ACAS II bulletin No 2
EUROCONTROL

RAs and 1000 ft level-off manoeuvres

Editorial

TCAS II provides a last resort safety net designed to prevent mid-air collisions between aircraft. It alerts the flight crew and provides Resolution Advisories (RA), in the vertical plane, when it computes a risk of collision with another aircraft within the next 35 seconds (or less, depending on the encounter geometry and altitude).

One common type of RA is that which is issued when aircraft are expected to level-off 1000 feet apart, and, at the same time, are crossing horizontally.

This method of vertical separation has been used safely - from an ATC standpoint - for years. Therefore, these RAs, often subsequently classed as 'operationally unnecessary', can be perceived as disturbing by controllers, and by a number of pilots.

Why do these RAs occur, should they be considered as useful or not, and what can we do to avoid them, or reduce their occurrence?

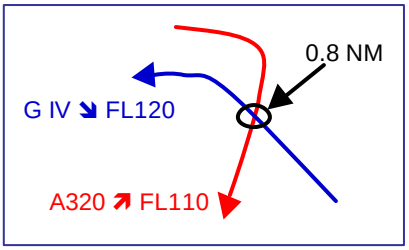
Events 1 and 2 illustrate RAs triggered in 1000 ft level off encounters, together with explanation of the behaviour of TCAS II. Events 3 (without TCAS) and Event 4 (with TCAS) illustrate the situation where one aircraft has bust its level - failed to level-off. These events highlight the effectiveness of TCAS II, and the necessity for it!

Finally, some considerations are given on potential actions to reduce the number of 'operationally unnecessary' RAs - either in the short term or in the long term. They would be expected to result in enhanced effectiveness of TCAS II, and thus in improved safety, overall.

John Law
ACAS Programme Manager,
EUROCONTROL March 2003

Event 1: RA generated in a 1000 ft level-off encounter

After take-off, a TCAS-equipped A320 is climbing to FL110 on the SID. Its rate of climb is 4300 fpm.

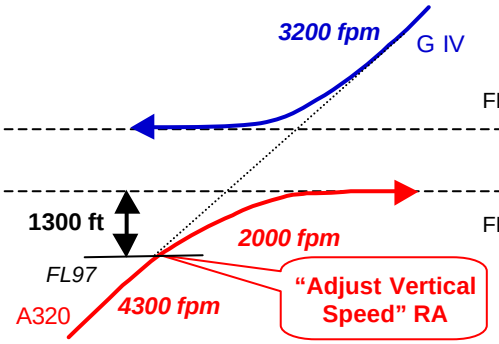


A Gulfstream IV on standard approach procedure is descending to FL120. Its rate of descent is 3200 fpm.

Both trajectories are converging so that the aircraft will pass at 0.8 NM apart, just at the moment where they will reach their respective cleared flight level.

The simultaneous horizontal **and** vertical convergence, combined with the high vertical rates, cause TCAS II to trigger an RA even though the standard separation is being correctly applied according to the procedure.

The A320 pilot receives an "Adjust Vertical Speed" RA when passing through FL97, i.e. 1300 ft below the cleared flight level, with a high rate of climb (4300 fpm). This RA requires that the rate of climb is limited to not more than 2000 fpm.



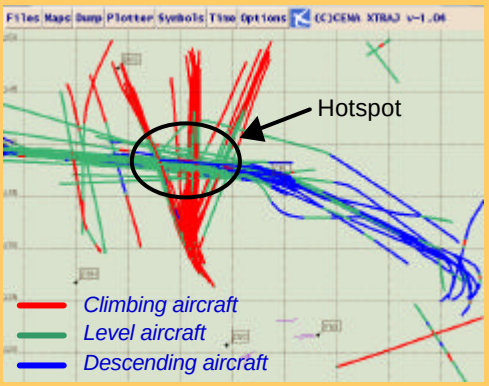
The A320 pilot reduces the rate of climb in accordance with his RA and he levels off at FL110 as cleared by the controller.

