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The Airbus TCAS Alert Prevention (TCAP)

1. Introduction

The Traffic Alert and Collision Avoidance System, known as TCAS, has been introduced in the 90's to prevent the risk of mid-air collisions. Today this safety goal has globally been reached.

However, a recurrent side-effect of TCAS introduction can be observed. This side-effect is what we call the 'nuisance' Resolution Advisories (RAs) or the operationally 'undesired' RAs, which occur during 1000ft separation level-off manoeuvres.

A new Safety Initiative has been launched by Airbus to solve this issue: The **TC**AS **A**lert **P**revention (TCAP), a new altitude capture enhancement to minimize cases of TCAS level-off RAs.

The objective of this new TCAP feature is twofold:

► To reduce the number of undesired TCAS RAs occurring during 1000ft level-off encounters. This is done by adapting the altitude capture law, so as to soften the aircraft arrival to an intended altitude when traffic is confirmed in the vicinity.

► Not to degrade the aircraft performance, in particular in descent, by a premature and excessive reduction of the vertical speed to reach the altitude target, when it is not justified.

2. Level-Off RAs

Level-off RAs occur during 1000ft level-off manoeuvres while everything is correctly done by the crew with regards to operations and clearance.

These operationally 'undesired' RAs can be characterised by the two following typical encounter geometries:

► One aircraft (in blue on fig. 1) is intending to level-off at a given level while another aircraft (in green on fig. 1) is already levelled at the adjacent level (1000ft above or below the first aircraft's intended level):

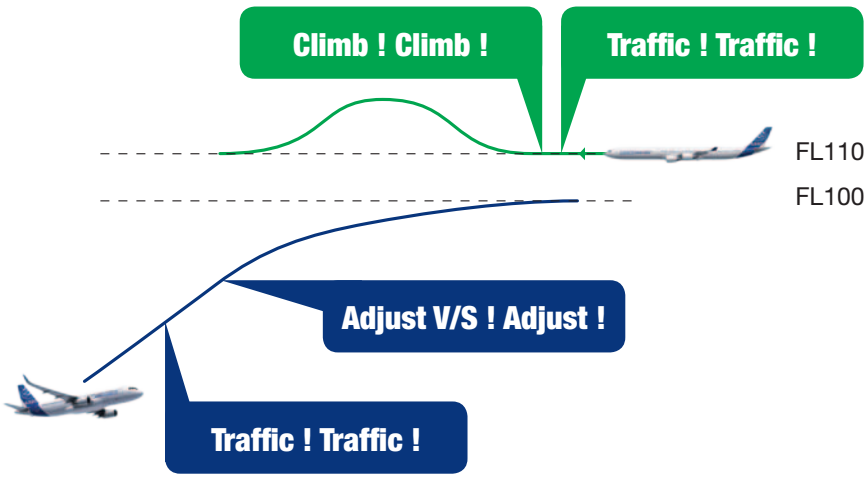


Figure 1
'Undesired' TCAS RAs occurring during a single 1000ft level-off manoeuvre

► One aircraft is climbing to level-off at a given level while another aircraft is descending to level-off at the adjacent level, 1000ft above the first aircraft's intended level (fig. 2).

Although these RAs do not imply a 'real' collision risk, they remain very stressful alerts. Above all, they impose - by procedure - an avoidance manoeuvre to both aircraft, leading to unnecessary deviations from initial trajectories and to potential repercussive traffic perturbations.

Let us take the example of an A320 (medium weight/CG, selected speed 300kt) climbing to FL130 with a rate of climb of 2800ft/min, while an A340-600 (light weight/medium CG, selected speed VMO-20kt) is descending to FL140 with a rate of descent of 2200 ft/min.

In such an encounter, the A320 TCAS will trigger a Traffic Advisory (TA) at FL116 and a RA at FL123. Simultaneously, the A340-600 TCAS will set off a TA at FL153 and a RA at FL147 (fig. 3).

