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AERONAUTICAL CIRCULAR
CIVIL AVIATION AUTHORITY – MACAO, CHINA

SUBJECT:

AIRBORNE COLLISION AVOIDANCE SYSTEM (ACAS)
OPERATIONAL PROCEDURES AND TRAINING REQUIREMENTS

EFFECTIVE DATE:

22 Jun 2022

CANCELLATION:

AC/OPS/021R00

GENERAL:

The President of Civil Aviation Authority – Macao, China, in exercise of his power under Paragraph 89 of the Air Navigation Regulation of Macao (ANRM) and Article 35 of the Statutes of Civil Aviation Authority, approved by the Decree-Law 10/91/M, established this Aeronautical Circular (AC).

1 Introduction

In view of the significant improvement to flight safety accompanied by the introduction of Airborne Collision Avoidance System (ACAS), the International Civil Aviation Organization (ICAO) introduced relevant provisions into the ICAO Annex 6, Part I and II regarding the equipage of ACAS, where provisions are reflected in the paragraph 4 of the Fifth Schedule of the Air Navigation Regulation of Macao (ANRM). However, it is important to note that the ability of ACAS to fulfill its role of assisting pilots in the avoidance of potential collisions is dependent on the correct and timely response by pilots to ACAS indications. Operational experience has shown that the correct response by pilots is dependent of the effectiveness of the initial and recurrent training in ACAS procedures.

The objectives of this AC are to highlight all necessary actions that shall be taken by pilots during an ACAS event, and to provide guidance for operators on the development of operational procedures and training program towards the use of airborne collision avoidance system.

2 Applicability

This AC is applicable to all Macao registered aircraft which are equipped or required to be equipped with an airborne collision avoidance system (ACAS II) as specified in paragraph 4 of the Fifth Schedule of the Air Navigation Regulation of Macao (ANRM).

3 Definitions

- Airborne Collision Avoidance System (ACAS)

  An aircraft system based on secondary surveillance radar (SSR) transponder signals which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders. Airborne Collision Avoidance System can be classified into ACAS I and ACAS II, in which:

  - ACAS I is only capable of providing TAs; and
  - ACAS II is capable of providing both TAs and RAs.

  For the purpose of this AC, unless otherwise specified, the use of the term "ACAS" refers to ACAS II.

- Traffic Advisory (TA)

  Traffic Advisory (TA) is intended to prompt visual acquisition and to act as a warning that a resolution advisory (RA) may follow. It indicates the approximate positions of intruding aircraft that may later cause RA(s).

- Resolution Advisory (RA)

  Resolution Advisory (RA) proposes vertical manoeuvres that are predicted to increase or maintain separation from threatening aircraft.

Note – The normal operating mode of ACAS is TA/RA. The TA-only mode of operation is used in certain aircraft performance limiting conditions caused by in-flight failures or as otherwise promulgated by the appropriate authority.

4 Use of Airborne Collision Avoidance System (ACAS)

4.1 The operator of the ACAS-equipped aircraft shall ensure that:

a) Each flight crew member has been appropriately trained to competency in the use of ACAS equipment and the avoidance of collisions; and

b) Appropriate procedures are established and incorporated into operations manuals regarding flight crew responses to the ACAS advisories (TAs and RAs).

4.2 ACAS indications shall be used by pilots in the avoidance of potential collisions, the enhancement of situational awareness, and the active search for, and visual acquisition of, conflicting traffic.

4.3 Nothing in the procedures specified in paragraph 5 hereunder shall prevent pilot-in-command from exercising his/her best judgment and full authority in the choice of the best course of action to resolve a traffic conflict or avert a potential collision.

4.4 ACAS training program shall be established to meet the performance-based training objectives as provided in the Appendix A to this AC.

5 Use of ACAS Indications

The indications generated by ACAS shall be used by pilots in conformity with the following safety considerations:

a) pilots shall not manoeuvre their aircraft in response to traffic advisories (TAs) only;

Note 1.- TAs are intended to alert pilots to the possibility of a resolution advisory (RA), to enhance situational awareness, and to assist in visual acquisition of conflicting traffic. However, visually acquired traffic may not be the same traffic causing a TA. Visual perception of an encounter may be misleading, particularly at night.

Note 2.- The above restriction in the use of TAs is due to the limited bearing accuracy and to the difficulty in interpreting altitude rate from displayed traffic information.

b) on receipt of a TA, pilots shall use all available information to prepare for appropriate action if an RA occurs; and

c) in the event of an RA, pilots shall:

1) respond immediately by following the RA as indicated, unless doing so would jeopardize the safety of the aircraft;

Note 1.- Stall warning, wind shear, and ground proximity warning system alerts have precedence over ACAS.

Note 2.- Visually acquired traffic may not be the same traffic causing an RA. Visual perception of an encounter may be misleading, particularly at night.

2) follow the RA even if there is a conflict between the RA and an air traffic control (ATC) instruction to manoeuvre;

3) not manoeuvre in the opposite sense to an RA;

Note.- In the case of an ACAS-ACAS coordinated encounter, the RAs complement each other in order to reduce the potential for collision. Manoeuvres, or lack of manoeuvres, that result in vertical rates opposite to the sense of an RA could result in a collision with the intruder aircraft.