In the event, both aircraft successfully levelled off and subsequently this RA was considered as operationally unnecessary. However, the RA reinforced the controller's clearance and had only one of the aircraft failed to level-off, then there would have been 20 seconds or less until the aircraft were at the same altitude. TCAS II also effectively provided a last resort protection against level bust.

RA "Hotspot"

High vertical rates (>3000 fpm) are very often achieved by modern aircraft like A320, A330, B737, B767, MD80, etc.

Scenarios such as illustrated by Event 1 are common, particularly around FL100 between arrivals and departures in TMAs. For instance, locations where this type of scenario is recurrent (RA "Hotspot") have been identified in several major European TMAs.



Example of RA "Hotspot" in Paris TMA (radar data)

Why does TCAS II trigger these RAs?

TCAS II processing of 1000 ft level-off encounters

TCAS II issues RAs when it calculates a risk of collision within a time threshold whose value depends on the aircraft's altitude.

In 1000 ft level-off encounters, TCAS II detects **simultaneous horizontal and vertical convergence**.

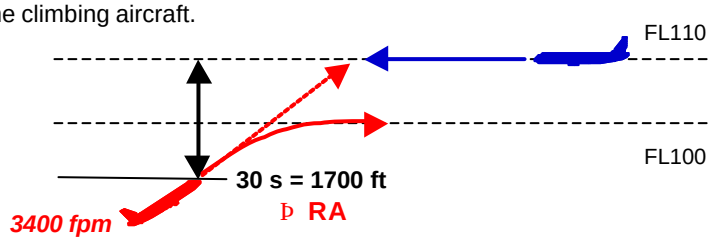
When the vertical closure rate is high, TCAS II can compute a risk of collision and generate an RA before a level-off manoeuvre is initiated by the aircraft.

The example below shows a single level-off encounter. The RA time threshold is 30 seconds for the climbing aircraft.

With this vertical closure rate of 3400 fpm, 30 seconds corresponds to 1700 ft. Therefore, an RA is generated.

If both aircraft were manoeuvring to level-off, the vertical convergence would be greater. Therefore the likelihood for an RA to be triggered would be higher.

Although this type of RA is often considered operationally unnecessary, it is not possible to further reduce the RA time threshold without degrading TCAS II safety performances.



Controller/Pilot appreciation

*ATC vertical separation of 1000 ft is the standard vertical separation applied between aircraft. Therefore, **controllers** can find it difficult to understand why TCAS II triggers RAs while the job is being done correctly. Furthermore, sometimes they do not understand why, even when traffic information is provided, flight crews still follow RAs.*

*From the **pilots'** perspective, studies show that about half of the pilots consider that these RAs are useful or even necessary although everything is correctly done.*

Background to 1000 ft vertical separation

*This value was determined 50 years ago and was computed for aircraft in level flight. At that time, most airliners were non-pressurised piston-engined aircraft, which could climb or descend only at 500 fpm. In this case, **1000 ft represented 2 minutes** of flight time.*

*Now, modern jet aircraft have high vertical performances and they can climb or descend at 5000 fpm (or even more). With such a vertical rate, **1000 ft only represents 12 seconds** of flight time, which is too short for taking effective corrective action if the level-off manoeuvre fails for whatever reason.*

*Currently, the potential operational constraint caused by an RA in a 1000 ft level-off encounter is **the price to pay for a significantly improved safety overall.***

TCAS II Version 7 features to address 1000 ft level-off encounters

TCAS II Version 7 includes features to reduce the number and the severity of RAs triggered in 1000 ft level-off encounters.

