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. They also provide the flightcrew the opportunity to visually acquire the intruding aircraft. A resolution advisory will provide a vertical avoidance maneuver that will increase separation when the computer predicts the threat aircraft is within approximately 25 seconds from the closest point of approach.

The system provides two types of flightdeck displays. A traffic display indicates the relative position of ATC transponder equipped aircraft. A resolution display for each pilot indicates the appropriate vertical maneuver to avoid a threat. 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 equipped aircraft. The Mode S transponder also provides discrete address replies to interrogations from ground stations and other TCAS II equipped aircraft.

The TCAS II system can only generate resolution advisories 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 aircraft with operative Mode S, Mode C or Mode A transponders. The TCAS II equipment is viewed as a supplement to the pilot who, with the aid of the ATC system, has the primary responsibility for avoiding mid-air collisions. The TCAS II system provides no indication of aircraft without operative transponders.

3. <u>AIRWORTHINESS CONSIDERATIONS</u>.

a. <u>Certification Program</u>. This AC provides guidance for the installation of TCAS II equipment and Mode S transponders. 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, the applicant's program must be directed toward airworthiness approval through the type certification or supplemental type certification process.

b. <u>Certification Plan</u>. A comprehensive certification plan should be developed by the applicant. It should include how the applicant plans to comply with the applicable certification requirements and should provide a listing of the substantiating data and necessary tests. Also, a system description and an estimated time schedule should be included. A well developed plan will be of significant value both to the applicant and the FAA.

c. <u>Equipment Installation</u>.

(1) Mode S Transponder. A Mode S transponder is required for TCAS II operation. It is an enhanced version of existing ATCRBS transponders that is interoperative and compatible with the current ATCRBS system. 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 Mode A and C transponders. A Mode S transponder may be installed independently or in conjunction with a TCAS II installation. The performance standard for Mode S is provided in paragraph (a)(1), Minimum Performance Standard, of TSO-C112. The discrete aircraft address for the Mode S transponder must be obtained from the appropriate airworthiness authorities 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 the discrete aircraft address may be obtained from the Federal Aviation Administration, Mike Monroney Aeronautical Center, Aircraft Registration Information, AVN-450, P.O. Box 25082, Oklahoma City, OK 73125, Telephone: (405) 680-3116.

(2) Pilot Control.

(i) A means to select the following modes of operation must be provided:

(A) Operation of the Mode S transponder only.

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

(C) Operation of the ATCRBS transponder only, if installed. It must not be possible to operate the TCAS II and ATCRBS transponder or the Mode S and ATCRBS transponder simultaneously.

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

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

(ii) The following additional features must also be provided:

(A) A means to select the assigned ATCRBS code.

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

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

(D) A means to suppress transponder altitude reporting.

(iii) The following optional controls may be provided:

(A) Selection of the weather radar only.

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

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

(D) Selection of actual/flight-level (FL) or relative altitude of traffic.

(3) Antennas. The active Mode S transponder shall have a top and bottom omni-directional antenna. The TCAS II shall have a top directional antenna and a bottom omni-directional or directional antenna.

(i) Directional antennas. For an aircraft installation, the TCAS II directional antenna should be located on the top forward fuselage as close to the centerline as possible. If more than one directional antenna is provided, locate the second antenna in a similar manner on the lower fuselage. The TCAS II antennas should be mounted on the aircraft with at least 20 db. isolation from other L-band frequency antennas. 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. 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, anti-icing provisions should be considered. Section 3 of Volume I of RTCA document DO-185 provides antenna selection and performance criteria. For propeller driven aircraft, the location and performance of the directional antenna must be investigated for minimum blockage and to ensure that the propellers do not interfere with system operation.

(ii) Omni-directional antennas. The TCAS II antennas should be mounted on the aircraft with at least 20 db. isolation from other L-band frequency antennas. The Mode S transponder antennas shall be mounted at locations chosen for adequate isolation and signal coverage. These antennas may be standard ATCRBS transponder antennas.

(iii) Structural analysis. A structural analysis of the antenna installations showing compliance with the applicable FAR should be submitted to the FAA. This includes the structural provisions for a beam steering unit (if installed) if it is not mounted in a standard avionics rack.

(4) The TCAS II Processor. The TCAS II processor unit computes information to identify and to display potential and predicted collision threats, and to issue resolution advisories to avoid the threat aircraft. The TCAS II processor unit must comply with the environmental requirements and minimum performance standards specified in TSO-C119a. A manufacturer of TSO equipment may obtain authorization to produce equipment which deviates from the detailed criteria of the TSO. The FAA aircraft certification office which is 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 document DO-185, Volumes I and II, Changes 1 through 6, Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment.

(5) Equipment Compatibility. An evaluation should be made to show that the TCAS II system will communicate with other approved TCAS II systems made by other manufacturers. This evaluation should include a TCAS II to TCAS II coordination demonstration, or equivalent, with at least one other manufacturer's approved TCAS II system. 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.

(6) Aircraft Performance.

(i) This paragraph, along with Table I, provides guidance on considerations and analysis to evaluate the need to inhibit TCAS II CLIMB and/or INCREASE CLIMB RAs because of 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 is likely they are beyond the capability of the aircraft, then TCAS II must know beforehand so it can change its strategy and issue an alternative RA. These performance limits shall be provided to TCAS II from the aircraft interface and discretes relative to altitude and/or configuration. However, the need to inhibit TCAS II CLIMB or INCREASE CLIMB RAs should be carefully considered since the alternative RAs will 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) 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.