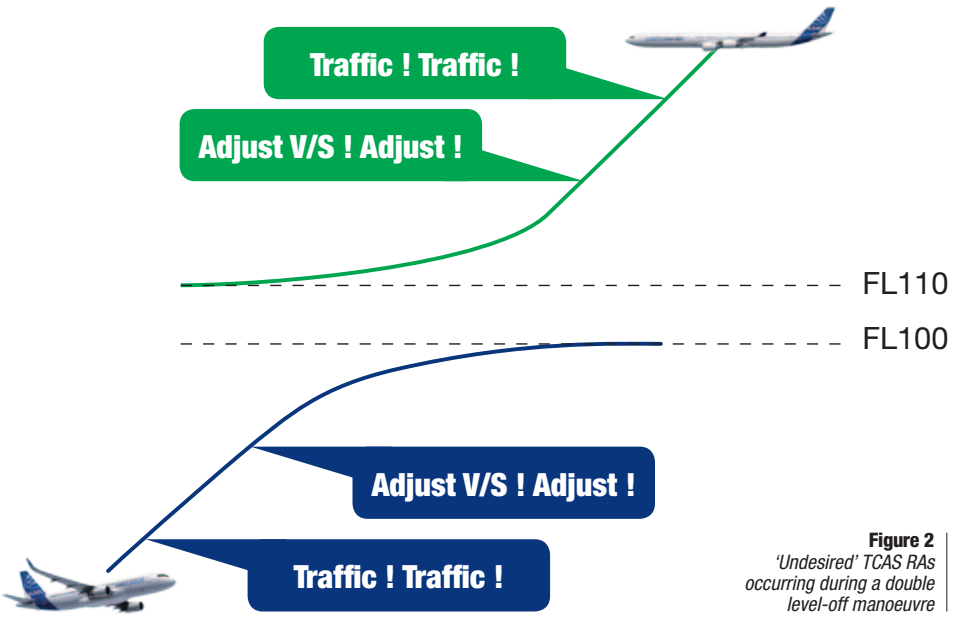


Figure 2
'Undesired' TCAS RAs occurring during a double level-off manoeuvre

3. Recommendations to Prevent these RAs

The first recommendation calls for pilots to reduce the vertical speed when approaching the assigned altitude or flight level.

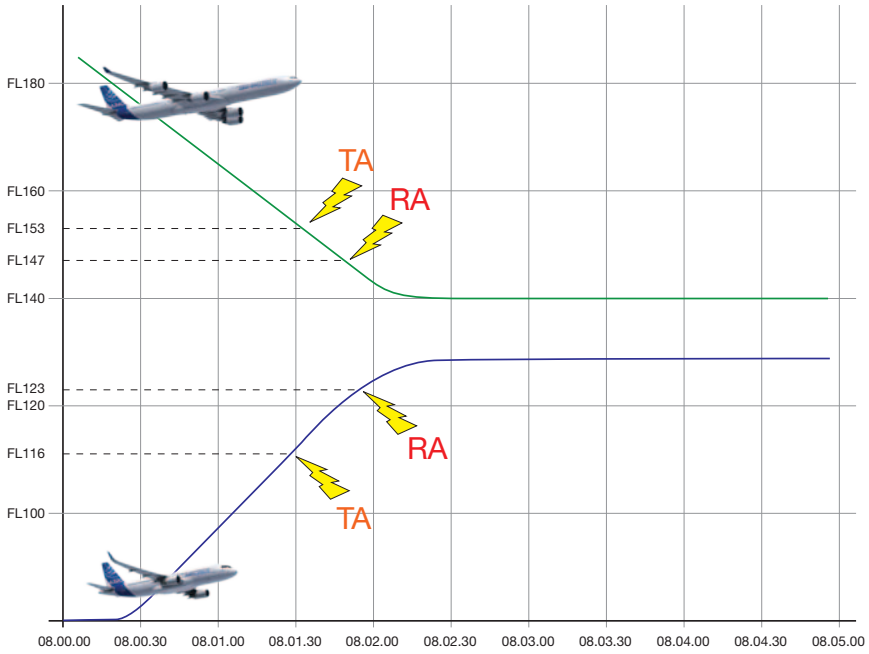
This preventive action limits the vertical convergence between aircraft and thus prevents crossing the TCAS alert triggering thresholds.