- *Some RA time threshold values are reduced for level aircraft to give TCAS II time to detect the start of a level-off manoeuvre by the other aircraft.*
- *The vertical tracking is improved to enable earlier detection of the level-off manoeuvre of the intruder.*
- *The RAs triggered in coordinated TCAS-TCAS encounters are more compatible with the ATC clearance encouraging a correct level-off.*
- *Crossing RAs (i.e. RAs requiring the pilot to cross the intruder altitude) can be generated only if a level bust actually occurs*

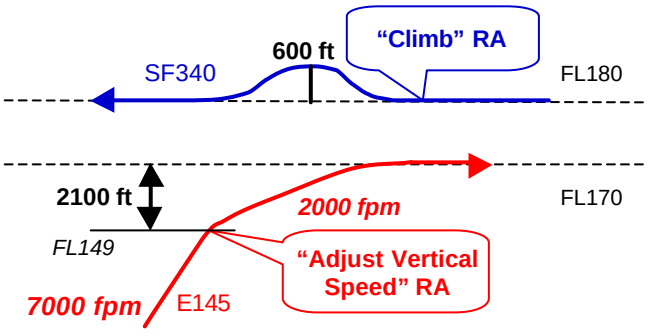
Operational monitoring programmes have confirmed that TCAS II Version 7 generates fewer RAs, particularly for level aircraft in single level-off encounters.

However, RAs are still generated in 1000 ft level-off encounters, although a very high percentage of these RAs are compatible with the ATC clearances.

Event 2: Excessive vertical rate approaching cleared flight level

A SF340 is level at FL180 flying a northeast route. An E145 is climbing cleared to FL170 and flying a southeast route. Both aircraft are converging towards the same point (the minimum distance is 1 NM).

As the E145 is climbing with a very high vertical rate (about 7000 fpm), the TCAS II of each aircraft triggers a coordinated RA.



The E145 pilot receives first a TA when passing through FL128. Then 18 seconds later at FL149, an "Adjust Vertical Speed" RA requesting to reduce the rate of climb to 2000 fpm is generated.

The SF340 receives a "Climb" RA 6 seconds later while the E145 passes through FL156 still with a very high vertical rate (i.e. 6600 fpm).

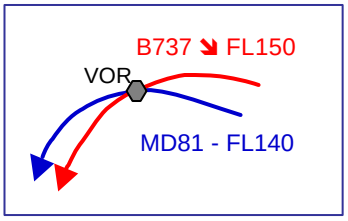
Excessive vertical rates may trigger RAs, which may also induce deviation of the level aircraft. This can be disruptive.

TCAS II is effective in level busts

These two events illustrate the effectiveness of TCAS II in level bust scenarios. Event 3 occurred before the European ACAS mandate while Event 4 took place recently.

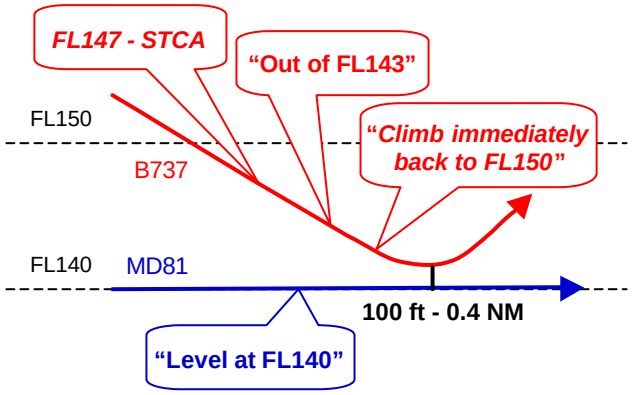
Event 3: Aircraft without TCAS

A MD81 and a B737, both inbound to a major European airport, are in a holding pattern.



The MD81 is level at FL140 and the B737 is cleared to descend to FL150. The B737 pilot acknowledges this instruction correctly but the aircraft does not level-off at FL150 as expected.

