U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Airworthiness Approval of Traffic Alert And Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders

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FOREWORD

This advisory circular (AC) provides applicants guidance for obtaining an airworthiness approval for traffic alert collision avoidance systems (TCAS II). It also provides guidance for certification of a stand-alone Mode S transponder system. This AC includes the TCAS II version 7.0 plus the new version 7.1 and performance standards for the optional functionality of TCAS II hybrid surveillance.

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Chapter 1. General Information.

1-1. Purpose of this Advisory Circular.

a. We've written this advisory circular (AC) to guide applicants seeking airworthiness approval for traffic alert and collision avoidance systems (TCAS II) version 7.1 that are certified to technical standard order (TSO)-C119c, Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment TCAS II and associated Mode S transponders. Guidance is also provided for those applicants seeking airworthiness approval for stand-alone Mode S transponders that are certified to technical standard order (TSO)-C112c, Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment. The guidance presented in this AC can also be used for those seeking airworthiness approval for traffic alert and collision avoidance systems (TCAS II) version 7.0 that are certified to TSO-C119b, Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment TCAS II and associated Mode S transponders.

b. This AC is not mandatory and does not constitute a regulation. In it, we describe an acceptable means, though it is not the only means, to gain airworthiness approval of TCAS II versions 7.0 and 7.1 systems. However, if you use the means described, you must follow it in all important respects.

1-2. Who does this AC apply to? Applicants seeking a type certificate (TC), amended type certificate (ATC), or supplemental type certificate (STC) under Title 14 of the Code of Federal Regulation (14 CFR) part 25 for initial approval and follow-on approvals of TCAS II equipment or stand alone Mode S transponder equipment. References to 14 CFR part 25 are appropriate when TCAS II is installed on transport category airplanes. When TCAS II is to be certified for non-transport category airplanes, use the equivalents to the above 14 CFR part 25 sections in other parts of the regulations. Although this AC is intended for TCAS II installed on transport category airplanes, it provides useful guidance for part 23 installations when the equivalent Advisory Circulars and sections of 14 CFR part 23 are referenced.

1-3. Cancellation. This revision cancels AC-20-151.

1-4. Significant Changes. This AC has been revised to accommodate the changes of TCAS version 7.1, incorporate lessons learned since the original AC, and add policy for optional hybrid surveillance.

1-5. Scope.

a. In this AC, we cover design aspects, characteristics, mechanization, testing, and the criticality of system failure cases for TCAS II Versions 7.0 and 7.1 and associated Mode S transponders. Our guidance is directed at systems that provide traffic advisories (TAs) and resolution advisories (RAs) in the vertical sense only (TCAS II), and where operational

performance standards are defined in technical documents developed by a joint air transport industry-government group (the RTCA, Inc. Special Committee SC-147).

b. We also cover optional functionality, such as TCAS II hybrid surveillance, that can be included in a TCAS II system.

c. We do not cover traffic symbology for traffic displays in which TCAS and ASAS (Airborne Separation Assistance System) are integrated.

d. We do not cover Mode S Extended Squitter or Mode S Elementary/Enhanced surveillance.

(1) For guidance on Mode S Elementary surveillance, refer to JAA Temporary Guidance Leaflet (TGL) 13 Revision 1, Certification of Mode S Transponder Systems for Elementary Surveillance.

(2) For guidance on Mode S Enhanced surveillance, refer to AMC 20-13, Certification of Mode S Transponder Systems for Enhanced Surveillance.

(3) AC guidance for Mode S extended Squitter, also known as automatic dependant surveillance – broadcast (ADS-B), is being developed. Until such time as this guidance material is available, contact the cognizant Aircraft Certification Office (ACO) for more information.

1-6. Recent TCAS Developments.

a. Since the early 1990s, an operational evaluation known as the TCAS Transition Program (TTP) collected and analyzed data on the performance and use of TCAS II in both the U.S. National Airspace System (NAS) 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 version 7.0, were implemented by industry in the late 1990s. TCAS II version 7.0 complies with the International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARP) for ACAS II. TCAS II V7.0 is mandated for carriage in Australia, India and certain European countries and was mandated for carriage in 2003 by ICAO. In addition, if you operate an aircraft that is equipped with TCAS II in RVSM airspace, it must be a TCAS II that meets TSO-C119b (version 7.0) or a later version.

b. Investigation of operational problems resulted in changes to TCAS II Version 7.0. The latest changes, known as V7.1, are now reflected in TSO-C119c.

c. While developing corrective action for the operational problems, the Federal Aviation Administration (FAA), along with industry representatives, decided to develop performance standards for TCAS II Hybrid Surveillance. That work resulted in creation of RTCA/DO-300, Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance.

Chapter 2. TCAS II System.

A. System Description.

2-1. What a TCAS System Is. TCAS II is an airborne traffic alert and collision avoidance system that interrogates ATC transponders in nearby aircraft and uses computer processing to identify and display potential and predicted collision threats. The system is designed to protect a volume of airspace around the TCAS II equipped aircraft. The system will provide appropriate aural and visual advisories to the flight crew to take action to ensure adequate separation when the computer analysis of the intruding aircraft transponder replies predict a penetration of the protected airspace.

2-2. System Advisories. The system provides two types of advisories.

a. Traffic advisories (TAs) indicate the relative positions of intruding aircraft that are approximately 40 seconds from the closest point of approach and may a short time later require a resolution advisory. TAs also give the flight crew the opportunity to visually acquire the intruding aircraft.

b. RAs provide a vertical avoidance maneuver to increase separation when the computer predicts the threat aircraft is within approximately 25 seconds from the closest point of approach.

2-3. System Flight Deck Displays. The system provides two types of flight deck displays:

a. A traffic display indicates the relative position of ATC transponder-equipped aircraft.

b. A resolution display for each pilot indicates the appropriate vertical maneuver to avoid a threat.

2-4. Mode S Transponder.

a. The TCAS II aircraft must be equipped with a Mode S ATC transponder, which provides air-to-air communications for coordinating the resolution maneuvers between TCAS II equipped aircraft.

b. The Mode S transponder also provides discrete-address replies to interrogations from ground stations and other aircraft equipped with TCAS II.

c. The TCAS II system can only generate RAs for intruders equipped with responding Mode S or Mode C transponders, which provide information on the altitude of the threat aircraft. Traffic advisories can be generated for any aircraft equipped with an operative Mode S or an air traffic control radar beacon system (ATCRBS) transponder, regardless of its ability to provide information on the intruder aircraft's altitude. We view TCAS II equipment as a supplement to the pilot who has the primary responsibility for avoiding midair collisions. The TCAS II system provides no indication of aircraft without operative transponders.

2-5. Hybrid Surveillance. Hybrid surveillance is an optional function of TCAS that is used as a means to decrease Mode S interrogations. Aircraft may use passive surveillance instead of active surveillance to track intruders that meet validation criteria and are not projected to be near-term collision threats. Active surveillance uses the standard TCAS transponder interrogation that provides range, bearing and altitude to the intruder. Passive surveillance uses data broadcast from other aircraft. Passive surveillance data is provided by an on-board navigation source, such as a global positioning system (GPS). The passive surveillance data is broadcast and received through the use of Mode S extended squitter, that is, 1090 megahertz (MHz) automatic dependent surveillance-broadcast (ADS-B). Hybrid surveillance does not degrade the performance of TCAS active surveillance. This is a requirement and is tested by ensuring that active surveillance performs as specified by the TCAS II performance standards.

B. System Components And Requirements.

2-6. Mode S Transponder.

a. A Mode S transponder is required for TCAS II operation. It is an enhanced version of ATCRBS transponders that is interoperable and compatible with the current ATCRBS. Each aircraft equipped with a Mode S transponder is assigned a discrete address code. Mode S also provides the air-to-air data link between TCAS II-equipped aircraft to coordinate resolution maneuvers. This ensures that the resolution advisory displayed in one TCAS II-equipped aircraft is compatible with the maneuver displayed in the other TCAS II equipped aircraft. It has the capability to provide a data link between the equipped aircraft and the ground, and performs all the functions of current ATCRBS transponders. A Mode S transponder may be installed independently or with a TCAS II installation. The performance standard for Mode S installed independently of TCAS is provided in technical standard order TSO-C112C, Requirements, paragraph 3.

b. The discrete aircraft address for the Mode S transponder must be obtained from the appropriate airworthiness authority of the country in which the aircraft is registered for each aircraft in which a Mode S transponder is installed. For U.S. registered aircraft, obtain the discrete aircraft address from the Federal Aviation Administration, Mike Monroney Aeronautical Center, Aircraft Registration Information, AFS-750, PO Box 25504, Oklahoma City, OK 73125, Telephone: (405) 954-3116.

Note: The ICAO 24-bit aircraft address is a uniquely assigned aircraft identification that also identifies the country of registration. For civil aircraft registered in the U.S., the ICAO 24-bit aircraft address is established as a function of the aircraft's registration number (for example, N1234A). There have been occurrences where two airplanes report identical ICAO 24-bit aircraft addresses. This problem can be caused when a change in registration numbers occurs. When an airplane's registration number is changed, the operator should verify that the ICAO 24-bit aircraft address and the new registration number have a one-to-one correspondence.

2-7. Pilot Control. A pilot control for the TCAS equipment shall be provided.

a. Provide a means to select the following:

(1) Operation of TCAS II in the TA/RA mode and Mode S transponder simultaneously.

(2) Operation of TCAS II in the TA mode and Mode S transponder simultaneously.

(3) Operation of TCAS II in the standby mode.

b. Also, provide the following additional features:

(1) A means to select the assigned ATCRBS (MODE A 4096) code.

(2) A means to initiate the transponder "IDENT" function.

(3) A means to initiate the TCAS II self-test.

(4) A means to suppress transponder altitude (Mode C) reporting.

c. The following optional controls may be provided:

(1) Selection of the weather radar only.

(2) Control to select the display of traffic within selected altitude bands.

(3) Selection of the weather radar and traffic display simultaneously.

(4) Selection of actual flight level (FL) or relative altitude of traffic.

(5) Selection of TCAS traffic information on multi-function displays.

2-8. Antennas. The Mode S transponder shall have a top and bottom omni-directional antenna (also know as diversity antennas). The TCAS II shall have a top directional antenna and a bottom omni-directional or directional antenna.

a. Directional antennas.

(1) For an aircraft installation, locate the TCAS II directional antenna on the top, forward fuselage as close to the centerline as possible.

(2) If more than one directional antenna is provided, locate the second antenna in a similar manner on the lower fuselage.

(3) Mount the TCAS II antennas on the aircraft with at least 20 decibel (dB) isolation from other L band frequency antennas.

(4) 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.

(5) The maximum height of the directional antenna is expected to be approximately 1 inch, and therefore is not considered susceptible to icing effects in the general area of the proposed installation. Otherwise, consider anti-icing provisions. RTCA/DO-185, Section 3, Volume I, provides antenna selection and performance criteria.

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

b. Omni-directional antennas. Mount the TCAS II 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 frequency antennas. Mount the Mode S transponder antennas at locations chosen for adequate isolation and signal coverage. These antennas may be standard ATCRBS transponder antennas.

c. Structural analysis. Submit a structural analysis of the antenna installations showing compliance with the applicable regulations of 14 CFR to the FAA.

2-9. The TCAS Processor. The TCAS II processor unit uses both transponder reply information and information from the aircraft to identify and to display potential and predicted collision threats, and to issue RAs to avoid the threat aircraft. The TCAS II processor unit must comply with the environmental requirements and minimum performance standards specified in TSO-C119b or TSO-C119c as applicable. A manufacturer of TSO equipment can obtain authorization to produce equipment that deviates from the detailed criteria of the TSO as provided for in 14 CFR § 21.609. The FAA ACO approving the initial installation of the TCAS II equipment must verify that the TCAS II processor design does not differ from the criteria specified in RTCA/DO-185A or RTCA/DO-185B as applicable. The TCAS II processor may include hybrid surveillance as optional functionality.

2-10. Traffic Display.

a. Purpose. The primary purpose of the traffic display is to aid the flight crew in the visual acquisition of transponder-equipped aircraft. This is accomplished by displaying the intruder aircraft's horizontal and, if altitude information is available, vertical position relative to the TCAS II equipped aircraft. The TCAS II systems provide traffic information on Mode A (no altitude data available), Mode C, and Mode S transponder-equipped aircraft. A secondary purpose of the traffic display is to give the flight crew confidence in proper system operation and time to prepare to maneuver the aircraft if TCAS II issues a RA.

b. Description. Traffic displays may take several forms. They may be independent, stand alone, integrated and time-shared with digital color radar, integrated with instantaneous vertical speed indicators (IVSI), or integrated with other displays such as electronic horizontal situation indicators (EHSI), navigation, or other multifunction displays. If the traffic display uses a multifunction display shared with other services such as aircraft communications addressing and reporting system (ACARS), the traffic display function must be immediately available for display by a single selection accessible to both pilots.

c. Symbology/Feature Criteria. The FAA worked closely with the Air Transport Association (ATA), National Aeronautical and Space Administration (NASA), and both the SAE S-7 and G-10 Committees to standardize TCAS II symbology and features. The consensus we reached for TCAS II symbols is provided in RTCA/DO-185. You can use other symbology and features, if you use human factors methodology to demonstrate that a clear and substantial benefit can be derived. Otherwise, the traffic display must depict or provide the symbology, features, or information provided in RTCA/DO-185A or RTCA/DO-185B, Section 2.2.6 as applicable.

2-11. Resolution Advisory Display.

a. Purpose. The purpose of the resolution advisory display is to give each pilot the information to readily correct the aircraft flight path or to prevent a maneuver that would significantly reduce the vertical separation between the pilot's aircraft (own aircraft) and a threat aircraft.

b. Description. The resolution advisory display may be integrated with the two primary IVSIs on the flight deck, integrated into the primary flight display (PFD), or incorporated into a head-up display (HUD). Refer to RTCA/DO-185A or RTCA/DO-185B Section 2.2.6 as applicable for descriptions and requirements for the various resolution display implementations.

c. Symbology. We worked closely with the ATA, NASA, and both the SAE S-7 and G-10 Committees to standardize TCAS II RA features. The consensus we reached for TCAS II RA displays is provided in RTCA/DO-185. You can use other symbology and features, if you use human factors methodology to demonstrate that a clear and substantial benefit can be derived. Otherwise, the RA display must depict or provide the symbology, features, or information shown in RTCA/DO-185A or RTCA/DO-185B Section 2.2.6 as applicable. The use of new TCAS symbology will require testing throughout the flight envelope to determine

accuracy, over/under shoot tendencies, flight technical error, and potential confusion resulting from the proposed symbology. If you are using new symbology, contact the appropriate FAA ACO early in the development cycle.

d. Failures. Provide indications for TCAS II failures (for example, TCAS II unable to generate RAs). Provide annunciation for the TA only mode. Electrical IVSI failures must also be annunciated.

2-12. Optional Caution/Warning Lights.

a. Discrete caution and/or warning lights may be installed that are separate from the traffic display. The purpose of these additional indicators is to annunciate the presence of potentially threatening intruder aircraft at times when the pilot's attention may be diverted from the primary TCAS display. Two different discrete TCAS II annunciators have been used:

(1) A discrete amber caution annunciator, which indicates the presence of a TCAS II TA. Installation of this discrete caution annunciator is optional. When installed, it must be located in each pilot's primary field of view and be inhibited below 400 feet above ground level (AGL).

