3.18.1.1.21.2.2 The range of the ACAS display is consistent with the navigation information. If the North-up provides range markings for the navigation information, dedicated range rings or arcs for the traffic information are not required.

3.18.1.1.21.2.3 An own aircraft symbol must be displayed when the North-up mode is selected. The own aircraft symbol is directional in shape and shown with the front of the symbol oriented in the direction of own aircraft's heading. If an own aircraft symbol is not depicted in a North-up mode, e.g. a way-point provided by a navigation system is centred on the display, traffic information cannot be displayed.

3.18.1.1.21.2.4 The traffic is displayed referenced to the front of the own aircraft symbol.

3.18.1.1.21.2.5 When a TA or RA is issued while a display is in a North-up mode, the written messages defined in 3.18.1.1.17.1 will be displayed.

3.18.1.1.21.2.6 Provisions are provided so that a pilot can switch from a North-up mode to a mode showing traffic in a heading up orientation with a single action when a TA or RA is issued.

3.18.1.2 **RA displays**

3.18.1.2.1 The RA display provides guidance on the vertical speed or pitch angle to be flown, and the range of vertical speeds or pitch angles to be avoided, to attain or maintain the desired vertical miss distance from an aircraft causing an RA.

3.18.1.2.2 In version 7.1 of the reference equipment, a corrective VSL RA is displayed using only one strength (i.e. 0 m/s), whatever the strength computed by the reference logic (see 3.15.14.1). In version 7.0 of the reference equipment, a corrective VSL RA is displayed using the computed strength.

3.18.1.2.3 Various implementations of the RA display have been approved for use, and each implementation has unique characteristics.

3.18.1.2.4 **RA/VSI (round dial VSI)**

3.18.1.2.4.1 This implementation indicates the vertical speeds to be flown and avoided using a series of red, green and black arcs displayed around the periphery of the vertical speed indicator (VSI).

Note.— The term "black arcs" refers to the area of the VSI scale, usually the background of the scale that is not illuminated by the lighted red and green arcs.

3.18.1.2.4.2 The scale of the VSI used to display RA information must have sufficient range to display the required red and green arcs for all RAs that can be generated by the collision avoidance logic. This requires a range of ±30.5 m/s (±6 000 fpm).

Note.— If the VSI does not have a range of ±30.5 m/s (±6 000 fpm), a means must be provided to display all corrective and preventive RAs, as well as own aircraft's actual vertical speed.

3.18.1.2.4.3 The red arcs on the RA/VSI indicate the vertical speed range that must be avoided to maintain or attain the ACAS-desired vertical miss distance from one or more intruders. The length of the red arc is adjusted as appropriate when the RA is strengthened or weakened by the CAS logic.

3.18.1.2.4.4 A green “fly-to” arc is used to provide a target vertical speed whenever a change in the existing vertical speed is desired or when an existing vertical speed (not less than 7.6 m/s (1 500 fpm)) must be maintained. The nominal size of the green arc is approximately that defined by the distance between the 1 500 and 2 000 fpm marks on the VSI scale. The size of the green arc remains constant no matter where the arc is placed on the display, with the exception of the multi-aircraft encounter described in 3.18.1.2.4.8.

3.18.1.2.4.5 The green arc is either wider than the red arc or offset from the red arc to assist in visually differentiating between the red and green arcs.

3.18.1.2.4.6 The green arc remains displayed for the entire duration of the RA. Its position moves to the appropriate position when an RA is strengthened or weakened by the CAS logic.

3.18.1.2.4.7 The portions of the VSI scale not covered by either a red or green arc remain black.

3.18.1.2.4.8 For the special situation where a multi-aircraft encounter results in an RA where neither a climb nor descent is permitted, a green arc is displayed from approximately -1.3 m/s to +1.3 m/s (–250 fpm to +250 fpm). The remainder of the VSI scale is then illuminated with red arcs.

