

## TCAS Pilot training issues

This Briefing Leaflet is based in the main on the ACAS bulletin issued by Eurocontrol in February of 2011. This 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.

In order to avoid confusion of the terms used it is a good idea to clarify the relationship between the terms TCAS and ACAS. At present, TCAS is the only commercially available implementation of the ICAO standard for ACAS II. While the terms are virtually interchangeable, Eurocontrol tends 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.

### Event 1: Overreaction to RA causes injuries

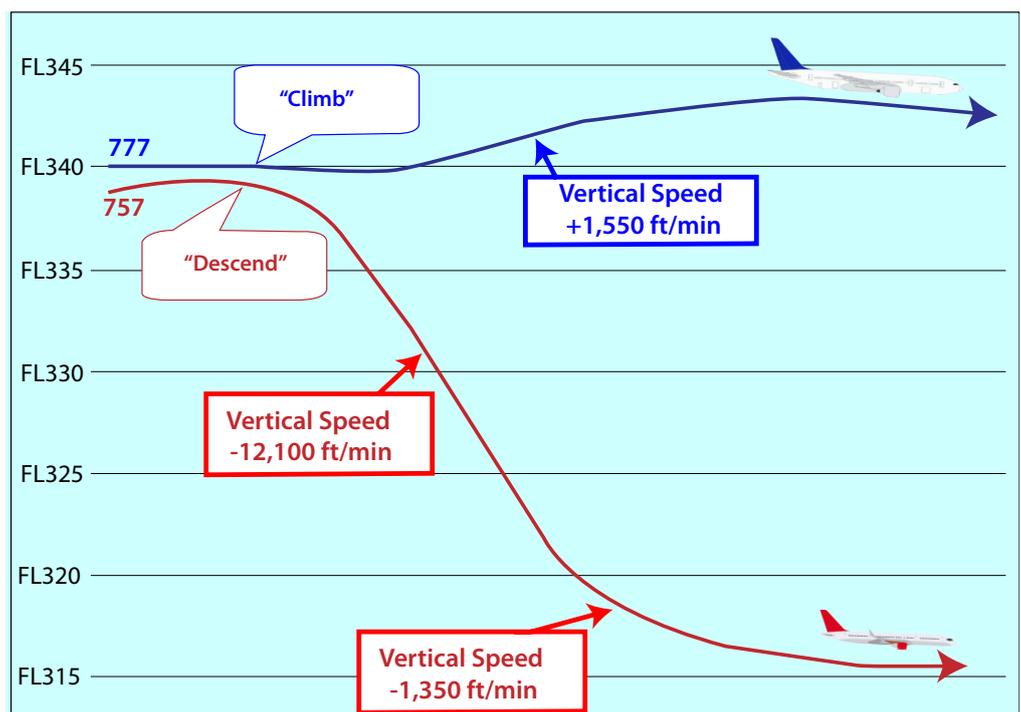
A 777 at FL340 is flying a heading of approximately 220 degrees. A 757 flying in the opposite direction is cleared, erroneously, to descend from FL390 to FL310 at a time when the aircraft are flying head-on, approximately 70 NM apart.

Some four minutes later, when the 757 is descending through FL343 and is 13 NM in front of the 777, the controller detects the conflict and instructs the 757 (using non-standard phraseology) to stop descending. There is no response from the 757 pilots but the aircraft's vertical rate starts to decrease. Five seconds later the controller instructs the 777 to turn right onto a heading of 270, which is acknowledged by the crew. Coordinated RAs are triggered – the 777 receives a "Climb" RA while the B757 receives a "Descend" RA.

The 777 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 757 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 757 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 757 weakens to "Adjust vertical speed" and soon after a "Clear of Conflict" message is posted.

The excessive reaction to the "Descend" RA caused the 757 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 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 (four 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.

### Training 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 five 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 which states: *“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 five seconds, and of  $1/3 g$  if the change is accomplished in approximately three 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 six degrees when the True Air Speed is 150 kts, four degrees at 250 kts, and two degrees at 500 kts. (These angles are derived from the formula: 1000 divided by TAS.)”*