(2) A discrete red warning annunciator that indicates the presence of a TCAS II RA. This red warning must be located in each pilot's primary field of view and be inhibited below 900 feet AGL. An IVSI with a lighted red arc or an alphanumeric message on the electronic attitude display indicator (EADI) is acceptable instead of this discrete warning annunciator.

b. Because of the number of TCAS II advisories expected in service, the basic aircraft master caution and warning system should not be interfaced with these TCAS II caution/warning discretes. Overuse of the primary aircraft caution and warning system tends to reduce its effectiveness in annunciating non-TCAS II system failures.

c. Discrete visual alerts should remain on until canceled by the pilot or until the aircraft is no longer considered an intruder or a threat by TCAS II.

2-13. Aural Alert Requirements.

a. Annunciate each TCAS II aural alert by a dedicated voice message over a cockpit speaker at a volume adequate for clear understanding at high cockpit noise levels, but not excessively loud at low noise levels. The evaluation includes the case where a flight crew member is wearing a headset, covering the outboard ear when appropriate. In turbo-prop aircraft where the aircrew utilizes headsets via the aircraft audio distribution panel, the aural messages should hold the same acceptable volume and intelligibility during both low and high cockpit noise levels.

b. Annunciate TCAS II TAs by the voice message "TRAFFIC, TRAFFIC" stated once for each TA.

c. Annunciate TCAS II RAs by the following voice messages, as appropriate:

(1) “CLIMB, CLIMB”-- climb at the rate depicted by the green (fly to) arc or line on the IVSI or other suitable indicator.

(2) “DESCEND, DESCEND”-- descend at the rate depicted by the green (fly to) arc or line on the IVSI or other suitable indicator.

(3) “MONITOR VERTICAL SPEED”-- ensure that vertical speed is out of the illuminated IVSI red arc or line, or other suitable indication.

(4) “ADJUST VERTICAL SPEED, ADJUST”-- modify the vertical speed to a value within the illuminated green arc or line, or outside the prohibited area on other suitable indications. This aural is annunciated only by V7.0 TCAS II units.

(5) ”LEVEL OFF, LEVEL OFF” -- reduce vertical speed to zero feet per minute. A green arc or line will be illuminated beginning at zero feet per minute. This can be issued as the initial RA or as a subsequent RA. This aural is annunciated only by V7.1 TCAS II units.

(6) “CLEAR OF CONFLICT”-- range is increasing, and separation is adequate; expeditiously return to the applicable clearance, unless otherwise directed by ATC.

(7) “CLIMB, CROSSING CLIMB, CLIMB, CROSSING CLIMB”-- climb at the rate depicted by the green (fly to) arc or line on the IVSI or other suitable indicator. Safe separation will best be achieved by climbing through the threat’s flight path.

(8) “DESCEND, CROSSING DESCEND, DESCEND, CROSSING DESCEND”-- descend at the rate depicted by the green (fly to) arc or line on the IVSI or other suitable indicator. Safe separation will best be achieved by descending through the threat’s flight path.

(9) “MAINTAIN VERTICAL SPEED, MAINTAIN”-- maintain the existing climb or descent rate as depicted by the green (fly to) arc or line on the IVSI or other suitable indicator. Safe separation is best achieved by not altering the existing vertical speed.

(10) “MAINTAIN VERTICAL SPEED, CROSSING MAINTAIN”-- maintain the existing climb or descent rate as depicted by the green (fly to) arc or line on the IVSI or other suitable indicator. Safe separation will best be achieved by not altering the existing vertical speed and climbing or descending through the threat’s flight path.

d. The following voice messages are required to annunciate enhanced TCAS II maneuvers when the initial RA does not provide sufficient vertical separation. The tone and inflection must connote increased urgency.

(1) “INCREASE CLIMB, INCREASE CLIMB”--climb at the rate depicted by the green (fly to) arc or line on the IVSI or other suitable indicator. Received after “CLIMB”

advisory, and indicates an additional climb rate is required to achieve safe vertical separation from a maneuvering threat aircraft.

(2) "INCREASE DESCENT, INCREASE DESCENT"--descend at the rate depicted by the green (fly to) arc or line on the IVSI or other suitable indicator. Received after "DESCEND" advisory, and indicates additional descent rate is required to achieve safe vertical separation from a maneuvering threat aircraft.

(3) "CLIMB - CLIMB NOW, CLIMB - CLIMB NOW"--climb at the rate depicted by the green (fly to) arc or line on the IVSI or other suitable indicator. Received after a "DESCEND" resolution advisory and indicates a reversal in direction is required to achieve safe vertical separation from a maneuvering threat aircraft.

(4) "DESCEND - DESCEND NOW, DESCEND - DESCEND NOW"--descend at the rate depicted by the green (fly to) arc or line on the IVSI or other suitable indicator. Received after a "CLIMB" resolution advisory and indicates a reversal in direction is required to achieve safe vertical separation from a maneuvering threat aircraft.

e. All TCAS II aural alerts must be inhibited below 400 ft AGL while descending and inhibited below 600 ft AGL while climbing.

f. Both increases and decreases in the threat level must be aurally annunciated.

g. In general, other messages that are clear and unambiguous will be evaluated on an individual basis. Do not use messages that contain negatives (for example, "DON'T CLIMB").

C. Airworthiness Considerations.

2-14. Certification Program.

a. This AC will guide your installation of TCAS II version 7.0 or 7.1 equipment and Mode S transponders. TCAS II installation includes the TCAS, the Mode S transponder, antennas, control panels and display components. All these component part numbers are certified initially as a single installed system. Any change in any of the system part numbers requires either a new Initial Approval or a Follow-On Approval. The system displays information and provides advisories in a number of formats. The degree of system integration to perform these functions is extensive and as a result, your program must be directed toward airworthiness approval through the type certification or supplemental type certification process.

b. Certification Plan. Develop a comprehensive certification plan. Include how you'll comply with the applicable certification requirements, and list the substantiating data and necessary tests in your plan. Include a system description and an estimated time schedule. Your well-developed plan will be of significant value both to you and us.

2-15. Equipment Compatibility Requirements. Make an evaluation to show that the TCAS II system communicates with other approved TCAS II systems made by other manufacturers. Include a TCAS II to TCAS II coordination demonstration, or equivalent, with at least one other manufacturer's approved TCAS II system in your evaluation. If it can be shown for a specific design that communication link failures are no more hazardous than encountering a Mode C intruder, then these tests are not necessary. Also, after completing mature bench tests, future certification experience may show that these tests are no longer necessary. Submit evidence to show that you performed TCAS/transponder interoperability bench tests using the same TCAS/transponder pairing (the same part numbers) as the installation seeking certification. Interoperability bench tests can be satisfied by either of the following:

a. Execute the following RTCA/DO-185A or RTCA/DO-185B tests as applicable, using the actual TCAS unit and Mode S transponder seeking certification:

(1) 2.4.2.2.3.1 and 2,
(2) 2.4.2.2.4.1,
(3) 2.4.2.2.4.2.1, 3 and 5-8, and,
(4) 2.4.2.2.5.

b. Execute the following tests in RTCA/DO-181C or RTCA/DO-181D as applicable, *Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*, using the actual TCAS unit and Mode S transponder seeking certification:

(1) Procedure 30,
(2) Procedure 31 a-d,
(3) Procedure 32a-c and d (1 & 2),
(4) Procedure 34,
(5) Procedure 36 a and c, and,
(6) Procedure 37 a and b.

c. Execute the following RTCA/DO-181C or RTCA/DO-181D tests as applicable, using a TCAS simulator coupled with the actual Mode S transponder:

(1) Procedure 31e,
(2) Procedure 32d (3-16),
(3) Procedure 33,
(4) Procedure 35,
(5) Procedure 36b,
(6) Procedure 37c and,
(7) Procedure 38.

2-16. Aircraft Performance Considerations. Use paragraphs 2-16 through 2-17 and Table 1 of this AC to help you evaluate the need to inhibit TCAS II CLIMB and/or INCREASE CLIMB RAs resulting from inadequate aircraft climb performance. The collision avoidance maneuvers posted as RAs by TCAS II assume an aircraft's ability to safely achieve them. If it's likely the

required response to CLIMB and INCREASE CLIMB RAs are beyond the performance capability of the aircraft, then TCAS II must know beforehand so it can change strategy and issue an alternative RA. These performance limits must be provided to TCAS II from the aircraft interface and discrete settings relative to altitude and/or aircraft configuration. However, carefully consider the need to inhibit TCAS II CLIMB or INCREASE CLIMB RAs since the alternative RAs may not provide the optimum solution to the encounter. Inhibiting these RAs will increase the likelihood of TCAS II:

a. Issuing crossing maneuvers (crossing through an intruder's altitude), thus increasing the probability that an RA may be thwarted by the intruder maneuvering,

b. Causing an increase in DESCEND RAs at low altitude, and

c. Providing no RAs if below the descend inhibit altitude of 1200 feet AGL during takeoff and 1000 feet AGL on approach.

2-17. Evaluating Aircraft Performance. The configuration interface may need switches or sensors, besides the basic airplane flap position switches, to prevent unnecessary TCAS II inhibits. For example, if CLIMB RAs need to be inhibited for the maximum takeoff flap setting only, and no switch exists to sense that position, install an additional switch instead of simply using one that may exist at lesser flap angle settings.

a. Because TCAS II can only accept a limited number of inputs related to airplane performance, it's not possible to automatically inhibit CLIMB and INCREASE CLIMB RAs in all cases where it may be appropriate to inhibit such RAs. In these cases, TCAS II may command maneuvers that may significantly reduce stall margins or result in stall warnings. Conditions where this may occur include bank angles greater than 15 degrees, weight/altitude/temperature combinations outside the envelope shown in Table 1, initial speeds below those shown in Table 1, one engine inoperative, leaving the aircraft configuration fixed for climb RAs on landing transition to go-around, and abnormal configurations such as landing gear not retractable. Provide information concerning this aspect of TCAS in the airplane flight manual (AFM) or airplane flight manual supplement (AFMS) so that flight crews may take appropriate action.

b. An aircraft's low altitude climb capability during takeoff, approach, or landing is significantly affected by the aircraft's configuration, true airspeed available during initial climb to safely trade for climb rate if needed, and the initial airspeed margin from the current stall speed.

(1) Table 1, Conditions 1 through 3 apply to the takeoff and initial climb configuration analysis.

(2) Table 1, Conditions 4 through 6 apply to the approach flap configuration analysis when operating in the terminal area with the flaps set at less than the landing flaps.

(3) Table 1, Conditions 7 through 9 apply to the landing flight regime analysis. To be consistent with normal operation, indicate in the AFM or AFMS that when a climb RA occurs

with the aircraft in the landing configuration, the pilot should initiate the normal go-around procedure when complying with the TCAS II RA. Therefore, we can assume that the flaps are being retracted from the landing position to the go-around position when evaluating Table 1, Conditions 7 through 9.

c. To prevent very unlikely combinations of events, such as weight/altitude/temperature limiting conditions, in conjunction with low airspeed, high drag configurations, and unusual encounter geometries causing climb inhibits when the aircraft's performance is more than adequate, the entry and exit conditions and RAs in Table 1 are structured into two classes of encounters.

(1) Maneuvers A and B represent reasonably severe combinations of entry conditions and RAs, and restricts the exit conditions to an airspeed of $1.2V_{S1}$ (or $1.13V_{SR1}$ for those airplanes that use reference stall speed (V_{SR}) in lieu of stalling speed (V_S)).

(2) Maneuver C, represents reasonably worst-case combinations of entry conditions and RAs, and this very unlikely event may require flying near stall warning conditions through the recovery.

(3) Airspeeds between $1.2V_{S1}$ (or $1.13V_{SR1}$ for those airplanes that use reference stall speed (V_{SR}) in lieu of stalling speed (V_S)) and stall warning represent a range of usable airspeeds that may be traded for climb performance (as is currently recommended for wind shear recovery) for evaluation of this low probability event. The altitude/temperature envelope represents a range of values that exist at busy airports in the continental United States. Operations outside this envelope may require special crew procedures if the normal AFM weight, altitude, temperature, and configuration limitations are not sufficiently compensating, such as operation at Mexico City.

d. For those airplanes that may routinely operate at low climb airspeeds during the clean configuration, enroute phase of flight, such as propeller commuter airplanes, consider providing a discrete to the TCAS II based on airspeed. Such an input, derived from a TCAS II interface system, would provide for CLIMB or INCREASE CLIMB RA inhibits when the airplane is in the clean configuration and operating below a certain airspeed. We consider such a scheme appropriate instead of an across-the-board inhibit for the clean configuration regardless of flight regime (which is not considered to provide the best overall level of safety as previously discussed for other configurations).

e. An aircraft's climb capability when operating at or near maximum approved operating altitude is also affected by excess thrust and true airspeed that may be available to safely trade for climb rate. Climb RAs should not be inhibited if the aircraft has adequate performance available or because it may exceed its maximum certificated altitude by several hundred feet during an RA. Configurations that should be evaluated in this flight regime are shown in Table 1, Conditions 10 and 11. If the aircraft is approved for significant alternative configurations, (such as spare engine pod and gear down operation,) then the initial airspeed used for the analysis should be appropriate for them. In the analysis of the aircraft's ability to

accelerate and return to the initial speed and altitude following the RA, an undershoot of approximately 200 feet is permissible.

f. In icing conditions, the aircraft limited performance weights are reduced, and sometimes the operating speeds increased, to account for icing system bleeds and residual ice drag on the unprotected surfaces. Therefore, the capability to perform the TCAS II maneuvers remains essentially unchanged, eliminating the need to provide additional RA inhibits under these circumstances. However, if a particular aircraft design shows marginal capability to operate in the icing environment, consider additional RA inhibits enabled by icing system activation.

g. If Table 1, Maneuver A causes operation at airspeeds below the minimum, then inhibit the CLIMB RA. If Table 1, Maneuver B or C causes operation at airspeeds below the minimum, then inhibit the INCREASE CLIMB RA. However, early recovery of 1 to 2 seconds is of little or no consequence on the collision avoidance maneuver and a higher overall level of safety will be achieved if inhibits are not provided under these circumstances, as previously discussed in paragraph 2-16.

