TCAS II and Level Bust

In an issue of HindSight dedicated to level bust, it is important also to mention the Traffic alert and Collision Avoidance System (TCAS II). Acting as the last safety barrier, TCAS is designed to mitigate imminent risks of collision, including those resulting from a level bust, by generating Resolution Advisories (RAs) to pilots...
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But TCAS is neither designed nor intended to prevent the occurrence of level busts – RAs will only be generated if another aircraft is in the vicinity. There have been several instances in which TCAS has "saved the day" by preventing serious incidents after a level bust. On the other hand, although the risk of collision was avoided, in some cases the following of TCAS RAs contributed to level bust occurring.

In this article I will look into the role of TCAS in level bust situations, give examples of its operations and provide statistics about the frequency of RAs in European airspace.

Nuisance RAs?

TCAS issues RAs when it calculates a risk of collision within a specified, altitude-dependent time threshold. On receiving an RA the pilot shall alter (or maintain) aircraft vertical speed as indicated by TCAS (often referred to as "flying the green arc"). Once the detected conflict has been resolved, TCAS will announce "Clear of Conflict". If both aircraft are TCAS-equipped, the RAs will be coordinated to ensure that they are issued in opposite vertical directions.

In order to be fully effective as a last-resort safety net, TCAS does not know the cleared level of either the aircraft on which it is installed or that of the intruder. TCAS predicts time to collision based on the closing and vertical speeds, it does not take into account any flight management system inputs or autopilot settings. That is one of the features that allows TCAS to mitigate human and other errors.

However, because TCAS does not know aircraft intentions, RAs can be issued when appropriate ATC instructions are being correctly followed by the aircraft. Since, with hindsight, these RAs are operationally not required, pilots and controllers refer to them as "nuisance"[1] RAs. But once an RA has been issued, it must take precedence over any ATC instructions.

In real time, the pilot cannot make an accurate assessment of whether the RA is in fact operationally required. There is a long list of things that could have gone wrong to lead to a level bust. Amongst these, undetected incorrect readback or wrong cleared level selection come to mind immediately. Once an RA has been issued there is no time to seek clarification – the RA must be responded to immediately.

1- Sometimes, these RAs are incorrectly referred to as "false RAs". A "false RA" occurs if there is no threat (other aircraft) which meets TCAS logic requirements for the generation of an RA.

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The pilot also cannot know what the other aircraft in conflict is going to do. Is it going to level off as cleared? Was the clearance correct? Nobody really knows how the situation is going to develop.

The pilot has no choice but to follow the RA – that is dictated by regulations and common sense. Later, with the benefit of hindsight, it may be determined whether an RA was operationally required or a nuisance.

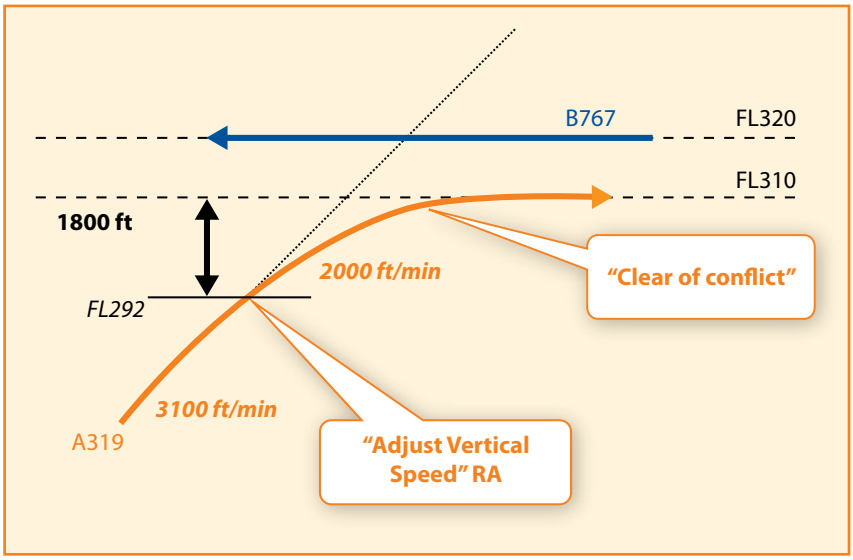
Why are RAs generated in level-off encounters?