(ii) 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 only, and no switch exists to sense that position, an additional switch should be installed in lieu of simply using one that may exist at lesser flap angles.

(iii) Because of the limited number of inputs to TCAS II for airplane performance inhibits, in some instances where inhibiting RAs would be appropriate it is not possible to do so. In these cases, TCAS II may command maneuvers which may significantly reduce stall margins or result in stall warning. Conditions where this may occur include bank angles greater than 15°, weight/altitude/temperature combinations outside the envelope shown in Table I, initial speeds below those shown in Table I, one engine inoperative, leaving configuration fixed for climb RA on landing transition to go-around, and abnormal configurations such as landing gear not retractable. The Airplane Flight Manual (AFM) or Airplane Flight Manual Supplement (AFMS) should provide information concerning this aspect of TCAS so that flightcrews may take appropriate action.

(iv) An aircraft's low altitude climb capability during takeoff, approach, or landing is significantly affected by the aircraft's configuration, initial climb true airspeed available to safely trade if needed for climb rate, and the initial airspeed margin from the current stall speed. Table I, Conditions 1-3 apply for the takeoff and initial climb configuration analysis. Conditions 4-6 apply for the approach flap configuration analysis when operating in the terminal area with the flaps set at less than the landing flaps. Conditions 7-9 apply for the landing flight regime analysis. To be consistent with normal operation, the AFM or AFMS should indicate 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, it may be assumed that the flaps are being retracted from the landing position to the go-around position when evaluating Conditions 7-9.

(v) To prevent very unlikely combinations of events, e.g., weight/altitude/temperature limiting conditions, in conjunction with low airspeed, high drag configurations, unusual encounter geometries, etc., causing climb inhibits when generally the aircraft's performance is more than adequate, the entry and exit conditions and RAs in Table I are structured into two classes of encounters. Maneuvers A and B represent reasonably severe combinations of entry conditions and RAs, and restricts the exit conditions to $1.2V_{S1}$. Maneuver C represents reasonably worst case combinations of entry conditions and RAs, and for this very unlikely event may require flying near stall warning conditions through the recovery. Airspeeds between $1.2V_{S1}$ and stall warning represent a range of usable airspeed that maybe traded for climb performance (as is currently recommended for windshear recovery) for evaluation of this low probability event. The altitude/temperature envelope represents a range of values which exist at busy airports in the continental USA. Operation routinely outside this envelope may require special crew procedures if the normal AFM weight, altitude, temperature, and configuration limitations are not sufficiently compensating, e.g., operation at Mexico City.

(vi) For those airplanes that may routinely operate at low climb airspeeds during the clean configuration en route phase of flight, e.g., propeller commuter airplanes, consideration should be given to 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. Such a scheme would be considered appropriate in lieu 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.

(vii) An aircraft's climb capability when operating at or near its maximum approved operating altitude is also affected by excess thrust and true airspeed, which may be available to safely trade if needed 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. The configurations that should be evaluated in this flight regime are shown in Table I, Conditions 10 and 11. If the aircraft is approved for significant alternative configurations, then the initial airspeed used for the analysis should be appropriate for them;

e.g., spare engine pod, gear down operation, etc. 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.

(viii) In icing conditions, the FAR limited performance weights must be debited and sometimes the operating speeds increased to account for icing system bleeds and residual ice 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, additional RA inhibits enabled by icing system activation should be considered.

(ix) If Maneuver A causes airspeeds below the minimum in Table I, then the CLIMB RA should be inhibited. If Maneuver B or C cause airspeeds below the minimum in Table I, then the INCREASED CLIMB RA should be inhibited. 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 3c(6)(i).

(x) System Inhibits. A summary of the inhibits (limitations) that have been programmed into the TCAS computer are given in Table II.

COND	FLIGHT REGIME	WEIGHT ALTITUDE TEMPERATURE[1]	THRUST	FLAPS	GEAR	AIRSPEED INITIAL	AIRSPEED MIN.	MANEUVER
1.	Takeoff	FAR 25 Climb Limit	Maximum Rated Takeoff	All Takeoff	UP	V_2+20[2]	1.2 V_{S1}[4] thru RA	A
2.	"	"	"	"	"	"	"	B
3.	"	"	"	"	"	AFM All-Engine Takeoff Speed[3]	15° Bank to Stall Warning[5] thru Recovery	C
4.	Approach	"	Spin up to Max. Go-Around Thrust During Maneuver from Thrust for Level Flight	Less than Landing	"	1.6 V_{S1}	1.2 V_{S1}[4] thru RA	A
5.	"	"	"	"	"	"	"	B
6.	"	"	"	"	UP or DN to UP	Min. Maneuver Speed from Training Procedures	15° Bank to Stall Warning[5] thru Recovery	C
7.	Landing Transitioning to Go-Around at RA	"	Spin up to Max. Go-Around Thrust During Maneuver from Thrust Required for 3° Guide Slope	Transition from Landing Flap to Go-Around Flap	DN to UP	$V_{REF}+10$	1.2 V_{S1}[4] thru RA	A
8.	"	"	"	"	"	"	"	B
9.	"	"	"	"	"	V_{REF}+ Airspeed Addition from Training Procedures	15° Bank to Stall Warning[5] thru Recovery	C
10.	En Route	Critical Wt/Alt Giving 0.3g to Buffet Onset	Thrust for Level Flt Increased to Max. Continuous if Required	UP	UP	Long-Range Cruise	Higher of 1.2 V_S[4] if Defined or Buffet Onset	A
11.	"	"	"	"	"	"	"	B