Table 1. Maneuvers

CONDITION	FLIGHT REGIME	WEIGHT ALTITUDE, TEMPERATURE[1]	THRUST	FLAPS	GEAR	AIRSPEED[2]		MANEUVER[3]
						INITIAL	MINIMUM	
1	Takeoff	Part 25 climb limit	Maximum rated takeoff	All takeoff	Up	V_2+20[4]	1.2V_{S1}[5] thru RA	A
2	Takeoff	Part 25 climb limit	Maximum rated takeoff	All takeoff	Up	V_2+20[4]	1.2V_{S1}[5] thru RA	B
3	Takeoff	Part 25 Climb limit	Maximum rated takeoff	All takeoff	Up	AFM all-engine takeoff speed[6]	15° bank to stall warning[7] thru recovery	C
4	Approach	Part 25 Climb limit	Spin up to max go-around thrust during maneuver from thrust for level flight	Less than landing	Up	1.6V_{S1}	1.2V_{S1}[5] thru RA	A
5	Approach	Part 25 Climb limit	Spin up to max go-around thrust during maneuver from thrust for level flight	Less than landing	Up	1.6V_{S1}	1.2V_{S1}[5] thru RA	B
6	Approach	Part 25 Climb limit	Spin up to max go-around thrust during maneuver from thrust for level flight	Less than landing	Up, or down to up	Min. maneuver speed from training procedures	15° bank to stall earning[7] thru recovery	C
7	Landing, Transition to Go-Around at RA	Part 25 Climb limit	Spin up to max go-around thrust during maneuver from thrust required for 3° glideslope	Transition from landing flap to go-around flap	Down to up	V_{REF} + 10	1.2V_{S1}[5] thru RA	A
8	Landing, Transition to Go-Around at RA	Part 25 Climb limit	Spin up to max go-around thrust during maneuver from thrust required for 3° glideslope	Transition from landing flap to go-around flap	Down to up	V_{REF} + 10	1.2V_{S1}[5] thru RA	B

Table 1. Maneuvers (continued)

CONDITION	FLIGHT REGIME	WEIGHT ALTITUDE, TEMPERATURE[1]	THRUST	FLAPS	GEAR	AIRSPEED[2]		MANEUVER[3]
						INITIAL	MINIMUM	
9	Landing, Transition to Go-Around at RA	Part 25 climb limit	Spin up to max go-around thrust during maneuver from thrust required for 3° glideslope	Transition from landing flap to go-around flap	Down to up	V_{REF} + airspeed addition from training procedures	15° bank to stall warning[7] thru recovery	C
10	En Route	Critical Wt/Alt giving 0.3g to buffet onset	Thrust for level flight increased to max continuous, if required	Up	Up	Long-range cruise	Higher of $1.2V_S$[5] if defined or buffet onset	A
11	En Route	Critical Wt/Alt giving 0.3g to buffet onset	Thrust for level flight increased to max continuous, if required	Up	Up	Long-range cruise	Higher of $1.2V_S$[5] if defined or buffet onset	B

Notes: 1. Weight = Lesser of climb limit or structural; Airport Pressure Altitude = sea level to 5300 ft; Temperature = ISA ± 50 °F; Conditions 1 through 3 evaluated 700 ft above airport; Conditions 4 - 9 evaluated 1700 ft above airport.

2. For those airplanes that use reference stall speed (V_{SR}) in lieu of stalling speed (V_S), replace 1.2 V_{S1} with 1.13 V_{SR1}, 1.2V_S with 1.13 V_{SR} and 1.6 V_{S1} with 1.5 V_{SR1}.

3. Maneuvers:

Maneuver A evaluates the TCAS II CLIMB RA. From the initial steady-state condition, after a 3-second pilot-reaction time delay, rotate the aircraft at 1.25 g to attain +1500 feet per minute climb. Hold until the total duration of the RA of 25 seconds has elapsed. Recover to attain the initial trim airspeed.

Maneuver B evaluates the TCAS II INCREASE CLIMB RA following a CLIMB RA. From the initial steady-state condition, after a 3-second pilot-reaction time delay, rotate the aircraft at 1.25 g to attain +1500 feet per minute climb. Hold until 15 seconds has elapsed from when the CLIMB RA was issued. Then, after a 1-second pilot reaction time-delay to the INCREASE CLIMB RA, rotate the aircraft again at 1.25 g to attain +2500 feet per minute climb and hold until the total duration of the RA of 25 seconds has elapsed. Recover to attain the initial trim airspeed.

Maneuver C evaluates a maximum duration TCAS II INCREASE CLIMB RA following a minimum duration CLIMB RA. From the initial steady-state condition, after a 3-second pilot-reaction time delay, rotate the aircraft at 1.25 g targeting +1500 feet per minute climb until 6 seconds has elapsed from when the CLIMB RA was issued. Then, after a 1-second pilot-reaction time delay to the INCREASE CLIMB RA, rotate the aircraft again at 1.25 g to attain +2500 feet per minute climb and hold until the total duration of the RA of 25 seconds has elapsed. Recover to attain the initial trim airspeed.

4. V_y + 10 for nontransport category aircraft without a defined V_2.

5. For those airplanes where the power-on stalling speed is significantly reduced from the power-off stalling speed, use 1.1 V_S or 1.08V_{SR} for those airplanes that use reference stall speed (V_{SR}) in lieu of stalling speed (V_S).

6. V_y for nontransport category aircraft without a defined V_2.

7. For those airplanes where the power-on stalling speed is significantly reduced from the power-off stalling speed, use V_{S1} or 0.94V_{SR1} for those airplanes that use reference stall speed (V_{SR}) in lieu of stalling speed (V_S).

h. A summary of the system inhibits (limitations) programmed into the TCAS II computer is given in Table 2 below.

Table 2. System Inhibits

INHIBIT	PARAMETERS
Increase Descent RA	Inhibited below 1650 ft AGL while climbing and inhibited below 1450 ft AGL while descending.
Descend RA	Inhibited below 1200 ft AGL while climbing and inhibited below 1000 ft AGL while descending.
TA Voice Messages	Inhibited below 400 ft AGL while descending and inhibited below 600 ft AGL while climbing.
RAs	Inhibited below 1100 ft AGL while climbing, and inhibited below 900 ft AGL while descending. (TCAS automatically reverts to TA only).
Self-Test	Can be inhibited when airborne.
Advisory Priority	Automatically reverts to TA only when higher priority advisories (such as GPWS/TAWS and windshear) occur.
Climb RA	Can be inhibited, based upon aircraft performance capability.
Increase Climb RA	Can be inhibited, based upon aircraft performance capability.

2-18. How Aircraft Systems Should Interface with TCAS II.

a. Pressure altitude information. The pressure altitude data must be from the most accurate source available in the aircraft and it must correspond to that being transmitted by the associated Mode S transponder. The accuracy of the altitude data must be at least that specified in RTCA-DO-185A or RTCA/DO-185B, paragraph 3.2.8 as applicable. It must be shown that the resolution of the altimetry source is compatible with TCAS II. The altitude source with the finest compatible resolution must be used. When available, the resolution should be in increments of 10 feet or less. Also provide information to indicate when the pressure altitude information is invalid.

b. Radio altitude information. Provide radio altitude information to the TCAS II to inhibit:

(1) INCREASE DESCENT RAs below 1650 ft AGL while climbing and below 1450 ft AGL while descending,

(2) DESCEND RAs below 1200 ft AGL while climbing and below 1000 ft AGL while descending,

(3) All TA voice messages (aural traffic advisories) below 400 ft AGL while descending and below 600 ft AGL while climbing, and

(4) All RAs below 1100 ft AGL while climbing and below 900 ft AGL while descending, to allow automatic sensitivity level selection when close to the ground, and to determine that individual targets are on the ground.

(5) Also provide information to indicate when the radio altitude information is invalid.

c. Aircraft configuration. Use discrete information from flaps, slat, landing gear, and/or other aircraft configuration sensors to ensure that TCAS II appropriately inhibits CLIMB and INCREASE CLIMB RAs to the airplane performance limits as described in paragraph 2-16 and 2-17.

d. Aircraft identification. Provide discrete information to the Mode S transponder for the unique aircraft Mode S identification code and its maximum airspeed capability.

e. Attitude. Aircraft pitch and roll attitude may be provided to assist with stabilization of the directional antenna function to assure surveillance and to ensure TA display data remain unaffected by aircraft normal maneuvers. If attitude information is used by TCAS II, provide information to indicate when the attitude data are invalid.

f. Heading. Aircraft heading may be provided for the TA display reference presentation. Information must also be provided to indicate when the heading data are invalid.

g. System failure display. Provide an indication to indicate when RAs are not possible due to failure of the TCAS II equipment or any of its sensors or displays.

h. Altitude alerter data. You may provide the current clearance altitude from the altitude alerter to enable TCAS II to select RAs that are more consistent with the aircraft's altitude clearance once the immediate collision threat has been resolved.

> **Note**: Altitude alert functionality is optional per RTCA/DO-185A and RTCA/DO-185B. Not all TSO-C119b or TSO-C119c TCAS II units will have this option available.

i. Mode S Transponder Gillham altitude input requirements. The Gillham format uses 11 discrete wires that, depending on which wires are turned off or on, represent an altitude value. The Gillham format is sometimes called a blind encoder, as error detection and/or correction on the wires is not conducted. For this reason, ARINC 718, Mark 3 Air Traffic Control Transponder (ATCRBS/MODE S), dated December 1989, states: "Pins have been reserved to permit the direct application of Gillham code data to the transponder. This practice is not encouraged because of concerns that a "stuck bit" in the coded input could be the cause of serious errors in TCAS II resolution advisories." This is a failure mode peculiar to the Gillham

code against which protection is virtually impossible. If Gillham coded altitude use cannot be avoided for the TCAS II installations, two sources of altitude information must be connected to the transponder and their values compared. All transponder altitude comparator failures must be annunciated.

2-19. Verifying and Validating TCAS II Software. It is required for the first installation of a manufacturer's TCAS II equipment to verify and validate TCAS II software using the procedures outlined below. Also, apply these procedures to subsequent software changes to a manufacturer's TCAS II equipment. A manufacturer may provide a design that partitions the software, which affects RAs from other software such as that necessary for the traffic display. The TCAS II manufacturer may not use the minor change authority of the TSO system to change any software not partitioned from the software that affects RAs.

a. Verification and validation of TCAS II software represents a unique challenge. Collision avoidance algorithms, commonly called "the CAS logic," are specified in detail in a formal statechart representation in the CAS requirements specification (CRS) in RTCA/DO-185A, Volume II and RTCA/DO-185B, Volume II. In addition, Attachment A of Volume II provides a software design specification in pseudocode that meets these requirements. This detail is required because the coordination algorithms in the CAS logic assume that the software implemented by all manufacturers will have exactly the same CAS logic. However, the surveillance software necessary to establish and maintain the relative tracks of nearby transponder-equipped aircraft and the software necessary to provide the interface with the Mode S transponder and with other aircraft sensors and displays, must be developed by the manufacturer of the TCAS II equipment. This hybrid approach to the specification of the software requirements means that the application of the software criteria in RTCA/DO-178B, Software Considerations in Airborne Systems and Equipment Certifications, dated December 1, 1992, for the detailed CAS requirements and the pseudocode software design have been satisfied by the FAA and our contractors, while the remaining requirements of RTCA/DO-178B are the responsibility of the manufacturer.

b. If software is used for the display of TCAS II RAs or in the operation of the Mode S transponder data link, the verification and validation of this software must be done to Level B requirements, as defined in RTCA/DO-178B. Also, apply these procedures when the TCAS II manufacturer develops the software requirements for the TCAS II processor associated with functions other than surveillance or the CAS logic. With the software design specified in RTCA/DO-185A, Volume II or RTCA/DO-185B, Volume II, the manufacturer of the TCAS II processor should conduct code walk-throughs and develop and perform module tests and module integration tests to verify that the specified software design was implemented correctly. This includes the surveillance software necessary to establish and maintain the relative tracks of nearby transponder-equipped aircraft.

c. The functional tests required by TSO-C119b and TSO-C119c, as described in RTCA/DO-185A, Volume I and RTCA/DO-185B, Volume I respectively, do not provide complete testing for the TCAS II processor software. However, coverage analysis performed on the CAS test suite, described in Volume I, demonstrated that each column of every transition

table and macro, and each identity transition in the CAS requirements specification in RTCA/DO-185A, Volume II or RTCA/DO-185B, Volume II is tested by the CAS test suite. Thus, the CAS test suite provides more than full decision coverage (but not full condition coverage) as defined in RTCA/DO-178B. TCAS II manufacturers must develop additional functional tests that correspond to the detailed requirements that they develop for the TCAS II processor. The potential consequences of software errors in the TCAS II processor or resolution display require the manufacturer to provide a structural coverage analysis showing single condition test coverage of all instructions at the source code that can affect the generation and display of RAs. These tests may be a combination of module tests, module integration tests and functional tests.

d. Equipment produced under a TSO has obtained FAA concurrence that the software for the equipment was produced in accordance with RTCA/DO-178B for a particular software level. Subsequent installations of the same TCAS II equipment on other aircraft types do not require any additional verification if the software and the interface is not changed.

2-20. Testing for Failures System Safety Analysis. Unannunciated failures of the TCAS II equipment, its associated transponder, or sensors or displays that could generate an incorrect resolution advisory, must be improbable. This can be accomplished using the methods described in AC 25.1309-1A, System Design and Analysis. We expect that a functional hazard assessment (FHA), a failure modes and effects analysis (FMEA), and a quantitative probability analysis of the TCAS II equipment, Mode S transponder, displays, and sensors (including altitude information sources) will be necessary to establish that a false RA is improbable. Specifically, show that the probability of an incorrect RA without a failure annunciation is on the order of 1.0 x 10-4 per flight hour in the terminal environment and 1.0 x 10-5 per flight hour in the enroute environment. The frequency of encounters where another aircraft could present a potential threat depends on the density of aircraft in the airspace. In terminal airspace, the frequency may be assumed to be once every 10 hours and, in enroute airspace, it may be once every 200 hours. You may establish different frequencies based on operational data. Provide these analyses for the first installation of TCAS II equipment on a new model aircraft. For subsequent installations of the same equipment in other aircraft, you may use some of the same analyses paying particular attention to the differences in the altitude sensors that are used.

> **Note**: Develop software involved in generating RAs to RTCA/DO178B, Level B standards.

Chapter 3. Test and Evaluation (Initial Approval).

3-1. General. Test the first installation of a manufacturer's TCAS II or Mode S transponder system. This will verify the design and installation performs its intended function under the expected operating conditions, and that there are no adverse interactions between the TCAS II Mode S transponder and existing aircraft systems. The test will also show that other aircraft equipment has not been adversely affected.

3-2 Create a Test Plan. Provide a test plan that includes adequate testing to perform this verification. This test plan will generally require a combination of ground tests, basic flight tests, and flight tests involving planned encounters with another TCAS II equipped aircraft. You can use an aircraft other than a transport category aircraft for either the TCAS II installation or for the air-to-air cooperative flights. The rest of this chapter lists and explains the minimum elements of the test plan.