As shown on table 1, the preventive rates to apply vary slightly depending on who is expressing the rule:

► Airbus (FCOM) recommend to limit the vertical speed to 1500 ft/min during the last 2000ft of a climb or descent.

► The FAA (AC20-151A, Appendix A Section III) call for a reduction of the vertical speed to between 500 and 1500ft/min, when between 1000 and 2000ft above or below the assigned altitude.

Figure 3
Example of nuisance TCAS alerts occurring during a double level-off manoeuvre



► ICAO (PANS-OPS Doc. 8168) recommend to adopt a vertical speed below 1500ft/min throughout the last 1000ft of climb or descent to the assigned altitude.

► Table 1 also includes the limits in vertical speed from three other sources.

As a matter of fact, these recommendations are rarely applied. Several airlines do not have them incorporated in their operational recommendations. Even when they are, some pilots confess they are not always applied. As a result there is still a significant number of undesired RAs observed during 1000ft level-off manoeuvres.

The second set of recommendation has been expressed by the French accident investigation authority Bureau d'Enquête et d'Analyses (BEA) following a mid-air incident, in March 2003, where a wrong response to an "ADJUST V/S" RA was observed in a context of a 1000ft level-off encounter. The BEA recommended that aircraft manufacturers study the possibility of taking into account TCAS alert triggering thresholds into their altitude capture laws.

This recommendation was followed by EUROCONTROL within the ACAS Bulletins and by several airlines who requested a modification of the altitude capture control laws with an earlier reduction of the vertical rate to prevent such recurrent undesired RAs.

	Vz	Dist. to level
AI FCOM	1500 ft/min	2000 ft
FAA	500-1500 ft/min	1000-2000 ft
ICAO	1500 ft/min	1000 ft
DLH	2000 ft/min 1000 ft/min	2000 ft 1000 ft
EUROCONTROL ACAS and RVSM programs	1000 ft/min	1000 ft
Swiss Regulation	1500 ft/min	1500 ft

Table 1
Recommendations to prevent level-off RAs

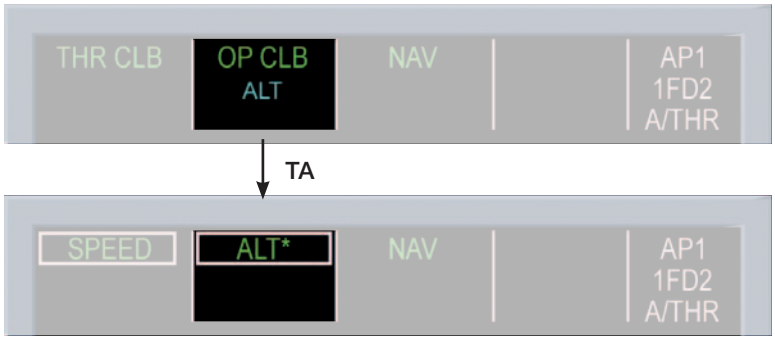


Figure 5
FMA upon TCAP activation when initially in OP CLB

TCAP Control/Law

4. The TCAP Function

In response to these requests for improvement, Airbus launched the feasibility study of a new system called TCAS Alert Prevention or TCAP.

The objective of this new TCAP feature is twofold:

► To reduce the number of undesired TCAS RAs occurring during 1000ft level-off encounters. This is done by adapting the altitude capture law, so as to soften the aircraft arrival to an intended altitude when traffic is confirmed in the vicinity.

► Not to degrade the aircraft performance, in particular in descent, by a premature and excessive reduction of the vertical speed to reach the altitude target, when it is not justified.

The TCAP activation logic is based on the Traffic Advisory (TA) triggered by the TCAS, which clearly confirms the presence of traffic in the aircraft vicinity.

