



ACAS II Bulletin

Focus on pilot training

WELCOME

Welcome to this 'new look' ACAS II Bulletin. Although we have a new layout, the aim of the publication remains the same, to alert operators and pilots to important safety issues, both operational and technical, relating to TCAS.

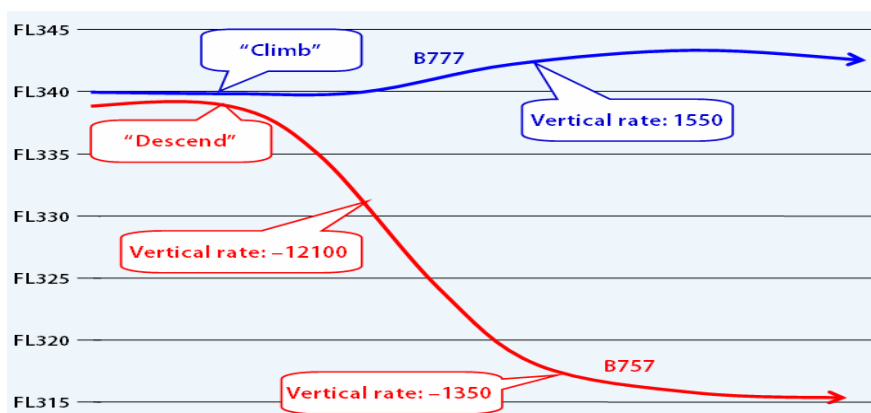
TCAS is the only commercially available implementation of the ICAO standard for ACAS II. Whilst the terms are virtually interchangeable, we tend to refer to ACAS when talking about the concept, and TCAS when talking about equipment, incidents, or encounters.

A clear understanding of the definitions, system operations and operating procedures is vital if ACAS is to achieve safety benefits. ACAS II has been mandated for several years, yet situations with inappropriate pilot responses are still being reported. These inappropriate responses have led to severe loss of separation or, in extreme cases, even accidents.

This ACAS Bulletin focuses on pilot training, featuring a number of events based on real-life incidents. Pilot actions in the featured events serve to underline the importance of both initial and recurrent training – so that flight crews respond correctly to RAs. This Bulletin also presents summary findings of some recent research into how pilots react to RAs.

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Event 1: overreaction to RA causes injuries



A B777 at FL340 is flying a heading of approximately 220 degrees. A B757 flying in the opposite direction is cleared, erroneously, to descend from FL390 to FL310 at a time when the aircraft are flying head-on, approximately 70 NM apart.

Some four minutes later, when the B757 is descending through FL343 and is 13 NM in front of the B777, the controller detects the conflict and instructs the B757 (using non-standard phraseology) to stop descending. There is no response from the B757 pilot but the aircraft's vertical rate starts to decrease. Five seconds later the controller instructs the B777 to turn right onto a heading of 270 which is acknowledged by the crew. Coordinated RAs are triggered – the B777 receives a "Climb" RA while the B757 receives a "Descend" RA.

The B777 crew responds to the "Climb" RA establishing a climb rate of 1550

ft/min within 9 seconds; however, they do not report the RA to ATC.

When the "Descend" RA is issued the B757 is at FL338. The pilot pushes hard on the controls and the descent rate increases rapidly. Simultaneously, the pilot wrongly notifies ATC that he is responding to a "Climb" RA. Within 8 seconds of the RA the B757 vertical rate increases to almost 12100 ft/min. Then, the pilot pulls back to arrest the excessive descent rate, reducing it to approximately 1350 ft/min in the next 11 seconds. The RA onboard the B757 weakens to "Adjust vertical speed" and soon after a "Clear of Conflict" message is posted.

The excessive reaction to the "Descend" RA caused the B757 to descend over 2000 ft in just 17 seconds, its airspeed increased by 30 kts and its pitch angle changed from 4.4 degrees nose up to 17.8 degrees nose down in just 7 seconds. When the pilot pulled back to

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Event 1 continued

arrest the excessive descent rate the acceleration changed from $-1.06g$ to $+2.48g$ (in 4 seconds) The resulting G-

forces caused injuries to 21 occupants (4 seriously) and damage to the interior of the aircraft. The aircraft had to divert to a

nearby airport to seek medical assistance for the injured.