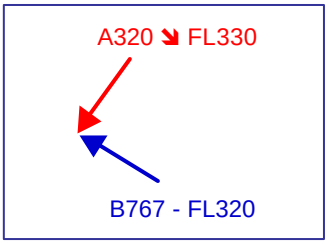
When the B737 passes FL147 still descending, the STCA (Short Term Conflict Alert) triggers an alert. As data blocks are overlapped on his display, the controller has first to question both pilots about their flight level. Then he instructs the B737 to climb immediately back to FL150.



The conflict could not be detected by ATC before the level bust. In addition, the controller had to spend some valuable seconds asking both pilots for their respective flight level. As a result, the **minimum distance between the aircraft was 0.4 NM and 100 ft**.

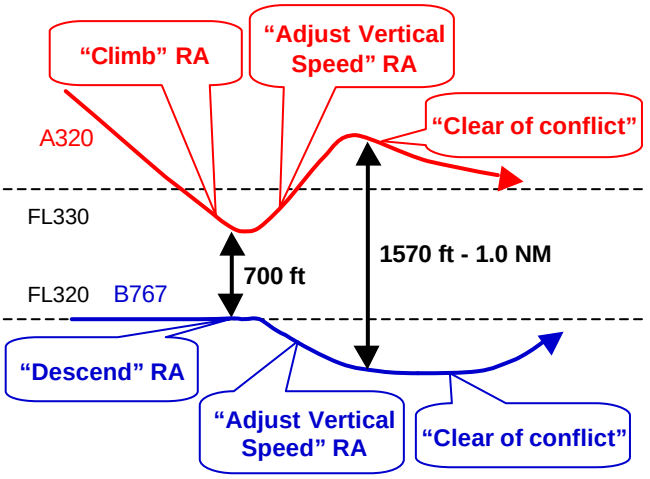
Event 4: Aircraft with TCAS

A B767 is level at FL320. An A320, level at FL340, is on a converging track.



The A320 is cleared to descend to FL330. The pilot reads back 320. However, it sounds like 330 and the controller does not detect the mistake. Consequently, the A320 does not level-off at FL330 and conflicts with the B767.

When the A320 passes FL328 still descending, the A320 receives a "Climb" RA. Then the B767 pilot receives a coordinated "Descend" RA four seconds later.



Both pilots followed the RAs, so that their coordinated manoeuvres resulted in a **vertical separation of 1570 ft** at the closest point (i.e. 1 NM). Moreover, the vertical separation was never less than 700 ft.

Level busts - A reality

*A NASA study has evaluated that there are **10 opportunities for level bust per altitude change instruction**. In addition, a UK study has concluded that on average, there is **1 level bust per commercial aircraft each year**.*

Many statistical analyses confirm the high number of level busts:

- ***more than 500 level busts reported per year** in a major European State since 1998;*
- *498 level busts reported by a major European airline from July 2000 to June 2002, i.e. **21 reported level busts per month**.*

It is very unlikely that the situation is different in other European States and for other European operators.

*There are multiple causes for level busts. One of the main causes is an **autopilot deficiency or failure** (about 20% of the reported level busts for two major European airlines). Other causes are clearance misheard, incorrect altimeter setting, taking another aircraft's clearance, etc.*

*A level bust, which occurs in a 1000 ft level-off encounter scenario, can be critical and result in a risk of collision. **TCAS II is an effective protection in the event of a level bust.***

Follow the RA !

Controllers are tending to provide more traffic information to pilots climbing or descending to level-off at 1000 ft from other aircraft. This traffic information can improve the pilots' situational awareness.

*However, **safety demands that flight crews must follow the RAs.***

ACAS II Bulletin No 1 - Safety Flash (July 2002) underlines the necessity to follow RAS.

What can be done to avoid these RAs?

Controllers and pilots consider that too many RAs are generated in 1000 ft level-off encounters. Some solutions can be envisaged to avoid these RAs, or at least to reduce their number.

Rule making

In order to increase safety and to minimise the likelihood of RAs in 1000 ft level-off encounters, it is proposed that aircraft have **a reduced vertical rate when approaching their cleared level**. Recommendations or rules already exist.

