in the DR field is not set in the DF=20 and 21 replies.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=1, VRC=0, CHC=0, HRC=0, and VSB=11. Repeat this interrogation one second later.

Show that RAC=’0000’ in the transponder DF=16 replies to the second UF=16 interrogation.

Interrogate the transponder once per second for the next 20 seconds with a UF=4 interrogation with RR=19.

Show that the ‘TCAS bit’ in the DR field in the replies is not set.

D.1.3 Procedure #32: Transmission of ACAS Capability Information to a Mode S Sensor

This test verifies that the transponder receives operational information from its associated ACAS unit and correctly reports this information in Data Link Capability Reports to a Mode S sensor and in special surveillance replies to another ACAS aircraft.

1. Command the transponder/ACAS in altitude reporting mode via a control interface (i.e. transponder in altitude reporting mode and ACAS in standby).
2. Interrogate the transponder with a non-acquisition UF=0 interrogation.

Show that the transponder replies with the correct capability information in the DF=0 reply (i.e., RI=0).

3. Interrogate the transponder with the following four interrogations:

- UF=4 with RR=17 and DI 7;
- UF=5 with RR=17 and DI 7;
- UF=20 with RR=17, DI=7, and RRS=0;
- UF=21 with RR=17, DI=7, and RRS=0.

Show, in each of the four cases, that the transponder replies with the correct capability information in the DF=20, 21 replies (i.e., BDS1=1, BDS2=0, bit 48=0, and bits 69, 70, 71, and 72 = 0000).

4. Repeat the procedures in steps D.1.3.2 and D.1.3.3 above for each of the following 2 cases:

- i. Command the ACAS in TA-ONLY mode via a control interface.

Show that the transponder replies with RI=2 in the DF=0 reply.

Show that the transponder replies with bit 48=1 and bits 69, 70, 71, and 72=’1001’ in the DF=20, 21 replies.

- ii. Command the ACAS into “TA/RA” mode via a control interface.

Show that the transponder replies with RI=3 in the DF=0 reply.

Show that the transponder replies with bit 48=1 and bits 69, 70, 71, and 72=’1101’ in the DF=20, 21 replies.

D.1.4 Procedure #34: Coordination

This test verifies that the transponder (1) accepts incoming UF=16 interrogations containing a TCAS Resolution Message and passes all necessary information to the ACAS unit, and (2) receives coordination information from the ACAS unit and correctly reports this information in outgoing DF=16 replies.

Ensure ownship ICAO address is greater than 0x999999. Power up the system. Command the ACAS into “TA/RA” mode via a control interface. Simulate ownship as airborne (radio altitude invalid) with a pressure altitude of 15,000 ft. Verify no RA is being generated. Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=2, CHC=0, HRC=0, VSB=7, and HSB=0.

1. Show that the transponder sends a DF=16 reply with VDS=48, ARA=0, RAC=0, RAT=0, and MTE=0.

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

2. Simulate a TCAS II equipped intruder with the following parameters:

- Distance from Ownship: ≤ 0.70 nautical miles
- Pressure Altitude: 14,700 ft
- Relative Bearing: 0 degrees
- ICAO Address: 0x999999
- CA: 6 (Air state unknown)
- FS: 2 (Alert, airborne)
- SL: 6
- RI: 3 (RA-capable)

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=2, CHC=0, HRC=0, VSB=7, and HSB=0.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
0	‘0100’	0	0	1	0x999999

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)

0	0	1	'0100'	0	0	0	1	0x999999	0	0
---	---	---	--------	---	---	---	---	----------	---	---

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

- Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=2, VRC=0, CHC=0, HRC=0, VSB=13, and HSB=0.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
'11100110000000'	'0100'	0	0	1	0x999999

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
'1110100000'	0	1	'0100'	0	0	0	1	0x999999	0	0

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

- Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=2, VRC=0, CHC=0, HRC=0, VSB=13, and HSB=0.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
'11100110000000'	0	0	0	1	0x999999

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
'1110100000'	0	1	0	0	0	0	1	0x999999	0	0

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

- Stop simulating the intruder. The RA will terminate.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=1, CHC=0, HRC=0, VSB=14, and HSB=0.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

TCAS II:

ARA (bits 41-54)	RAC (55-58)	RAT (59)	MTE (60)	TTI (61-62)	TID (63-88)
'11100110000000'	0	1	0	1	0x999999

OR

ARA (41-54)	RAC (55-58)	RAT (59)	MTE (60)	TTI (61-62)	TID (63-88)
0	0	1	0	0	0

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
'1110100000'	0	1	0	1	0	0	1	0x999999	0	0

OR

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
0	0	1	0	1	0	0	0	0	0	0

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

D.1.5 Procedure #36: Transponder Replies to Incoming TCAS Resolution Messages

This test verifies that:

- Whenever the transponder replies with a valid Coordination Reply Message to an incoming TCAS Resolution Message, the incoming message is successfully delivered to the ACAS unit; and
 - Whenever the transponder's internal queue is full or some other condition is present which would prevent delivery of the message to the ACAS, the transponder does not reply with a valid Coordination Reply Message to an incoming TCAS Resolution Message and does not pass the incoming data to the ACAS.
1. Command the ACAS into "TA/RA" mode via a control interface. Interrogate the transponder with a UF=16 interrogation containing a valid TCAS Resolution Message when all of the following conditions are true: the transponder is reporting

that it has an operational ACAS; no transponder queues are full; and no ACAS failure conditions exist.

Demonstrate that the transponder transmits a valid Coordination Reply Message and that the incoming coordination information is correctly output on the transponder/ACAS interface.

2. Interrogate the transponder with a UF=16 interrogation containing a valid TCAS Resolution Message when an ACAS failure condition is present (the transponder is reporting no resolution advisory capability).

Demonstrate that the transponder does not send a valid Coordination Reply Message and does not output the incoming coordination information on the transponder/ACAS interface.

Demonstrate that when an ACAS failure is present, the transponder still replies to interrogations that do not contain information directed to the transponder/ACAS interface.

Note: When the transponder does not send a valid reply, it may either send no reply or send a DF=16 interrogation with all 56 bits of the MV field equal to ZERO.

D.1.6 Procedure #37: Transponder/ACAS Throughput

This test verifies that the interrogation input rate requirement and the reply rate limiting requirement referenced above are met by the transponder. In addition, this test is important for demonstrating that the transponder's internal structures (e.g., queues, timing) have been designed in such a way that they are compatible with any ACAS unit with which the transponder is paired.