4) as soon as possible, as permitted by flight crew workload, notify the appropriate ATC unit of any RA which requires a deviation from the current ATC instruction or clearance;

Note.- Unless informed by the pilot, ATC does not know when ACAS issues RAs. It is possible for ATC to issue instructions that are unknowingly contrary to ACAS RA indications. Therefore, it is important that ATC be notified when an ATC instruction or clearance is not being followed because it conflicts with an RA.

5) promptly comply with any modified RAs;

6) limit the alterations of the flight path to the minimum extent necessary to comply with the RAs;

7) promptly return to the terms of the ATC instruction or clearance when the conflict is resolved; and

8) notify ATC when returning to the current clearance.

Note 1.- Procedures in regard to ACAS-equipped aircraft and the phraseology to be used for the notification of manoeuvres in response to a resolution advisory are contained in the PANS-ATM (ICAO Doc 4444), Chapters 15 and 12, respectively.

Note 2.- Where aircraft can provide automatic following of an RA when the autopilot is engaged supported by a link between ACAS and autopilot, the operational procedures in items 4) and 8) still apply.

6 High Vertical Rate (HVR) Encounters

Operator shall specify appropriate procedures to avoid unnecessary RAs in aircraft at or approaching adjacent altitudes or flight levels. Pilots shall use the appropriate procedures by which an aircraft climbing or descending to an assigned altitude or flight level, especially with an autopilot engaged, may do so at a rate less than 8 m/sec or 1500 ft/min (depending on the instrumentation available) throughout the last 300 m (1000 ft) of climb or descent to the assigned level when the pilot is made aware of another aircraft at or approaching an adjacent altitude or flight level, unless otherwise instructed by ATC.

Note – Detailed information on High Vertical Rate (HVR) encounters and guidance material concerning the development of appropriate procedures is contained in the Appendix B to this AC.

– END –

Appendix A ACAS Training Guidelines for Pilots

1 Introduction

1.1 During the implementation of ACAS and the operational evaluations by States, several operational issues were identified that were attributed to deficiencies in pilot training programs. To address these deficiencies, a set of performance-based training objectives for ACAS pilot training was developed. The training objectives cover: theory of operation; pre-flight operations; general in-flight operations; response to traffic advisories (TAs); and response to resolution advisories (RAs). The training objectives are further divided into areas of: ACAS academic training; ACAS manoeuvre training; ACAS initial evaluation; and ACAS recurrent qualification.

1.2 ACAS academic training material has been divided into items that are considered essential training and those that are consider desirable. Those items that are deemed to be essential are a requirement for each ACAS operator. In each area, a list of objectives and acceptable performance criteria is defined. All manoeuvre training is considered essential.

1.3 In developing this material, no attempt was made to define how the training program should be implemented. Instead, objectives were established that define the knowledge a pilot operating ACAS is expected to possess and the performance expected from a pilot who has completed ACAS training. Therefore, all pilots who operate ACAS equipment should receive the ACAS training described below.

2 ACAS Academic Training

2.1 General

2.1.1 This training is typically conducted in a classroom environment. The knowledge demonstrations specified in this section may be achieved through the successful completion of written tests or providing correct responses to non-real-time computer-based training (CBT) questions.

2.2 Essential items

2.2.1 ***Theory of operation***: The pilot must demonstrate an understanding of ACAS operation and the criteria used for issuing TAs and RAs. This training should address the following topics:

2.2.1.1 *System operation*

Objective: Demonstrate knowledge of how ACAS functions.

Criteria: The pilot must demonstrate an understanding of the following functions:

a) Surveillance:

1) ACAS interrogates other transponder-equipped aircraft within a nominal range of 14NM; and

2) ACAS surveillance range can be reduced in geographic areas with a large number of ground interrogators and/or ACAS-equipped aircraft. A minimum surveillance range of 4.5 NM is guaranteed for ACAS aircraft that are airborne.

Note.– If the operator's ACAS installation provides for the use of the Mode S extended squitter, the normal surveillance range may be increased beyond the normal 14NM. However, this information is not used for collision avoidance purposes.

b) Collision avoidance:

1) TAs can be issued against any transponder-equipped aircraft that responds to the ICAO Mode C interrogations, even if the aircraft does not have altitude-reporting capability;

Note.– SSR transponders having only Mode A capability do not generate TAs. ACAS does not use Mode A interrogations; therefore, the Mode A transponder codes of nearby aircraft are not known to ACAS. In ICAO SARPs, Mode C minus the altitude is not considered Mode A because of the difference in the pulse intervals. ACAS uses the framing pulses of replies to Mode C interrogations and will track and may display aircraft equipped with an operating Mode A/C transponder whether or not the altitude-reporting function has been enabled.

2) RAs can be issued only against aircraft that are reporting altitude and in the vertical plane only;

3) RAs issued against an ACAS-equipped intruder are coordinated to ensure that complementary RAs are issued;

4) failure to response to an RA deprives the aircraft of the collision protection provided by its ACAS. Additionally, in ACAS-ACAS encounters, it also restricts the choices available to the other aircraft's ACAS and thus renders the other aircraft's ACAS less effective than if the first aircraft were not ACAS-equipped; and

5) manoeuvring in a direction opposite to that indicated by an RA is likely to result in further reduction in separation. This is particularly true in the case of an ACAS-ACAS coordinated encounter.