Let's look at a scenario that involves one aircraft in a level flight and the other climbing (or descending) to its cleared level 1000 feet below (or above) – so-called 1000-foot level-off encounters.

Many jets can easily climb and descend several thousand feet a minute and the pilots often maintain high vertical rates very close to the cleared level. Based on these high vertical rates TCAS calculations may indicate a collision threat with another aircraft in the vicinity. Consequently, an RA will be generated. In the case of two aircraft descending and climbing towards each other, their combined closing speed will make RAs even more likely.

The illustration below gives a real-life example of how these RAs occur. A B767 was level at FL320 and an opposite-direction A319 was cleared to FL310 (which was correctly acknowledged by the crew). The Airbus climbed at 3100 ft/min. At this altitude the time threshold for RA generation is 35 seconds. With this vertical closure speed of 3100 ft/min, 35 seconds corresponds to 1800 ft. As a result, the Airbus received an "Adjust Vertical Speed" RA 1800 feet before its cleared level as TCAS detected a threat (the B767). The Airbus pilot followed the RA, reducing the aircraft's vertical speed to 2000 ft/min, and received a "Clear of Conflict" message before reaching its cleared level. The Boeing did not receive an RA as narrower parameters for RA generation apply to aircraft in a level flight.

If the reduction of vertical speed had not been prompt enough, the RA would have been strengthened and issued to both aircraft involved (typically "Climb" and "Descend", respectively).



The "Adjust Vertical Speed" RA that TCAS will issue to a fast climbing or descending aircraft calls for a reduction (never an increase) of the vertical speed to not greater than the limit indicated on the TCAS display - to 2000, 1000, 500 or 0 (i.e. level-off) ft/min.

Once an RA has been issued, it must take precedence over any ATC instructions.

Many of these "Adjust Vertical Speed" RAs will not cause an aircraft to depart from the current ATC clearance or instruction and, therefore, pilots do not have to report them. However, if an RA report has been received, the controller shall not attempt to issue any instructions to the reporting aircraft until the pilot reports "Clear of Conflict".

New ICAO provisions that were put in place in November 2008 recommend that the pilots reduce their vertical to 1500 ft/min in the last 1000 feet be-

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fore the level-off[2]. That should contribute to a reduction in the number of these RAs.

In some cases, following an "Adjust Vertical Speed" RA may cause the aircraft to bust its cleared level when levelling at the cleared level would have been perfectly safe. This happens because TCAS chooses RAs which minimise the manoeuvre from the current trajectory – in the case of fast climbing and descending aircraft it will be the reduction of their vertical speed, i.e. the "Adjust Vertical Speed" RA. If the "Clear of Conflict" message is not posted before the aircraft reaches its cleared level (remember, TCAS does not know the cleared level), the pilot will continue to fly "the green arc" through the cleared level and a level bust will occur. These level busts are usually minimal and, in any case, if the aircraft get too close the RA will be strengthened or reversed.