### Events 2 & 3: contrasting responses to crossing RAs

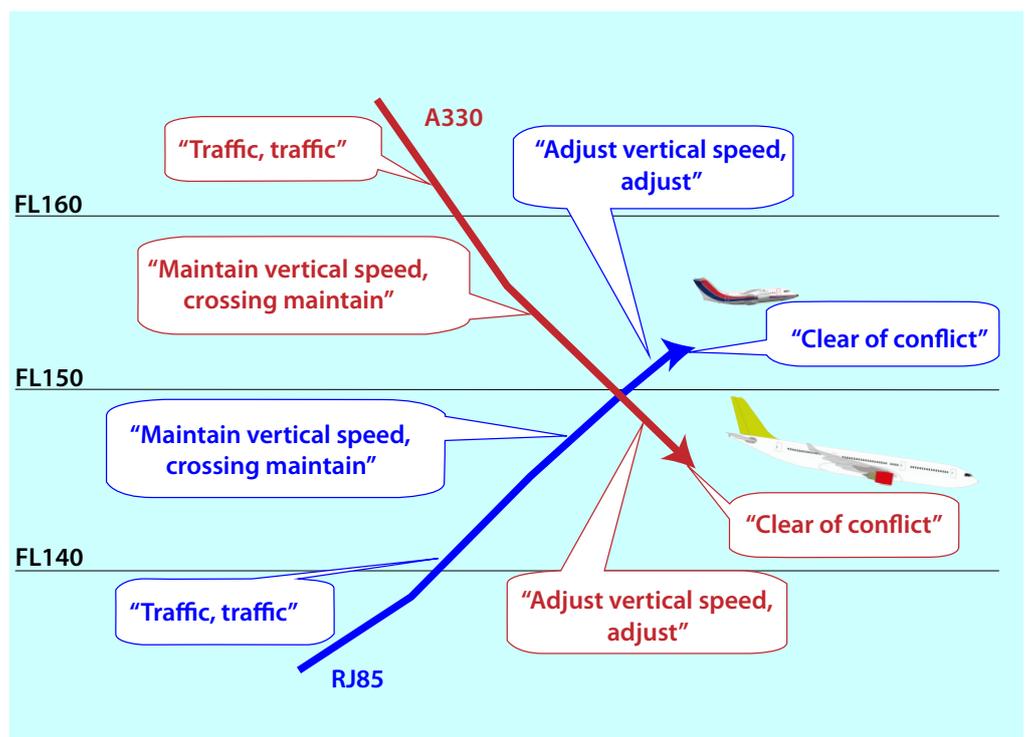
RAs requiring the pilot to cross through the altitude of an intruder aircraft are rare. They account for less than 2% of all RAs. ACAS is designed to select non-altitude crossing RAs if these provide the desired vertical separation at the Closest Point of Approach. Only when that cannot be achieved will 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.



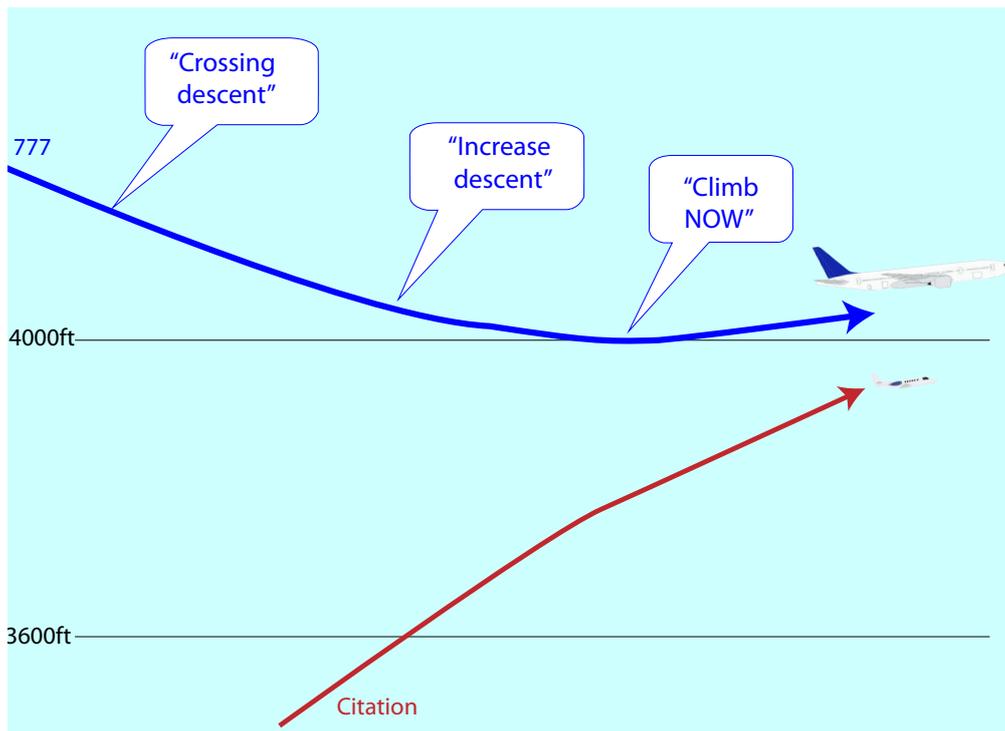
When the aircraft are 1.6 NM and 850 ft apart, a first RA is issued for the A330 – “Maintain vertical speed, crossing maintain”. The A330 at this point is descending at almost 2500 ft/min and this RA tells the pilot to continue this vertical speed crossing through the level of the threat aircraft. Two 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.