3-3. Basic Ground Tests.

a. Bearing accuracy. Demonstrate the bearing estimation accuracy of the TCAS II system as installed in the aircraft. Measure the bearing accuracy using a calibrated 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. The bearing accuracy may also be measured using a fixed transponder location while rotating the test aircraft on a compass rose while measuring the bearing angles at 30-degree intervals. Alternately, the airplane is fixed and the transponder may be moved (refer to Appendix B for cautionary note on testing). Manual readout of the bearing estimate may be done directly from a plan position display on the traffic advisory display. Alternatively, the bearing estimates may be automatically recorded or read from a special test display. A maximum error of ±15 degrees in azimuth is acceptable; however, larger errors are acceptable in the area of the tail (for example, within ±45 degrees of the tail) when that area is not visible from the cockpit. In this case, aircraft structure may interfere with the signal path.

b. Sensor failures. Evaluate simulated failures of the aircraft sensors integrated with TCAS II to determine that the resulting system failure state agrees with the predicted results. These tests should be part of the ground test plan.

c. Electromagnetic interference (EMI). Survey the flight deck EMI to determine that the TCAS II equipment is not a source of objectionable conducted or radiated interference to previously installed systems or equipment, and that operation of the TCAS II equipment is not adversely affected by conducted or radiated interference from previously installed systems and equipment. Pay attention for possible interference with TCAS II equipment from weather radar, particularly if operating in the C-band.

d. Evaluate the general arrangement and operation of controls, displays, circuit breakers, annunciators, and placards of the TCAS II system. Conduct a human factors evaluation of the controls, displays and annunciators. Evaluate the TCAS controls and the controls of installed systems that interact with TCAS (for example, transponders) to determine that they are designed and located to prevent inadvertent actuation. Evaluate TCAS displays and annunciations to determine that they support flight crew awareness of TCAS status changes which could result from TCAS mode selections, intentional pilot actuation of other installed systems, or inadvertent pilot actions with TCAS or other installed systems. Evaluate TCAS displays to ensure all information is, at a minimum, legible, unambiguous, and attention-getting (as applicable). In particular, where transponder functions are integrated with other system controls, ensure that unintended transponder mode switching, especially switching to STANDBY or OFF, is not possible. Pay close attention to line select keys, touch screens or cursor controlled trackballs as these can be susceptible to unintended mode selection resulting from their location in the flight deck (for example proximity to a foot rest or adjacent to a temporary stowage area).

e. Evaluate the TCAS II self-test features and failure mode displays and annunciators.

f. Verify that the pressure altitude source and radio altimeter are properly interfaced with the TCAS II equipment.

g. Verify that the windshear and the ground proximity warning system/terrain awareness warning system (GPWS/TAWS) warnings and TCAS II voice alerts are compatible. Also, verify that windshear or GPWS/TAWS warnings can be clearly understood and that TCAS II is automatically switched to the TA Only mode when TCAS II and windshear voice or GPWS/TAWS announcements simultaneously occur. The alert priorities should be windshear, GPWS/TAWS and then TCAS II.

h. Verify the performance of TCAS II traffic display by observing any available area traffic.

i. Evaluate the TCAS II system installation for satisfactory identification, accessibility, and visibility during both day and night conditions.

j. Determine that any configuration of discretes associated with the TCAS II logic, including inhibits of climb RAs, operate properly. (Changes in logic or function with aircraft configuration, altitude, or speed.)

k. Verify that the ICAO 24-bit aircraft address and maximum airspeed are correct. Additionally, verify that other features, which may be optional, such as extended squitter, aircraft identification reporting, hybrid surveillance or other data link uses also function correctly. Verify that the transponder and data sources meet the requirements of the failure condition classifications associated with the features. For example, an unannunciated failure of the transponder extended squitter resulting in erroneous information being transmitted is at least a major failure condition.

l. If connected, verify that the altitude alerter is providing correct data to TCAS and that the TCAS II version 7.0 or 7.1 logic, as applicable, correctly weakens or strengthens the displayed RA using the altitude alerter input.

m. Verify that the air/ground inputs are connected properly.

> **Note 1**: CAUTION! - When the aircraft is on the ground, the Mode S transponder must be inhibited from replying to any Mode A, Mode C, Mode A/C/S all-call interrogations and Mode S-only all-call interrogations.
>
> **Note 2**: This inhibit is usually accomplished via an appropriate transponder pin connected through the weight-on-wheels switch, but it might also be accomplished through some other automatic means (for example, velocity/altitude algorithm, etc.). The inhibit means must be verified during ground testing.
>
> **Note 3**: While on the ground, the transponder normally should stop output of acquisition squitters (short squits), and should continue output of extended squitters (known as long squits or ADS-B) in the surface format, and it should reply to any discretely-addressed aircraft interrogations. This too should be verified during ground testing. The exact conditions for transmission of acquisition squitter are specified in DO-181D section paragraph 2.2.18.2.6, Acquisition Squitter Protocols.

3-4. Basic Flight Tests.

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

b. Evaluate TCAS II aural messages for acceptable volume and intelligibility during both low and high cockpit noise levels (idle descent at low speed and high power at maximum operating limit speed V_{mo}) with headset covering outboard ear only (when appropriate) and without headsets. In the case of turbo-prop aircraft where the aircrew utilizes headsets via the aircraft audio distribution panel, the aural messages should hold the same acceptable volume and intelligibility during both low and high cockpit noise levels. If the TCAS II TEST is used to simulate voice announcements, ensure that the audio level is not changed by use of the TEST function.

c. Demonstrate that traffic information remains valid and usable when the aircraft is pitched ±15 degrees and rolled approximately 30 degrees during normal maneuvers by observing area traffic in the traffic advisory display.

d. Evaluate the effective surveillance range of the traffic display, including target azimuth reasonableness and track stability. Use of targets of opportunity or a non-transport category (low speed) aircraft as a target for these tests is permissible.

e. Determine that any configuration discretes (changes in logic or function with aircraft configuration, altitude, or speed) associated with the TCAS II logic, including inhibits of climb RAs, operate properly unless previously demonstrated during ground tests.

f. Perform the additional flight tests in RTCA/DO-185A or RTCA/DO-185B, paragraph 3.4.4 as applicable, unless previously accomplished under TSO-C119b or TSO-C119c respectively.

g. Evaluate TCAS II for noninterference during coupled autopilot and flight director approaches to the lowest minimums approved for the aircraft.

h. Before any cooperative flight tests at any altitude involving the TCAS II-equipped aircraft and another aircraft, fly both aircraft in close formation to ensure matched altimetry readouts. These checks should be flown at the speeds and altitudes to be used for the tests.

i. Evaluate all selectable modes of the TCAS II to determine that they perform their intended function and that the operating mode is clearly and uniquely annunciated.

j. Re-evaluate any previously installed aircraft systems that required changes as a result of the TCAS II installation. (For example, electronic flight instrument system (EFIS), flight director (FD), PFD, navigation displays (ND), IVSI, interface etc.)

k. If hybrid surveillance functionality is included, perform the flight tests in RTCA/DO-300, Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid surveillance, dated December 13, 2006, paragraph 3, unless previously accomplished under TSO-C119c.

3-5. Planned Encounter Flight Tests. The objective of these flight tests is to demonstrate adequate TCAS II surveillance and to verify smooth, predictable TCAS II performance. First establish the appropriate safety rules, static system leak test (if necessitated by having opened the system), and altimeter correlation between the encounter aircraft and the TCAS aircraft. The following encounters between the TCAS II aircraft and a dedicated intruder aircraft should be flown to assure that the TCAS II aircraft system performs its intended function by generating TAs and RAs and is consistent with RTCA/DO-185A or RTCA/DO-185B as applicable, and RTCA/DO-300 if appropriate. The intruder aircraft must be equipped with transponders capable of Mode A, Mode C, and for those tests necessary, Mode S, TCAS II and ADS-B Mode S extended squitter if appropriate. These tests are also intended to expose the installed TCAS II system to a reasonable number of carefully controlled encounters that are likely to occur in service. This matrix covers the envelope of encounter speeds, altitudes, and geometries that have in the past identified flaws in surveillance, logic, and antenna mechanization that were not detected earlier by bench tests. Fly the following encounters:

a. Intruder overtaking TCAS II aircraft (from the aft quadrants).

b. Head-on.

(1) Low and high closure speeds.

(2) Above climb limit, TCAS II to TCAS II.

(3) TCAS II against Mode C with TCAS II above intruder and above climb limit (intent is to force TCAS II aircraft to descend.)

(4) At 3000 feet over calm water to evaluate multipath protection.

c. Converging.

(1) Crossing (intruder above TCAS II, descending or vice versa.)

(2) Evaluate the TA-only mode during planned encounters.

(3) Evaluate a mix of intruder transponder modes (A, C, S and S with extended squitter) but primary emphasis should be on TCAS II-to-TCAS II coordination, and on Mode C replies from the intruder aircraft.

(4) Evaluate a mix of encounters with TCAS II both above and below the intruder.

(5) If a flight test is necessary to ensure compatibility with other designs, verify correct air-to-air coordination between the test TCAS II and another manufacturer's previously approved equipment (refer to paragraph 2-15).

(6) Evaluate the effect of electrical transients (bus transfer) during encounters. The TCAS II should not experience adverse effects. No false TAs or RAs should be generated as a result of electrical transients. Normal TCAS II functions and displays should be restored within approximately three seconds.

3-6. Mode S Transponder Tests.

a. This guidance doesn't cover Mode S Extended Squitter or Mode S Elementary/Enhanced surveillance.

b. The tests described in these paragraphs may be used to obtain the certification of a stand-alone Mode S transponder installation (an installation without TCAS II). These tests should also be used to evaluate a Mode S transponder installed as part of a TCAS II installation. The tests primarily verify the installed antenna(s) are compatible with the Mode S transponder and provide an adequate response to ground radar interrogations during normal aircraft maneuvers.

c. Additionally, these tests demonstrate that the Mode S transponder functions properly as installed and does not interfere with other aircraft electronic equipment. The need for a detailed flight test is reduced when the Mode S transponder and antenna installation are identical or similar to that of previously approved ATCRBS transponder installation. If a previously installed and certified transponder is being upgraded, all of the guidance in this section is not necessarily required to approve the upgrade. A careful examination of the proposed transponder upgrade should be accomplished to determine which of the tests specified in this section are necessary and appropriate. Typical testing associated with the initial installation and certification of a new transponder may not be necessary when upgrading a previously approved transponder. For example, if a software upgrade is being considered which would add extended squitter functionality to a transponder in a previously approved installation, detailed flights would not be required if appropriate ground testing adequately evaluates the added functionality.

> **Note 1**: CAUTION! When conducting flight testing of the transponder or TCAS system, you must prevent being a source of interference to ATC or other TCAS aircraft operating in the area. For example, using a fixed transponder to simulate an intruder aircraft can cause data to be transmitted which produce false targets for the ground ATC surveillance systems or airborne TCAS aircraft. These false indications of "intruder aircraft" could result in unnecessary ATC communications and possibly in TCAS induced aircraft maneuvers. Therefore, conduct such testing in coordination with ATC.
>
> **Note 2**: The conduct of this test requires cooperation with ATC radar 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, communication will be required with the controller monitoring the aircraft and reporting transponder performance data.

d. If the Mode S transponder uses a top mounted antenna in addition to a bottom mounted antenna installed at, or near, the same location used by a previously approved ATCRBS transponder antenna, conduct a comprehensive ground test and evaluation in accordance with Appendix B and perform a functional flight test. The transponder code, altitude reporting and "IDENT" features of the transponder should be exercised during normal maneuvering. There should be no objectionable behavior observed by the ATC controller.

e. If a Mode S transponder is installed in an aircraft which does not have a previously approved ATCRBS transponder installation, or that uses a bottom mounted antenna location which differs significantly from that used by a previously approved ATCRBS transponder antenna, conduct the following ground and flight tests:

> NOTE: References to the radar facility are references to the radar that provides the data used by the ATC controller(s) during the flight test for monitoring the aircraft and reporting transponder

performance data. These are not references to the ATC facility with the radar displays used by the controllers.

(1) Conduct ground tests and evaluations per Appendix B.

(2) Climb and Distance Coverage. Begin at a distance of at least 10 nautical miles (NM) from, and an altitude of 2000 to 3000 feet above the radar facility and using a transponder code assigned by ATC, fly on a heading that will pass the aircraft over the radar facility. At a distance of 5 to 10 NM beyond the radar facility, fly the aircraft at its normal maximum climb attitude to within 90 percent of the certificated altitude for the aircraft, maintaining the aircraft heading within 5 degrees of the track from the radar facility. After reaching the maximum altitude for which the aircraft is certificated, fly level at the maximum altitude to 160 NM for turbojet and some turboprop powered airplanes (or 80 NM for most other aircraft) from the radar facility. (Distance from the radar facility is a function of the airplane's maximum certificated altitude.) Communicate with the ATC controller for evidence of transponder dropout. During the flight, check the "IDENT" mode of the ATC transponder to assure that it is performing its intended function. There should be no unexpected dropouts (no return for two or more sweeps). Uncontrollable ringing that hinders use of the ground radar is unsatisfactory.

(3) Long Range Reception. At 90 percent of maximum certificated altitude, perform left and right 360-degree turns, at bank angles of 8 to 10 degrees. The aircraft should be at least 160 (or 80) NM from the radar facility. During these turns, request that the ATC controller monitor the radar displays. There should be no dropouts (no return for two or more sweeps).

(4) High Angle Reception. Perform two 360-degree turns, one to the right and one to the left, at bank angles of 8 to 10 degrees with the airplane at a distance of 50 to 70 NM from the radar facility and at an altitude of at least 35,000 feet or within 90 percent of the maximum altitude for which the aircraft is certificated. There should be no dropouts (no return for two or more sweeps). Switch the transponder to a new code assigned by the ATC controller. The aircraft secondary return on the ATC controllers radar display should indicate a Mode A code change.

(5) High Altitude Cruise. Within 90 percent of the aircraft's maximum certificated altitude or its maximum operating altitude beginning at a point 160 (or 80) NM from the radar facility fly on a course that will pass over the radar facility. The ATC controller should report no unexpected transponder dropout or "ring around."

(6) Surveillance Approach. Beginning at or above 90 percent of the certificated maximum altitude for the aircraft, perform a letdown and approach to a runway of an airport served by Airport Surveillance Radar (ASR) having an ATCRBS facility. Make the approach at the maximum normal rate of descent. Normal approach and landing configuration for the aircraft should continue down to an altitude of 200 feet or less above the ground radar antenna elevation. Not more than one dropout should occur for any 10 sweeps during final approach. Uncontrolled ringing that hinders use of the ground radar is unsatisfactory.

(7) Holding and Orbiting Patterns.

(a) At an altitude of 2000 feet above the radar antenna or minimum obstruction clearance altitude (whichever is greater) with landing flaps and gear extended, fly left and right 360-degree turns approximately 10 miles from the radar facility. There should be no signal dropouts.

(b) At an altitude of 2000 feet above the radar antenna or minimum obstruction clearance altitude (whichever is greater), fly 45 degree sectors of left and right 10 mile orbital patterns around a radar facility with gear and landing flaps extended. There should be no signal dropouts.

(8) Altitude Reporting. Conduct a functional test of the altitude encoder by comparison with ATC displayed altitudes. Verify correspondence at several altitudes between ATC readings and the Captain's altimeter, when set at or corrected to 29.92 inches of mercury (or equivalent).

Chapter 4. Follow-on Approvals (STCs or Amended STC).

4-1. The Need for Tests and a Plan.

a. Flight-testing of TCAS II or Mode S transponder systems for follow-on approvals (previously approved TCAS II or Mode S transponder equipment installed in a different aircraft type) may need to be conducted to verify that the design and installation performs its intended function under the expected operating conditions. Determine that there are no adverse interactions between the TCAS II or Mode S transponder and existing aircraft systems, and that prior approvals of present aircraft equipment have not been compromised.

b. Provide a test plan including adequate aircraft ground testing and evaluations to verify that the design and installation performs its intended function when installed in a different aircraft type under the expected operating conditions. There should be no adverse interactions between the TCAS II or Mode S transponder and existing aircraft systems, and prior approvals of present aircraft equipment should not be compromised. This test plan will generally require a combination of ground tests, basic flight tests, and flight tests involving planned encounters with a Mode C equipped aircraft, or the use of a suitably located fixed transponder. The test plan should contain, as a minimum, the elements of paragraph 3-6 and those covered in the next paragraphs.

> **Note**: CAUTION! When flight testing the transponder or TCAS system, you must prevent being a source of interference to ATC or other TCAS aircraft operating in the area. For example, using a fixed transponder to simulate an intruder aircraft can cause data to be transmitted which produce false targets for the ground ATC surveillance systems or airborne TCAS aircraft. False indications of "intruder aircraft" could result in unnecessary ATC communications and possibly in TCAS induced aircraft maneuvers. Conduct such testing in coordination with ATC.