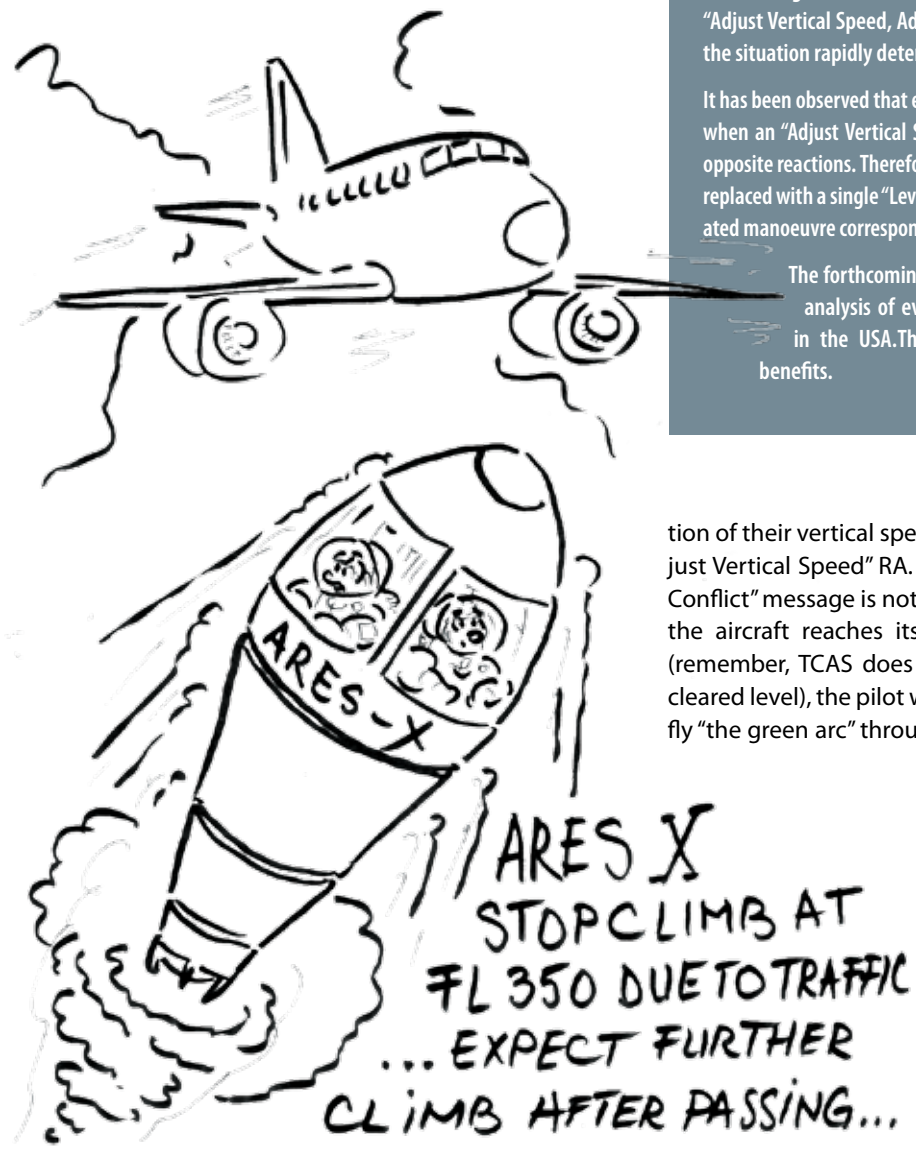
The forthcoming TCAS version 7.1 will replace all "Adjust Vertical Speed" RAs with a single "Level-off" RA (which is intended to address the issue mentioned above). Unfortunately, we are unlikely to see an aircraft with version 7.1 any time soon[3]. At the time of writing there has been no regulatory decision as to when version 7.1 will be implemented and the manufacturers will not have the software ready before the beginning of 2012.

New "Level-off" RA

One of the changes that will be brought about by TCAS II version 7.1 will be a new "Level-off" RA. With the existing version of TCAS numerous cases have been reported in which pilots responded to the "Adjust Vertical Speed, Adjust" RAs by increasing vertical speed instead of reducing it. As a result, the situation rapidly deteriorated.

It has been observed that enhancements in training alone can improve the behaviour of a flight crew when an "Adjust Vertical Speed, Adjust" RA is issued; however, they are not sufficient to avoid all opposite reactions. Therefore, to fully address the issue the "Adjust Vertical Speed, Adjust" RAs will be replaced with a single "Level-off" RA. The "Level-off" aural message is straightforward and the associated manoeuvre corresponds to the standard manoeuvre already performed in critical situations.

The forthcoming introduction of the new "Level-off" RA has been preceded by detailed analysis of events and radar data from core Europ an airspace and two busy TMAs in the USA.The studies concluded that the "Level-off" RA will bring operational benefits.



TCAS – preventing the consequences of level bust

The case described below shows how TCAS operates when a level bust has occurred and the aircraft are in horizontal proximity.