3.18.1.2.4.9 Inertial quickening of the vertical speed function is typically provided on these types of displays.

3.18.1.2.5 **RA/VSI (integrated tape VSI on a primary flight display (PFD))**

3.18.1.2.5.1 This implementation indicates the vertical speeds to be flown and avoided using a series of red, green and black zones displayed within the vertical speed tape portion of the PFD.

Note.— The term “black zones” refers to the area of the VSI scale, usually the background of the scale, that is not covered by either a red or green zone.

3.18.1.2.5.2 The red zone on the RA/VSI indicates the vertical speed range that must be avoided to maintain or attain the ACAS-desired vertical miss distance from one or more intruders. The length (height) of the red zone is adjusted as appropriate when the RA is strengthened or weakened by the CAS logic.

3.18.1.2.5.3 A green “fly-to” zone is used to provide a target vertical speed whenever a change in the existing vertical speed is desired and when an existing vertical speed (not less than 7.6 m/s (1 500 fpm)) must be maintained. The nominal size of the green zone is approximately that defined by the distance between the 1 500 and 2 000 fpm marks on the VSI scale. The size of the green zone remains constant no matter where the zone is placed on the display, with the exception of the multi-aircraft encounter described in 3.18.1.2.4.7.

3.18.1.2.5.4 The green zone is wider than the red zone to assist in visually differentiating between the red and green zone.

3.18.1.2.5.5 The position of the green zone moves to the appropriate position when an RA is strengthened or weakened by the CAS logic.

3.18.1.2.5.6 The portions of the VSI scale not covered by either a red or green zone remain black.

3.18.1.2.5.7 For the special situation where a multi-aircraft encounter results in an RA where neither a climb nor descent is permitted, a green zone is displayed from approximately –1.3 m/s to +1.3 m/s (-250 fpm to +250 fpm). The remainder of the VSI scale is then illuminated with red zones.

3.18.1.2.5.8 Inertial quickening of the vertical speed function is typically provided on these types of displays.

3.18.1.2.5.9 The scale of the VSI tape must have sufficient range to display the required red and green zones for all RAs that can be generated by the collision avoidance logic. This requires a range of ±30.5 m/s (±6 000 fpm).

Note.— If the vertical speed tape does not have a range of ±30.5 m/s (±6 000 fpm), a means must be provided to display all corrective and preventive RAs, as well as the own aircraft's actual vertical speed.

3.18.1.2.6 **Pitch cues on the PFD**

3.18.1.2.6.1 This implementation indicates the pitch angles to be flown and/or avoided while responding to an RA.

3.18.1.2.6.2 A red trapezoid, or another similar geometric shape, overlaying the other information on the PFD indicates the range of pitch angles that must be avoided to maintain or attain the ACAS-desired vertical miss distance from one or more intruders. When the trapezoid is displayed, the other information shown on the PFD must remain readily discernible and readable.

3.18.1.2.6.3 The trapezoid begins at the bottom of the PFD and extends upward to the desired pitch angle for up-sense RAs; for down-sense RAs, the trapezoid begins at the top of the PFD and extends downwards to the desired pitch angle. The closed end of the trapezoid corresponds to the pitch angle that will provide the vertical speed desired by the ACAS RA.

3.18.1.2.6.4 The red trapezoid remains displayed for the entire duration of the RA. It moves as appropriate when an RA is strengthened or weakened by the CAS logic.

3.18.1.2.6.5 The use of a green "fly-to" target at the closed end of the trapezoid is permitted to provide a target pitch angle whenever a change in the existing vertical speed is desired. However, no manufacturer has implemented this permitted feature.

3.18.1.2.6.6 When an RA is displayed, a written annunciation of "TCAS", "TFC", or "TRAFFIC", written in red, must be displayed in the primary field of view of each pilot. The exact implementation of the annunciation is left to the discretion of the manufacturer, but the annunciation must be compatible with the implementation of other mode annunciations.