4-2. Ground Tests and Evaluations.

a. Evaluate the general arrangement and operation of controls, displays, circuit breakers, annunciators, and placards of the TCAS II system. Conduct a human factors evaluation of the controls, displays and annunciators. Evaluate the TCAS controls and the controls of installed systems that interact with TCAS (for example, transponders) to determine that they are designed and located to prevent inadvertent actuation. Evaluate TCAS displays and annunciations to determine that they support flight crew awareness of TCAS status changes which could result from TCAS mode selections, intentional pilot actuation of other installed systems, or inadvertent pilot actions with TCAS or other installed systems. Evaluate TCAS displays to ensure all information is, at a minimum, legible, unambiguous, and attention-getting (as applicable). In particular, where transponder functions are integrated with other system controls, ensure that

unintended transponder mode switching, especially switching to STANDBY or OFF, is not possible. Pay close attention to line select keys, touch screens or cursor controlled trackballs as these can be susceptible to unintended mode selection resulting from their location in the flight deck (for example proximity to a foot rest or adjacent to a temporary stowage area).

b. Evaluate the TCAS II self-test features and failure mode displays and annunciators.

c. Verify that the pressure altitude source and radio altimeter are properly interfaced with the TCAS II equipment.

d. Measure the performance of the directional antenna for 360 degrees coverage at 30 degree intervals, as specified under basic ground tests, paragraph 3-3.a.

e. Evaluate the TCAS II system installation for satisfactory identification, accessibility, and visibility during both day and night conditions.

f. Determine that any configuration discretes (changes in logic or function with aircraft configuration, altitude, or speed) associated with the TCAS II logic, including inhibits of climb RAs, operate properly.

g. Verify that the ICAO 24-bit aircraft address and maximum airspeed are correct. Verify that the transponder and data sources meet the requirements of the failure condition classifications associated with the features.

h. Verify that the windshear and GPWS/TAWS warnings and TCAS II voice alerts are compatible. Also, verify that windshear and GPWS/TAWS warnings can be clearly understood and that TCAS II is automatically switched to the TA Only mode when TCAS II and windshear voice or GPWS/TAWS announcements simultaneously occur. The alert priorities should be windshear, GPWS/TAWS, and then TCAS II.

i. If connected, verify that the altitude alerter is providing correct data to TCAS and that the TCAS II logic correctly weakens or strengthens the displayed RA using the altitude alerter input.

j. Verify that the air/ground inputs are connected properly.

> **Note 1**: CAUTION! - When the aircraft is on the ground, the Mode S transponder must be inhibited from replying to any Mode A, Mode C, Mode A/C/S all-call interrogations and Mode S-only all-call interrogations.
>
> **Note 2**: This inhibit is usually accomplished via an appropriate transponder pin connected through the weight-on-wheels switch, but it might also be accomplished through some other automatic means (for example, velocity/altitude algorithm, etc.). The inhibit means must be verified during ground testing.

Note 3: While on the ground the transponder normally should stop output of acquisition squitters (short squits), and should continue output of extended squitters (known as long squits or ADS-B) in the surface format and it should reply to any discretely addressed aircraft interrogations. This too should be verified during ground testing. The exact conditions for transmission of acquisition squitter are specified in DO-181D, paragraph 2.2.18.2.6, Acquisition Squitter Protocols.

4-3. Flight Tests.

a. The certification policy for follow-on approvals (STC or amended STC) of TCAS II version 7.0 or 7.1 units is that flight tests may not be required, if the appropriate testing is performed on the ground to certify that the version 7.0 or 7.1 unit was correctly installed and that any new interfaces operate correctly with the TCAS II logic.

b. If we determine that certification flight-testing is required, demonstrate the following:

(1) Verify proper operation of the traffic display by observing proximate traffic, at least one traffic advisory and at least one resolution advisory. Confirm that the appropriate aural alerts occur correctly with the traffic advisory and resolution advisory. The advisories may be generated by:

(a) Planned encounters with an intruder aircraft operating a transponder with Mode C capability.

Note: Before any cooperative flight tests at any altitude involving the TCAS II equipped aircraft and another aircraft, fly both aircraft in close formation to assure matched altimetry readouts. These checks should be flown at the speeds and altitudes to be used for the tests.

(b) Encounters with an operating Mode C transponder installed at a fixed ground location, which reports an appropriate test altitude.

Note: CAUTION! When flight testing the transponder or TCAS system, you must prevent being a source of interference to ATC or other TCAS aircraft operating in the area. For example, using a fixed transponder to simulate an intruder aircraft can cause data to be transmitted which produce false targets for the ground ATC surveillance systems or airborne TCAS aircraft. These false indications of "intruder aircraft" could result in unnecessary ATC communications and possibly in TCAS induced aircraft maneuvers. Conduct such testing in coordination with ATC.

(c) Encounters with aircraft targets of opportunity.

(d) The use of suitable test equipment during ground tests.

Note: CAUTION! When ground testing the transponder or TCAS system, you must prevent being a source of interference to ATC or other TCAS aircraft operating in the area. Ground maintenance checks or ramp testing (such as altimetry or bearing accuracy testing) can cause data to be transmitted which produce false targets for the ground ATC surveillance systems or airborne TCAS aircraft. These false indications of "intruder aircraft" could result in unnecessary ATC communications and possibly in TCAS induced aircraft maneuvers. Conduct such testing in coordination with ATC and use antenna shielding (transmission absorption covers or caps) to prevent test data that could generate false intruder information from being transmitted. Using high-powered, hangar-mounted transponders to conduct ramp testing is not an acceptable means to test either transponder ramp or TCAS.

(2) During all phases of flight, determine if there is any mutual interference with any other aircraft system.

(3) Evaluate TCAS II aural messages for acceptable volume and intelligibility during both low and high cockpit noise levels (idle descent at low speed and high power at V_{mo}) with and without headsets, covering the outboard ear where appropriate. In turbo-prop aircraft where the aircrew uses headsets via the aircraft audio distribution panel, the aural messages should hold the same acceptable volume and intelligibility during both low and high cockpit noise levels. If the TCAS II TEST is used to simulate voice announcements, ensure that the audio level is not changed by use of the TEST function.

(4) Evaluate the effective surveillance range of the traffic display, including target azimuth reasonableness and track stability. You may use a non-transport (low speed) Mode C equipped aircraft as a target or a fixed transponder or suitable test equipment for these tests.

Note: CAUTION! When flight testing the transponder or TCAS system, you must prevent being a source of interference to ATC or other TCAS aircraft operating in the area. For example, using a fixed transponder to simulate an intruder aircraft can cause data to be transmitted which produce false targets for the ground ATC surveillance systems or airborne TCAS aircraft. These false indications of "intruder aircraft" could result in unnecessary ATC communications and possibly in TCAS induced aircraft maneuvers. Conduct such testing in coordination with ATC.

(5) Evaluate the Mode S transponder air-to-ground ATCRBS function against an appropriate ground facility.

(6) Determine that any configuration discretes associated with the TCAS II logic, including inhibits of aural annunciations and RAs, operate properly unless previously demonstrated during ground tests. (These include changes in logic or function with aircraft configuration, altitude, or speed.)

(7) Evaluate TCAS II for noninterference during coupled autopilot and flight director approaches to the lowest minimums approved for the aircraft.

(8) Evaluate all selectable modes of the TCAS II to determine that they perform their intended function.

(9) Reevaluate any previously installed aircraft systems that have required changes as a result of the TCAS II installation (such as EFIS, FD, PFD, ND, IVSI, and interface).

4-4. Upgrading an Existing TCAS II Installation. If you are upgrading an existing approved TCAS II installation to a higher TCAS II version (i.e. version 7.0 or 7.1), and the higher version installation is only a software change, then no additional certification flight tests are required to obtain a follow-on STC, amended STC or amended TC. The appropriate aircraft ground tests of paragraph 4-2 are considered sufficient to ensure that the higher version TCAS II software is operating properly. However, if the upgrade to a higher version TCAS II unit involves changes other than a software change (such as the addition of new interfaces), flight tests in accordance with paragraph 4-3b may be required.

Chapter 5. Airplane Flight Manual Supplement.

5-1. What to Include in Your Airplane Flight Manual Supplement. The Airplane Flight Manual Supplement (AFMS) should provide the appropriate system limitations and procedures, and a comprehensive description of all normal modes of operation, including expected flight crew actions.

5-2. TCAS V7.1 AFMS Example. Refer to Appendix A for an example of the elements and extent of detail that may be shown by a typical AFMS (specific performance data, inhibits and procedures may vary with system design and aircraft type).

Appendix A. Example TCAS II V7.1 AFMS.

INTRODUCTION.
Descriptive material and procedures in this Airplane Flight Manual Supplement (AFMS) example may, when appropriate, be replaced by reference in the AFMS to the TCAS II equipment supplier's pilot operating guide. However, the AFMS reference to this guide must specify date and revision level; and not be open ended, such as, "or later revision," unless the pilot's guide is specifically FAA approved. Also, the AFMS must define the specific configuration approved from the various options contained in the pilot's guide; for example, which model control panel, whether the pilot initiated self-test is available in flight, range features, TA vertical display features, and so forth.

-EXAMPLE-

AIRPLANE FLIGHT MANUAL SUPPLEMENT

(Example for an aircraft equipped with IVSI/RA displays)

DESCRIPTION.

The TCAS II is an on-board collision avoidance and traffic situation display system with computer processing to identify and display intruding and threatening collision aircraft, and issue resolution advisories in the form of vertical maneuver guidance on the pilot and copilot's instantaneous vertical speed indicators (IVSI). From the transponder replies, TCAS II determines relative altitude, range, and bearing of any ATCRBS or Mode S equipped aircraft with altitude reporting. From this, TCAS II will determine the level of advisory using standardized algorithms. The TCAS II will resolve multiple aircraft encounters. ATCRBS-equipped aircraft that only reply with Mode A information will not provide altitude information; therefore, TCAS II will not issue resolution advisories for these aircraft but can issue traffic advisories. The TCAS II will not detect aircraft that are not equipped with transponders.

The TCAS II installation consists of one TCAS II processor, one top mounted directional antenna, one bottom mounted blade (or directional antenna), one Mode S transponder with control panel and top and bottom antennas, one traffic advisory display with control panel (if not combined with the IVSI/RA indicators), two resolution advisory displays, one overhead speaker for voice messages, (caution/warning lights), and associated wiring.

The TCAS II provides two levels of advisories:

1. If the traffic gets within 25 to 48 seconds, depending upon altitude, of projected Closest Point of Approach (CPA), it is then considered an intruder, and an aural and visual traffic advisory (TA) is issued. This level calls attention to what may develop into a collision threat using the traffic advisory display and the voice message, "TRAFFIC - TRAFFIC." It permits mental and physical preparation for a possible maneuver to follow and assists the pilot in achieving visual acquisition of the intruding aircraft.

2. If the intruder gets within 15 to 35 seconds, depending upon altitude, of CPA, it is considered a threat, and an aural and visual resolution advisory (RA) is issued. This level provides a recommended vertical maneuver using modified IVSIs and voice messages to provide adequate vertical separation from the threat aircraft or prevents initiation of a maneuver that would place the TCAS II aircraft in jeopardy. The TCAS II is considered a backup system to the "SEE AND AVOID" concept and the ATC surveillance. The TCAS II resolution advisories are annunciated by the following voice messages, as appropriate, along with the expected pilot response:

(1) "CLIMB, CLIMB"--climb at the rate depicted by the green (fly to) arc on the IVSI, nominally between 1,500 and 2,000 fpm.

(2) "DESCEND, DESCEND"--descend at the rate depicted by the green (fly to) arc on the IVSI nominally between 1,500 and 2,000 fpm.

(3) "MONITOR VERTICAL SPEED"--ensure that vertical speed is out of the illuminated IVSI red arc until the RA is completed.

(4) "LEVEL OFF, LEVEL OFF" -- reduce vertical speed to zero feet per minute. A green arc will be illuminated beginning at zero feet per minute. This can be issued as the initial RA or as a subsequent RA.

(5) "CLEAR OF CONFLICT"--range is increasing, and separation is adequate. Expeditiously return to the applicable ATC clearance, unless otherwise directed by ATC.

(6) "CLIMB, CROSSING CLIMB, CLIMB, CROSSING CLIMB"--climb at the rate depicted by the green (fly to) arc on the IVSI, nominally between 1,500 and 2,000 fpm. Safe separation will best be achieved by climbing through the threat's flight path.

(7) "DESCEND, CROSSING DESCEND, DESCEND, CROSSING DESCEND"--descend at the rate depicted by the green (fly to) arc on the IVSI, nominally between 1,500 and 2,000 fpm. Safe separation will best be achieved by descending through the intruder's flight path.

(8) "MAINTAIN VERTICAL SPEED, MAINTAIN"--continue the existing climb or descent rate, or other vertical speed, as depicted by the green (fly to) arc on the IVSI.

(9) "MAINTAIN VERTICAL SPEED, CROSSING MAINTAIN"--continue the existing climb or descent rate, or other vertical speed, as depicted by the green (fly to) arc on the IVSI. Safe separation will best be achieved by not altering the existing vertical speed and climbing or descending through the threat's flight path.

The following voice messages annunciate enhanced TCAS II maneuvers when initial RA does not provide sufficient vertical separation. The tone and inflection indicate increased urgency.

(1) "INCREASE CLIMB, INCREASE CLIMB"--climb at the rate depicted by the green (fly-to) arc on the IVSI, nominally between 2,500 and 3,000 fpm. Received after "CLIMB" advisory, and indicates additional climb rate is required to achieve safe vertical separation from a maneuvering aircraft.

(2) "INCREASE DESCENT, INCREASE DESCENT"--descend at the rate depicted by the green (fly-to) arc on the IVSI, nominally between 2,500 and 3,000 fpm. Received after "DESCEND" advisory, and indicates additional descent rate is required to achieve safe vertical separation from a maneuvering aircraft.

(3) "CLIMB – CLIMB NOW, CLIMB – CLIMB NOW"--climb at the rate depicted by the green (fly-to) arc on the IVSI, nominally between 1,500 and 2,000 fpm. Received after a "DESCEND" resolution advisory and indicates a reversal in direction is required to achieve safe vertical separation from a maneuvering threat aircraft.

(4) "DESCEND – DESCEND NOW, DESCEND – DESCEND NOW"-descend at the rate depicted by the green (fly-to) arc on the IVSI, nominally between 1,500 and 2,000 fpm. Received after a "CLIMB" resolution advisory and indicates a reversal in direction is required to achieve safe vertical separation from a maneuvering threat aircraft.