The EUROCONTROL ACAS Programme recommends that pilots climb or descend at a rate less than 1000 fpm in the last 1000 ft to level-off. The EUROCONTROL RVSM Programme also recommends a similar rate for RVSM operations.

Two core area European States have published regulations in their AIPs, which require the vertical rate, in the last 1000 ft before level-off at the cleared altitude, to be below 1500 fpm. This can be expected to improve the compatibility of TCAS II with ATC, and bring improvements in safety.

In addition, a proposal for a recommendation to reduce the vertical rate to less than 1500 fpm in the last 1000 ft before level-off at the cleared altitude, is under discussion within ICAO for inclusion in Annex 6, Aircraft operations.

Near/Medium term: procedure modifications

Two solutions could be adopted to improve operations in locations where RA "Hotspots" have been identified:

- **To increase the vertical separation between aircraft to 2000 ft in specific cases** (e.g. between arrivals and departures).
- **To avoid simultaneous horizontal and vertical convergence of aircraft** by modifying either the horizontal route or the vertical trajectory.

These proposals, which could be implemented in a **relatively short term**, are also likely to provide improvements in safety.

Two procedure modifications in line with these proposals have already been implemented by one ANSP to address identified RA "Hotspots". Neither of these procedure modifications have had any significant effect on capacity.

- 2000 ft vertical separation is now applied between Geneva arrivals and Lyon departures.
- In Paris TMA, the MOSUD arrival descent point from FL140 to FL120 is delayed by 4 NM on a tactical basis. Thus RAs are avoided with the departures climbing to FL110. As a bonus, a STCA "Hotspot" has also been suppressed.

Long term: technical modifications

Potential solutions include a modification of aircraft autoflight systems and a TCAS logic modification:

- Modification of the altitude capture laws of the autopilot by an earlier reduction of vertical rate. This would reduce the probability to RAs during level-off. Although this solution will require a lengthy development and certification process, it is expected to provide significant contribution to safety.
- Radical redesign of the TCAS logic to use own aircraft selected flight level. This would require a lengthy development and certification process. Unlike the other proposed solutions, overall ATM safety would not be improved.

These modifications must be viewed as **long term solutions**.

Conclusion

Despite several specific features, TCAS II still generates some RAs in 1000 ft level-off encounters, which can be perceived as operationally unnecessary. This perception results from the fact that 1000 ft is the standard ATC vertical separation applied between aircraft.

Some of these RAs are necessary, particularly in the case of level busts, which are not infrequent events. Therefore, **pilots must follow all RAs**.

RAs in 1000 ft level-off encounters are generally due to high or very high vertical rates. Therefore, it can be easily appreciated that these RAs contribute to the prevention of some level busts where there would be a risk of collision. These RAs are justified from a TCAS standpoint, and are not false alerts.

Where 1000 ft level-off RAs are recurrent, it could serve to highlight a potential safety issue in ATM design, or procedures.

This issue involves all ATM actors:

- *Pilots*: TCAS II is an effective protection in the event of level busts: follow the RA! Where possible, the vertical rate should be reduced in the last 1000 ft before level-off.
- *Aircraft Operators*: Where feasible, operational procedures should be implemented requiring a vertical rate <1500 fpm in the last 1000 ft from a cleared altitude.
- *Aircraft Manufacturers*: Autoflight system designs should take into account TCAS performance when determining vertical rates for altitude capture.
- *Controllers*: It should be noted that these RAs are justified from a TCAS standpoint. Traffic information may improve the pilots' situational awareness.
- *Aviation Authorities and Service Providers*: Airspace design and procedures should take into account any potential safety issues highlighted by TCAS II monitoring.

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This is one of a series of ACAS Bulletins planned to address specific TCAS operational issues. For more detailed information on ACAS and TCAS, please refer to the ACAS II brochure and training material available on the ACAS Programme website

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