Table I

1. Weight = Lesser of climb limit or structural; Airport Pressure Altitude = S.L. to 5300 ft; Temperature = ISA +/- 50°F(10°C); Conditions 1-3 evaluated 700 ft above airport; Conditions 4-9 evaluated 1700 ft above airport.
2. V_Y + 10 for nontransport category aircraft without a defined V_2.
3. V_Y for nontransport category aircraft without a defined V_2.
4. 1.1 V_S for those airplanes where the power-on stalling speed is significantly reduced from the power-off stalling speed.
5. V_{S1} for those airplanes where the power-on stalling speed is significantly reduced from the power-off stalling speed.

TABLE I MANEUVERS

A. This maneuver is to evaluate the TCAS II CLIMB RA. From the initial steady state condition, after an expected 3-second pilot reaction time delay, rotate the aircraft at 1.25g 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.

B. This maneuver is to evaluate the TCAS II INCREASE CLIMB RA following a CLIMB RA. From the initial steady state condition, after an expected 3-second pilot reaction time delay, rotate the aircraft at 1.25g to attain +1500 feet per minute climb. Hold until 15 seconds has elapsed from when the CLIMB RA was issued. Then, after an expected 1-second pilot reaction time delay to the INCREASE CLIMB RA, rotate the aircraft again at 1.25g 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.

C. This maneuver is to evaluate a maximum duration TCAS II INCREASE CLIMB RA following a minimum duration CLIMB RA. From the initial steady state condition, after an expected 3-second pilot reaction time delay, rotate the aircraft at 1.25g targeting +1500 feet per minute climb until 6 seconds has elapsed from when the CLIMB RA was issued. Then, after an expected 1-second pilot reaction time delay to the INCREASE CLIMB RA, rotate the aircraft again at 1.25g to attain +2500 feet per minute climb and hold until the total duration of the RA of 24 seconds has elapsed. Delay recovery 1 second to account for expected pilot reaction time delay to the end of the encounter. Recover to attain the initial trim airspeed.

TABLE II SYSTEM INHIBITS

A summary of the inhibits (limitations) that have been programmed into the TCAS computer.

INHIBIT	PARAMETERS
Increase Descent RA	Inhibited below 1450 ft AGL.
Descend RA	Inhibited below 1200 ft AGL while climbing & inhibited below 1000 ft AGL while descending.
RA & TA Voice Messages	Inhibited below 400 ft AGL while descending & inhibited below 600 ft AGL while climbing. (TCAS automatically reverts to TA only).
Close-Range Surveillance	May not function at separations of less than approximately 900 ft.
Self-Test	Can be inhibited when airborne.
Advisory Priority	Can revert to TA ONLY when higher priority advisories (e.g., GPWS, Windshear) occur.
Climb RA	1500 fpm can be inhibited, based upon aircraft performance capability.
Increase Climb RA	2500 fpm can be inhibited, based upon aircraft performance capability.
Altitude Limit for Climb RA	Can be inhibited, based upon aircraft performance capability.

(7) Aircraft Interfaces.

(i) Pressure altitude information. The pressure altitude data should be obtained from the most accurate source available in the aircraft and shall correspond to that being transmitted by the associated Mode S transponder. The accuracy of the altitude data shall be at least that specified in Appendix A of RTCA document DO-185. It shall be shown that the resolution of the altimetry source is compatible with TCAS II. The altitude source with the finest compatible resolution should be used. When available, the resolution should be in increments of 10 feet or less. Information should also be provided to indicate when the pressure altitude information is invalid.

(ii) Radio altitude information. Radio altitude information shall be provided to TCAS II to inhibit DESCEND resolution advisories below 1000 feet AGL, INCREASE DESCENT resolution advisories below 1450 feet AGL, all resolution advisories and aural traffic advisories below 400 feet AGL, to allow automatic sensitivity level selection when close to the ground, and to determine that individual targets are on the ground. Information shall also be provided to indicate when the radio altitude information is invalid.

(iii) Discrete information from aircraft configuration sensors such as flaps, slat, landing gear, etc., should be used to ensure that TCAS II appropriately inhibits climb and increased climb RAs to the airplane performance limits as described in paragraph 7c(6).

(iv) Aircraft identification. Discrete information shall be provided to the Mode S transponder for the unique aircraft Mode S identification code and its maximum airspeed capability.

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

(vi) Heading. Information of aircraft heading may be provided for use of surveillance reference and for the TA display reference presentation. Information shall also be provided to indicate when the heading data are invalid.

(vii) System failure display. An indication shall be provided to indicate when resolution advisories are not possible due to failure of the TCAS II equipment or any of its sensors or displays.

(8) Traffic Display.

(i) Purpose. The primary purpose of the traffic display is to aid the flightcrew 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 will 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 provide the flightcrew with confidence in proper system operation and to give them time to prepare to maneuver the aircraft in the event TCAS II issues a resolution advisory.