1. Command the ACAS into “TA/RA” mode via a control interface. Interrogate the transponder with UF=16 interrogations for 5 seconds at a continuous rate of 16.6 milliseconds, i.e., 60 interrogations per second.

Demonstrate that the transponder accepts all interrogations, transmits a valid reply to each interrogation, and correctly outputs the information on the transponder/ACAS interface in the order that it was received by the transponder.

2. Interrogate the transponder with UF=16 interrogations for 5 seconds at a rate greater than that at which the transponder can accept all interrogations.

Note: In some installations, interrogating at a high rate with all UF=16 interrogations causes the transponder's internal queue to fill, thus stopping the transponder's acceptance of and reply to interrogations because of the full queue, rather than because of the reply rate limiting. If this is the case, it is necessary to interrogate the transponder with a mix of short and long interrogations; this mix should include the largest number of UF=16 interrogations that is possible while at the same time avoiding any queue overflow. This will allow the reply rate limiting feature to be tested.

Demonstrate that the reply rate limiting feature is exercised (i.e., there is a mechanism which recognizes the high interrogation rate and stops the transponder

from accepting and replying to replies before the transponder overheats or otherwise becomes adversely affected).

Demonstrate that the transponder can accept and reply to at least the number of interrogations specified in RTCA/DO-181E §2.2.13.3.1.c.

Demonstrate that for each accepted interrogation, and only for each accepted interrogation, the transponder transmits a valid reply and correctly outputs the information on the transponder/ACAS interface in the order that it was received by the transponder.

D.2 Tests using a DO-181F Transponder

The following tests are derived from those contained in RTCA/DO-181F.

D.2.1 Procedure #30: Sensitivity Level Operation

This test verifies that the transponder receives sensitivity level information from the ACAS unit and correctly reports this information in outgoing DF=0, 16 replies.

1. Command the ACAS into “TA/RA” mode via a control interface. Simulate ownship as airborne (radio altitude invalid) with a pressure altitude of 15,000 ft.

Interrogate the transponder with a UF=0 and a UF=16 non-acquisition interrogation.

Show that the transponder correctly reports the ACAS status (RI=3) and sensitivity level (SL=6 for TCAS II, SL=3 for ACAS Xa) in the DF=0 and DF=16 replies.

2. Reduce ownship pressure altitude to 4000 ft. Interrogate the transponder with a UF=0 and a UF=16 non-acquisition interrogation.

Show that the transponder correctly reports the ACAS status (RI=3) and sensitivity level (SL=4 for TCAS II, SL=3 for ACAS Xa) in the DF=0 and DF=16 replies.

3. Simulate ownship radio altitude to a value less than 1000 ft.

Interrogate the transponder with a UF=0 and a UF=16 non-acquisition interrogation.

Show that the transponder correctly reports the ACAS status (RI=2) and sensitivity level (SL=2) in the DF=0 and DF=16 replies.

4. Command the ACAS into standby mode via a control interface.

Interrogate the transponder with a UF=0 and a UF=16 non-acquisition interrogation.

Show that the transponder correctly reports the ACAS status (RI=0) and sensitivity level (SL=1) in the DF=0 and DF=16 replies.

D.2.2 Procedure #31: Transmission of RA Report for a Transponder Operating with an RTCA/DO-185A/B or DO-385A Compatible ACAS

These tests verify that when the ACAS only provides BDS=48 content to the transponder (i.e. no BDS=49 content is provided), the transponder sends replies to interrogations with RR=19, DI=7, and RRS=1. All of the following tests check that the BDS=49 content is zeroed out in the replies.

1. Test the initial condition:

Ensure ownship ICAO address is greater than 0x111111. Power up the system. Command the ACAS into “TA/RA” mode via a control interface. Simulate ownship as airborne (radio altitude invalid) with a pressure altitude of 15,000 ft. Verify no RA is being generated. Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the ‘TCAS bit’ in the DR field is not set in the DF=4, 5, 20, and 21 replies.

2. Test RAI=0 and RAI=1 with the first RA, and with bit values corresponding to ARA≠0 and RAC≠0:

Simulate a TCAS II equipped intruder with the following parameters:

- Distance from Ownship: ≤ 0.70 nautical miles
- Pressure Altitude: 14,800 ft
- Relative Bearing: 0 degrees
- ICAO Address: 0x111111
- CA: 6 (Air state unknown)
- FS: 2 (Alert, airborne)
- SL: 6
- RI: 3 (RA-capable)

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=1, CHC=0, HRC=0, and VSB=14.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the ‘TCAS bit’ in the DR field is set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19, DI=7, and RRS=0 paired with UF=4, 5, 20, and 21 interrogations with RR=19, DI=7, and RRS=1.

Show that the ‘TCAS bit’ in the DR field is set in the DF=20 and 21 replies.

Show that the BDS=48 fields are reported correctly in DF=20 and 21 replies as follows:

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
'11000010000000'	'1000'	0	0	1	0x111111

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
'1000100000'	0	1	'1000'	0	0	0	1	0x111111	0	0

Show that bits 41-88 are 0 in DF=20 and 21 replies containing BDS=49.

Stop simulating the intruder.

Interrogate the transponder once per second for the next 30 seconds with a UF=4 interrogation with RR=19, DI=7, and RRS=0 paired with a UF=4 interrogation with RR=19, DI=7, and RRS=1.

Show that for 18 ± 1 seconds after the end of the RA, the 'TCAS bit' in the DR field of the DF=20 replies remains set and that the BDS=48 fields are reported correctly in DF=20 replies as follows:

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
'11000010000000'	'1000'	1	0	1	0x111111

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
'1000100000'	0	1	'1000'	1	0	0	1	0x111111	0	0

Show that bits 41-88 are 0 in DF=20 and 21 replies containing BDS=49.

Show that after 18 ± 1 seconds, the 'TCAS bit' in the DR field of the DF=20 replies is not set and that the BDS=48 fields are reported correctly in DF=20 replies as follows:

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
0	0	0	0	0	0

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
0	0	1	0	0	0	0	0	0	0	0

Show that bits 41-88 are 0 in DF=20 and 21 replies containing BDS=49.

3. Test with RAI=0 and RAI=1, with bit values corresponding to ARA≠0 and RAC=0:

Simulate a Mode C intruder with the following parameters:

- Distance from Ownship: 0.0625 nautical miles to 0.25 nautical miles
- Pressure Altitude: 15,200 ft
- Relative Bearing: 0 degrees

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the ‘TCAS bit’ in the DR field is set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19, DI=7, and RRS=0 paired with UF=4, 5, 20, and 21 interrogations with RR=19, DI=7, and RRS=1.

