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EUROCONTROL

ACAS II Bulletin
Reversing to resolve

WELCOME

Welcome to another issue of ACAS II Bulletin. This issue is dedicated to another rare but critical RA, the reversal (i.e. "Climb NOW" or "Descend NOW") RA.

On some occasions, when an initially issued RA is no longer predicted to provide sufficient vertical spacing, it will be modified to either increase the strength or reverse its sense (a reversal RA). Although making up less than 1% of all RAs, by their nature of reversing the vertical sense of the aircraft, reversals are the most challenging RAs to fly.

The first event in this bulletin illustrates how correct pilot responses to both reversal and crossing RAs provided successful collision avoidance in a situation where separation provision had been seriously compromised. This event also demonstrates the benefits of pilots practising flying RAs in the simulator.

The second event shows how rapidly the situation can deteriorate when RAs are not followed. The final event serves as a reminder that co-ordinated RAs do not occur with aircraft that are not TCAS II equipped, and describes a reversal RA against a small aircraft.

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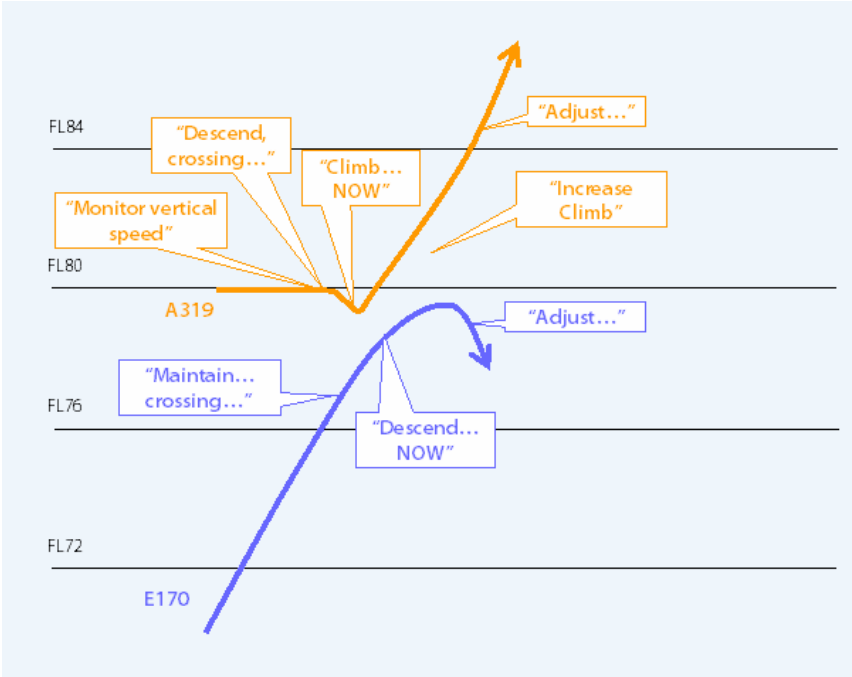
Event 1: Reversal RAs successfully followed

A departing Embraer E170 is climbing to FL70 and talking to the departure controller. An inbound Airbus A319 on a reciprocal heading is maintaining FL80 and talking to the TMA controller. When the E170 calls on the TMA frequency, the controller overlooks the fact that the two aircraft are on opposite tracks and instructs the E170 to climb to FL90.

When the distance between the aircraft reduces to 5.5 NM horizontally and less than 900 feet vertically, TCAS generates a TA in both aircraft. Thirteen seconds after the TA, coordinated RAs are issued: a "Monitor vertical speed" RA for the A319 (which tells the crew to stay in level flight) and maintain crossing climb ("Maintain vertical speed, crossing maintain") RA for the E170 (which means that the crew should continue to climb with the current rate, crossing through the level of the other aircraft). The monitor vertical speed climb RA for the A319 changes to "Descend crossing, descend" within a second of the initial RA.

Simultaneously, the controller instructs the E170 to stop the climb and then, a few seconds later, to take an avoiding action by making a 130-degree right



turn. The pilot does not turn but responds saying that he is following an RA. The A319 pilot, prompted by the controller, also reports a TCAS RA while starting to descend in response to the second RA.

When the aircraft are less than 3 NM and 200 feet apart, TCAS assesses that the previously issued RAs are not enough to provide sufficient vertical spacing and generates reversal RAs: a reversal descent ("Descend, descend NOW") RA for the climbing E170 and a reversal climb ("Climb, climb NOW") RA for the descending A319. Both pilots respond to the reversal RAs.