(ii) Description. The traffic display may take several forms. Traffic displays may be independent, stand-alone, integrated and time-shared with digital color radar, integrated with the flightcrew's Instantaneous Vertical Speed Indicators (IVSI), or integrated with other displays such as Electronic Horizontal Situation Indicators (EHSI), navigation, or other multi-function displays. If the traffic display uses a multi-function display that is shared with other services such as ACARS, the traffic display function shall be immediately available for display by a single selection accessible to both pilots.

(iii) Symbology/Feature Criteria. The FAA has worked closely with the ATA, NASA, and both the SAE S-7 and G-10 Committees in an effort to standardize TCAS II symbology and features. A consensus has been reached for TCAS II symbols and they are provided in this AC. Other symbology and features may be used provided the applicant uses human factors technology to demonstrate that a clear and substantial benefit can be derived by its use. Otherwise, the traffic display must depict or provide the following symbology, features, or information:

(A) Own Aircraft Symbol. This shall be an aircraft-like symbol. For fixed range displays, it should be located so as to provide a minimum of 2.5NM range to six o'clock position (indicating an aircraft is 2.5NM behind the TCAS II equipped aircraft) and a minimum of 6NM range to the twelve o'clock position (indicating an aircraft is 6NM in front of the TCAS II equipped aircraft). The symbol color should be white or cyan and should be the same color as the range ring.

(B) The Intruder Aircraft at the Traffic Advisory (TA) Level. This symbol shall be shaped as a circle and should be solid amber in color. This symbol must be positioned to depict its relative bearing and distance to the TCAS II aircraft. TAs and RAs must be displayed whenever the appropriate CAS Logic is satisfied, regardless of display/surveillance switch positions (above/below) intended for other traffic.

(C) The Threat Aircraft at the Resolution Advisory (RA) Level. This symbol shall be shaped as a square and it should be solid red in color. Since red is of low conspicuity, the use of other graphical techniques to enhance this symbol (such as outlining) should be evaluated, and research in this area is encouraged.

(D) Proximate Traffic. When a TA or RA is present, a symbol shall be depicted for transponder equipped aircraft within 1200 feet relative altitude and 6NM (or the minimum range, whichever is less). This symbol shall be shaped like a diamond and colored solid white or cyan but not the same color as own aircraft symbol. It is required to display proximate traffic only when the requirements to display a TA or an RA exist. The display of proximate traffic under these circumstances will assist the pilot in the detection of the intruder aircraft. Proximate traffic may also be displayed even when no TA or RA exists.

(E) Other Traffic. Other transponder equipped traffic within +/- 9900 feet of ownship may be displayed. This symbol should be shaped as an open diamond and should be the same color as proximate traffic. The ability to display other traffic has been determined by service experience to be a significant aid to the flightcrew's situational awareness and incorporation of this feature is highly recommended.

NOTE: All transponder equipped aircraft without altitude reporting will be considered co-altitude by TCAS. Therefore, it will become a solid diamond the same color as proximate traffic when within 6NM and may represent a serious threat that cannot be resolved by TCAS.

(F) Relative Altitude Display. Relative altitude is the difference between the other aircraft's altitude and the TCAS II equipped aircraft's altitude. This should be presented in a digital format rounded off to the nearest one hundred feet. This digital information should be centered on the intruder aircraft symbol and positioned above or below the intruder symbol when the intruder aircraft is above or below the TCAS II aircraft respectively. The digital data should include a leading zero and a plus or minus sign as appropriate. For example, -05 positioned below the threat symbol (solid red square) would indicate the threat aircraft is 500 feet below the TCAS II aircraft. This digital data should conform to the color of the threat aircraft symbol. Co-altitude situations should be depicted as "00" (without the + or - symbol). The "00" symbol may be placed above the traffic symbol if the other aircraft closed from above, and vice versa.

(G) Displayed Traffic Range. The range of the displayed traffic is horizontal (slant range corrected) when altitude is available. Slant range is displayed when altitude information is not available.

(H) The Range "Ring". There should be markings surrounding the own aircraft symbol at each of the twelve o'clock positions. These markings may be small dots, small lines or indices, or asterisks. Enhancement of the 3, 6, 9, and 12 o'clock positions is permissible. A solid range ring is not recommended due to clutter. A range ring of 2NM radius is required for small fixed range displays such as 3 ATI (ARINC Specification 408A for 3 inch Air Transport Indicator) displays and the entire range ring must be depicted. A range ring radius of 3NM has been found acceptable for all other displays. The radius must remain scaled to the range selected for variable range displays. When the traffic display is integrated with an EHSI or a Navigation Display (ND), a partial range ring is permissible for Arc or Expanded display modes. Full or partial range rings are acceptable when integrated with weather radar displays. The color should be the same as own aircraft symbol. The 2 or 3NM range ring is not required when the range of the display exceeds 20NM.

(I) Off Scale Symbology. RA or TA traffic which is off-scale shall be indicated by placing one half of the appropriate symbol at the edge of the active display area in the direction of the measured bearing of the traffic for fixed range displays. Data tags and appropriate vertical trend arrows shall remain fixed in the normal design position relative to the traffic symbol even if a portion of the information is masked by the edge of the active display area. An alternative method for variable range displays would be to annunciate a message "TRAFFIC OFF-SCALE", "OFF-SCALE", or "TA(RA if appropriate) OFF-SCALE".