2.2.1.2 *Advisory thresholds*

Objective: Demonstrate knowledge of the criteria for issuing TAs and RAs.

Criteria: The pilot must be able to demonstrate an understanding of the methodology used by ACAS to issue TAs and RAs and the general criteria for the issuance of these advisories to include:

a) ACAS advisories are based on time to closest point of approach (CPA) rather than distance. The time must be short and vertical separation must be small, or projected to be small, before an advisory can be issued. The separation standards provided by air traffic services are different from those against which ACAS issues alerts;

b) thresholds for issuing a TA or RA vary with altitude. The thresholds are larger at higher altitudes;

c) TAs generally occur from 20 to 48 seconds prior to CPA. When ACAS is operated in TA-only mode, RAs will be inhibited;

d) RAs occur from 15 to 35 seconds before the projected CPA; and

e) RAs are chosen to provide the desired vertical separation at CPA. As a result, RAs can instruct a climb or descent through the intruder aircraft's altitude.

2.2.1.3 *ACAS limitations*

Objective: To verify that the pilot is aware of the limitations of ACAS.

Criteria: The pilot must demonstrate a knowledge and understanding of the ACAS limitations including:

a) ACAS will neither track nor display non-transponder-equipped aircraft, nor aircraft with an inoperable transponder, nor aircraft with a Mode A transponder;

b) ACAS will automatically fail if the input from the aircraft's barometric altimeter, radio altimeter, or transponder is lost;

Note.– In some installations, the loss of information from other on-board systems such as an inertial reference system (IRS) or attitude and heading reference system (AHRS) may result in an ACAS failure. Individual operators should ensure that their pilots are aware of what types of aircraft system failures will result in an ACAS failure.

c) some aircraft within 380 ft above ground level (AGL) (nominal value) will not be displayed. If ACAS is able to determine that an aircraft below this altitude is airborne, it will be displayed;

d) ACAS may not display all proximate transponder-equipped aircraft in areas of high-density traffic; however, it will still issue RAs as necessary;

e) because of design limitations, the bearing displayed by ACAS is not sufficiently accurate to support the initiation of horizontal maneuvers based solely on the traffic display;

f) because of design limitation, ACAS will neither display nor give alerts against intruders with a vertical speed in excess of 10000 ft/min. 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; and

g) stall warnings, ground proximity warning system (GPWS) warnings and wind shear warnings take precedence over ACAS advisories. When either a GPWS or wind shear warning is active, ACAS will automatically switch to the TA-only mode of operation except that ACAS aural annunciations will be inhibited. ACAS will remain in TA-only mode for 10 seconds after the GPWS or wind shear warning is removed.

2.2.1.4 *ACAS inhibits*

Objective: To verify that the pilot is aware of the conditions under which certain functions of ACAS are inhibited.

Criteria: The pilot must demonstrate a knowledge and understanding of the various ACAS inhibits including:

a) increase descent RAs are inhibited below 1450 (±100) ft AGL;

b) descend RAs are inhibited below 1100 (±100) ft AGL;

c) all RAs are inhibited below 1000 (±100) ft AGL;

d) all ACAS aural annunciations are inhibited below 500 (±100) ft AGL. This includes the aural annunciation for TAs; and

e) altitude and configuration under which climb and increase climb RAs are inhibited. ACAS can still issue climb and increase climb RAs when operating at the aircraft's maximum altitude or certified ceiling. However, if aircraft performance at maximum altitude is not sufficient to enable compliance with the climb rate require by a climb RA, the response should still be in the required sense but not beyond the extent permitted by aircraft performance limitations.

Note.– In some aircraft types, climb or increase climb RAs are never inhibited.

2.2.2 ***Operating procedures***: The pilot must demonstrate the knowledge required to operate ACAS and interpret the information presented by ACAS. This training should address the following topics:

2.2.2.1 *Use of controls*

Objective: To verify that the pilot can properly operate all ACAS and display controls.

Criteria: Demonstrate the proper use of controls including:

a) aircraft configuration required to initiate a self-test;

b) steps required to initiate a self-test;

c) recognizing when the self-test is successful and when it is unsuccessful. When the self-test is unsuccessful, recognizing the reason for the failure, and, if possible, correcting the problem;

d) recommended usage of traffic display range selection. Low ranges are used in the terminal area, and the higher display ranges are used in the en-route environment and in the transition between the terminal and en-route environment;

e) if available, recommended usage of the "Above/Below" mode selector. "Above" mode should be used during climb, and "Below" mode should be used during descent;

f) recognition that the configuration of the traffic display, i.e. range and "Above/Below" selection, does not affect the ACAS surveillance volume;

g) selection of lower ranges on the traffic display to increase display resolution when an advisory is issued;

h) if available, proper selection of the display of absolute or relative altitude and the limitations of using absolute display option if a barometric correction is not provided to ACAS; and

i) proper configuration to display the appropriate ACAS information without eliminating the display of other needed information.