3.18.1.2.6.7 For the special situation where a multi-aircraft encounter results in an RA where neither a climb nor descent is permitted, two red trapezoids are simultaneously displayed. One begins at the top of the PFD and extends downward to the pitch angle that will result in level flight, while the other begins at the bottom of the PFD and extends upward to the pitch angle that will result in level flight. Sufficient room is left between the two trapezoids to permit the own aircraft reference on the PFD to fit between the two trapezoids.

3.18.1.2.7 **Heads-up display (HUD)**

3.18.1.2.7.1 This implementation indicates the vertical flight path to be flown and avoided using a unique display symbology on the HUD.

3.18.1.2.7.2 A trapezoid overlaying the other information on the HUD indicates the flight path that must be flown to maintain or attain the ACAS-desired vertical miss distance from one or more intruders.

3.18.1.2.7.3 The trapezoid begins at the bottom of the display and extends upward to the desired flight path angle for up-sense RAs; for down-sense RAs, the trapezoid begins at the top of the display and extends downward to the desired flight path angle. The closed end of the trapezoid corresponds to the flight path that will provide the vertical speed desired by ACAS.

3.18.1.2.7.4 The trapezoid remains displayed for the entire duration of the RA. It moves as appropriate when an RA is strengthened or weakened by the CAS logic.

3.18.1.2.7.5 When an RA is displayed, the HUD displays a written annunciation of “TCAS” or “TRAFFIC”. The exact implementation of the annunciation is compatible with the implementation of other mode annunciations on the HUD.

3.18.1.2.7.6 A flight path target is provided whenever a change in the existing vertical speed is desired. A box consisting of lines twice the width of the lines comprising the trapezoid is displayed at the top (up-sense RA) or bottom (down-sense RA) of the trapezoid for all RAs except initial preventive RAs. The flight path target remains displayed for the entire duration of the RA. It moves to the appropriate position when an RA is strengthened or weakened by the CAS logic.

3.18.1.2.7.7 For the special situation where a multi-aircraft encounter results in an RA where neither a climb nor a descent is permitted, two trapezoids are simultaneously displayed. One begins at the top of the display and extends downward to the flight path angle that will result in level flight, while the other begins at the bottom of the display and extends upward to the flight path angle that will result in level flight. Sufficient room is left between the two trapezoids to display the flight path target box and the own aircraft reference symbol.

3.18.1.2.7.8 When an RA is displayed, some displays will automatically be decluttered by removing certain data and symbols. Items such as ground speed, mach, wind speed and direction, digital heading, digital selected course, and digital selected heading may be removed if this does not interfere with the pilot's ability to comply with the RA or operate the aircraft in compliance with the appropriate regulations and requirements. The navigation data, as well as the guidance cue, remain displayed at all times.

3.18.1.2.7.9 RA guidance is available in all display modes.

3.18.2 Aural annunciations

3.18.2.1 ACAS aural alerts are presented by voice announcements only.

3.18.2.2 An aural annunciation is generated when the first RA of an encounter is displayed and each time a subsequent change in the advisory is displayed (strengthened or weakened). An aural annunciation is also provided to indicate that the ACAS aircraft is clear of conflict with all threatening aircraft.

3.18.2.3 The aural annunciations used are shown in Table 3-4. An annunciation can be interrupted before it is completed if the CAS logic determines that a higher priority aural annunciation should be announced. The prioritization of the aural annunciations is defined in RTCA DO-185B.

3.18.2.4 The annunciations for an RA reversal and for an increase rate RA indicate the previously annunciated RA has reversed or been increased in strength, respectively. These aural annunciations are spoken with a sense of urgency.

3.18.2.5 Aural annunciations are automatically inhibited by annunciations issued by reactive and predictive wind shear systems, and GPWS/terrain avoidance warning systems (TAWS), which have a higher priority, and below an altitude determined by the CAS logic.

3.18.2.6 When a higher priority warning system (wind shear or GPWS) has an active warning, ACAS is automatically placed into the “TA Only” mode of operation.