After another 5 seconds, the RA for the A319 strengthens to "Increase climb". The aircraft continue to follow the RAs and as the vertical separation increases, the RAs for both aircraft weaken to "Adjust vertical speed, adjust", in this instance requiring a reduction in vertical rates to 0 ft/min. When the aircraft pass each other they are separated by 0.15 NM horizontally and 1370 feet vertically.

"Clear of conflict" messages are posted for both aircraft 30 seconds after the first RAs.

Learning points:

- **Always follow the RA:** Follow the RA even if the RA is contradictory to ATC instructions.
- **Responding to reversal RAs:** Pilots must be prepared to respond to reversal RAs within 2.5 seconds. Reversal RAs require a 1,500 ft/min. climb or descent rate.
- **Only one sense reversal can occur per conflict**, but as shown by this example, RAs can be strengthened and/or weakened subsequent to the reversal.
- **Simulator training:** Both crews involved in the incident were trained in simulators for RA reversals which helped them to fly the aircraft in the challenging conditions. However, both crews were surprised by the large control input required to follow the reversal RAs.

Event 2: RA not followed causes a reversal

A Boeing B777 is heading south at FL300 while a McDonnell Douglas MD80 is on an easterly heading climbing to FL290. Their tracks will intersect.

The controller asks the MD80 crew to confirm that their requested level is FL310. The MD80 pilot response is "Roger, climbing FL310" but this incorrect read back is undetected by the controller.

When the MD80 is passing through FL293, a Short Term Conflict Alert warns the controller of the separation loss. Reacting to the alert, the controller instructs the MD80 pilot to descend immediately to FL290 and provides traffic information on the B777. However, the read-back from the MD80 pilot is incomprehensible and there is no decrease in the MD80 rate of climb.

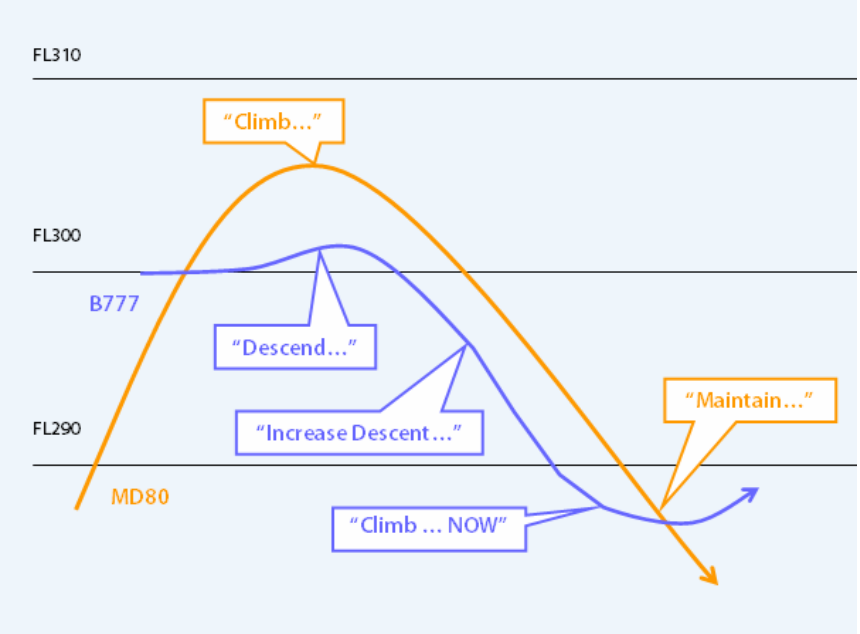
The controller then tells the B777 crew to climb to FL310 and provides traffic information on the MD80. The B777 pilot asks for confirmation of the climb instruction. The controller confirms the instruction, tells the pilot to expedite the climb and additionally issues a 30-degree left turn. The B777 crew responds to these instructions. In the meantime, the MD80 reaches FL303. At this point, the controller again instructs the MD80 to descend, this time to FL300, and turn left 30-degrees. These instructions are correctly acknowledged.

The MD80 rate of climb decreases and it briefly levels off at FL306. At this point, the B777 which has started to climb is passing through FL302. The horizontal distance between the aircraft decreases to 5 NM and TCAS generates coordinated RAs: the B777 receives a "Descend" RA and the MD80 a "Climb" RA.

The B777 crew stops the climb, starts following the "Descend" RA and reports the RA to the controller. The MD80 pilot ignores the RA and follows the last controller instruction to descend. As a result both aircraft are descending and the spacing between them is rapidly decreasing.

The RA for the B777 strengthens to "Increase descent" to which the crew responds correctly increasing the descent rate to 2500 ft/min. Inexplicably, the MD80 continues to descend and the pilot also increases the vertical rate.

When the aircraft are passing FL288, an RA reversal occurs: the descending B777 gets a reversal climb ("Climb, climb NOW") RA, while, the still descending MD80, gets a maintain descent ("Maintain vertical speed, maintain") RA, telling the pilot to continue the current descent rate.