Figure A-1. TCAS II/Transponder Control Panel (Example)

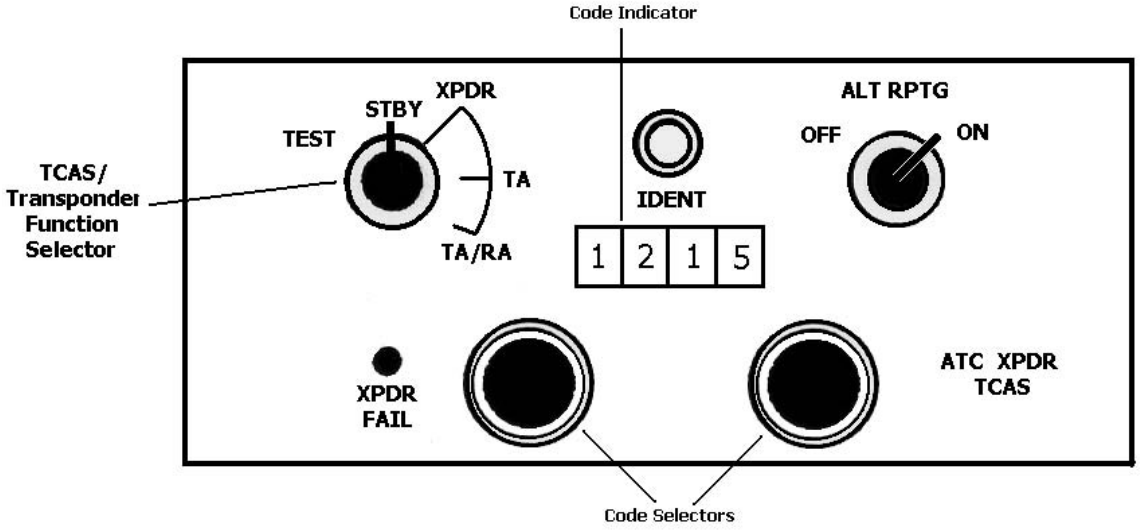


Table A-1. TCAS II/Transponder Function Selector

TEST	Holding the TCAS II/Transponder function selector in TEST for 2 to 3 seconds will activate the system test sequence. In the TEST position, read maintenance messages on the display. Use discretion when selecting TEST in flight, since both TCAS II and the transponder will be inhibited for approximately 20 seconds. The function selector is spring loaded to STBY.
STBY	Activates TCAS II and XPDR warmup cycles.
XPDR	Transponder is on. TCAS II is in warmup cycle.
TA	Transponder is on. Only the "Traffic Advisory", or "TA" function of the TCAS II is on. No "Resolution Advisories" will be received in this position. The written warning "TA ONLY" will appear on the display, and the yellow "RA OFF" flag will be in view on both IVSIs.
TA/RA	Transponder is on. All TCAS II functions are on. No TCAS II flags should be present on either IVSI.
XPDR Fail Light (Red)	Indicates a transponder system failure when the transponder is on. Comes on during "TEST", but goes off after approximately 3 seconds if the transponder is OK.
Code Indicator	Indicates code selected with the code selectors.
IDENT	Causes the word IDENT to flash in the aircraft data block on the ATC display.
ALT RPTG	Provides automatic altitude reporting to ATC.
Code Selectors	Select the transponder code. Left and right selectors consist of a large knob and a small knob. Each knob controls one digit of the code.

Figure A-2. TCAS II – Traffic Display (Example)

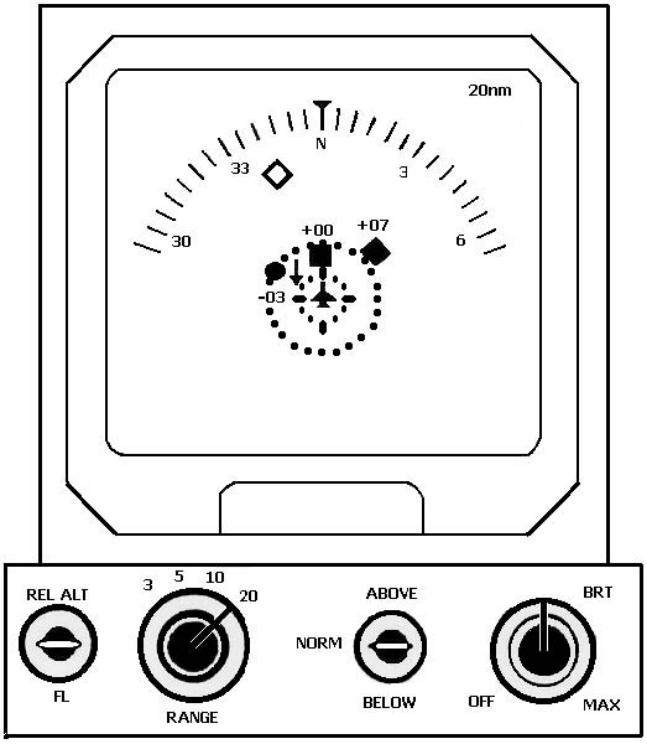


Table A-2. Displayed Aircraft Symbols (Examples)

Arrow indicates that the target is climbing ↑ or descending ↓ at a rate of at least 500 fpm.	
Relative altitude is displayed in the proximity of the aircraft symbol in hundreds of feet. A "+" preceding the relative altitude indicates the target is above you and a "-" indicates it is below you.	
◊	Unfilled white diamond. Non-threatening traffic without altitude reporting. If altitude reporting, the altitude data will be displayed.
+07 ◇	Solid White diamond. Proximity traffic 700 feet above. Non-threatening, altitude reporting traffic within 1200 feet vertically and 6nm horizontally. Aircraft without altitude reporting will be assumed to be co-altitude and will be displayed as a solid diamond when within 6nm even though they may not be within 1200 feet vertically.
● ↓ -03	Solid yellow circle. "TA", 300 feet below, descending with a rate of at least 500 fpm.
+00 ■	Solid red square. "RA", level at your altitude.
✈	Ownship. Airplane symbol in white just below the center of CRT. On a dedicated display or when in the TFC Mode on a combination TCAS II/RADAR Display.
(Compass Arc)	This arc is repeater of the Captains compass. (Not required for TCAS II Display)
(Range Rings)	3nm – Small ring with ticks at clock positions 5 NM – Large ring made of dots.

Figure A-3. TCAS II Traffic Display (Example)

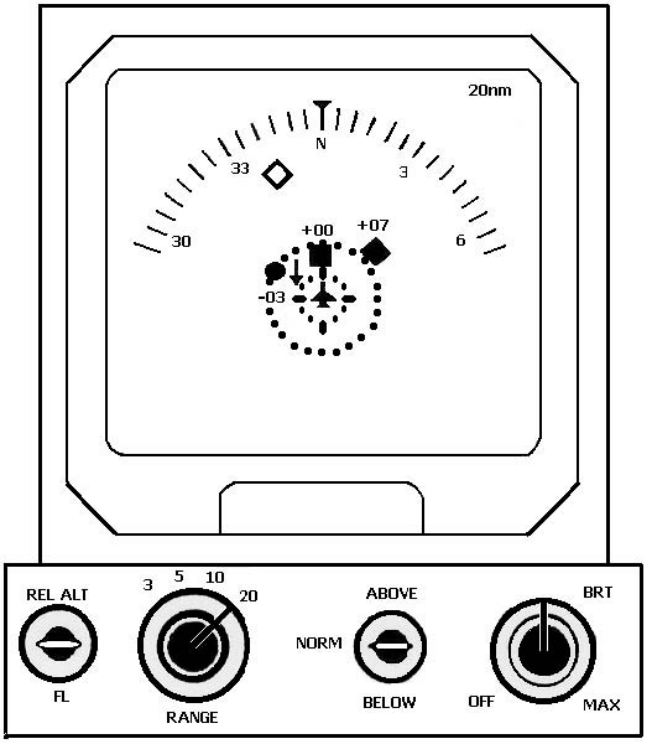


Table A-3A. Paddle Switch REL ALT/FL Switch

REL ALT	Paddle switch is spring loaded to the center position. Display shows related altitude "REL ALT" in hundreds of feet above (+) or below (-) your aircraft.
FL	Allows display of traffic flight levels, referenced to 29.92, for 15 seconds. Your FL is displayed in lower left corner. Three digits are shown, except for negative flight levels that are shown as – xxx. When the current barometric pressure is not available and the TCAS II aircraft is below FL 180, the FL position is automatically inhibited.
RANGE	The maximum forward range on the traffic display is set at range selected by the range knob. Ranges of 3, 5, 10, 20 NM are available and the selected range is annunciated on the traffic display.
BRT Knob	Controls brightness of the display.

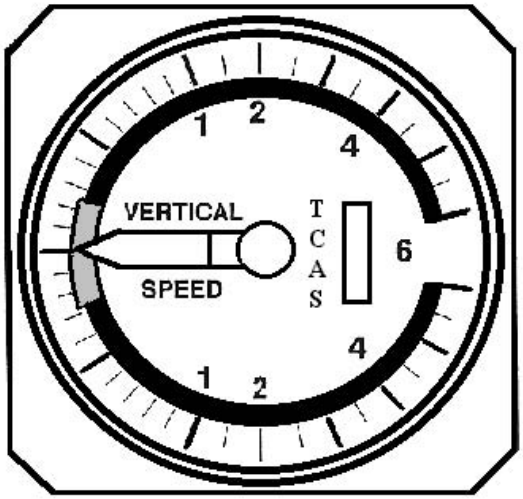
Table A-3B. Above/Norm/Below Switch

ABOVE	Displays altitude-reporting traffic from 2700 feet below to 9900 feet above the TCAS II aircraft. The selection of this mode is annunciated by ABOVE being displayed on the traffic display. This selection has no effect on the functioning of the collision avoidance logic.
NORM	Displays altitude reporting traffic from 2700 feet below to 2700 feet above the TCAS II aircraft.
BELOW	Displays altitude-reporting traffic from 2700 feet above to 9900 feet below the TCAS II aircraft. The selection of this mode is annunciated by BELOW being displayed on the traffic display. This selection has no effect on the functioning of the collision avoidance logic.

OFF-SCALE TRAFFIC ADVISORY - If TCAS II tracks an intruder that is outside the selected range of the display but that has entered the Caution or Warning areas, one-half of the appropriate symbol will appear at the appropriate bearing at the edge of the display area. The symbol will appear in its proper color and have its data tag displayed, providing there is room. For example, a TA intruder with a high closure rate, and which is directly ahead and 300 feet below your airplane will appear as an amber-filled half circle at the 12 o'clock position on the edge of the display area. The data tag "-03" will appear below the half symbol. If this intruder is above your altitude, the data tag is not visible. An off-scale RA intruder will appear as a red-filled half square with data tag displayed if room permits.

NO BEARING ADVISORIES - When TCAS II cannot track the bearing of an intruder, the traffic advisory will appear in the lower center of the display just below the own-airplane symbol. The advisory will present appropriate color-coded traffic information. This phenomenon usually is caused either by temporary antenna shielding (caused by steep bank angles) or a failure in the TCAS II bearing antenna. Up to two lines of information can be displayed. "TA 5.2 -06↑" for example means an intruder is creating a Traffic Advisory 5.2 nautical miles away, 600 feet below, and climbing in excess of 500 FPM. This advisory is written in amber or yellow. "RA 0.6 00" means resolution advisory traffic is 0.6 nautical miles away at the same altitude. This advisory is written in red. TCAS II's ability to compute a traffic or resolution advisory is *not* degraded by lack of bearing information.

Figure A-4. TCAS II Instantaneous Vertical Speed Indicator (Example)



Red Arc

Green Arc

Key to Colors in Figures

Table A-4. Instantaneous Vertical Speed Indicator

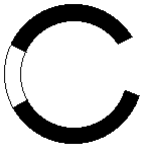
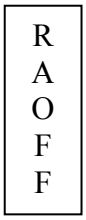
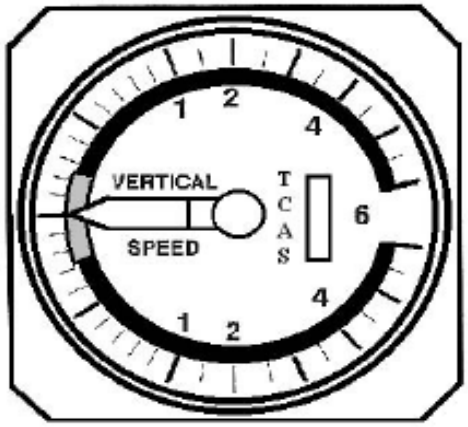
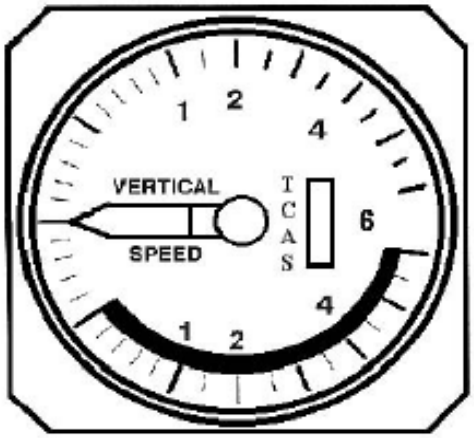
Indicates vertical speed in feet per minute. The IVSI is a normal instantaneous vertical speed indicator, and the presence of the lights or the flags will not interfere with the ability of the needle to indicate vertical speeds.	
	RED/GREEN EYEBROW LIGHTS. Eyebrow lights are invisible until they illuminate as part of a TCAS II "RESOLUTION ADVISORY", or system "TEST". These lights indicate a vertical speed regime which will provide safe traffic separation. The green lights form a wider band than red lights.
IVSI Status Window Flags	
T C A S 	BLACK. Normal operation.
T C A S 	AMBER FLAG. Indicates Unusable TCAS II information.
T C A S 	WHITE "RA OFF" FLAG. Always displayed when TCAS II/TRANSPONDER function selector is in STBY, XPDR, or TA. Will also be displayed with selector in RA/TA if "RAs" are inhibited and/or inoperative.

Figure A-5. TCAS II Examples – Preventive RAs

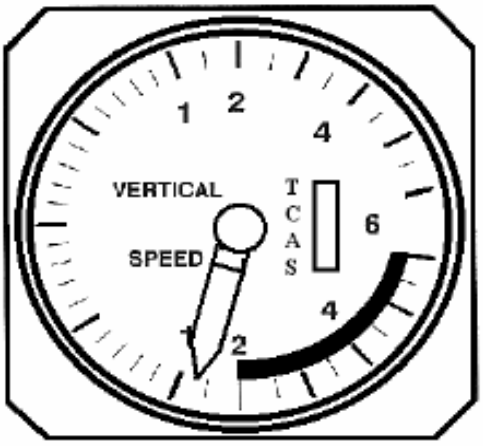
NOTE: No change in vertical speed is required when these RAs are issued.



(a) Preventive
Aural: **MONITOR VERTICAL SPEED**
Pilot Response: No action required. Maintain the vertical speed within the green arc.



(b) Preventive
Aural: **MONITOR VERTICAL SPEED**
Pilot Response: No Action Required. If a descent is initiated, it must be limited to less than 500 fpm.



(c) Preventive
Aural: **MONITOR VERTICAL SPEED**
Pilot Response: No action required.
Descent rate cannot be greater than 2,000 fpm.