3.18.2.7 When a TA is initially issued, the aural annunciation “TRAFFIC-TRAFFIC” is spoken once. No aural annunciation is issued when an RA against an intruder reverts to a TA at the end of an encounter.

3.18.2.8 The “TRAFFIC-TRAFFIC” annunciation will be pre-empted by any annunciation associated with an RA.

3.18.3 Visual alerts

3.18.3.1 A red visual alert is required in the primary field of view for each pilot. The red arcs on an RA/VSI display will fulfil this requirement. Likewise, conspicuous illumination of the red zones on the vertical speed tape, appropriate pitch guidance, or a suitable written message (termed a Visual Alert) on a PFD will fulfil this requirement.

3.18.3.2 If a written message is shown on the PFD, it is required to flash or otherwise be highlighted in accordance with industry alerting standards. If a written message is shown on the PFD, it will be one of the messages shown in Table 3-4.

3.18.3.3 The written message “CLEAR OF CONFLICT” is prohibited from being in red, amber or yellow.

3.19 CONTROLS

3.19.1 Means are provided to select the following modes of operation:

a) operation of Mode S transponder only. The selection of this mode places ACAS into Standby, i.e. it is not transmitting interrogations;

b) operation of the Mode S transponder and ACAS in the TA/RA mode;

c) operation of the Mode S transponder and ACAS in the TA Only mode; and

d) ACAS self-test.

3.19.2 The controls for the Mode S transponder and ACAS are typically located on a single control panel.

3.19.3 The traffic display controls depend on the type of display used and the features available on the display. The following types of controls are used as appropriate:

a) *Altitude range selector.* If the traffic display provides an option for displaying proximate and other traffic with relative altitudes between ±823 m (±2 700 ft) and a maximum of ±3 018 m (±9 900 ft) (see 3.18.1.1.11.1), a switch is provided to permit a pilot to control the vertical range of the display. The control panel markings for this selector use the annotations of Above, Normal and Below, or a suitable abbreviation of these words. When the Above or Below mode is selected, it is shown on the traffic display;

b) *Range selector.* On variable range displays (see 3.18.1.1.16), a switch is provided to permit the desired display range to be selected;

c) *Actual altitude.* If the traffic display provides an option for displaying the actual altitude of an intruder (see 3.18.1.1.6.4), a switch is provided to change between the display of relative and actual altitude in the intruder's altitude data block;

d) *Traffic override.* On shared displays (see 3.18.1.1.20), a switch is provided to override the traffic display and the traffic that has popped-up and is no longer required for visual acquisition, e.g. return an EICAS display to its normal function; and

e) *Display mode selector.* On displays that provide both a full-time and a part-time display mode, a means is provided to permit a pilot to select the desired display mode.

Table 3-4. ACAS aural annunciations

RA	*Aural Annunciation*	*Visual Alert*
Corrective Climb	Climb, Climb	CLIMB
Corrective Descend	Descend, Descend	DESCEND
Altitude Crossing Climb	Climb, Crossing Climb Climb, Crossing Climb	CROSSING CLIMB
Altitude Crossing Descend	Descend, Crossing Descend Descend Crossing Descend	CROSSING DESCEND
Corrective Reduce Climb	(TCAS version 7.0) Adjust Vertical Speed, Adjust (TCAS version 7.1) Level Off, Level Off	(TCAS version 7.0) ADJUST V/S (TCAS version 7.1) LEVEL OFF
Corrective Reduce Descent	(TCAS version 7.0) Adjust Vertical Speed, Adjust (TCAS version 7.1) Level Off, Level Off	(TCAS version 7.0) ADJUST V/S (TCAS version 7.1) LEVEL OFF
Reversal to a Climb	Climb, Climb NOW Climb, Climb NOW	CLIMB NOW
Reversal to a Descend	Descend, Descend NOW Descend, Descend NOW	DESCEND NOW
Increase Climb	Increase Climb Increase Climb	INCREASE CLIMB
Increase Descent	Increase Descent Increase Descent	INCREASE DESCENT
Initial Preventive RA	Monitor Vertical Speed	MONITOR V/S
Non altitude crossing maintain rate RA	Maintain Vertical Speed, Maintain	MAINTAIN V/S
Altitude crossing, maintain rate RA	Maintain Vertical Speed, Crossing Maintain	MAINTAIN V/S CROSSING
Weakening of corrective RA	(TCAS version 7.0) Adjust Vertical Speed, Adjust (TCAS version 7.1) Level Off, Level Off	(TCAS version 7.0) ADJUST V/S (TCAS version 7.1) LEVEL OFF
Clear of Conflict	Clear of Conflict	CLEAR OF CONFLICT