Learning points:

- **Pilots should avoid excessive responses to RAs:** RAs never require vertical rates as excessive as described above. Responses to RAs must be followed as indicated on the flight deck instruments.
- **Vertical rates for initial RAs:** For initial RAs requiring a change in vertical speed, initiation of a response in the proper direction must be made within 5 seconds of the RA being displayed. For example, the "Descend" and "Climb" RAs require vertical speeds of 1500 ft/min. The change in vertical speed is accomplished by an acceleration of approximately $1/4 g$ to obtain the required vertical speed.
- **Vertical rates for subsequent RAs:** The response time is reduced to 2.5 seconds for subsequent RAs. The acceleration within which the change in vertical speed is accomplished is $1/3 g$ for increase rate and reversal RAs and $1/4 g$ for weakening and strengthening RAs.
- **Practical advice how to achieve the required acceleration is provided in JAA-TGL 11:** "An acceleration of approximately $1/4 g$ will be achieved if the change in pitch attitude corresponding to a change in vertical speed of 1500 ft/min is accomplished in approximately 5 seconds, and of $1/3 g$ if the change is accomplished in approximately 3 seconds. The change in pitch attitude required to establish a rate of climb or descent of 1500 ft/min from level flight will be approximately 6 degrees when the True Air Speed is 150 kts, 4 degrees at 250 kts, and 2 degrees at 500 kts. (These angles are derived from the formula: 1000 divided by TAS.)"

Events 2 & 3: contrasting responses to crossing RAs

RAs requiring the pilot to cross through the altitude of an intruder aircraft are rare. They account for less than 2% of all RAs. ACAS is designed to select non-altitude crossing RAs if these provide the desired vertical separation at the Closest Point of Approach. Only when that cannot be achieved will an RA with altitude crossing be posted. They are less intuitive than other RAs as they may give the pilot an impression that they are being wrongly directed towards the other aircraft. The following two events illustrate contrasting flight crew responses to crossing RAs, with correspondingly different outcomes.

Event 2

An RJ85 is cleared after departure to climb to FL150 on a heading of 330 degrees. An A330 is flying on a heading of 300 degrees descending towards its destination. The predicted trajectories of both aircraft are expected to cross with

a horizontal separation of less than 1 mile. The air traffic controller planned to clear the A330 to FL160 (1000 ft above the RJ85). However, the controller clears the A330 to FL150 by mistake.

Some time later, the controller instructs the RJ85 to turn right onto a heading of 345 degrees. When the aircraft are 2.5 NM and 2100 ft apart TAs are issued for both aircraft. A few seconds later, Short Term Conflict Alert warns the controller of the impending conflict. The controller issues avoiding action instructions to both aircraft:

"A330 turn right heading 360 degrees"

"RJ85 turn left heading 270 degrees."

He subsequently gives the A330 a further instruction to turn onto a heading of 035 degrees and provides traffic information to the RJ85 pilot.

When the aircraft are 1.6 NM and 850 ft apart, a first RA is issued for the A330 –

"Maintain vertical speed, crossing maintain". The A330 at this point is descending at almost 2500 ft/min and this RA tells the pilot to continue this vertical speed crossing through the level of the threat aircraft. Two seconds later, the RJ85 which is climbing at 1500 ft/min, also receives a "Maintain vertical speed, crossing maintain" RA. Both pilots follow their RAs and make reports to ATC.

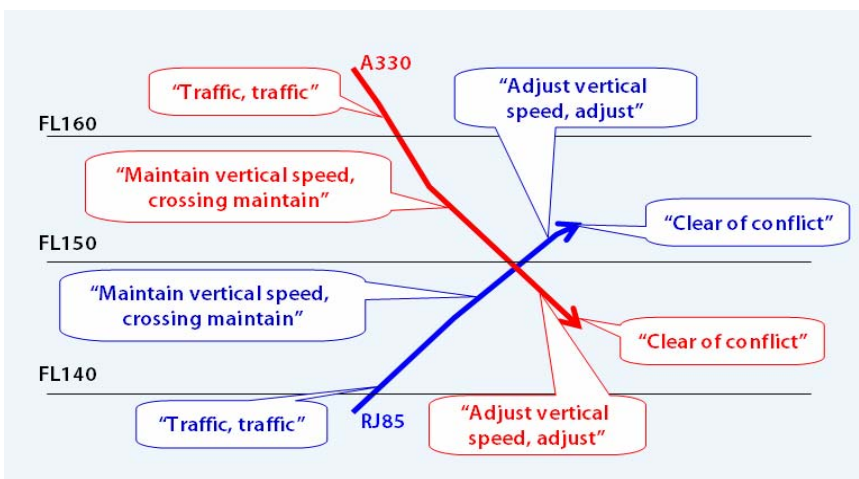
When the aircraft pass each other the A330 is over 600 ft below the RJ85, both RAs weaken to "Adjust vertical speed, adjust" which is soon followed by a "Clear of conflict" announcement.

Learning points:

- **RAs provide successful mitigation** against the risk of a mid-air collision.
- **Follow RAs:** Correct and prompt responses to RAs are necessary to reduce the risk of serious incidents or accidents.
- **Crossing RAs:** Although they are rare, training programmes should cover them.