The activation of TCAP is fully transparent to the pilot who will note the same mode changes with TCAP as without TCAP. The TCAP case only resulting in an earlier reduction of the Rate Of Descent/ Rate Of Climb (ROD/ROC). This means that upon TCAP activation at TA:

- If the aircraft is initially in a vertical guidance mode other than the altitude capture mode (for example in a climb or descent mode), the vertical mode automatically reverts to the altitude capture mode (ALT* for Airbus HMI) with the new TCAP altitude control law active (ALT*$_{TCAP}$ control law) (fig. 5).
- If the vertical mode is initially the altitude capture mode (ALT* with the conventional altitude capture control law active), the vertical mode remains the altitude capture mode but with the new ALT*$_{TCAP}$ control law active. The Flight Mode Annunciator still displays ALT* (fig. 6).

Conventionnal ALT* Control/Law

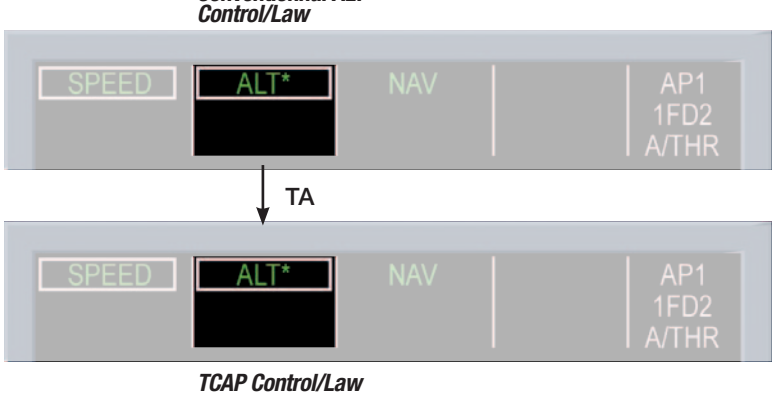


Figure 6
*FMA upon TCAP activation when initially in ALT**

TCAP Control/Law

Once activated, the ALT*$_{TCAP}$ control law remains active till the end of the capture (with ALT* mode engaged) even if the triggering TA ceases. This is to avoid triggering a new TA.

Finally, it is important to note that TCAP activation does not impact the lateral trajectory and associated lateral guidance mode, nor the Auto-Pilot, Flight Director and Auto-Thrust engagement status.

5. Adapted TCAP Altitude Capture Control Law (ALT*$_{TCAP}$)

The objective of the Alt*$_{TCAP}$ control law is to acquire and hold one or several consecutive vertical speed targets until the aircraft reaches its intended altitude by adopting a classical 0.05g parabola profile.

When in ALT*$_{TCAP}$ control law, a vertical load factor of 0.15g is applied to ensure a rapid reduction of the vertical speed and thus a more efficient prevention of the RAs. It also gives a reliable sensorial feedback to the crew to indicate TCAP function activation if ALT* mode was previously engaged.

The ALT*$_{TCAP}$ vertical speed targets have been defined so as to efficiently prevent level-off RAs while minimizing the increase of the altitude capture phase duration. They are function of current aircraft vertical speed and distance to targeted level at the time of the TA and are computed in decreasing sequence in case of consecutive vertical speed targets (e.g. if a new TA occurs).

The average impact on the altitude capture time is an increase of 40 seconds compared to the conventional altitude capture law, remembering that TCAP control law activation is limited to a TA occurrence.