Note.— TCAS version 7.0 of the reference equipment uses "Adjust Vertical Speed, Adjust" instead of "Level Off, Level Off" for the aural annunciation and "ADJUST V/S" instead of "LEVEL OFF" for the visual alert, because the messages from this version have to cover a range of vertical speed limit strengths (see 3.15.14.1) while TCAS version 7.1 announces all the strengths as 0.

3.20 STATUS AND FAILURE ANNUNCIATIONS

3.20.1 Visual annunciations are provided to indicate the normal operating and the failure modes of ACAS. The colour of the annunciations conforms to industry alerting standards for information (level 0) or advisory (level 1) annunciation, as appropriate. The colour of the level 1 annunciation is amber or yellow.

3.20.2 The ACAS Traffic Display is capable of annunciating the following ACAS operating modes and failure conditions:

a) ACAS in Standby or turned off (Level 0 annunciation);

b) ACAS operating in the TA Only mode (Level 0 annunciation);

c) ACAS has failed (Level 1 annunciation);

d) The Traffic Display is unable to display traffic (Level 1 annunciation); and

e) A pilot-initiated self-test is in progress (Level 0 annunciation).

3.20.3 The RA display provides the capability to annunciate the following ACAS operating modes and failure conditions:

a) ACAS in Standby or turned off (Level 0 annunciation);

b) ACAS operating in the TA Only mode (Level 0 annunciation);

c) the RA display has failed (Level 1 annunciation);

d) ACAS has failed (Level 1 annunciation); and

e) a pilot-initiated self-test is in progress. (Level 0 annunciation).

3.21 ACAS LIMITATIONS

3.21.1 ACAS performance and effectiveness is limited by several system, operational and/or performance limitations. These limitations are as follows.

3.21.1.1 ACAS will not detect non-transponder equipped aircraft, or aircraft with an inoperative transponder.

3.21.1.2 ACAS will not issue RAs for traffic without an altitude reporting transponder.

3.21.1.3 ACAS will not issue advisories against aircraft having vertical rates in excess of 50.8 m/s (10 000 fpm). In addition, the design implementation may result in some short-term errors in the tracked vertical speed of an intruder during periods of high vertical acceleration by the intruder.

3.21.1.4 ACAS will not display a maintain rate RA that calls for a vertical rate greater than 22.4 m/s (4 400 fpm). This restriction arises because the VSI will not have sufficient room to display the green “fly-to” arc.

3.21.1.5 ACAS will automatically fail if the input from the aircraft's barometric altimeter, radio altimeter or transponder is lost. If the transponder's altitude reporting feature is disabled, ACAS will not be able to receive own aircraft's barometric altitude and thus will automatically fail. Some installations also require a valid input from the aircraft's inertial reference system (IRS) or aircraft heading and reference system to be operational.

3.21.1.6 Certain RAs are inhibited at altitudes based on inputs from the radio altimeter. All thresholds shown below have hysteresis of ±30.5 m (±100 ft). These inhibits are as follows:

3.21.1.6.1 All RAs are inhibited below 305 m (1 000 ft) AGL.

3.21.1.6.2 Increase Descent RAs are inhibited below 442 m (1 450 ft) AGL.

3.21.1.6.3 Descend RAs are inhibited below 335 m (1 100 ft) AGL.

3.21.1.6.4 Climb and Increase Climb RAs can be inhibited above predetermined altitudes or in certain aircraft configurations. These inhibits are set via programme pins during installation. ACAS includes provisions for these inhibits to be set in real time via inputs from a flight management system, but this feature is implemented on only a limited number of aircraft.