A Fokker 100 was at FL310 approaching its destination. The crew requested descent and was cleared to FL290, 1000 feet above a Boeing 737 in a level flight on a crossing track. However, the Fokker crew made an incorrect autopilot input indicating FL210 as their cleared level. The Fokker commenced a slow descent to FL288 when the crew received a TCAS RA to climb.

Simultaneously, the crew of the B737 received an RA to descend. Both crews complied with their RAs promptly and both aircraft passed 1100 feet apart with horizontal spacing below 3 NM.

How often do RAs occur?

TCAS RAs are rare events. Extensive monitoring conducted from September 2007 to March 2008 in the core European airspace found that 743 aircraft were involved in 617 encounters in which at least one of the aircraft involved received an RA[4]. That gives an average of 3 RAs per day in the area covered by the study. The average duration of an RA was 33 seconds.

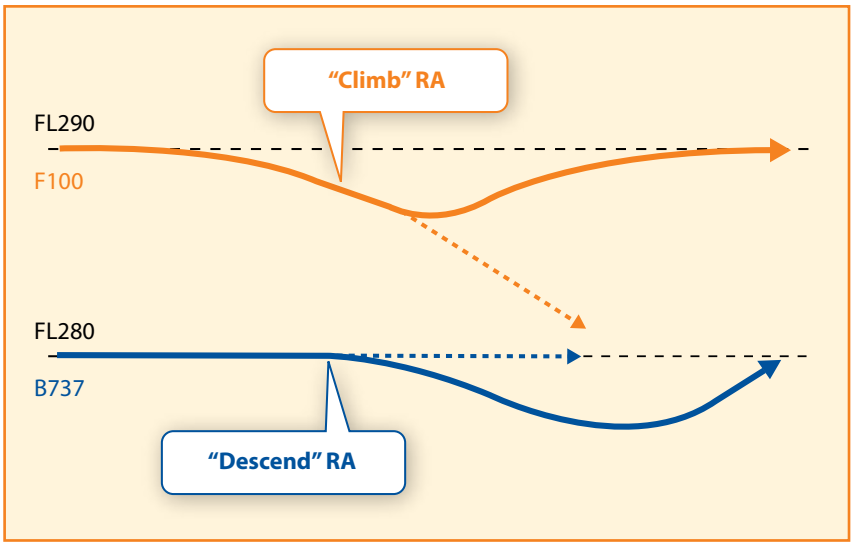
Only 17% of all encounters resulted in a coordinated RA (i.e. in 83% of the encounters, an RA was generated on board only one of the aircraft involved). Reasons for this include the geometry of the conflict being such that the RA was not generated on the threat aircraft or the threat aircraft was not TCAS-equipped.

The majority of RAs (61%) were solely "Adjust Vertical Speed" RAs. In 2% of cases "Adjust Vertical Speed" RAs were followed by either a "Climb" or "Descend" RA – these are the cases in which a level bust most likely occurred or was about to.

It is not known how many RAs happened outside the area covered by the study but it has been estimated (using the number of flight hours in the area covered by monitoring and in the whole of European airspace) that some 18 RA encounters happen each day in Europe as a whole.

Conclusions

RAs in 1000-foot level-off encounters generally occur due to high vertical speeds. Although some of these RAs are, with the benefit of hindsight, operationally not required, pilots are mandated to follow all RAs. If a level bust occurs, TCAS will issue an RA that, if followed correctly, will resolve an imminent risk collision. ■



2 - Doc. 8168, vol. 1, para. 3.3: "Pilots should use appropriate procedures by which an aeroplane 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/s (or 1 500 ft/min) throughout the last 300 m (or 1 000 ft) of climb or descent to the assigned altitude or flight level when the pilot is made aware of another aircraft at or approaching an adjacent altitude or flight level, unless otherwise instructed by ATC. These procedures are intended to avoid unnecessary airborne collision avoidance system (ACAS II) resolution advisories in aircraft at or approaching adjacent altitudes or flight levels. For commercial operations, these procedures should be specified by the operator."

3 - Once the implementation schedule of TCAS II version 7.1 is known we will provide readers with detailed information about changes that the new TCAS version brings.

4 - For more information see http://www.eurocontrol.int/safety-nets/public/standard_page/PASS.html