Note.– The wide variety of display implementations makes it difficult to establish more definitive criteria. When the training program is developed, these general criteria should be expanded to cover specific details for an operator's specific display implementation.

2.2.2.2 *Display interpretation*

Objective: To verify that the pilot understands the meaning of all information that can be displayed by ACAS.

Criteria: The pilot must demonstrate the ability to properly interpret information displayed by ACAS including:

a) other traffic, i.e. traffic within the selected display range that is not proximate traffic, or causing a TA or RA to be issued;

b) proximate traffic, i.e. traffic that is within 6 NM and ±1200 ft;

c) non-altitude reporting traffic;

d) no bearing TAs and RAs;

e) off-scale TAs and RAs. The selected range should be changed to ensure that all available information on the intruder is displayed;

f) traffic advisories. The minimum available display range that allows the traffic to be displayed should be selected to provide the maximum display resolution;

g) resolution advisories (traffic display). The minimum available display range of the traffic display that allows the traffic to be displayed should be selected to provide the maximum display resolution;

h) resolution advisories (RA display). Pilots should demonstrate knowledge of the meaning of the red and green areas or the meaning of pitch or flight path angle cues displayed on the RA display. For displays using red and green areas, pilots should demonstrate knowledge of when the green areas will and will not be displayed. Pilots should also demonstrate an understanding of the RA display limitations, i.e. if a vertical speed tape is used and the range of the tape is less than 2500 ft/min, how an increase rate RA will be displayed; and

i) if appropriate, awareness that navigation displays oriented "Track-Up" may require a pilot to make a mental adjustment for drift angle when assessing the bearing of proximate traffic.

Note.– The wide variety of display implementations will require the tailoring of some criteria. When the training program is developed, these criteria should be expanded to cover details for an operator's specific display implementation.

2.2.2.3 *Use of the TA-only mode*

Objective: To verify that the pilot understands the appropriate times to select the TA-only mode of operation and the limitations associated with using this mode.

Criteria: The pilot must demonstrate the following:

a) knowledge of the operator's guidance for the use of TA-only mode;

b) reasons for using this mode and situations in which its use may be desirable. These include operating in known close proximity to other aircraft such as when visual approaches are being used to closely spaced parallel runways or taking off towards aircraft operating in a VFR corridor. If TA-only mode is not selected when an airport is conducting simultaneous operations from parallel runways separated by less than 1200 ft, and to some intersecting runways, RAs can be expected. If an RA is received in these situations, the response should comply with the operator's approved procedures; and

c) the TA aural annunciation is inhibited below 500 (±100) ft AGL. As a result, TAs issued below 500 ft AGL may not be noticed unless the TA display is included in the routine instrument scan.

2.2.2.4 *Crew coordination*

Objective: To verify that pilots adequately brief other crew members on how ACAS advisories will be handled.

Criteria: Pilots must demonstrate that their pre-flight briefing addresses the procedures that will be used in responding to TAs and RAs including:

a) division of duties between the pilot flying and the pilot not flying, including a clear definition of whether the pilot flying or the pilot-in-command will fly the aircraft during a response to an RA;

b) expected call-outs;

c) communications with ATC; and

d) conditions under which an RA may not be followed and who will make this decision.

Note1.– Different operators have different procedures for conducting pre-flight briefings and for responding to ACAS advisories. These factors should be taken into consideration when implementing the training program.

Note2.– The operator must specify the conditions under which an RA need not be followed, reflecting advice published by States' Civil Aviation Authorities. This should not be an item left to the discretion of a crew.

Note3.– This portion of the training may be combined with other training such as crew resource management (CRM).

2.2.2.5 *Reporting requirements*

Objective: To verify that the pilot is aware of the requirements for reporting RAs to the controller and other authorities.

Criteria: The pilot must demonstrate the following:

a) the use of the phraseology contained in the Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM, ICAO Doc 4444); and

b) where information can be obtained regarding the need for making written reports to various States when an RA is issued. Various States have different reporting requirements and the material available to the pilot should be tailored to the airline's operating environment.

2.3 Desirable items

2.3.1 *Advisory thresholds*

Objective: Demonstrate knowledge of the criteria for issuing TAs and RAs.

Criteria: The pilot must be able to demonstrate an understanding of the methodology used by ACAS to issue TAs and RAs and the general criteria for the issuance of these advisories to include:

a) the TA altitude threshold is 850 ft below FL 420 and 1200 ft above FL 420;

b) when the vertical separation at CPA is projected to be less than the ACAS-desired separation, an RA requiring a change to the existing vertical speed will be issued. The ACAS-desired separation varies from 300 ft at low altitude to a maximum of 700 ft above FL 300;

c) when the vertical separation at CPA is projected to be greater than the ACAS-desired separation, an RA that does not require a change to the existing vertical speed will be issued. This separation varies from 600 to 800 ft; and

d) RA fixed-range thresholds vary between 0.2 NM at low altitude and 1.1 NM at high altitude. These fixed-range thresholds are used to issue RAs in encounters with slow closure rates.