(J) No Bearing Display. When the TCAS II system uses a bottom omni-directional antenna and the upper directional antenna loses track on the intruder aircraft, the threat aircraft can no longer be depicted on the traffic display with the correct bearing. The relative altitude or the actual altitude or flight level (if the actual altitude mode has been selected) and range should be digitally presented. This information must be colored to conform to the threat level (amber for TAs and red for RAs). There are several acceptable formats that may be displayed depending upon the type of altitude information being displayed. Some examples are as follows:

(1) "TA 1.2NM/+11↓" depicting a TA intruder at 1.2NM and 1100 feet above ownship and descending at a rate greater than 500 fpm.

(2) "RA 4.6NM/FL230" depicting an RA threat at 4.6NM at Flight Level 230.

(3) "TA 8.8NM/00" depicting a co-altitude TA intruder at 8.8NM.

(4) "RA 3.3NM/165 " depicting an RA threat at 3.3NM at a barometric altitude of 16,500 feet MSL.

(5) "TA 5.5NM" depicting a mode A (no altitude reporting) TA intruder at 5.5NM.

NOTE: The TA or RA which precedes the range information in the above examples may be omitted if display space is limited.

(K) Mode A Transponder Equipped Aircraft. A data tag shall not be associated with the symbol for targets which are not reporting altitude. Note that an RA will not be generated for targets not reporting altitude.

(L) Other aircraft Vertical Speed. A vertical arrow should be located immediately to the right of the other aircraft symbol display if the vertical speed of the other aircraft is equal to or greater than 500 feet per minute with the arrow pointing up for climbing traffic and down for descending traffic. The color of the tag should be the same as the symbol.

(M) TA Only Mode. The ability to inhibit the RA mode of operation should be provided to prevent the display of unwanted RAs. This feature should be pilot selectable, and suitably annunciated. In this mode of operation, all TAs (and threat aircraft that would ordinarily be displayed as RAs) will be displayed as TAs.

(iv) Optional Features/Symbology.

(A) Compass Heading. Aircraft heading and/or a compass rose may be included in the traffic display, and it should be colored white.

(B) Actual Intruder Altitude. A switch may be provided to select the display of the intruders actual barometric altitude in place of relative altitude. The display of actual barometric altitude should be displayed as a three digit number representing hundreds of feet above MSL; e.g., 007 for 700 feet MSL and 210 for 21000 feet MSL. Clear and unambiguous indication must be provided on the display that the actual intruder altitude mode has been selected. Actual altitude tags shall be positioned above or below the traffic symbol in a manner consistent with relative altitude data tags. The display of actual barometric altitude below the transition altitude (18,000 MSL in the U.S.) requires a barometric pressure correction from ownship. If barometric pressure corrections are not incorporated, the display of actual barometric altitudes below the transition altitude is considered potentially ambiguous and may be displayed by pilot selection only for approximately 15 seconds per selection.

(C) Range Selection/Reversion. Traffic displays may incorporate a variable range feature, and there must be a means to manually select each range. A feature may be provided to automatically select the optimum range when an RA/TA occurs. In addition, if a dedicated TCAS mode is provided within a multifunction display, the selection of that mode may automatically change the range of the display to a predetermined value.

(D) Maximum Number of Displayed Targets. There currently are no requirements to establish a maximum number of displayed targets when TA or RA conditions exist. (For 3 ATI displays, a maximum of 12 targets has been found acceptable.) Overlapping traffic symbols should be displayed with the appropriate information overlapped. If display technology requires prioritization of symbols, this shall be accomplished to allow the maximum display of data.

(E) Traffic Display Switch. A switch may be provided which will display all traffic within the range of the display and within 2700 feet vertically of own aircraft. This switch may be either momentary or a lock-on type of switch.

(F) Extended Altitude Surveillance Switch. A switch may be provided to select the viewing of traffic from 2700 feet below own aircraft to a maximum of 9900 feet above own aircraft and the viewing of traffic from 2700 feet above own aircraft to a maximum of 9900 feet below own aircraft.

(9) Resolution Display.

(i) Purpose. The purpose of the resolution display is to provide each pilot with the information to readily correct the aircraft flight path or to prevent a maneuver that would significantly reduce the vertical separation between ownship and a threat aircraft.

(ii) Description. The resolution display may be integrated with the two primary IVSIs on the flightdeck. These displays depict red arcs along the perimeter of round dial IVSIs or red vertical lines on vertical tape IVSIs that must be avoided in order to maintain safe vertical separation. The pilot's task is to maneuver the aircraft promptly to achieve a vertical speed just out of the illuminated red arc or line (within the green "fly to" arc or line) when presented or to maintain a vertical speed out of the illuminated red arc or line that most nearly complies with the ATC clearance.