Show that the ‘TCAS bit’ in the DR field is set in the DF=20 and 21 replies.

Show that the RA report fields are correctly reported in the DF=20 and 21 replies as listed below:

TCAS II:

ARA (bits 41-54)	RAC (55-58)	RAT (59)	MTE (60)	TTI (61-62)	TIDA (63-75)	TIDR (76-82)	TIDB (83-88)
’11100010000000’	0	0	0	2	’1101000000000’	*	**

* Not equal to 0 and equal to the value provided by the ACAS on the transponder/ACAS interface.

** Equal to the value provided by the ACAS on the transponder/ACAS interface.

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TIDA (63-73)	TIDR (74-80)	TIDB (81-86)	DSI (87)	SPI (88)
’1010100000’	0	1	0	0	0	0	0	’00010100011’	*	**	0	0

* Not equal to 0 and equal to the value provided by the ACAS on the transponder/ACAS interface.

** Equal to the value provided by the ACAS on the transponder/ACAS interface.

Show that bits 41-88 are 0 in DF=20 and 21 replies containing BDS=49.

Stop simulating the intruder.

Interrogate the transponder once per second for the next 30 seconds with a UF=4 interrogation with RR=19, DI=7, and RRS=0 paired with a UF=4 interrogation with RR=19, DI=7, and RRS=1.

Show that for 18 ± 1 seconds after the end of the RA, the ‘TCAS bit’ in the DR field in the reply remains set, and that the RA report fields are correctly reported in the DF=20 replies as listed below:

TCAS II:

ARA (bits 41-54)	RAC (55-58)	RAT (59)	MTE (60)	TTI (61-62)	TIDA (63-75)	TIDR (76-82)	TIDB (83-88)
‘11100010000000’	0	1	0	2	‘1101000000000’	*	**

* Not equal to 0 and equal to the value provided by the ACAS on the transponder/ACAS interface.

** Equal to the value provided by the ACAS on the transponder/ACAS interface.

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TIDA (63-73)	TIDR (74-80)	TIDB (81-86)	DSI (87)	SPI (88)
‘1010100000’	0	1	0	1	0	0	0	‘00010100011’	*	**	0	0

Show that bits 41-88 are 0 in DF=20 and 21 replies containing BDS=49.

Show that after 18 ± 1 seconds, the ‘TCAS bit’ in the DR field in the reply is not set and the RA report fields are correctly reported in the DF=20 replies listed below.

TCAS II:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
0	0	0	0	0	0

ACAS Xa:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
0	0	1	0	0	0	0	0	0	0	0

Show that bits 41-88 are 0 in DF=20 and 21 replies containing BDS=49.

- Test RAI=1 with no prior RA, and bit values corresponding RAC≠0 and then RAC=0:

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=1, CHC=0, HRC=0, and VSB=14. Repeat this interrogation one second later.

Show that RAC='1000' in the transponder DF=16 reply to the second UF=16 interrogation.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations.

Show that the 'TCAS bit' in the DR field is not set in the DF=4, 5, 20, and 21 replies.

Interrogate the transponder with UF=4, 5, 20, and 21 interrogations with RR=19, DI=7, and RRS=0 paired with UF=4, 5, 20, and 21 interrogations with RR=19, DI=7, and RRS=1.

Show that the 'TCAS bit' in the DR field is not set in the DF=20 and 21 replies.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=1, VRC=0, CHC=0, HRC=0, and VSB=11. Repeat this interrogation one second later.

Show that RAC='0000' in the transponder DF=16 reply to the second UF=16 interrogation.

Interrogate the transponder once per second for the next 20 seconds with a UF=4 interrogation with RR=19, DI=7, RRS=0 paired with a UF=4 interrogation with RR=19, DI=7, RRS=1.

Show that the 'TCAS bit' in the DR field in the DF=20 replies is not set.

D.2.3 Procedure #32: Transmission of ACAS Capability Information to a Mode S Sensor and to other ACAS Aircraft for a Transponder Capable of Being Loaded Directly by ACAS

This test verifies that the transponder receives operational information from its associated ACAS unit and correctly reports this information in Data Link Capability Reports to a Mode S sensor and in special surveillance replies to another ACAS aircraft.

1. Command the transponder/ACAS in altitude reporting mode via a control interface (i.e. transponder in altitude reporting mode and ACAS in standby).
2. Interrogate the transponder with a non-acquisition UF=0 interrogation.

Show that the transponder replies with the correct capability information in the DF=0 reply (i.e., RI=0).

3. Interrogate the transponder with the following four interrogations:

- UF=4 with RR=17 and DI≠7;
- UF=5 with RR=17 and DI≠7;
- UF=20 with RR=17, DI=7, and RRS=0;
- UF=21 with RR=17, DI=7, and RRS=0.

Show, in each of the four cases, that the transponder replies with the correct capability information in the DF=20, 21 replies (i.e., BDS1=1, BDS2=0, bits 43, 44, 45, and 46 = 0000, bit 48=0, and bits 69, 70, 71, and 72 = 0000).

4. Repeat the procedures in Steps 2 and 3 above for each of the following cases in sub-step i and ii below. For each case use the following values for validating that the ACAS version is correctly reported in the Data Link Capability Report:

DO-185B / ED-143 TCAS II: Bits 43 – 46: 0000, Bits 71, 72: 01

DO-385A / ED-256A ACAS Xa: Bits 43 – 46: 0001, Bits 71, 72: 11

- i. Command the ACAS into “TA/RA” mode via a control interface.

Show that the transponder replies with RI=2 in the DF=0 reply.

Show that the transponder replies with bits 43, 44, 45, 46, 71 and 72 reporting the correct ACAS version, bit 48=1, bit 69=1 and bit 70=0 in the DF=20, 21 replies.

- ii. Command the ACAS into “TA/RA” mode via a control interface.

Show that the transponder replies with RI=3 in the DF=0 reply.

Show that the transponder replies with bits 43, 44, 45, 46, 71 and 72 reporting the correct ACAS version, bit 48=1, bit 69=1 and bit 70=1 in the DF=20, 21 replies.