3 ACAS Manoeuvre Training

3.1 When training pilots to properly respond to ACAS-displayed information, TAs and RAs are most effective when accomplished in a flight simulator equipped with an ACAS display and controls similar in appearance and operation to those in the aircraft. If a simulator is utilized, CRM aspects of responding to TAs and RAs should be practiced during this training.

3.2 If an operator does not have access to an ACAS-equipped simulator, the initial ACAS evaluation should be conducted by means of an interactive CBT with an ACAS display and controls similar in appearance and operation to those in the aircraft the pilot will fly. This interactive CBT should depict scenarios in which real-time responses must be made. The pilot should be informed whether or not the responses made were correct. If the response was incorrect or inappropriate, the CBT should show what the correct response should be.

3.3 The scenarios in the manoeuvre training should include initial RAs that require a change in vertical speed; initial RAs not requiring a change in vertical speed; maintain rate RAs; altitude crossing RAs; increase rate RAs; RA reversals; weakening RAs; RAs issued while the aircraft is at a maximum altitude, and multi-aircraft encounters. In all scenarios,

excursions should be limited to the extent required by the RA. The scenarios should be concluded with a return to the original flight profile. The scenarios should also include demonstrations of the consequences of not responding to RAs, slow or late responses, and manoeuvring opposite to the direction called for by the displayed RA as follows:

3.3.1 *TA responses*

Objective: To verify that the pilot properly interprets and responds to TAs.

Criteria: The pilot must demonstrate:

a) proper division of responsibilities between the pilot flying and the pilot not flying. The pilot flying should continue to fly the aircraft and be prepared to respond to any RA that might follow. The pilot not flying should provide updates on the traffic location shown on the ACAS traffic display and use this information to help visually acquire the intruder;

b) proper interpretation of the displayed information. Visually search for the traffic causing the TA at a location shown on the traffic display. Use should be made of all information shown on the display, note being taken of the bearing and range of the intruder (amber circle), whether it is above or below (data tag), and its vertical speed direction (trend arrow);

c) other available information is used to assist in visual acquisition. This includes ATC “party-line” information, traffic flow in use, etc.;

d) because of the limitations described in 2.2.1.3 e), that no manoeuvres are made based solely on the information shown on the ACAS display; and

e) when visual acquisition is attained, right of way rules are used to maintain or attain safe separation. No unnecessary manoeuvres are initiated. The limitations of making manoeuvres based solely on visual acquisition are understood.

3.3.2 *RA responses*

Objective: To verify that the pilot properly interprets and responds to RAs.

Criteria: The pilot must demonstrate:

a) proper division of responsibilities between the pilot flying and the pilot not flying. The pilot flying should respond to the RA with positive control inputs, when required, while the pilot not flying is providing updates on the traffic location, checking the traffic display and monitoring the response to the RA. Proper CRM should be used. If the operator’s procedures require the pilot-in-command to fly all RAs, transfer of aircraft control should be demonstrated;

b) proper interpretation of the displayed information. The pilot recognizes the intruder causing the RA to be issued (red square on display). The pilot responds appropriately;

c) for RAs requiring a change in vertical speed, initiation of a response in the proper direction within five seconds of the RA being displayed. Pilot actions must focus on tasks related to manoeuvring the aircraft in response to the RA and flight crew coordination, avoiding distractions that may interfere with a correct and timely response. After initiating the manoeuvre, and as soon as possible, as permitted by flight workload, ATC is notified using the standard phraseology if the manoeuvre requires a deviation from the current ATC instruction or clearance;

Note *– In the event of an RA, pilots should respond immediately and manoeuvre as indicated, unless doing so would jeopardize the safety of the aircraft.*

d) for RAs not requiring a change in vertical speed, focus on tasks associated with following the RA, including preparedness for a modification to the initially displayed RA where a change in vertical speed may be required. Distractions that may interfere with a correct and timely response must be avoided;

e) recognition of and the proper response to modifications to the initially displayed RA:

1) for increase rate RAs, the vertical speed is increased within 2 ½ seconds of the RA being displayed;

2) for RA reversals, the manoeuvre is initiated within 2 ½ seconds of the RA being displayed;

3) for RA weakening, the vertical speed is modified to initiate a return towards level flight within 2 ½ seconds of the RA being displayed; and

4) for RAs that strengthen, the manoeuvre to comply with the revised RA is initiated within 2 ½ seconds of the RA being displayed;

f) recognition of altitude crossing encounters and the proper response to these RAs;

g) for RAs that do not require a change in vertical speed, the vertical speed needle or pitch angle remains outside the red area on the RA display;

h) for maintain rate RAs, the vertical speed is not reduced. Pilots should recognize that a maintain rate RA may result in crossing through the intruder's altitude;

i) that if a justified decision is made to not follow an RA, the resulting vertical rate is not in a direction opposite to the sense of the displayed RA;

j) that the deviation from the current clearance is minimized by leveling the aircraft when the RA weakens and when "Clear of Conflict" is annunciated, executing a prompt return to the current clearance; and notifying ATC as soon as possible, as permitted by flight crew workload;

k) that when possible, an ATC clearance is complied with while responding to an RA. For example, if the aircraft can level at the assigned altitude while responding to a reduce climb or reduce descent RA, it should be done;