As the B777 vertical rate starts to change from descent to climb, a "Clear of conflict" message is issued for both aircraft. The aircraft pass each other with a spacing of 2 NM and just 100 feet. The turns issued by the controller just prior to the RA helped to increase the horizontal distance and reduced the risk of collision.

Learning points:

- **Undetected read-back errors** remain one of the main causal factors of incidents.
- **ATC horizontal avoiding instructions** will not normally adversely affect any TCAS RA and may help to reduce the risk of a collision. However, when already responding to an RA, the pilot may not be able to turn the aircraft and fly the RA at the same time.
- **Always follow the RA:** Follow the RA even if the RA is contradictory to ATC instructions.
- **Follow RAs promptly:** When promptly followed, RAs mitigate the risk of a mid-air collision. For initial RAs requiring a change in vertical speed, initiation of a response in the correct direction must be made within 5 seconds of the RA being displayed. The response time is reduced to 2.5 seconds for subsequent RA changes.

Event 3: Crossing and reversal RAs against a VFR

In this event the pilot of a small non-TCAS II equipped aircraft saw and tried to avoid a large military transport aircraft by descending. The crew of the military aircraft was following a "Descend" RA to avoid the small aircraft until a reversal to a "Climb NOW" RA occurred. This event should serve as a reminder that TCAS coordination does not take place with unequipped aircraft and that threat aircraft avoidance manoeuvres based on the "see and avoid" principle may be in the same vertical sense as the RA.

A military transport C17 is in a holding pattern at FL40, turning onto a heading of 220 degrees, awaiting an approach clearance. The visibility is good (over 20 km) in daylight conditions. The crew has been advised by ATC of traffic 500 feet above in their 10–11 o'clock position. The traffic is a Glasair single-engine aircraft on a solo cross-country flight at FL45. It is equipped with a Mode S transponder but not TCAS and is not in contact with ATC.

Although the C17 crew does not have the Glasair in sight, the ATC traffic information is consistent with a Traffic Advisory (TA) the crew has just received. All five crew members start to search for the traffic.

The Glasair pilot has been observing the C17 for some time. He mistakenly assesses that the conflicting aircraft is at the same altitude. In order to keep clear of the other aircraft, he decides to descend, rather than turn, as he wants to maintain visual contact.

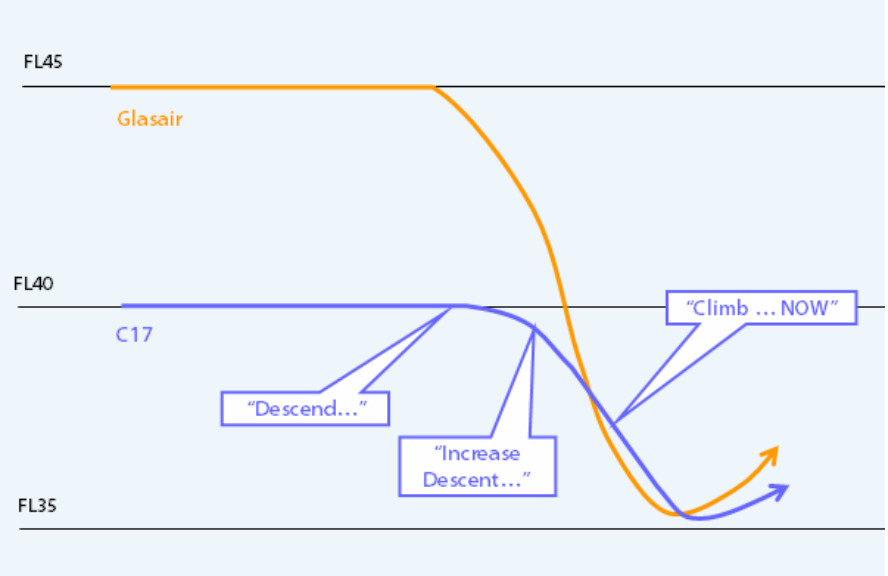
Ten seconds after the TA, the separation between the aircraft reduces to 2.2 NM and 500 feet. With the Glasair still being above, a "Descend" RA (which requires a vertical rate of 1500 ft/min) is issued to the C17 crew. After 7 seconds, as the C17 starts to descend, the RA strengthens to "Increase Descent" (which requires a vertical rate of 2500 ft/min).

As the aircraft get closer and the C17 is descending in response to the RA, the Glasair, which is still above the C17, increases its descent to high speed dive (over 3000 ft/min.) as the pilot believes he needs to stay below the C17.