D.2.4 Procedure #34: Coordination

This test verifies that the transponder (1) accepts incoming UF=16 interrogations containing a TCAS Resolution Message and passes all necessary information to the ACAS unit, and (2) receives coordination information from the ACAS unit and correctly reports this information in outgoing DF=16 replies.

D.2.4.1 **Procedure #34: Coordination for a Transponder Operating with an RTCA/DO-185A/B Compatible ACAS**

1. Ensure ownship ICAO address is greater than 0x999999. Power up the system. Command the ACAS into “TA/RA” mode via a control interface. Simulate ownship as airborne (radio altitude invalid) with a pressure altitude of 15,000 ft. Verify no RA is being generated. Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=2, CHC=0, HRC=0, VSB=7, and HSB=0.

Show that the transponder sends a DF=16 reply with VDS=48, ARA=0, RAC=0, RAT=0, and MTE=0.

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

2. Simulate a TCAS II equipped intruder with the following parameters:
 - Distance from Ownship: < 0.80 nautical miles

- Pressure Altitude: 14,700 ft
- Relative Bearing: 0 degrees
- ICAO Address: 0x999999
- CA: 6 (Air state unknown)
- FS: 2 (Alert, airborne)
- SL: 6
- RI: 3 (RA-capable)

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=2, CHC=0, HRC=0, VSB=7, and HSB=0.

Note: To produce a valid test result, this UF=16 interrogation must be sent when the intruder is initially simulated and therefore before the RA is generated by the ACAS under test. The expected DF=16 reply contents assume the reply occurs before the RA is initiated.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
0	'0100'	0	0	1	0x999999

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

- Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=2, VRC=0, CHC=0, HRC=0, VSB=13, and HSB=0.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
'11100110000000'	'0100'	0	0	1	0x999999

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

- Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=2, VRC=0, CHC=0, HRC=0, VSB=13, and HSB=0.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
'11100110000000'	0	0	0	1	0x999999

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

5. Stop simulating the intruder. The RA will terminate.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=1, CHC=0, HRC=0, VSB=14, and HSB=0.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

ARA (bits 41-54)	RAC (bits 55-58)	RAT (bit 59)	MTE (bit 60)	TTI (bits 61-62)	TID (bits 63-88)
0	0	1	0	0	0

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

D.2.4.2 Procedure #34: Coordination for a Transponder Operating with an RTCA/DO-385A Compatible ACAS Xa

1. Ensure ownship ICAO address is greater than 0x999999. Power up the system. Command the ACAS into “TA/RA” mode via a control interface. Simulate ownship as airborne (radio altitude invalid) with a pressure altitude of 15000 ft. Verify no RA is being generated. Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=2, CHC=0, HRC=0, VSB=7, and HSB=0.

Show that the transponder sends a DF=16 reply with VDS=48, ARA=0, RAC=0, RAT=0, and MTE=0.

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

2. Simulate a TCAS II equipped intruder with the following parameters:
 - Distance from Ownship: < 0.70 nautical miles
 - Pressure Altitude: 14,800 ft
 - Relative Bearing: 0 degrees
 - ICAO Address: 0x999999
 - CA: 6 (Air state unknown)
 - FS: 2 (Alert, airborne)

- SL: 6
- RI: 3 (RA-capable)

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=2, CHC=0, HRC=0, VSB=7, and HSB=0.

Note: To produce a valid test result, this UF=16 interrogation must be sent when the intruder is initially simulated and therefore before the RA is generated by the ACAS under test. The expected DF=16 reply contents assume the reply occurs before the RA is initiated.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

ARA (bits 41-50)	LDI (51- 52)	RMF (53- 54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
0	0	1	'0100'	0	0	0	1	0x999999	0	0

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=2, VRC=0, CHC=0, HRC=0, and VSB=13.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

ARA (bits 41-50)	LDI (51- 52)	RMF (53- 54)	RAC (55- 58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
'1110100000'	0	1	'0100'	0	0	0	1	0x999999	0	0

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

- Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=2, VRC=0, CHC=0, HRC=0, VSB=13, and HSB=0.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

ARA (bits 41-50)	LDI (51- 52)	RMF (53- 54)	RAC (55- 58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
'1110100000'	0	1	0	0	0	0	1	0x999999	0	0

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

- Stop simulating the intruder. The RA will terminate.

Interrogate the transponder with a UF=16 interrogation with UDS=48, MTB=0, CVC=0, VRC=0, CHC=0, HRC=0, and VSB=0.

Show that the transponder sends a DF=16 reply with VDS=48 and the following fields:

ARA (bits 41-50)	LDI (51-52)	RMF (53-54)	RAC (55-58)	RAT (59)	MTE (60)	CNT (61)	TTI (62)	TID (63-86)	DSI (87)	SPI (88)
0	0	1	0	1	0	0	0	0	0	0

Show that the coordination information in the MU field is correctly output on the transponder/ACAS interface.

D.2.5 Procedure #36: Transponder Replies to Incoming TCAS Resolution Messages

This test verifies that:

- Whenever the transponder replies with a valid Coordination Reply Message to an incoming TCAS Resolution Message, the incoming message is successfully delivered to the ACAS unit; and
 - Whenever the transponder's internal queue is full or some other condition is present which would prevent delivery of the message to the ACAS, the transponder does not reply with a valid Coordination Reply Message to an incoming TCAS Resolution Message and does not pass the incoming data to the ACAS.
1. Command the ACAS into “TA/RA” mode via a control interface. Interrogate the transponder with a UF=16 interrogation containing a valid TCAS Resolution Message when all of the following conditions are true: the transponder is reporting that it has an operational ACAS; no transponder queues are full; and no ACAS failure conditions exist.

Demonstrate that the transponder transmits a valid Coordination Reply Message and that the incoming coordination information is correctly output on the transponder/ACAS interface.

2. Interrogate the transponder with a UF=16 interrogation containing a valid TCAS Resolution Message when an ACAS failure condition is present (the transponder is reporting no resolution advisory capability). Demonstrate that the transponder does not send a valid Coordination Reply Message and does not output the incoming coordination information on the transponder/ACAS interface.

Demonstrate that when an ACAS failure is present the transponder still replies to interrogations that do not contain information directed to the transponder/ACAS interface.

Note: When the transponder does not send a valid reply, it may either send no reply or send a DF=16 reply with all 56 bits of the MV field equal to ZERO.

D.2.6 Procedure #37: Transponder/ACAS Throughput and Delivery of Messages to ACAS

This testing verifies correct operation of the transponder in high-density coordination situations. The first four scenarios test that, in the presence of significant numbers of 1030 MHz TCAS Broadcast Interrogation Messages, the transponder provides TCAS Resolution Messages (1030 MHz discretely addressed coordination interrogations) to the ACAS in a timely manner.