l) that when simultaneous conflicting instructions to manoeuvre are received from ATC and an RA, the RA is followed and, as soon as possible, as permitted by flight crew workload, ATC is notified using the standard phraseology;

m) a knowledge of the ACAS multi-aircraft logic and its limitations, and that ACAS can optimize separation from two aircraft by climbing or descending towards one of them. For example, ACAS considers as intruders only aircraft that it finds to be a threat when selecting an RA. As such, it is possible for ACAS to issue an RA against one intruder, which results in a manoeuvre towards another intruder that is not classified as a threat. If the second intruder becomes a threat, the RA will be modified to provide separation from that intruder;

n) a knowledge of the consequences of not responding to an RA and manoeuvring in the direction opposite to the RA; and

o) that a prompt response is made when a climb RA is issued while the aircraft is at the maximum altitude.

4 ACAS Initial Evaluation

4.1 The pilot's understanding of the academic training items should be assessed by means of a written test or interactive CBT that records correct and incorrect responses to questions.

4.2 The pilot's understanding of the manoeuvre training items should be assessed in a flight simulator equipped with an ACAS display and controls similar in appearance and operation to those in the aircraft the pilot will fly, and the results assessed by a qualified instructor, inspector, or check pilot. The range of scenarios should include: initial RAs requiring a change in vertical speed; initial RAs that do not require a change in vertical speed; maintain rate RAs; altitude crossing RAs; increase rate RAs; RA reversals; weakening RAs; RAs issued while the aircraft is at the maximum altitude, and multi-aircraft encounters. In all scenarios, excursions should be limited to the extent required by the RA. The scenarios should be concluded with a return to the original flight profile. The scenarios should also include demonstrations of the consequence of not responding to RAs, slow or late responses, and manoeuvring opposite to the direction called for by the displayed RA.

4.3 If an operator does not have access to an ACAS-equipped simulator, the initial ACAS evaluation should be conducted by means of an interactive CBT with an ACAS display and controls similar in appearance and operation to those in the aircraft the pilot will fly. This interactive CBT should depict scenarios in which real-time responses must be made, and a record should be made of whether or not each response was correct. The CBT should include all types of RAs described in 4.2.

5 ACAS Recurrent Training

5.1 ACAS recurrent training ensures that pilots maintain the appropriate ACAS knowledge and skills. ACAS recurrent training should be integrated into and/or conducted in conjunction with other established recurrent training programs. An essential item of recurrent training is the discussion of any significant issues and operational concerns that have been identified by the operator.

5.2 ACAS monitoring programs periodically publish findings from their analyses of ACAS events. The results of these analyses typically discuss technical and operational issues related to the use and operation of ACAS. This information is available from ICAO or directly from the monitoring programs. ACAS recurrent training programs should address the results of monitoring programs in both the academic and simulator portions of recurrent training visits.

Note.– ACAS monitoring programs are carried out by some States and international organizations including the United States' Federal Aviation Administration (FAA) and the European Organization for the Safety of Air Navigation (EUROCONTROL).

5.3 Recurrent training should include both academic and manoeuvre training and address any significant issues identified by line operating experience, system changes, procedural changes, or unique characteristics such as the introduction of new aircraft/display systems or operations in airspace where high numbers of TAs and RAs have been reported.

5.4 Pilots should fly all scenarios once every four years.

5.5 Pilots should complete all scenarios once every two years if CBT is used.

Appendix B ACAS High Vertical Rate (HVR) Encounters

1 ACAS Performance during HVR Encounters

1.1 Data collected by ACAS monitoring programs continue to show that a large percentage of ACAS RAs are a result of climbing or descending aircraft maintaining a high vertical speed while approaching their ATC-assigned altitude. Changes have been made to the ICAO Standards and Recommended Practices (SARPs) and guidance material (see ICAO Annex 10, Volume I) that have been effective in reducing the frequency of occurrence of these types of RAs, but these types of RAs continue to occur with a high degree of regularity in airspace throughout the world. It has been determined that no further changes are feasible within ACAS to address this issue without resulting in an unacceptable degradation of the safety provide by ACAS.

1.2 Modern aircraft and their flight guidance systems (autopilots, flight management systems, and autothrottles) are designed to fly specific flight profiles that provide fuel and time-efficient flight paths. An integral concept of the design of the flight guidance systems includes allowing an aircraft to quickly climb to higher, more efficient operating altitudes and to remain at these altitudes as long as possible, which results in descents also being made with high vertical speeds. For economic benefits, the high vertical speeds used in a climb or descent are retained as long as feasible before initiating a smooth capture of the aircraft's assigned altitude.

1.3 The design of the flight guidance systems can result in vertical speeds in excess of 15 m/s (or 3000 ft/min) until they are within 150 m (or 500 ft) of the aircraft's assigned altitude. When a climbing or descending aircraft maintains a vertical speed in excess of 15 m/s (or 3000 ft/min) until it is within 150 m (or 500 ft) of the aircraft's assigned altitude, it is less than 30 seconds away from being at the adjacent IFR altitude, which may be occupied by an ACAS-equipped aircraft flying level at that altitude. If the intruder aircraft is horizontally within the protected area provided by ACAS, there is a high probability that an RA against the climbing or descending aircraft will be issued just as the intruder aircraft begins to reduce its vertical speed to capture its assigned altitude.