Twelve seconds later the C17 is descending at 2000 ft/min. The separation between the aircraft reduces to just 1.2 NM and the Glasair is just below the C17. At this point the RA for the descending C17 changes to a reversal climb ("Climb, climb NOW") RA which requires the crew to establish a 1500 ft/min. climb.

When the C17 pilots respond to the reversal RA and its rate of descent is reducing, the Glasair passes directly underneath the C17. At the Closest Point of Approach the aircraft are separated by just 26 feet vertically and 0.05 NM (92 metres) horizontally. To put these numbers in perspective: the height of a C17 is 55 feet and the wingspan is 52 metres.

During the RA manoeuvres the C17 crew continues to try to acquire the traffic visually. It is only during the climb in response to the "Climb NOW" RA that they see the Glasair passing directly beneath them.



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Learning points:

- **Response to reversal RAs:** Pilots must be prepared to respond to reversal RAs within 2.5 seconds. Reversal RAs require a 1500 ft/min. climb or descent rate (see learning points for event 1).
- **RAs are only coordinated between two TCAS equipped aircraft:** If both aircraft are TCAS II equipped then the RAs are coordinated to ensure that manoeuvres are compatible. An RA can be generated against all altitude reporting aircraft (equipped with a Mode S or Mode A/C transponder) regardless of whether they carry TCAS.
- **Threat aircraft which are not TCAS equipped may manoeuvre based on the "see and avoid" principle or ATC instructions.** These manoeuvres are not coordinated with TCAS. As a result, these threat aircraft may perform avoidance manoeuvres that could cause an RA reversal in the equipped aircraft

Some statistics…

Although most RAs are reported through the aircraft operator or ANSP reporting systems, there are no complete European-wide statistics on the frequency of their occurrence. In order to gain an insight into the matter, EUROCONTROL undertook a 6-month RA monitoring exercise from 2007 to 2008 using six Mode S radars, covering a large portion of European core airspace.

The monitoring exercise found that in the vast majority of encounters (80%) only one aircraft involved in the encounter received an RA. Reasons were:

- the geometry of the conflict was such that the RA was not generated on the TCAS-equipped threat aircraft; or
- the threat aircraft was not TCAS equipped; or
- the threat's TCAS was in Traffic Advisory (TA) only mode.

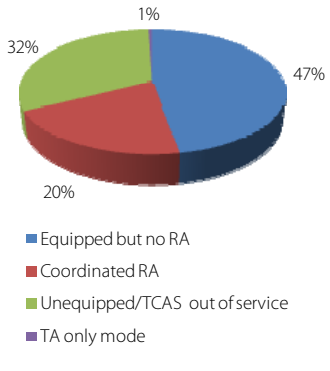
The data shows that in the vast majority of cases collision avoidance depends on the actions of one crew and emphasises the need for correct responses to RAs.

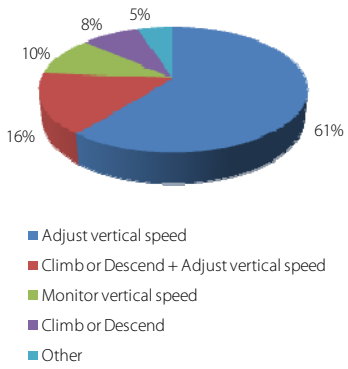
On average three RA encounters were observed each day in the monitored area. RAs are much more frequent in TMAs than they are in en-route airspace, mainly due to higher vertical rates and more manoeuvres by aircraft.

The most common RA (61%) was a single "Adjust vertical speed" RA. The other most frequently occurring RAs were a sequence of "Climb" or "Descend" weakening to "Adjust vertical speed" RAs (16%), single "Monitor vertical speed" RA (10%) and single "Climb" or "Descend" RA (8%). RA reversals occurred only in less than 1% of cases.

In another monitoring exercise it was observed that RA crossings occur only in 2% of cases.

Other European monitoring activities noted comparable results on RA distribution; however, RA frequency and distribution outside Europe, especially in the USA, differs due to their different traffic and airspace environments.





Conclusions

- Training can help pilots successfully fly the rarest and most challenging of RAs.
- Following RAs promptly and correctly mitigates the risk of possible collision and deterioration of the potential conflict.
- ATC horizontal avoiding instructions will not adversely affect any TCAS RA.
- Although an RA can be generated against a non-TCAS II equipped altitude reporting aircraft, the avoiding action will not be co-ordinated. Consequently the non-TCAS equipped aircraft may manoeuvre in the same direction using the 'see and avoid' principle or ATC instructions. If such manoeuvres are detected TCAS II will change the RA, if appropriate.
- TCAS RAs are relatively rare but are nonetheless safety critical events. In the majority of cases only one aircraft in the encounter will receive an RA.

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