Verification associated with these tests may be accomplished through internal data recording, monitoring of interface data if applicable, or other methods proposed by the manufacturer.

D.2.6.1 Scenario A

This test verifies that the transponder can receive and process incoming TCAS Resolution Messages and TCAS Broadcast Interrogation Messages under the maximum unique TCAS Resolution Messages and TCAS Broadcast Interrogation Messages.

Command the ACAS into “TA/RA” mode via a control interface.
Interrogate the Mode S transponder with the following:

- 50 Unique TCAS Broadcast Interrogation Messages, followed by,
- 6 Unique TCAS Resolution Messages.

All transmitted within a 100-msec burst every second for 10 seconds.

UF=16 MU Field Contents TCAS Resolution Message									
UDS	MTB	CVC	VRC	CHC	HRC	HSB	VSF	MID	Timing
48	0	0	2	0	0	0	7	1	1 per second
48	0	0	1	0	0	0	14	2	1 per second
48	0	0	2	0	0	0	7	3	1 per second
48	0	0	1	0	0	0	14	4	1 per second
48	0	0	2	0	0	0	7	5	1 per second
48	0	0	1	0	0	0	14	6	1 per second
UF=16 MU Field Contents TCAS Broadcast Interrogation Message									
UDS	MID								Timing
50	1								1 per second
50	2								1 per second

UF=16 MU Field Contents TCAS Resolution Message									
UDS	MTB	CVC	VRC	CHC	HRC	HSB	VSF	MID	Timing
...									
50	50							1 per second	

Verify that:

1. The transponder replies to all 6 of the TCAS Resolution Messages and successfully transmits data to the ACAS for all 6 messages in the order input to the transponder.
2. The first TCAS Resolution Message data is received by the ACAS within 10 ms of receipt by the transponder.
3. Data for the remaining 5 TCAS Resolution Messages are transmitted to the ACAS as quickly as the interface permits and that any waiting TCAS Resolution Message is given priority on the interface over any waiting TCAS Broadcast Interrogation Messages.
4. All TCAS Broadcast Interrogation Message data is successfully transmitted to the ACAS.

D.2.6.2 Scenario B

This test verifies that the transponder is able to receive and process incoming TCAS Resolution Messages and TCAS Broadcast Interrogation Messages under the maximum re-interrogation rate and transponder to ACAS transmission rate.

Command the ACAS into “TA/RA” mode via a control interface. Interrogate the Mode S transponder with the following:

- 10 Unique TCAS Broadcast Interrogation Messages, followed by,
- 1 TCAS Resolution Message.

The 11-message block is transmitted 6 times (i.e., 66 messages) within a 100 ms burst every second for 10 seconds.

During every one-second interval, each TCAS Resolution Message and each TCAS Broadcast Interrogation Message have a unique MID subfield as shown below.

UF=16 MU Field Contents TCAS Resolution Message									
UDS	MTB	CVC	VRC	CHC	HRC	HSB	VS	MID	Timing
48	0	0	2	0	0	0	7	1	1 per second
48	0	0	1	0	0	0	14	2	1 per second
48	0	0	2	0	0	0	7	3	1 per second
48	0	0	1	0	0	0	14	4	1 per second
48	0	0	2	0	0	0	7	5	1 per second
48	0	0	1	0	0	0	14	6	1 per second
UF=16 MU Field Contents TCAS Broadcast Interrogation Message									
UDS	MID								Timing
50	1								1 per second
50	2								1 per second
...									
50	60								1 per second

Verify that:

1. The transponder replies to all 6 of the TCAS Resolution Messages and successfully transmits data to the ACAS in the order input to the transponder within 10 ms of receipt by the transponder.
2. All TCAS Broadcast Interrogation Message data is successfully transmitted to the ACAS.

D.3 Aircraft Based/Test Bench Interoperability Tests

CAUTION: When ground testing ACAS and/or transponder systems, it is necessary to take precautions to prevent being a source of interference to ATC or other ACAS aircraft operating in the area. False ACAS and/or ADS-B In indications of “intruder aircraft” could result in unnecessary ATC communications or in ACAS induced aircraft maneuvers. Conduct such testing in coordination with ATC and use antenna shielding on the transponder antenna (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, radiated testing can be used provided that the altitude reported by the traffic system via Mode C, Mode S, and ADS-B all provide altitude at ground level.

D.3.1 Sensitivity Level (SL Field) & Reply Information (RI Field) Reporting

Goal: Verify that the ACAS system correctly reports the Sensitivity Levels (SL) and Air-to-Air Reply Information (RI) when in “ACAS STANDBY”, “TA-ONLY”, and “TA/RA” modes of operation. Additionally, verify that the transponder receives operational information from its associated ACAS and correctly reports the ACAS Operational Status in outgoing ADS-B Aircraft Operational Status Messages.

1. Use the pilot control to put the ACAS system in “TA/RA” mode. Interrogate the transponder with a UF=16 non-acquisition interrogation.

Verify that SL is reported as a value between 3-7 in the transponder’s reply.

Verify that RI = 3 (On-board ACAS with resolution capability) in the transponder’s reply.

2. Use the pilot control to put the ACAS system in “TA-ONLY” mode. Interrogate the transponder with a UF=16 non-acquisition interrogation.

Verify that SL is unchanged from the value in step a for TCAS II units and a value of 2 for ACAS Xa units.

Verify that RI = 2 (On-board ACAS with resolution advisory capability inhibited) in the transponder’s reply.

3. Use the pilot control to put the ACAS system in “ALT ON” mode or “ACAS Standby” (the transponder is on and reporting altitude; the ACAS function is in standby). Interrogate the transponder with a UF=0 non-acquisition interrogation.

Verify that RI = 0 (No-Operating ACAS) in the transponder’s reply.

4. With the ACAS system still in “ALT ON” or “ACAS Standby” mode, monitor Register 6,5 Aircraft Operational Status Message.

Verify that the “Collision Avoidance Operational” bit = 0 (Bit 11 of the ME field) in the ADS-B Operational Status Message.

5. Use the pilot control to put the ACAS system in “TA-ONLY” mode.

Verify that the “Collision Avoidance Operational” bit = 0 (Bit 11 of the ME field) in the ADS-B Operational Status Message.