1.4 Figure B-1 provides a representation of the encounter geometry of this scenario. ACAS typically issues a climb RA, which calls for a climb at 8 m/sec (or 1500 ft/min). Depending on the altitude of the level aircraft, this RA will typically be issued when the intruder aircraft is approximately 150 m (or 500 ft) below its assigned altitude and the vertical speed of the intruder is in excess of 15 m/s (or 3000 ft/min).

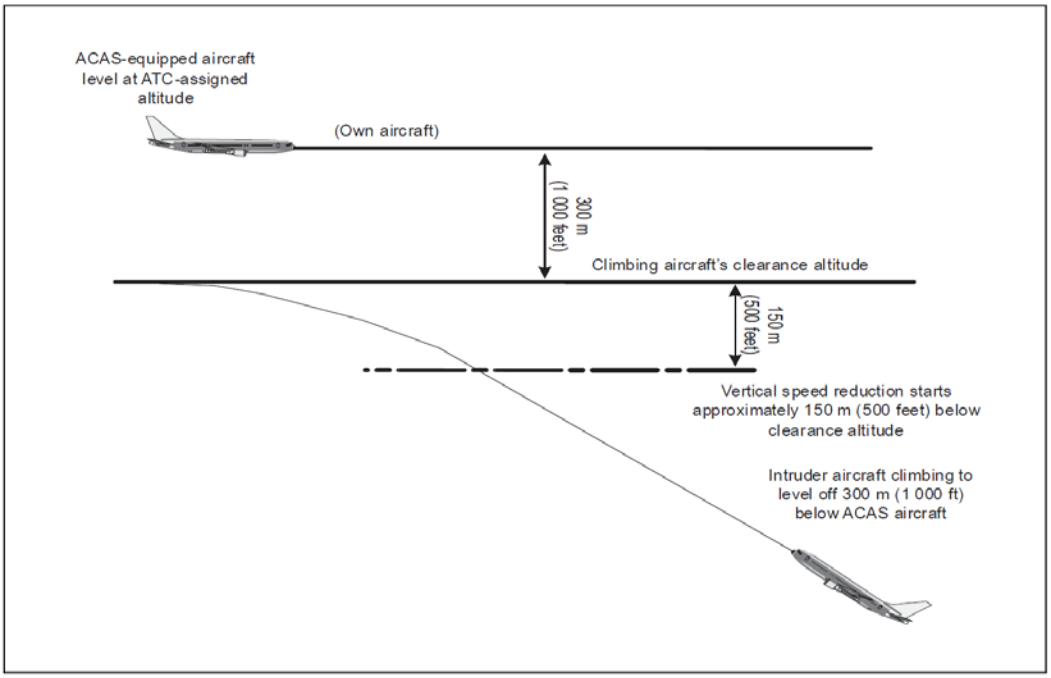

Figure B-1 Representative HVR encounter geometry

1.5 ACAS in the level aircraft is tracking a climbing/descending (intruder) aircraft and is using replies to its interrogations to determine the intruder's altitude and its vertical speed. The ACAS track is updated once per second. The intruding aircraft's information, along with the track of the level ACAS aircraft (own aircraft), is used within ACAS to determine if the intruder aircraft is currently a threat or will be in the near future.

1.6 In determining whether the intruder aircraft will be a threat in the future, ACAS projects the existing vertical speed of the intruder and own aircraft, to estimate the vertical separation that will exist at the closest point of horizontal approach during the encounter. These projections use the current vertical speed of both aircraft, and ACAS is not aware of the intruder aircraft's intend to level at an adjacent altitude above or below its own aircraft's current altitude. Should this projection be less that the ACAS desired vertical separation, an RA will be issued.

1.7 Should the intruder aircraft continue to climb/descend with the high vertical speed until it is 15 to 25 seconds from being at the same altitude as the level ACAS aircraft (again depending on the ACAS aircraft's altitude), ACAS will issue an RA calling for the own aircraft to manoeuvre to increase vertical separation from the intruder aircraft.

2 Operational Impacts of RAs Resulting from HVR Encounters

2.1 Shortly after ACAS issues the RA (climb RA for the encounter geometry shown in Figure B-1), the intruder aircraft begins reducing its vertical rate to capture its assigned altitude.

2.2 While the intruder aircraft is initiating its level-off, the ACAS aircraft has started responding to its RA and may have left its assigned altitude. Both pilots and controllers agree that RAs issued in this encounter geometry are unwelcome. The RAs can be disruptive to a controller's current traffic flow and plans, and thus represent an increase in their workload. The response to the RA can also result in a loss of standard ATC separation if another aircraft is above the ACAS aircraft.

2.3 Pilots have reported that these types of RAs decrease their confidence in the performance of ACAS. These RAs typically occur repeatedly in the same geographic area, and repeated RAs of this type result in pilots being reluctant to follow the RA. This can be potentially hazardous in the event that the intruder aircraft passes through its assigned altitude.