(iii) Symbology. The resolution display must depict a red illuminated arc or line for corrective RAs. Corrective RAs should also depict a green "fly to" symbol; for example, when a climb RA is issued on a round dial IVSI, a red colored arc should be depicted (adjacent to the IVSI scale) from -6000 FPM to +1500 FPM and a green fly-to arc or line from +1500 FPM to approximately 2000 FPM. The resolution display must also depict an illuminated arc to be avoided for preventive RAs. A green "fly to" arc or line is not required in this case since the current aircraft vertical speed is satisfactory. The color of the preventive RA arc or line should be red. The same requirements for round dial RA displays are applicable to vertical tape RA displays in PFD's. Some applicants may wish to integrate the RA display within an EADI or PFD. There are several good reasons to pursue the development of this technology within PFD's and EADI's. The basic concepts of a warning area and a "fly to" area must be retained. The use of new TCAS symbology such as target pitch attitudes or flight path angles will require testing throughout the flight envelope to determine accuracy, over/undershoot tendencies, flight technical error, and potential confusion with flight director symbology. Applicants pursuing this technology should contact the appropriate FAA ACO early in the development cycle.

(iv) Failure indications must be provided for TCAS failures (TCAS unable to generate RAs). Annunciation must be provided for the TA only mode. Electrical IVSI failures must also be annunciated.

(10) Caution/Warning Lights.

(i) Discrete caution and/or warning lights may be installed which 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:

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

(B) A discrete red warning annunciator which 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 400 feet AGL. An IVSI with a lighted red arc, or an alphanumeric message on the EADI is acceptable in lieu of this discrete warning annunciator.

(ii) Because of the numerous 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 would tend to reduce its effectiveness in annunciating non-TCAS II system failures.

(iii) Discrete visual alerts should remain on until cancelled by the pilot or until the aircraft is no longer considered an intruder or a threat by TCAS II.

(11) Aural Alerts.

(i) Each TCAS II aural alert should be annunciated 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 crewmember is wearing a headset, covering the outboard ear when appropriate.

(ii) The TCAS II Traffic Advisories (TAs) should be annunciated by the voice message "TRAFFIC, TRAFFIC" stated once for each TA.

(iii) The TCAS II Resolution Advisories (RAs) should be annunciated by the following voice messages, as appropriate:

(A) "CLIMB, CLIMB, CLIMB" (Climb at the rate depicted by the green (fly to) arc or line on the IVSI or other suitable indicator.)

(B) "DESCEND, DESCEND, DESCEND" (Descend at the rate depicted by the green (fly to) arc or line on the IVSI or other suitable indicator.)

(C) "MONITOR VERTICAL SPEED-MONITOR VERTICAL SPEED" (Spoken only once if softening from a previous corrective advisory.) Assure that vertical speed is out of the illuminated IVSI red arc or line.

(D) "REDUCE CLIMB-REDUCE CLIMB" (Reduce vertical speed to a value within the illuminated green arc or line.)

(E) "CLEAR OF CONFLICT" (Range is increasing, and separation is adequate; expeditiously return to the applicable clearance, unless otherwise directed by ATC.)

(F) "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.

(G) "REDUCE DESCENT-REDUCE DESCENT" (Reduce vertical speed to a value within the illuminated green arc or line.)

(H) "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.

(iv) 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.

(A) "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.

(B) "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.

(C) "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 sense is required to achieve safe vertical separation from a maneuvering threat aircraft.

(D) "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 sense is required to achieve safe vertical separation from a maneuvering threat aircraft.

(v) All TCAS II aural alerts must be inhibited below 400 feet AGL.

(vi) Both increases and decreases in the threat level must be aurally annunciated. However decreases in threat level need only be annunciated once, e.g., a "monitor vertical speed" aural which follows a climb RA should only be annunciated once.

(vii) In general, other messages which are clear and unambiguous will be evaluated on an individual basis. Messages which use negatives should not be used (e.g., "DON'T CLIMB").

d. Software Verification and Validation. The verification and validation of TCAS II software using the procedures outlined below are required for the first installation of a manufacturer's TCAS II equipment. These procedures shall also be applied to subsequent software changes to a manufacturer's TCAS II equipment. A manufacturer may provide a design that partitions the software which affects resolution advisories from other software (level 3) such as that necessary for the traffic display. If the partitioned software is initially approved by the FAA, verification and validation for the level 3 software may be accomplished by the TCAS II manufacturer using the minor change authority of the TSO system.

(1) The verification and validation of the TCAS II software represents a unique challenge because the collision avoidance algorithms, commonly called "CAS logic," as contained in Volume II of RTCA document DO-185, represent a software design specification. 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 and design does not permit the direct application of the software criteria contained in RTCA document DO-178A. The CAS logic has been provided by Volume II of RTCA document DO-185.

(2) If software is used for the displays of TCAS II resolution advisories or in the operation of the Mode S transponder data link, the verification and validation of this software should be done to level 2, as defined in RTCA document DO-178A. These procedures should also be applied where the TCAS II manufacturer develops the software requirements for the TCAS II processor associated with functions other than surveillance or the CAS logic. Where the software design is specified by Volume II of RTCA document DO-185, 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 has been implemented correctly. This includes the surveillance software necessary to establish and maintain the relative tracks of nearby transponder equipped aircraft.

(3) The functional tests required by TSO C-119a as described in Volume I of RTCA document DO-185, do not provide complete testing for the TCAS II processor software. The TCAS II manufacturer must develop additional functional tests which correspond to the detailed requirements which it develops for the TCAS II processor. The potential consequences of software errors in the TCAS II processor or resolution display require that the manufacturer provide a structural coverage analysis to show single condition test coverage of all instructions at the source code which can affect the generation and display of resolution advisories. The tests which provide this may be a combination of module tests, module integration tests and functional tests.