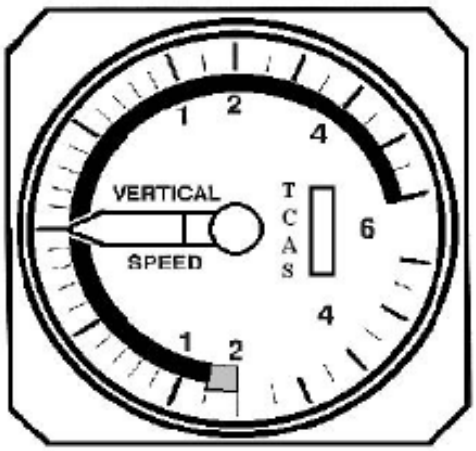
Red Arc

Green Arc

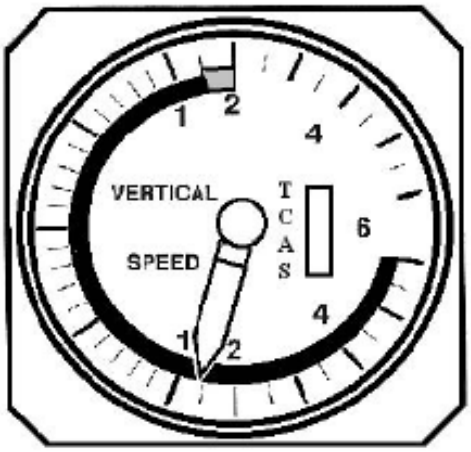
Key to Colors in Figures

Figure A-6. TCAS II Examples – Initial Corrective RAs

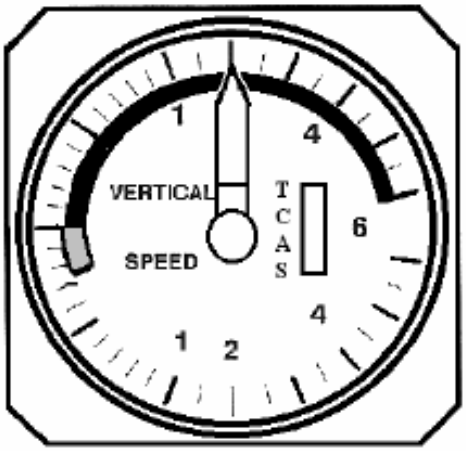
NOTE: Pilot response to these initial corrective RAs is expected within 5 seconds. Pilots should promptly and smoothly fly to the green arc.



(a) Corrective
Aural: **DESCEND, DESCEND**
Pilot Response: Smoothly establish a descent rate between 1,500 fpm and 2,000 fpm



(b) Corrective
Aural: **CLIMB, CLIMB**
Pilot Response: Smoothly establish a climb rate between 1,500 fpm and 2,000 fpm.

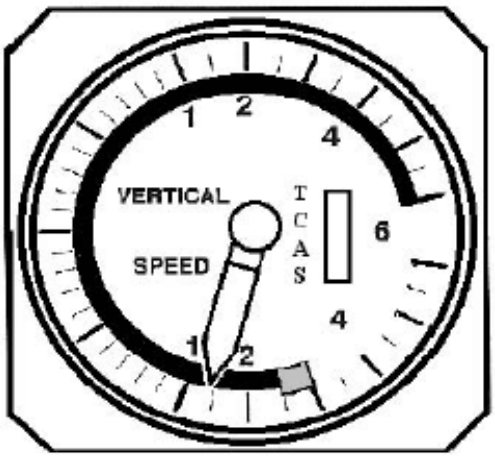


(c) Corrective
Aural:
LEVEL OFF, LEVEL OFF
Pilot Response: Smoothly reduce vertical speed to zero fpm.

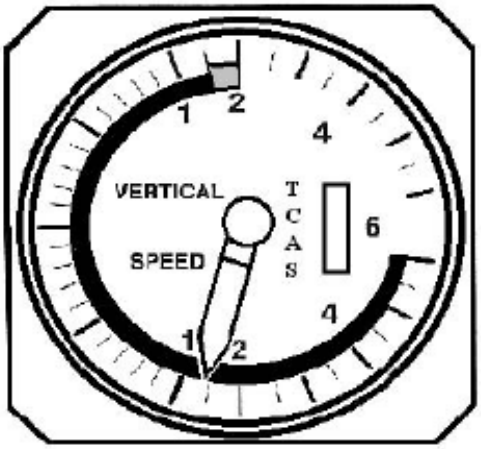
Key to Colors in Figures

Figure A-7. TCAS II Examples – Modifications to Initial Corrective RAs

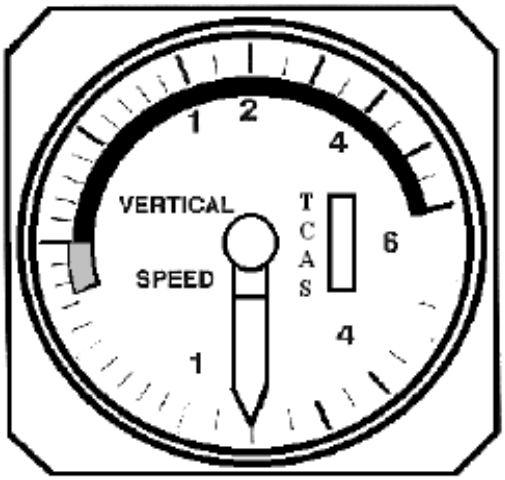
NOTE: Pilot response to these modified RAs is expected within 2.5 seconds. Pilots should promptly and smoothly fly to the green arc.



(a) Increase
Aural: **INCREASE DESCENT, INCREASE DESCENT**
Pilot Response: Increase the descent rate, fly to the green arc, 2,500 fpm to 3,000 fpm.



(b) Reversal
Aural: **CLIMB, CLIMB NOW**
Pilot Response: Reverse descent rate and immediately start a climb between1,500 fpm and 2,000 fpm.



(c) Weakening
Aural:
LEVEL OFF, LEVEL OFF
Pilot Response: Smoothly reduce vertical speed to between 0 and - 250 fpm.

Key to Colors in Figures

SECTION I – LIMITATIONS.

(1) Pilots are authorized to deviate from their current ATC clearance to comply with a TCAS II resolution advisory (RA).

(2) Maneuvers based solely on a traffic advisory (TA) or on information displayed on the traffic display are not authorized.

SECTION II - EMERGENCY PROCEDURES.

No change from basic airplane flight manual.

SECTION III – PROCEDURES.

(1) TCAS II Flight Procedures:

Compliance with a TCAS II resolution advisory (RA) is necessary unless the pilot considers it unsafe to do so, or unless the pilot has information about the cause of the RA and can maintain safe separation for example visual acquisition of, and safe separation from, a nearby aircraft on a parallel approach.

> **NOTE: CAUTION!** Once a non-crossing RA has been issued, safe operation could be compromised if current vertical speed is changed, except as necessary to comply with the RA. This is because TCAS II-to-TCAS II coordination may be in progress with the intruder airplane, and any change in vertical speed that does not comply with the RA may negate the effectiveness of the other airplane's compliance with its RA.
>
> **NOTE: WARNING.** Noncompliance with a crossing RA by one airplane may result in reduced vertical separation; therefore, safe horizontal separation must also be assured by visual means.

Because of the limited number of inputs to TCAS II for airplane performance inhibits, in some instances where inhibiting RAs may be appropriate it is not possible to do so. In these cases, TCAS II may command maneuvers that may significantly reduce stall margins or result in stall warning. Therefore, the stall warning stick shaker must be respected when following an RA. Conditions where this may occur include:

(a) Bank angle in excess of 15 degrees.

(b) One engine inoperative.

(c) Abnormal configurations such as landing gear not retractable, etc.

(d) Leaving airplane in inappropriate configurations when climb RA occurs.

(e) Operation at airports outside of 0 to 5,300 feet MSL or temperatures outside of ISA ±50°F.

(f) Speeds below normal operating speeds.

(g) Buffet margin less than 0.3 g.

The TCAS II RA algorithms are based on the pilot initiating the initial 0.25 g acceleration maneuver within approximately 5 seconds. Pilot response is expected within approximately 2.5 seconds if an additional RA is issued. (The increase rate and rate reversal RAs are based on a 0.35 g acceleration maneuver.) Because of these requirements and the rate limits of the autopilots, all RA responses must be hand-flown and not with the autopilot or autothrottles engaged.

> **NOTE:** Evasive maneuvering should be limited to the minimum required to comply with the RA. Excessive responses to RAs are not desirable or appropriate because of other potential traffic and ATC consequences. From level flight, proper response to an RA typically results in an overall altitude deviation of 300 to 500 feet in order to successfully resolve a traffic conflict.

Modified advisories are posted after the response to an initial advisory has been completed and the TCAS II airplane is projected to have adequate altitude separation from the intruder. The initial RA is said to weaken, indicating a return towards the original flight path or clearance is allowed. When the initial advisory weakens, the green arc is repositioned to indicate level flight, the magnitude of the red arc decreased, and "LEVEL OFF, LEVEL OFF" is announced. The modified RA indicates a return to level flight so that the altitude displacement in response to the initial RA can be minimized. This RA will remain displayed until the "CLEAR OF CONFLICT" aural annunciation is issued. Following the weakening advisory will greatly reduce the ultimate altitude deviation caused by the original corrective resolution advisory.

If a "CLIMB" RA is issued while in the landing configuration, initiate normal go-around procedures.

> **NOTE:** Initiating go-around procedure for a "CLIMB" RA does not mandate a missed approach. It is intended to ensure the airplane is properly configured for the TCAS II maneuver. In most cases, the TCAS II event will be resolved with only minor deviation to the intended flight path, and sufficient time and altitude may exist to recover safely to the desired flight path.

The pilot should not initiate evasive maneuvers using information from the traffic display only or on a traffic advisory (TA) only without visually sighting the traffic. These displays and advisories are intended only for assistance in visually locating the traffic and lack the flight path

trends necessary for use in evasive maneuvering. However, unnecessary resolution advisories can be issued by TCAS II when other aircraft are operating at an altitude adjacent to the one that has been assigned to the climbing or descending TCAS aircraft. When climbing or descending in an environment where these unnecessary advisories are considered likely to occur (based on either airspace design, air traffic communications, visual acquisition or utilization of traffic displays), a reduction in vertical velocity is recommended until reaching the assigned altitude. As appropriate, the vertical velocity should be reduced to a rate between 500 and 1,500 ft/min, when approaching an altitude between 1,000 and 2,000 ft. above or below the altitude assigned in the ATC instruction or clearance.

After deviating from an ATC clearance or instruction in response to a TCAS II RA, notify ATC of the deviation as soon as possible.

Following a TCAS II "CLEAR OF CONFLICT" advisory, the pilot should expeditiously return to the applicable ATC clearance unless otherwise directed by ATC.

> **NOTE:** The threat aircraft track or altitude information can be lost during an RA. If so, the RA will terminate without a "CLEAR OF CONFLICT" annunciation.

(2) TCAS II Operation:

Pilot-Initiated TCAS II self-test:

(a) The TCAS II should be tested using the pilot-initiated self-test feature during cockpit preparation. A successful test is indicated by (**provide test results from particular TCAS II system**).

(b) Use of the self-test function in flight will inhibit TCAS II operation for up to (**provide time for a particular TCAS II system**) seconds.

(c) The ATC transponder will not function during some portion of the self-test sequence.

(d) All aircraft systems providing information to TCAS II must be operating in their normal mode during the Self-Test.

Ground Operation:

(a) The TCAS II should not be selected out of STBY to TA-only or TA/RA mode until taking the active runway for departure.

(b) The TCAS II should be selected to STBY immediately after clearing runway following landing.

TA Mode:

(a) The TA position should only be used to preclude unnecessary RAs when intentionally operating near other aircraft such as to closely spaced parallel runways (less than 1200 feet apart).

(b) In TA mode, RAs will not be issued.

WX-ONLY Mode:

(a) When WX-ONLY mode is selected, traffic information, traffic advisories, and resolution advisories are inhibited on the weather radarscope. Therefore, this mode should be used only in the event TCAS interferes with weather information. (This example is to show the kind of procedure to be developed. Procedures will vary depending upon installation; such as pop-up display modes, PFD/ND implementation, etc.)

(3) TCAS II System Characteristics:

(a) "CLIMB" RAs are inhibited with flaps greater than XX degrees.

(b) When below 1000 feet AGL, the TCAS II will automatically switch into the TA only mode.

(c) "INCREASE CLIMB" RAs are inhibited with flaps greater than XX degrees.

(d) "DESCEND" RAs are inhibited below 1200 feet AGL while climbing and below 1000 feet AGL while descending.

(e) "INCREASE DESCENT" RAs are inhibited below 1450 feet AGL.

(f) Voice messages are inhibited below 600 feet AGL while climbing and below 400 feet AGL while descending.

(g) The TCAS II surveillance may not function at distances less than 900 feet.

(h) During windshear and/or GPWS/TAWS warnings, TCAS II switches automatically into a TA only mode with aural annunciation inhibited. In this mode, RAs are not issued and current RAs become TAs. The TCAS II remains in TA Only mode for 10 seconds after the windshear or GPWS/TAWS warning is removed. TCAS II aural annunciations are enabled immediately following the removal of the windshear or GPWS/TAWS warning aural annunciation.

(4) TCAS II Abnormal Procedures:

> **NOTE:** These examples are to show the kinds of abnormal procedures to be developed. Procedures will vary depending upon the installation, such as dual Mode S, and so forth.

RA OFF Flag in IVSI.

(a) Verify TCAS II/transponder function selector is in TA/RA position.

(b) If TA/RA is selected and "RA OFF" flag is in view, then the pilot with the operable IVSI (flag not in view) should be the pilot flying.

AMBER FLAG in IVSI.

(a) Check XPDR FAIL light.

(b) If OFF, select other altitude source.

(c) If ON, select alternate ATCRBS transponder. (TCAS II will no longer be available).

XPDR FAIL Light Illuminated.

(a) Select alternate ATCRBS transponder. (TCAS II will no longer be available.)

SECTION IV – PERFORMANCE

No change from basic airplane flight manual.

Appendix B. Transponder Ground Tests & Evaluations.

1. Tests and Evaluations. Using a suitable calibrated transponder test set, conduct the following tests:

> **Note:** CAUTION! When conducting any ground testing of the transponder or TCAS system, you must prevent being a source of interference to ATC or other TCAS aircraft operating in the area. Ground maintenance checks or ramp testing (such as altimetry or bearing accuracy testing) can cause data to be transmitted which produce false targets for the ground ATC surveillance systems or airborne TCAS aircraft. These false indications of "intruder aircraft" could result in unnecessary ATC communications and possibly in TCAS induced aircraft maneuvers. Therefore, conduct such testing in coordination with ATC and use antenna shielding (that is, transmission absorption covers or caps) to prevent test data that could generate false intruder information from being transmitted. Using high-powered, hangar-mounted transponders to conduct ramp testing is NOT an acceptable means for conducting either TCAS or transponder ramp testing.

a. Mode Test. Identifies modes of operation. Interrogations are made in Modes A, C, and S (uplink format 11) to determine which modes the transponder replies to. These are the modes tested during the Auto Test sequence.

b. Reply Delay. Interrogates with valid modes and verifies Reply delay minus Range delay (average of best 8 out of 13 replies) equals:

(1). 128.00 μs (±0.25 μs) for Mode S.

(2). 3.00 μs (±0.50 μs) for ATCRBS.

c. Reply Jitter. Interrogates with valid modes and verifies, using best 8 out of 13 replies. Reply Jitter (changes In Reply Delay) is less than or equal to:

(1). 0.05 μs for Mode S.

(2). 0.06 μs for Intermode (All-Call).

(3). 0.10 μs for ATCRBS.

d. ATCRBS Reply. Interrogates with ATCRBS (Modes A and C) interrogations and verifies:

(1). F1 to F2 spacing is 20.3 μs (±0.10 μs).

(2). F1 and F2 pulse width between the 0.5 amplitude point on the leading and trailing edge is 0.45 μs (±0.10 μs).

e. SLS Level. Interrogates with valid ATCRBS Interrogations including P2 pulse. Interrogations are conducted with P2 level at -9 dB and then again at 0 dB. Test verifies:

(1). Transponder does not reply when P2 level is at 0 dB (UUT is suppressed).