6. Via the ACAS/transponder interface, set the ACAS unit in “TA/RA” mode.

Verify that the “Collision Avoidance Operational” bit = 1 (Bit 11 of the ME field) in the ADS-B Operational Status Message.

D.3.2 ACAS Capability Information

Goal: Verify that correct ACAS capability information is inserted into the transponder’s Register 1,0, Data Link Capability Report. Additionally for version 3 or beyond ADS-B transmitting systems, verify that the transponder receives capability information from

its associated ACAS and correctly reports Collision Avoidance Coordination Capability information in outgoing ADS-B Aircraft Operational Status Messages.

Note: To perform this test correctly, during the following steps D.3.2.1 through D.3.2.6, it is necessary to monitor the transponder's Data Link Capability Report (Register 1,0) and decode information from the MB field. In referencing specific bits of the MB field "bit 1" is the first bit of the MB field. One method of extracting this data is to interrogate the transponder with a UF=4 interrogation with RR=17. The MB field of the DF=20 response will have this data.

1. Use the pilot control to put the ACAS system in "ALT ON" or "ACAS Standby" mode (the transponder is on and reporting altitude; the ACAS function is in standby). Interrogate the transponder and extract Register 1,0, Data Link Capability Reports.

Verify that the "CAS Out of Standby" bit = 0 (Bit 16 of the MB field).

2. Use the pilot control to put the ACAS system in "TA-ONLY" mode.

Verify that the "CAS Out of Standby" bit = 1 (Bit 16 of the MB field).

Verify that the "CAS RA/TA Capability" bit = 0 (Bit 38 of the MB field).

3. Use the pilot control to put the CAS system in "TA/RA" mode.

Verify that the "CAS Out of Standby" bit = 1 (Bit 16 of the MB field).

Verify that the "CAS RA/TA Capability" bit = 1 (Bit 38 of the MB field).

4. Bits 11-14 and 39-40 of the MB field are used to convey ACAS capability information.

Note: Details of these bits can be found in § 2.2.3.9.3.2.3.2.1 of RTCA DO-185B and § 2.2.3.8.3.2.3.2.1 of RTCA DO-385A. In these documents the bits are shown as the bits of the response and not of the MB field; as such they are shown in the MOPS as bits 43-46, and 71-72; subtract 32 from the bit number in the MOPS to find the bit number in the MB field.

Verify proper value for bits 11-14 and bits 39-40 are shown for the installation on the aircraft:

MB Field Bits	TSO-C119c,d,e TCAS	TSO-C219a ACAS Xa
11-14	0000 = Non-extended version	0001 = ACAS Xa Version 1(1)
39-40	1,0 = RTCA/DO-185B and ED-143	1,1 = CAS Extended Version Number

⁽¹⁾ An RTCA/DO-181E transponder will report this as 0000; this field was not previously defined.

5. Turn off the GPS unit(s) supplying position to the ACAS system.

Verify that the “CAS Hybrid Surveillance Capability” bit = 0 (Bit 37 of the MB field; hybrid surveillance not fitted).

6. Turn on the GPS unit(s) supplying position to the ACAS system, allow it to obtain a position fix, and monitor Register 1,0, Data Link Capability Report.

Verify that the “CAS Hybrid Surveillance Capability” bit = 1 (Bit 37 of the MB field; hybrid surveillance fitted).

If the system does not have a Version 3 ADS-B Out transmitting system, this test ends here.

Note: The next steps require monitoring Aircraft Operational Status Messages (Register 6,5) and decoding information from the ME field. In referencing specific bits of the ME field “bit 1” is the first bit of the ME field.

7. Monitor bits 23-24, 33-34, 35-37, & 38-39 of Register 6,5, the Aircraft Operational Status Message.

Note: Details of these bits can be found in § 2.2.3.2.7.2.4.8 of RTCA DO-260C. They convey Collision Avoidance Coordination capability information. In DO-260C the bits are shown as the bits of the squitter and not of the ME field; as such they are shown in the MOPS as bits 55-56, 65-66, 67-69 & 70-71; subtract 32 from the bit number in the MOPS to find the bit number in the MB field.

Verify that proper values for bits 23-24, 33-34, 35-37, & 38-39 of the ME field are shown for the installation of the aircraft.

ME Field Bits	TSO-C119c/d/e	TSO-C219a
23-24	00 = No RWC capability or no capability of the RWC function to receive TCAS Resolution Messages or ADS-B OCMs	00 = No RWC capability or no capability of the RWC function to receive TCAS Resolution Messages or ADS-B OCMs
33-34	00 = Vertical Only	00 = Vertical Only
35-37	000 = Active CAS (TCAS II) or no CAS	001 = Active CAS (not TCAS II)
38-39	00 = Reserved	

D.3.3 RA Message Pass Through & Transmission of RA Report by Transponder

Goals: Verify correct operation of the ACAS/transponder interface in both directions, i.e., transponder->ACAS and ACAS->transponder. Verify that the transponder reports RA information in the appropriate format.

Note 1: This test requires monitoring RA Reports (Register 3,0) and decoding information from the MB field. In referencing specific bits of the MB field “bit 1” is the

first bit of the MB field. One method of extracting this data is to interrogate the transponder with a UF=4 interrogation with RR=19.

Note 2: Scenario A sets up an encounter between ownship and an ACAS-equipped intruder, resulting in a Climb sense RA. Scenario A verifies that RA Report information is correctly passed from the ACAS to the transponder and transmitted in outgoing transponder DF=20 RA Reports. Scenario B uses the same encounter geometry, but results in a Descend sense RA because the intruder is the master (has the lower Mode S address) and has previously transmitted a coordination interrogation containing ‘Do not pass above.’ Scenario B verifies both that incoming coordination information is correctly passed from the transponder to the ACAS and that RA Report information is correctly passed from the ACAS to the transponder and transmitted in outgoing transponder DF=20 RA Reports.

D.3.3.1 Scenario A

This test verifies that ownship selects a Climb sense RA and correctly reports this information in outgoing RA Reports.

1. “Climb” scenario

Input:

Own:	Z	= 12,200 ft	at T = 0
	ZDOT	= 0 fpm	from T = 0 to 90
Int1:	Equip	= TCAS II	
	R	= 6.2 NM	at T = 0
	RDOT	= -360 kt	from T = 0 to 90
	Z	= 12,000 ft	from T = 0 to 90
	ZDOT	= 0 fpm	from T = 0 to 90
	Intruder Mode S address = 0x000001		

For this test ensure the ACAS unit is in “TA/RA” mode. Interrogate the transponder with UF=4 interrogations with RR=19 and receive DF=20 responses.