(4) Equipment produced in accordance with a technical standard order may have obtained FAA concurrence that the software for the equipment was produced in accordance with the criteria of RTCA document DO-178A for a particular software level. Nevertheless, it is the responsibility of the applicant who first installs a manufacturer's TCAS II equipment in an aircraft to demonstrate to the appropriate FAA ACO that the system software used for the TCAS II equipment, Mode S transponder and new sensors and displays necessary to provide resolution advisories have been developed in accordance with the criteria outlined above. Data from the TSO process may be sufficient to establish that the appropriate verification and validation have been accomplished, but the ACO may require additional tests and analysis of the software for the installed TCAS II system. Subsequent installations of the same TCAS II equipment on other aircraft types do not require any additional verification if the software is not changed.

e. System Safety Analyses. A false resolution advisory has the potential of causing a mid-air collision. Failures of the TCAS II equipment and its associated sensors and displays which could provide a false resolution advisory must be improbable. This should be established using the methods described in AC 25.1309-1A, System Design and Analysis. It is expected that a failure modes and effects analysis (FMEA) and a quantitative probability analysis of the TCAS II equipment, Mode S transponder, and altitude information source will be necessary to establish that an incorrect resolution advisory is improbable. For the purposes of a numerical analysis, the probability of an incorrect resolution advisory without a TCAS II failure indication should be on the order of 1.0 x 10-5 per flight hour in the enroute environment and 1.0 x 10-4 per flight hour in the terminal area. The frequency of encounters which would produce a resolution advisory can be assumed to be once per 200 hours in the enroute environment and once per 10 hours in the terminal area, unless the applicant can establish different frequencies based on operational data. These analyses should be provided for the first installation of a particular model of TCAS II equipment. Subsequent installations of the same equipment in other aircraft may make use of the same analyses with particular attention to the differences in own altitude sensors.

f. Test and Evaluation (Initial Approval). Testing of the first of a manufacturer's TCAS II system for its initial approval in an aircraft should be conducted to verify that the design and installation performs its intended function under the expected operating conditions, that there are no adverse interactions between the TCAS II and existing aircraft systems, and that prior approvals of present aircraft equipment have not been compromised. The applicant should 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. The use of other than a transport category aircraft for either the TCAS II installation or for the air-to-air cooperative flights is acceptable. The test plan should contain, as a minimum, the following elements:

(1) Basic Ground Tests.

(i) Bearing Accuracy Tests. Bearing estimation accuracy of the TCAS II system shall be demonstrated as installed in the aircraft. The bearing accuracy may be measured 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. Manual readout of the bearing estimate may be accomplished directly from a plan position display on the traffic advisory display. Alternatively, the bearing estimates may be automatically recorded or may be 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 ± 45 degrees from the tail and the area is not visible from the cockpit. In this case, aircraft structure may interfere with the signal path.

(ii) Sensor failures. Simulated failures of the aircraft sensors integrated with TCAS II should be evaluated to determine that the resulting system failure state agrees with the predicted results. These tests should be part of the ground test plan.

(iii) Electromagnetic Interference (EMI). A flightdeck EMI survey should be made 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. Attention should be given to possible interference with TCAS II equipment from weather radar, particularly if operating in the C-band.

(iv) Evaluate the general arrangement and operation of controls, displays, circuit breakers, annunciators, and placards of the TCAS system.

(v) Self Test. Evaluate the TCAS self test features and failure mode displays and annunciators.

(vi) Verify that the pressure altitude source and radio altimeter are properly interfaced with the TCAS equipment.

(vii) Verify that the windshear and GPWS warnings and TCAS II voice alerts are compatible. Also, verify that windshear warnings can be clearly understood when TCAS II and windshear voice announcements simultaneously occur. If TCAS II, windshear and GPWS aural warnings have been prioritized, the alert priorities should be windshear, GPWS and then TCAS II.

(viii) Verify the performance of TCAS II traffic display by observing any available area traffic.

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

(x) Determine that any configuration 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.)

(xi) Verify that the Mode S identification code and maximum airspeed are correct.

(2) Basic Flight Tests.

(i) During all phases of flight, determine if there is any mutual interference with any other aircraft system. Weather radar should be operating during the flight test.

(ii) 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 headset covering outboard ear only (when appropriate) and without headsets. 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.

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

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

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

(vi) Perform the additional flight tests in Appendix 2 of this AC unless previously accomplished under TSO-C119a.

(vii) Evaluate TCAS for noninterference during coupled Autopilot and Flight Director approaches to the lowest minimums approved for the aircraft.

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

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

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

(3) 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. Having established 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 insure that the TCAS II aircraft system performs its intended function by generating TAs and RAs and is consistent with RTCA document DO-185. The intruder aircraft should be equipped with transponders capable of Mode A, Mode C, and for those tests making it necessary, Mode S, and TCAS II. These tests are also intended to expose the installed TCAS II system to a reasonable number of carefully controlled encounters which are likely in service. This matrix covers the envelope of encounter speeds, altitudes, and geometries which have in the past identified flaws in surveillance, logic, and antenna mechanization that were not detected earlier by bench tests.

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

(ii) Head-on.

(A) Low and high closure speeds.

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

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

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

(iii) Converging.

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

(v) Evaluate the TA only mode during planned encounters.

(vi) A mix of intruder transponder modes (A, C, and S) should be evaluated, but primary emphasis should be on TCAS II to TCAS II coordination, and on Mode C replies from the intruder aircraft.