(2). Transponder replies when P2 level is at -9 dB (UUT is not suppressed).

f. ATCRBS-Only All-Call. Interrogates with an ATCRBS-only All-Call and verifies:

(1). If Mode S is valid, no reply is received from a Mode S transponder.

(2). If no Mode S, reply is received from an ATCRBS transponder.

g. Mode S All-Call. Interrogates with the ATCRBS (mode A) Mode S All-Call. Address received in downlink format (DF) 11 is then used in an uplink format (UF) 4 interrogation to solicit a DF4 reply. The address received is decoded and compared with the address sent.

h. Invalid ICAO 24-bit aircraft address. Interrogates with Mode S interrogations using two addresses different from the address determined by the Mode S All-Call, UF11. Test verifies no reply is received. Addresses used are one greater and 256 greater than the correct address.

i. SPR On/Off. Interrogates with a Mode S interrogation with the Synchronous Phase Reversal (SPR) on, verifying correct reply is received. Then same interrogation is sent again with the SPR off, verifying no reply is received.

j. Mode S UF0. Interrogates with Mode S uplink format 0 (Short air-to-air surveillance, ACAS) verifying reply is received that has correct altitude (compared with Mode C altitude), address (compared with Mode Test address) and format.

k. Mode S UF4. Interrogates with Mode S uplink format 4 (Surveillance, altitude request), verifying reply is received that has correct altitude (compared with Mode C altitude), address (compared with Mode Test address) and format.

l. Mode S UF5. Interrogates with Mode S uplink format 5 (Surveillance, identity request) verifying reply is received that has correct identity (compared with Mode A identity), address (compared with Mode Test address) and format.

m. Mode S UF11. Interrogates with Mode S uplink format 11, verifying reply is received that has correct address (compared with Mode Test address) and format.

n. Mode S UF16. Interrogates with Mode S uplink format 16 (Long air-to-air surveillance, ACAS), verifying reply, if received, has correct altitude (compared with the Mode C altitude), address (compared with Mode Test address) and format. No reply to UF16 does not fail Mode S in Auto Test.

o. Mode S UF20. Interrogates with Mode S uplink format 20 (Comm A, altitude request) verifying reply received has correct altitude (compared with Mode C altitude), address (compared with Mode Test address) and format. No reply to UF20 does not fail Mode S in Auto Test.

p. Mode S UF21. Interrogates with Mode S uplink format 21 (Comm A, identity request) verifying reply received has correct identity (compared with Mode A identity), address (compared with Mode Test address) and format. No reply to UF21 does not fail Mode S in Auto Test.

q. Acquisition Squitter. Verifies squitters are being received from the UUT every 0.8 to 1.2 seconds.

r. Frequency. Verifies frequency of transponder is 1090 MHz (± frequency tolerance as specified by equipment manufacturer). Frequency is displayed in the Auto Test screen.

s. Diversity. Verifies diversity isolation (power level difference between UUT "On" antenna squitters and "Off" antenna squitters) is greater than or equal to 20 dB. Diversity isolation is displayed in Auto Test screen.

> **Note:** To ensure >=20 dB dynamic range, test must be run within 50 feet (15.24 meters) of UUT antenna being tested.

t. MTL Difference. Verifies Receiver Sensitivity (MTL) to Mode A interrogations equals MTL to Mode C interrogations (±1.0 dB).

u. Altitude Reporting. Verifies the reported altitude in the AC field of DF0, DF4, D16, and D20 corresponds to the value provided from the on-board altitude source to the transponder and is reported with the quantization indicated by the Q bit in the AC field. For aircraft with 25 foot or better pressure altitude sources, pressure altitude information should be reported in 25-foot increments. Pressure altitude data obtained from a source with larger than 25-foot resolution shall not be reported using 25-foot increments.

Note: To ensure the correct reporting of altitude with the proper quantization, the aircraft altitude must be incremented over a 300-foot range in 25 foot increments.

Appendix C. Background.

1. Early TCAS. The airline industry has been working with the Air Transport Association of America (ATA) since 1955 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 FAA announced our decision to implement an aircraft collision avoidance concept called the Traffic Alert and Collision Avoidance System (TCAS). The concept is based upon agency and industry development efforts in the areas of beacon based collision avoidance systems and air-to-air discrete address communications techniques utilizing Mode S airborne transponder message formats.

a. 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 flight crew 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. On 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, 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 flight crew operated the system, the evaluation was primarily for the purpose of data collection and its correlation with flight crew and observer observation and response.

b. Later versions of TCAS II manufactured by Bendix/King Air Transport Avionics Division were installed and approved on United Airlines airplanes in early 1988. Similar units manufactured by Honeywell were installed and approved on Northwest Airlines airplanes in late 1988. This limited installation program operated TCAS II units approved for operation as a full-time system 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.

Appendix D. Related Documents.

1. 14 CFR Parts. You can apply current portions of 14 CFR for the design, substantiation, certification and operational approval of TCAS II and Mode S transponders. Sections prescribing requirements for these types of systems are listed below. Order copies of 14 CFR Parts 21, 23, 25, 27, 29, 43, 91, 121, and 135 from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402-9325, telephone (202) 512-1800, fax (202) 512-2250. You can also get copies from the Government Printing Office (GPO), electronic CFR Internet website at http://www.gpoaccess.gov/cfr/.

14 CFR § 25.301 Loads.

14 CFR § 25.303 Factor of safety.

14 CFR § 25.305 Strength and deformation.

14 CFR § 25.561 General.

14 CFR § 25.603 Materials.

14 CFR § 25.609 Protection of structure.

14 CFR § 25.629 Aeroelastic stability requirements.

14 CFR § 25.869 Fire protection: systems.

14 CFR § 25.1301 Function and installation.

14 CFR § 25.1303 Flight and navigation instruments.

14 CFR § 25.1307 Miscellaneous equipment.

14 CFR § 25.1309 Equipment, systems, and installations.

14 CFR § 25.1316 System Lightning Protection.

14 CFR § 25.1317 High-intensity Radiated Field (HIRF) Protection.

14 CFR § 25.1321 Arrangement and visibility.

14 CFR § 25.1322 Warning, caution, and advisory lights.

14 CFR § 25.1331 Instruments using a power supply.

14 CFR § 25.1333 Instrument systems.

14 CFR § 25.1335 Flight director systems.

14 CFR § 25.1351 Electrical Systems and Equipment: General.

14 CFR § 25.1353 Electrical equipment and installations.

14 CFR § 25.1355 Distribution system.

14 CFR § 25.1357 Circuit protective devices.

14 CFR § 25.1381 Instrument lights.

14 CFR § 25.1431 Electronic equipment.

14 CFR § 25.1541 Markings and Placards: General.

14 CFR § 25.1581 Airplane Flight Manual: General.

14 CFR § 25.1585 Operating procedures.

> **Note:** References to 14 CFR part 25 are appropriate when installing TCAS II on transport category airplanes. When TCAS II is to be certified for non-transport category airplanes, use the equivalents to the above 14 CFR part 25 sections in other parts of the regulations.

2. FAA ACs. You will find a current list of advisory circulars on the FAA Internet website http://www.faa.gov/regulations_policies/advisory_circulars/.

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

AC 20-115, *Radio Technical Commission on Aeronautics (RTCA) Document DO-178B.*

AC 25.1309-1 *System Design and Analysis.*

AC 25-11A, *Electronic Flight Deck Displays*.

AC 120-55B, *Air Carrier Operational Approval and Use of TCAS II.*

3. FAA Technical Standard Orders. You will find a current list of TSOs on the FAA Internet website Regulatory and Guidance Library at http://rgl.faa.gov. You will also find the TSO Index of Articles at the same site.

TSO-C112c, *Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*.

TSO-C119c, *Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II.*

4. Industry Publications. Order RTCA documents from RTCA, Inc., 1828 L Street N.W. Suite 805, Washington D.C. 20036 or order online at www.rtca.org.

RTCA/DO-160F, *Environmental Conditions and Test Procedures for Airborne Equipment,* dated December 6, 2007.

RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certifications, dated* December 1, 1992.

RTCA/DO-181C (or later revision), *Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment,* dated June 12, 2001 .

RTCA/DO-185A, *Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance Systems II (TCAS II),* dated December 16, 1997.

RTCA/DO-185B, *Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance Systems II (TCAS II),* dated June 19, 2008.

RTCA/DO-300, *Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance,* dated December 13, 2006.

5. SAE International. Order SAE documents from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, telephone (724) 776-4970, fax (724) 776-0790. Also, order copies online at www.sae.org.

ARP 926B, *Fault/Failure Analysis Procedure,* dated June 11, 1997.

ARP 1834A, *Fault/Failure Analysis for Digital Systems and Equipment,* dated June 1, 1997.

ARP 4102/7, *Electronic Displays,* dated July 1, 1988.

ARP 4102/8, *Flight Deck Head-Up Displays*, dated November 1, 1998.

ARP 4754, *Certification Considerations for Highly Integrated or Complex Aircraft Systems,* dated November 1, 1996.

ARP 4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment,* dated December 1, 1996.

6. AERONAUTICAL RADIO, INC. (ARINC). Publications are available from ARINC, 2551 Riva Road, Annapolis, Maryland 21401; telephone 1-800-633-6882 or online at www.arinc.com.

ARINC 718, *Mark 3 Air Traffic Control Transponder (ATCRBS/MODE S),* dated December 1989.

ARINC 735, *Mark 2 Traffic Alert And Collision Avoidance System (TCAS)*, dated January 2003.

7. International Civil Aviation Organization (ICAO). Publications are available from ICAO, Attention: Customer Service unit, 999 University Street, Montreal, Quebec, Canada H3C5H7; telephone +1 514-954-8022, facsimile: 514-954-6769, sitatex YULCAYA, email: sales@icao.int or on line at http://www.icao.int.

Airborne Collision Avoidance System (ACAS) Manual document 9863, First Edition dated 2006.

8. JAA. JAA documents are available from the Information Handling Services (IHS). Information on prices, where and how to order is available on both the JAA web site: www.jaa.nl and the IHS web site: www.avdataworks.com. JAA documents transposed to publications of the European Aviation Safety Agency (EASA) are available on the EASA web site at www.easa.eu.int.

JAA Temporary Guidance Leaflet (TGL) 13 Revision 1.

9. EASA. Publications are available on the EASA web site at www.easa.eu.int.

AMC 20-13 Certification of Mode S Transponder Systems for Enhanced Surveillance.

Appendix E. Definitions and Acronyms.

1. Definitions.

a. Active surveillance. Using TCAS interrogations and subsequent replies to update or acquire a TCAS track.

b. Advisory. Message given to alert the flight crew of converging aircraft and/or a potential collision.

c. 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.

d. Alert. Indication (aural or visual) that informs the flight crew in a timely manner about converging aircraft or potential collision.

e. 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 (ES) and the universal asynchronous transceiver (UAT) broadcast on 978MHz.

f. Coast. Condition which occurs when TCAS II 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.

g. Corrective resolution advisory (RA). Advises the pilot to either deviate from current vertical speed, such as CLIMB when the aircraft is level, or to maintain an existing climb or descent rate.

> **Note:** In TCAS II Version 7.0 and V7.1, 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.

h. Discrete. Separate, complete and distinct signal.

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

j. False advisory. Advisory caused by a false track or TCAS II malfunction.

k. Fruit. Intruder replies corrupted by the receipt of undesired transponder replies elicited by ground interrogators and other TCAS II interrogators.

l. Hybrid Surveillance. Combined use of active and passive surveillance to update a TCAS track.

m. Incorrect resolution advisory (RA). 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.

n. Intruder. Aircraft satisfying the TCAS II traffic advisory detection criteria.

o. Mode A. Type of secondary surveillance radar (SSR) equipment or mode of operation that replies by selected 4096 code (nonaltitude) when interrogated.

p. Mode C. Type of secondary surveillance radar (SSR) equipment or mode of operation that replies with aircraft altitude information when interrogated.

q. Mode S. Type of secondary surveillance radar (SSR) equipment that replies to Mode A and Mode C ground interrogations, a discrete address, and other aircraft information in response to interrogations from the ground or air.

r. Other traffic. Aircraft more than ±1200 feet vertical or 6 nautical miles (NM) from own aircraft that are neither RA nor TA.

s. Passive surveillance. The use of airborne position messages to update a TCAS track**.**

t. Preventive resolution advisory. Requires a pilot to avoid certain deviations from current vertical rate (for example, a Do Not Climb RA when the aircraft is level).

u. Proximate traffic. Aircraft within 6 NM in range and within ±1,200 feet vertically from own aircraft, but does not meet the TCAS II thresholds of a TA or RA.

v. Resolution advisory (RA). Aural voice and display information provided by TCAS II to a flight crew, advising that a particular maneuver should, or should not, be performed to attain or maintain minimum safe vertical separation from an intruder.

w. Resolution display. Shows vertical guidance depicting areas to “fly to” and/or avoid above or below the TCAS II equipped aircraft.

x. Sense. A direction that an RA may take (either Climb or Descend) relative to the existing flight path of own aircraft.

y. Threat. An intruder that satisfies the threat detection logic and thus requires an RA.

z. Track. Estimated position and velocity of a single aircraft based on correlated surveillance data reports.

aa. Traffic. Aircraft with an operating transponder capable of being tracked and displayed by a TCAS-equipped aircraft.

bb. Traffic advisory (TA). Aural voice and display information from TCAS II to a flight crew, identifying the location of nearby traffic meeting certain minimum separation criteria.

cc. Traffic display. Horizontal position of transponder-equipped aircraft relative to the TCAS II equipped aircraft.

2. Acronyms.

Table E-1 Acronyms.

Acronym	Definition
14 CFR	Title 14 of the Code of Federal Regulations
ACARS	Aircraft communications addressing and reporting system
ADS-B	Automatic dependent surveillance - broadcast
AFM	Airplane flight manual
AFMS	Airplane flight manual supplement
AGL	Above ground level
ASR	Airport surveillance radar
ATA	Air Transport Association
ATC	Amended type certificate
ATC	Air traffic control
ATCRBS	Air traffic control radar beacon system
CAS	Collision avoidance algorithm , or CAS logic
CRS	CAS requirements specification
dB	Decibel
DRVSM	Domestic reduced vertical separation minimum
EADI	Electronic attitude display indicator
EFIS	Electronic flight instrument system
EHSI	Electronic horizontal situation indicators
EMI	Electromagnetic interference
FAA	Federal Aviation Administration
FD	Flight director
FHA	Functional hazard assessment
FL	Flight level

Table E-2 Acronyms. (continued)

FMEA	Failure modes and effects analysis
FPM	Feet Per Minute
GPS	Global positioning system
GPWS/TAWS	Ground proximity warning system/terrain awareness warning system
HUD	Heads-up device
ICAO	International Civil Aviation Organization
IVSI	Instantaneous vertical speed indicators
MHz	Megahertz
NAS	National Aerospace System
ND	Navigation display
NM	Nautical mile
PFD	Primary flight display
RA	Resolution advisory
SARP	Standards and Recommended Practices
STC	Supplemental type certificate
TA	Traffic advisory
TC	Type certificate
TCAS II	Traffic alert and collision avoidance system
TSO	Technical standard order
TTP	TCAS transition program
V_{mo}	Maximum operating limit speed