3.21.1.7 Aural annunciations are inhibited below 152 m (500 ft) AGL.

3.21.1.8 Because of the IL algorithms (see 3.7.3), ACAS may not display all proximate transponder-equipped aircraft in areas of high-density traffic.

3.21.1.9 The bearing displayed by ACAS is not sufficiently accurate to support the initiation of horizontal manoeuvres based solely on the traffic display. As a result, horizontal manoeuvres based solely on information displayed on the traffic display are prohibited.

3.21.1.10 GPWS and TAWS warnings and wind shear warnings take precedence over ACAS advisories. When either a GPWS/TAWS or wind shear warning is active, ACAS aural annunciations will be inhibited and ACAS will automatically be placed in the TA Only mode.

3.22 ADDITIONAL FUNCTIONALITY

3.22.1 ACAS has the capability to communicate with the ground-based ATC system via Mode S when the necessary complementary features have been installed. ACAS can provide the ground system with the RAs that are displayed to the pilot. These RAs may be displayed to the air traffic controller if the technical and operational requirements defined by the user have been fulfilled. Evaluations in several States have resulted in decisions not to display RA information to the air traffic controller. Nevertheless, other States and organizations are currently investigating new approaches to the display of RA information to controllers.

3.22.2 Airborne ACAS equipment can receive SL commands from ground-based Mode S sensors. This provides the ability to uplink commands that could place ACAS in the TA Only mode or reduce the alarm thresholds in specific geographic areas.

Note.— Operational procedures must be developed and coordinated prior to transmitting SL commands from the ground. To date, this capability has not been implemented or evaluated in any State. There is strong opposition to the implementation of this functionality from at least one user group.

Chapter 4

RELATIONSHIP BETWEEN ACAS PERFORMANCE, SAFETY AND AIRSPACE CONFIGURATION

Note.— 1 000 or 2 000 ft of vertical separation is also written as 300 or 600 m in 5.3.2 of Doc 4444, PANS-ATM.

4.1 ASSUMPTIONS REGARDING AIRSPACE CONFIGURATION AND OPERATION INCLUDED IN ACAS

4.1.1 Tracking thresholds

4.1.1.1 Although ACAS can track aircraft with vertical rates in excess of 50.8 m/s (10 000 fpm), RAs are not generated against such aircraft. This is because it is difficult to predict the vertical rates with sufficient accuracy to suggest appropriate RAs. The aircraft involved are implicitly considered to be military and far more able to manoeuvre vertically than own aircraft.

4.1.1.2 Vertical accelerations that exceed ±1.25 g will cause severe errors in ACAS tracking. These manoeuvres give altitude replies that are so different from the projected level that they are considered as erroneous and ACAS continues its current altitude projections. Vertical accelerations in aircraft operating within civil airspace should be kept below ±1.25 g.

4.1.2 Horizontal distance thresholds for RAs

4.1.2.1 Although ACAS advisories are primarily based on estimated time to collision, they also can be triggered when proximity becomes too small. This may interfere with some operational procedures — for example with closely spaced parallel runways. Table 4-1 shows the threshold horizontal spacing (expressed as Distance MODification (DMOD)) at different altitudes.

Table 4-1. Threshold horizontal spacing at different altitudes

Above altitude (m)	Above altitude (ft)	DMOD (m)	DMOD (NM)
6 096	20 000 MSL	2 037	1.1
3 048	10 000 MSL	1 482	0.8
1 524	5 000 MSL	1 019	0.55
716	2 350 AGL	648	0.35
305	1 000 AGL	370	0.2