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

(viii) If a flight test is necessary to insure compatibility with other designs, verify correct air-to-air coordination between the test TCAS II and another manufacturer's previously approved equipment (see paragraph 3c(5)).

(ix) 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.

(4) Mode S Transponder Flight Tests. The flight tests described by this section may be used to obtain the certification of a stand-alone Mode S transponder installation. These tests should also be used to evaluate a Mode S transponder which is intended for use with a TCAS II installation. The purpose of these tests is to primarily verify that the installed antenna(s) are compatible with the Mode S transponder and provide an adequate response to ground radar interrogations during normal aircraft maneuvers. In addition, the flight test is a demonstration 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 is identical or similar to that of previously approved ATCRBS transponder installation.

(i) If the Mode S transponder uses a top mounted antenna in addition to a bottom mounted antenna which is installed at or near the same location used by a previously approved ATCRBS transponder antenna, conduct a comprehensive ground test in accordance with Appendix 3 and conduct 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 ground controller.

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

(A) Conduct Ground Tests Per Appendix 3

(B) Climb and Distance Coverage. Beginning at a distance of at least 10NM from, and an altitude of 2000 to 3000 feet above that of the radar facility and using a transponder code assigned by the ATC, fly on a heading that will pass the aircraft over the facility. At a distance of 5 to 10NM beyond the facility, fly the aircraft at its normal maximum climb attitude to within 90 percent of the maximum altitude for which the aircraft is certificated, maintaining the aircraft at a 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 160NM for turbojet and some turboprop powered airplanes (or 80NM for most other aircraft) from the nearest radar facility. (Distance from the radar facility is a function of the airplane's maximum certificated altitude.) Communicate with the ground radar personnel 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 dropouts (no return for two or more sweeps). Uncontrollable ringing that hinders use of the ground radar is unsatisfactory.

(C) 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 nearest radar facility. During these turns, the radar displays should be monitored and there should be no signal dropouts (no return for 2 or more sweeps).

(D) 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 70NM from the nearest 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 2 or more sweeps). Switch the transponder to a code not selected by the ground controller. The aircraft secondary return should disappear from the scope. The controller should then change his control box to "common sense" and a single slash should appear on the scope at the aircraft's position.

(E) 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 nearest radar facility fly on a course which will pass over the radar facility. There should be no transponder dropout or "ring-around".

(F) Surveillance Approach. Beginning at or above 90 percent of the maximum certificated altitude of the aircraft, perform a letdown and approach to a runway of an airport served by Airport Surveillance Radar (ASR) having an ATCRBS facility. The approach should be made at the maximum normal rate of descent and normal approach and landing configuration for the aircraft and 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.

(G) Holding and Orbiting Patterns.

(1) 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.

(2) 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.

(H) 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).

g. Follow-On Approvals (STC or Amended TC). Flight testing of TCAS II systems for follow-on approvals (previously approved TCAS II equipment installed in a different aircraft type) should be conducted to verify that the design and installation performs its intended function under the expected operating conditions, that there are no adverse interactions between the TCAS II and existing aircraft systems, and that prior approvals of present aircraft equipment have not been compromised. The applicant should provide a flight 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 a Mode C equipped aircraft, or the use of a suitably located fixed transponder. The test plan should contain, as a minimum, the following elements:

(1) Ground Tests.

(i) Evaluate the general arrangement and operation of controls, displays, circuit breakers, annunciators, and placards of the TCAS II system.

(ii) Evaluate the TCAS II self test features and failure mode displays and annunciators.

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

(iv) Measure the performance of the directional antenna for 360 degrees coverage at 30 degree intervals, as specified under basic certification ground tests.

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

(vi) Determine that any configuration 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.)

(vii) Verify that the Mode S identification code and maximum airspeed are correct.

(viii) Verify that the windshear and GPWS warnings and TCAS II voice alerts are compatible. Also, verify that windshear warnings can be clearly understood when TCAS II and windshear voice announcements and GPWS simultaneously occur. If TCAS II windshear and GPWS aural warnings have been prioritized the alert priorities should be windshear, GPWS and then TCAS II.

(2) Flight Tests.

(i) Proper operation of the traffic display should be verified 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: Prior to any cooperative flight tests at any altitude involving the TCAS II equipped aircraft and another aircraft, both aircraft should be flown 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.

(C) Encounters with aircraft targets of opportunity.

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

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

(iii) 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. 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.

(iv) Evaluate the effective surveillance range of the traffic display, including target azimuth reasonableness and track stability. Use of a nontransport (low-speed) Mode C equipped aircraft as a target or a fixed transponder or suitable test equipment for these tests is permissible.

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

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

(vii) Evaluate TCAS II for noninterference during coupled Autopilot and Flight Director approaches to the lowest minimums approved for the aircraft.

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

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

h. Airplane Flight Manual Supplement (AFMS). The AFMS should provide the appropriate system limitations and procedures, and a comprehensive description of all normal modes of operation including what actions are expected by the flightcrew in each case. Appendix 1 provides an example of the elements and extent of detail that may be shown by a typical AFMS (specific performance data and procedures may vary with system design and aircraft type).

4. <u>OPERATIONAL APPROVAL</u>. Operational approval of TCAS II is addressed by AC 120-55.