Event 3

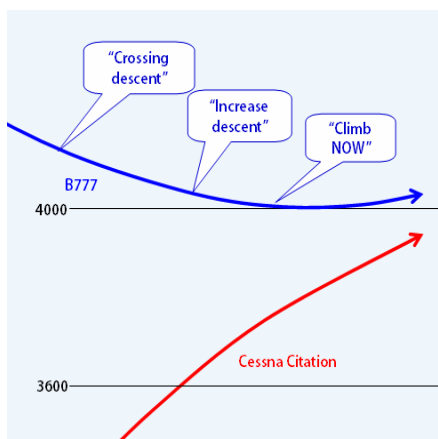
A Cessna Citation is on the ground requesting start up and departure clearance. The Citation is not equipped with TCAS II. Its maximum take-off mass is below 5700 kg, so the aircraft is outside the current equipage mandate. The tower controller clears the Citation to climb to 3000 ft after take-off. The pilot reads back "4000 ft" and this incorrect read-back is not detected by



the controller. Consequently, once airborne the aircraft is climbing to 4000 ft. At the time when the Citation gets airborne, a B777 is being vectored for an ILS approach to its destination. The B777 is cleared to descend to 4000 ft on a heading of 185 degrees. The B777 and the Citation are on radio frequencies of different ATC sectors.

As the aircraft converge, the Citation is turning onto a northerly heading, passing through 3000 feet climbing 3300 ft/min. At this point the B777 crew gets a TA against the Citation. Although not required, the B777 pilot reports the TA to ATC, "We have a traffic alert". During this radio transmission a "Crossing descent" RA is generated.

The B777 controller sees the conflict developing and suspects that an RA could already have been issued (but not



yet reported). He is aware that he should not issue any instructions to aircraft experiencing RAs, so he asks the B777 crew if they can climb back to 5000 ft, rather than instructing them to climb. Soon after that the RA on board the B777 strengthens to "Increase descent".

The B777 crew does not respond to the RAs and the B777 levels off at 4000 ft. Later, the Captain stated that seeing the

other aircraft on the TCAS display he was concerned that a descent would put his aircraft closer to the Citation.

The aircraft pass each other on a reciprocal heading just 0.5 NM apart horizontally and 100-200 ft vertically. Just seconds before they pass each other, the B777 receives a "Climb" RA. The B777 crew responds to this RA but by then the Citation is already behind.

Learning points:

B777 crew:

- **"Increase descent" or "Increase climb" (i.e. strengthening RAs).** RAs must be followed as a matter of priority. An initial RA will strengthen if insufficient response to the initial RA is detected, or if either aircraft accelerates toward the other aircraft. Pilots must be prepared to respond to strengthening RAs within 2.5 seconds.
- **"Climb NOW" or "Descend NOW" (i.e. reversal RAs)** will be posted when the intruder aircraft manoeuvres vertically in the direction of the other aircraft and the current RA is deemed to be not effective any more. RA reversals are rare (less than 1% of all RAs). Pilots must be prepared to respond to reversal RAs within 2.5 seconds.
- **TCAS traffic display:** it must not be used to try to determine the degree of collision risk.
- **Reporting to ATC:** RAs that require a departure from the current ATC clearance or instruction must be reported to ATC. TAs are not required to be reported to ATC.

Citation crew:

- **Vertical speed:** 1000 feet before level off the vertical speed should not exceed 1500 ft/min if the flight crew is made aware of another aircraft at or approaching an adjacent altitude or flight level.

ATC:

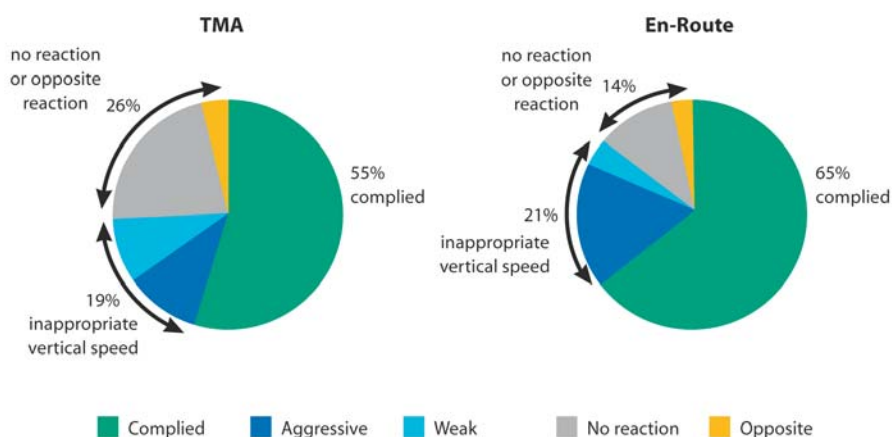
- **In the absence of an RA report,** ATC horizontal avoiding instructions will not adversely affect TCAS II RAs.