3 Frequency of Occurrence

3.1 ACAS monitoring shows that the frequency of occurrence is dependent on how airspace is structured and managed. Data from the past indicate that up to 70 per cent of the RAs issued are caused by the intruder aircraft maintaining a high vertical speed while approaching its assigned altitude. Depending on the airspace structure and the flow of traffic, it is possible to have several of these RAs issued within one hour, although airspace containing a lower density of traffic will have relatively few RAs of this type. Some air traffic service providers have been able to change their traffic flows and/or operational procedures to reduce the occurrence of these types of RAs, but these types of RAs continue to occur with a high degree of regularity in airspace throughout the world.

3.2 HVR RAs have been observed in both terminal and en-route airspace, although because of the previously higher vertical separation above FL 290 in non-RVSM airspace, very few RAs of this type have been observed above FL 290 in the past. With the current reduced separation, it is possible that HVR RAs may occur more frequently above FL 290 in RVSM airspace. Many HVR RAs occur in close proximity to large airports where departures are kept below arriving aircraft until some distance from the aircraft before being allowed to climb to higher altitudes, and a large percentage of these RAs occur in geographic areas where there is a concentration of climbing and descending aircraft.

4 ACAS Features that Reduce the Likelihood of RAs being Issued in these Situations

4.1 ACAS recognizes HVR encounters, such as that shown in Figure B-1. When this encounter geometry is detected, the issuance of RAs can be delayed by up to ten seconds. This delay allows additional time for the intruder aircraft to initiate a level-off and for ACAS to then detect this level-off. However, when the intruder aircraft maintains a vertical speed in excess of 15 m/s (or 3000 ft/min) until it is within 150 m (or 500 ft) of its assigned altitude, even this 10-second delay may be insufficient for ACAS to detect the level-off, and an RA may be issued. Safety studies have shown that further delays in issuing the RA result in unacceptable degradation in the safety provided by ACAS.

4.2 Consideration has also been given to providing ACAS with information regarding the intruder aircraft's intent. However, this is not considered to be a viable approach to reducing these types of RAs while retaining the existing level of safety provided by ACAS.

4.3 A solution to the problem of HVR encounters has been found and implemented in some aircraft. This solution comprises a) the coupling of the autopilot with ACAS; and b) the introduction of a new altitude capture logic. The first item will provide the detection of an intruder (e.g. issuance of a traffic advisory (TA)). The second item will enable the aircraft's auto-flight system to adjust the vertical profile in order to prevent the issuance of RAs. In combination, these two improvements should provide a significant reduction of the disruptive RAs occurring during HVR encounters.

5 Operator-specified Procedures

5.1 Due to the operational impacts on pilots and controllers caused by these types of RAs, and the continued existence of these RAs and the constraints on further modifications to ACAS, operators should specify procedures by which an aircraft climbing or descending to an assigned altitude or flight level with an autopilot engaged may do so at a rate less than 8 m/sec (or 1500 ft/min) within 300 m (or 1000 ft) of the assigned level. Such procedural changes should provide an immediate operational benefit to both pilots and controllers by reducing the occurrence of HVR RAs.

5.2 The implementation of such procedures will not completely eliminate these RAs, but in the absence of other solutions, such as the redesign of airspace, their implementation will reduce the frequency of these undesirable RAs until a technical solution can be developed. Options that operators should consider include flying the entire climb or descent at a preselected rate, modifying the climb or descent in the latter stage and employing use of less than economic climb thrust in lower airspace.

5.3 A recommended procedure would call for a climbing or descending aircraft to adjust its vertical rate when approaching an assigned altitude or flight level, and when the pilot is aware that there is an aircraft at or approaching an adjacent altitude or flight level. The crew can be made aware of the presence of that aircraft by several means, including information provided by an air traffic controller, an ACAS TA or by visual acquisition. When a crew of an intruder aircraft becomes aware that another aircraft is at or approaching an adjacent altitude or flight level, it is recommended that the vertical speed of the intruder aircraft be reduced to less than 8 m/s (or 1500 ft/min) when approaching an altitude that is 300 m (or 1000 ft) above or below the assigned altitude or flight level.

Note.– There is no intent in this recommendation to require a modification in vertical speed for every level-off. This is not necessary and would introduce a significant increase in pilot workload.

5.4 When the autopilot is in the altitude capture mode, subsequent vertical mode changes such as the selection of vertical speed mode may cause some autopilots either to cancel the altitude capture or to not properly capture the selected altitude. Altitude deviations represent a significant percentage of pilot deviations, and the performance of the autopilot during any altitude capture should be closely monitored in accordance with existing procedures.

5.5 Additional tasks may be required during some level-off manoeuvres. However, the procedure is a recommendation, not a requirement. Further, the procedure does not suggest that adjustments to the aircraft's vertical speed be made unless the pilot is aware that traffic is at an adjacent altitude.

5.6 The operator should specify procedures that the pilot may use to reduce vertical speed when an autopilot is engaged, as appropriate for the type of aircraft. Also, the operator should consider authorizing pilots to use a modest vertical speed throughout a climb or descent when the vertical interval is not large – such a change of altitude in a holding pattern – specifying how this should be accomplished.