Verify that the DR field in the DF=20 response from the transponder is NOT equal to 2, 3, 6, or 7 before any resolution advisory information has been received from the ACAS unit.

Verify DR field in the DF=20 reply is equal to 2, 3, 6, or 7 as soon as an RA is issued.

Verify that the DR field in the DF=20 reply is equal to 2, 3, 6, or 7 for about 18 seconds immediately after the RA has been removed.

Verify that the DR field in the DF=20 reply is NOT equal to 2, 3, 6, or 7 after the previous verification.

2. Repeat the Step 1 “Climb” scenario while monitoring Register 3,0. Bits 9-56 of the MB field are used to convey subfields in MB for RA reports.

Note 1: Details of these bits can be found in § 2.2.3.9.3.2.3.1.1 of RTCA DO-185B and § 2.2.3.8.3.2.3.1 of RTCA DO-385A. In these documents the bits are shown as the bits of the response and not of the MB field; as such they are shown in the MOPS as bits 41-88; subtract 32 from the bit number in the MOPS to find the bit number in the MB field.

Verify proper value for bits 9 – 56 are shown for the installation on the aircraft.

Note 2: For the following tables, the subfields within the bits indicated with an asterisk (*) are dependent upon the ACAS version.

Note 3: For the following tables, an ‘X’ indicates a “Don’t Care” bit (may be either a 0 or a 1).

- i. While there is no RA information available:

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	000000000000000000	000000000000000000
RAT (bit 27)	0	
Bits 28-30*	000	
Threat Address (31 -54)	000000000000000000000000	
Bits 55-56*	00	

- ii. While the RA is active:

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	110000100000000000	100010000000010000
RAT (bit 27)	0	
Bits 28-30*	001	
Threat Address (31 -54)	000000000000000000000001	
Bits 55-56*	00	

- iii. For about 18 seconds after the RA is removed:

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	110000100000000000	100010000000010000
RAT (bit 27)	1	
Bits 28-30*	001	
Threat Address (31 -54)	00000000000000000000000000000001	
Bits 55-56*	00	

iv. Following the 18 seconds, the information in Table 1 is again reported.

3. Via the ACAS/transponder interface set the ACAS unit in “TA-ONLY” mode and repeat the D.3.3.1.1 “Climb” scenario. Interrogate the transponder with UF=4 with RR=19 interrogations and receive DF=20 responses.

Verify DR field in the DF=4 reply is never equal to 2, 3, 6, or 7 and that no RA is ever issued.

4. Repeat the D.3.3.1.1 “Climb” scenario while monitoring Aircraft Status Subtype 2 (Register 6,1 Subtype 2).

Verify the following:

While there is no RA information available, this squitter does not exist (there is no data).

a. While the RA is active:

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	110000100000000000	100010000000010000
RAT (bit 27)	0	
Bits 28-30*	001	
Threat Address (31 -54)	00000000000000000000000000000001	
Bits 55-56*	00	

b. For about 25 seconds after the RA is removed

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	110000100000000000	100010000000010000
RAT (bit 27)	1	
Bits 28-30*	001	
Threat Address (31 -54)	000000000000000000000001	
Bits 55-56*	00	

c. After about 25 seconds after the RA is removed, there is no squitter (the count of the squitter stops incrementing).

D.3.3.2 Scenario B

This test verifies that ownship selects a Descend sense RA and correctly reports this information in outgoing RA Reports.

1. “Descend” scenario

Input:

Own: Z = 12,200 ft at T = 0
 ZDOT = 0 fpm from T = 0 to 90
 Own Mode S address is higher than ABC12316

Int1: Equip = TCAS II
 R = 6.2 NM at T = 0
 RDOT = -360 kt from T = 0 to 90
 Z = 12,000 ft from T = 0 to 90
 ZDOT = 0 fpm from T = 0 to 90
 Intruder Mode S address = 0x000001

Msg: UF=16 containing VRC = ‘do not pass above’ (see table below)

UF=16 MU Field Contents									
TCAS Resolution Message									
UDS	MTB	CVC	VRC	CHC	HRC	HSB	VSb	MID	Timing
48	0	0	2	0	0	0	7	1	From T = 0 to 90

In hex the full MU field is “30 08 00 07 00 00 01”.

For this test ensure the ACAS unit is in “TA/RA” mode. Interrogate the transponder with UF=4 interrogations with RR=19 and receive DF=20 responses.

Verify that the DR field in the DF=20 response from the transponder is NOT equal to 2, 3, 6, or 7 before any resolution advisory information has been received from the ACAS unit.

Verify DR field in the DF=20 reply is equal to 2, 3, 6, or 7 as soon as an RA is issued.

Verify that the DR field in the DF=20 reply is equal to 2, 3, 6, or 7 for about 18 seconds immediately after the RA has been removed.

Verify that the DR field in the DF=20 reply is NOT equal to 2, 3, 6, or 7 after the previous verification.

2. Repeat the same “Descend” scenario.

Verify that bits 9 – 56 in the DF=20 reply are correct for the installation on the aircraft.

Note 1: Bits 9-56 of the MB field are used to convey subfields in MB for RA Reports. Details of these bits can be found in § 2.2.3.9.3.2.3.1.1 of RTCA DO-185B and § 2.2.3.8.3.2.3.1 of RTCA DO-385A. In these documents the bits are shown as the bits of the response and not of the MB field; as such they are shown in the MOPS as bits 41-88; subtract 32 from the bit number in the MOPS to find the bit number in the MB field.

Note 2: For the following tables, the subfields within the bits indicated with an asterisk (*) are dependent upon the ACAS version.

Note 3: For the following tables, an ‘X’ indicates a “Don’t Care” bit (may be either a 0 or a 1).