Research shows the importance of pilot training

Do pilots always react to RAs and are they always flown correctly?

Recent research by EUROCONTROL has found that climb/descend RAs are correctly complied with in 65% of cases in en-route airspace and only 55% of cases in TMAs. The graph adjacent provides a breakdown of RAs that are not correctly complied with in TMAs and airspace respectively.

ACAS training is crucial to ensure that pilots correctly interpret and react to RAs and the ACAS pilot training is very important. Prompt and correct reaction to RAs is fundamental. The potential consequences of not reacting to an RA are clear, and responses that are too weak or too aggressive can have a negative impact on the effectiveness of TCAS.



Reaction to RAs in TMAs (<FL135) and in En-Route airspace (> FL135)

Study results for climb/descend RAs

In 19% of the cases in TMAs and 21% in En-Route airspace, climb/descend RAs are followed, but with an inappropriate vertical speed, either too high or too low. In 26% of the cases in TMAs and 14% in En-Route airspace, there is either no reaction from the crew or an opposite response.

Sources of training material

Replay Interface for TCAS Alerts

RITA2 (Replay Interface for TCAS Alerts) is a tool designed for the ACAS II training of air traffic controllers and also as an additional source of information to reinforce the ACAS training of flight crews.

RITA2 provides the synchronous replay of reported and analysed ACAS II (TCAS II Version 7) events, which have been selected for their relevance to training issues. It shows on the same screen, both what the pilots and the controller could see and the radio exchanges.

The most appropriate use of RITA2 is through briefing sessions to small groups. The replay of relevant events with RITA2 may also help introductory presentations on ACAS II (performances, operational impact, regulation, etc.).

The package is available to qualified stakeholders as a CD-ROM for PC. The user guide includes descriptions, commentaries and lessons-learned about each incident.

ICAO guidelines for recurrent training

ICAO guidelines for ACAS stipulate both practical manoeuvre training using aircraft simulators (or suitable CBT) and theory training for pilots. ACAS should be included in recurrent training sessions and flight crews must be tested to ensure they are fully conversant with ACAS procedures, capabilities and limitations, and know how to respond correctly to RAs.

The ICAO guidelines for pilot training on ACAS / TCAS are contained in Doc. 9863 and in the attachments to PANS-OPS Doc. 8168. The relevant sections of these documents as well as training materials can all be found on the EUROCONTROL website: www.eurocontrol.int/acas.

Presentation for pilots

Whilst many aircraft operators have developed their own training materials and company bulletins, other sources of material exist, including an updated EUROCONTROL "Overview of ACAS II" presentation for pilots covering:

- How TCAS works
- How pilots should respond to TAs and RAs
- Examples of common problems and learning points

The EUROCONTROL presentation can be downloaded from:

www.eurocontrol.int/acas



ACAS II Bulletins

ACAS II Bulletins provide practical event-related information and learning points. They can be downloaded free of charge from Bulletins and Safety Messages page of the EUROCONTROL website: www.eurocontrol.int/acas

ACAS training

ACAS training material is also available on the EUROCONTROL IANS E-learning system. Whilst developed originally for air traffic controllers, it also contains information relevant to pilots including:

- Overview of the ACAS concept
- Description of the responsibilities of both pilots and air traffic controllers during a TCAS RA encounter
- Description of the TCAS II logic and its operation.

The full module can be accessed without prior registration at: trainingzone.eurocontrol.int under the Direct Access Modules, Air Traffic Control folders.

TCAS videos

There are TCAS training videos clips produced by NATS and Flight Safety Foundation available on SKYbrary: www.skybrary.aero



Conclusions

- Whilst RAs are rare events, when they happen the situation may be critical, and correct action must be taken. Recurrent training will improve flight crew understanding of how TCAS works, how they should respond to RAs, as well as the limitations of TCAS.
- Monitoring programmes have identified a number of situations where pilot responses are inappropriate – aircraft operators and training facilities should consider making these the focus of recurrent training sessions.
- Updated training material for pilots is available on the EUROCONTROL ACAS training pages: www.eurocontrol.int/acas

All events described in this ACAS II Bulletin are based on real-life incidents. They have been de-identified here to support training and promote safety culture. Descriptions of the events have been simplified and/ or abbreviated for clarity and to facilitate the training process. The sole objective of the ACAS II Bulletin is the prevention of future accidents and incidents rather than assigning blame.

Whilst this issue focuses on training for flight crew, training is equally important for air traffic controllers. This will be the focus of the next ACAS II Bulletin.

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