### Training 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 equipment 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 777 is being vectored for an ILS approach to its destination. The 777 is cleared to descend to 4000 ft on a heading of 185 degrees. The 777 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 777 pilot reports the TA to ATC, “We have a traffic alert”. During this radio transmission a “Crossing descent” RA is generated.

The 777 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 777 crew if they can climb back to 5000 ft, rather than instructing them to climb. Soon after that the RA on board the 777 strengthens to “Increase descent”.

The 777 crew does not respond to the RAs and the 777 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 777 receives a “Climb” RA. The 777 crew responds to this RA but by then the Citation is already behind.

### Training points:

777 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.

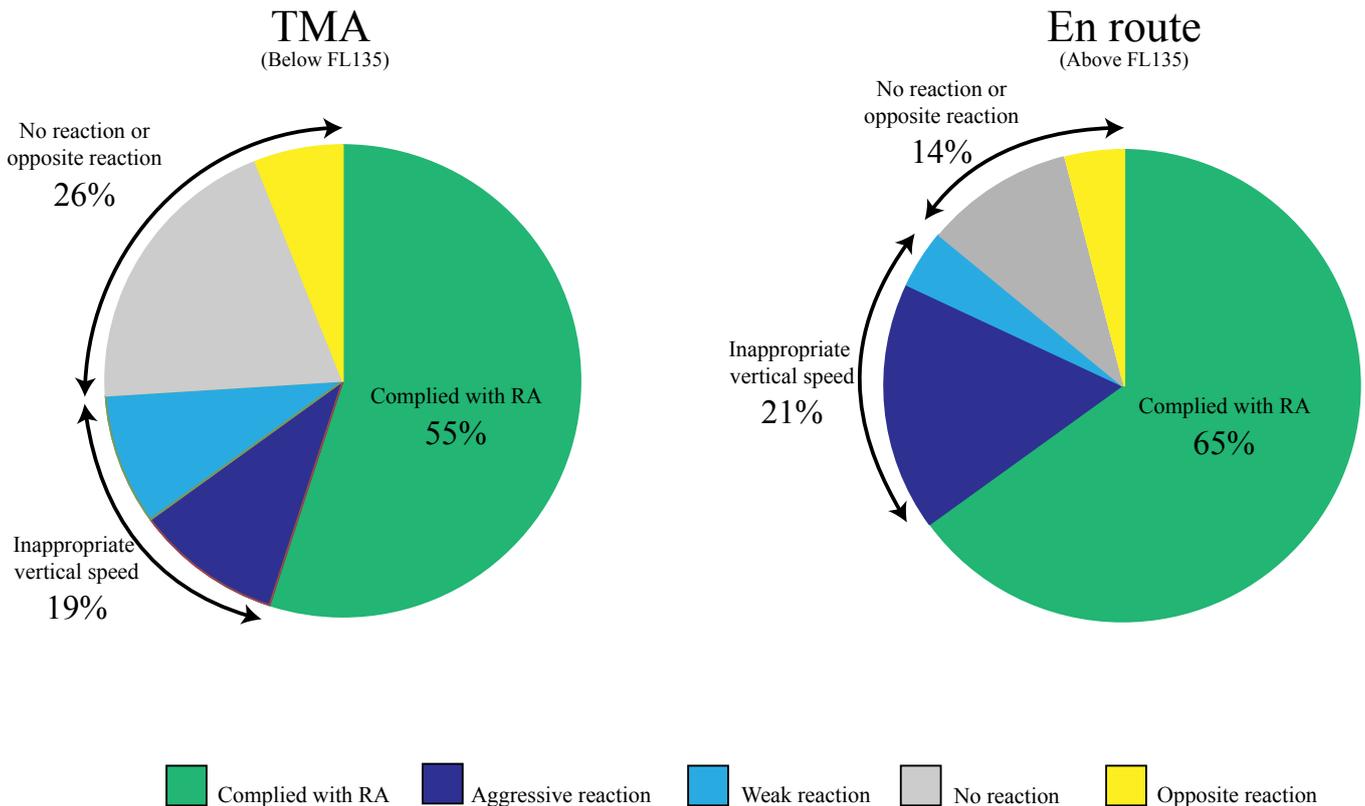
**Research shows the importance of pilot training**

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.

### TCAS/ACAS training information

ACAS training material is also available on the EUROCONTROL IANS E-learning system. While 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](http://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: click [here](#) to access

### Conclusions

While 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.