Note 4: Ownship may select different Descend-sense RAs depending on the precise geometry and surveillance noise instantiated during this test. The expected output in Scenario B allows for either a corrective Descend or a preventive Descend-sense Monitor Vertical Speed, as either RA type verifies that ownship selects a Descend sense RA based on received coordination messages.

i. While there is no RA information available:

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	000000000000000000	000000000000000000
RAT (bit 27)	0	
Bits 28-30*	000	
Threat Address (31 -54)	000000000000000000000000000000	
Bits 55-56*	00	

ii. While the RA is active:

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	111001100000000100	111010000000010100
RAT (bit 27)	0	
Bits 28-30*	001	
Threat Address (31 -54)	00000000000000000000000001	
Bits 55-56*	00	

- OR – (see Note 4 above):

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	1010000000000000100	101000100000010100
RAT (bit 27)	0	
Bits 28-30*	001	
Threat Address (31 -54)	000000000000000000000001	
Bits 55-56*	00	

- iii. For about 18 seconds after the RA is removed:

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	1110011000000000100	111010000000010100
RAT (bit 27)	1	
Bits 28-30*	001	
Threat Address (31 -54)	00000000000000000000000000000001	
Bits 55-56*	00	

- OR – (see Note 4 above)

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	1010000000000000100	101000100000010100
RAT (bit 27)	1	
Bits 28-30*	001	
Threat Address (31 -54)	000000000000000000000000000001	
Bits 55-56*	00	

- iv. Following the 18 seconds, the information in Table 1 is again reported.

3. Via the ACAS/transponder interface set the ACAS unit in “TA-ONLY” mode and repeat the D.3.3.2.1 “Descend” scenario. Interrogate the transponder with UF=4 with RR=19 interrogations and receive DF=20 responses.

Verify DR field in the DF=4 reply is never equal to 2, 3, 6, or 7 and that no RA is ever issued.

4. Repeat the D.3.3.2.1 “Descend” scenario while monitoring Aircraft Status Subtype 2 (Register 6,1 Subtype 2).

Verify the following:

- i. While there is no RA information available, this squitter does not exist (there is no data).
- ii. While the RA is active:

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	111001100000000100	111010000000010100
RAT (bit 27)	0	
Bits 28-30*	001	
Threat Address (31 -54)	00000000000000000000000000000001	
Bits 55-56*	00	

- OR (see Note 4 above)-

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	101000000000000100	101000100000010100
RAT (bit 27)	0	
Bits 28-30*	001	
Threat Address (31 -54)	00000000000000000000000000000001	
Bits 55-56*	00	

- iii. For about 25 seconds after the RA is removed:

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	111001100000000100	111010000000010100
RAT (bit 27)	1	
Bits 28-30*	001	
Threat Address (31 -54)	00000000000000000000000000000001	
Bits 55-56*	00	

- OR (see Note 4 above)-

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	101000000000000100	101000100000010100
RAT (bit 27)	1	
Bits 28-30*	001	
Threat Address (31 -54)	00000000000000000000000000000001	
Bits 55-56*	00	

- iv. After about 25 seconds after the RA is removed, there is no squitter (the count of the squitter stops incrementing).

D.3.4 Robust Transponder and ACAS Throughput

Goal: Validate the interrogation input rate requirement is met by the system.

Note: Part of this test requires verification that the ACAS has received all the messages from the transponder. There are various ways of doing this – any of which are acceptable. For example, either of the following are acceptable:

- The ACAS manufacturer provides debug output from the unit detailing the messages it receives from the transponder.
- The A429 busses between the transponder and the ACAS are “broken out” and recorded.

Other ways may also be acceptable. It is not enough to show that the transponder has processed the message; it is necessary to show that the message has been accepted by the ACAS system.

1. Enable the ACAS/transponder interface and put the ACAS unit in “TA/RA” mode.
2. Interrogate the transponder with UF = 16 interrogations for 30 seconds at a continuous rate 60 interrogations per second with an MU field that will cause it to be passed to the ACAS unit. One such MU field is (in hex) “30 00 00 00 00 00 00”.

Verify the transponder reply rate does not drop below 99% over the entire interval.

Verify the system never shows an ACAS failure.

Verify that the ACAS system has received all 60 of these messages every second. It is acceptable to only evaluate the last 10 seconds of the test.

If the system has a RTCA/DO-181E or prior transponder, this test ends here.

3. Interrogate the transponder with UF = 16 interrogations for 30 seconds at a continuous rate that brings the transponder reply rate between $30\% < x < 70\%$ with an MU field that will cause it to be passed to the ACAS unit.

Verify the system never shows an ACAS failure over the entire interval.

Verify that the ACAS system has received 60 or more messages every second for at least the last 10 seconds of the test.

D.4 Transmission of ADS-B TCAS RA Broadcast

Goal: Verify that the transponder transmits ADS-B TCAS RA Broadcasts in the correct format and at the appropriate times. This test sets up an encounter between ownship and an ACAS-equipped intruder, resulting in a Climb sense RA, and verifies that ADS-B TCAS RA Broadcasts are correctly transmitted.

Input:

Own: Z = 12,200 ft at T = 0
 ZDOT = 0 fpm from T = 0 to 90
 Int1: Equip = TCAS II
 R = 6.2 NM at T = 0
 RDOT = -360 kt
 Z = 12,000 ft
 ZDOT = 0 fpm
 Intruder Mode S address = 0x000001

For this test ensure the ACAS unit is in “TA/RA” mode.

Note 1: Details of the bits in the expected output can be found in § 2.2.3.8.3.2.10.1 of RTCA DO-385A. In these documents, the bits are shown as the bits of the response and not of the ME field; as such they are shown in the MOPS as bits 41-88; subtract 32 from the bit number in the MOPS to find the bit number in the ME field.

Note 2: For the following tables, the subfields within the bits indicated with an asterisk (*) are dependent upon the ACAS version.

Ensure that DF=17 ADS-B TCAS RA Broadcast Messages are transmitted with the following data:

1. While there is no RA active, DF=17 ADS-B TCAS RA Broadcast Messages are not transmitted.

2. While there is an RA active, DF=17 ADS-B TCAS RA Broadcast Messages are transmitted with the following data (see Note 1):

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	11000010000000000000	100010000000010000
RAT (bit 27)	1	
Bits 28-30*	001	
Threat Address (31 -54)	000000000000000000000001	
Bits 55-56*	00	

3. For about 25 seconds after the RA is removed, DF=17 ADS-B TCAS RA Broadcast Messages are transmitted with the following data:

	TSO C119c,d,e TCAS II	TSO C219a ACAS Xa
Bits 9-26*	11000010000000000000	100010000000010000
RAT (bit 27)	1	
Bits 28-30*	001	
Threat Address (31 -54)	000000000000000000000001	
Bits 55-56*	00	

4. After about 25 seconds after the RA is removed, DF=17 ADS-B TCAS RA Broadcast Messages are not transmitted. Allow the test to run for 90 seconds after the RA ends to ensure no spurious DF=17 messages are transmitted.