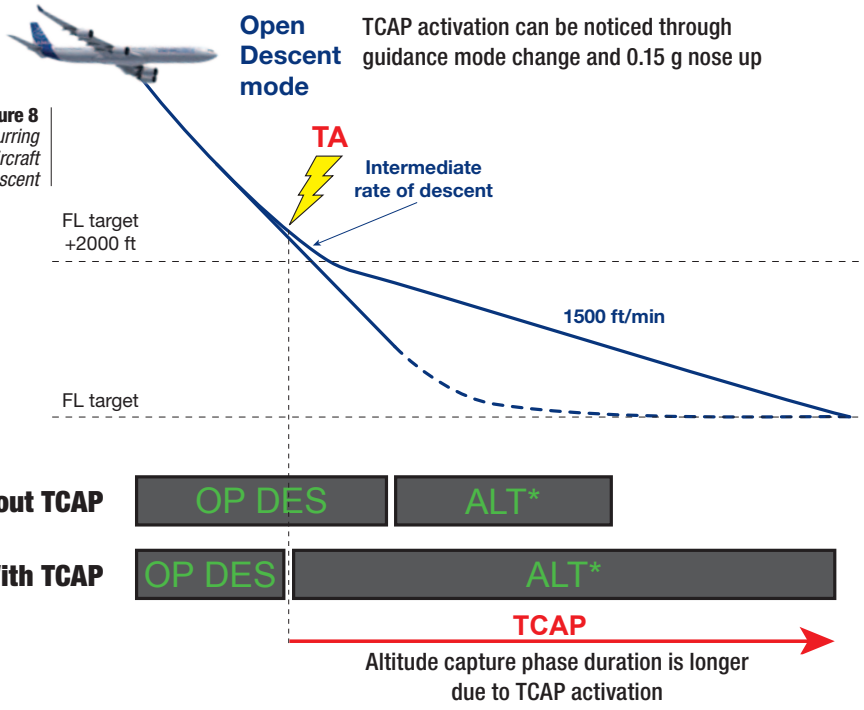


Figure 8
Early TA occurring when the aircraft is in descent

Example 1: Early TA occurring when the aircraft is in descent

The aircraft is descending in OP DES mode when a TA occurs above the last 2000ft. The ALT* mode immediately engages with ALT*$_{TCA}$ control law active and an associated vertical load factor of 0.15g: the rate of descent is reduced to an intermediate vertical speed target greater than 1500ft/min till reaching the last 2000ft, where the vertical speed target becomes 1500ft/min (fig. 8).

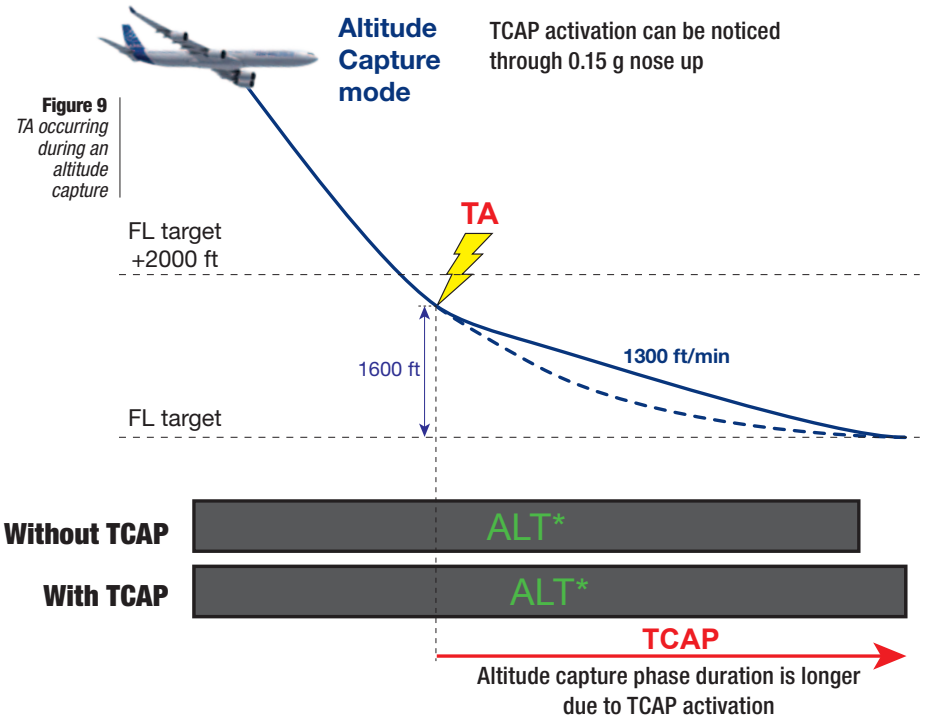


Figure 9
TA occurring during an altitude capture

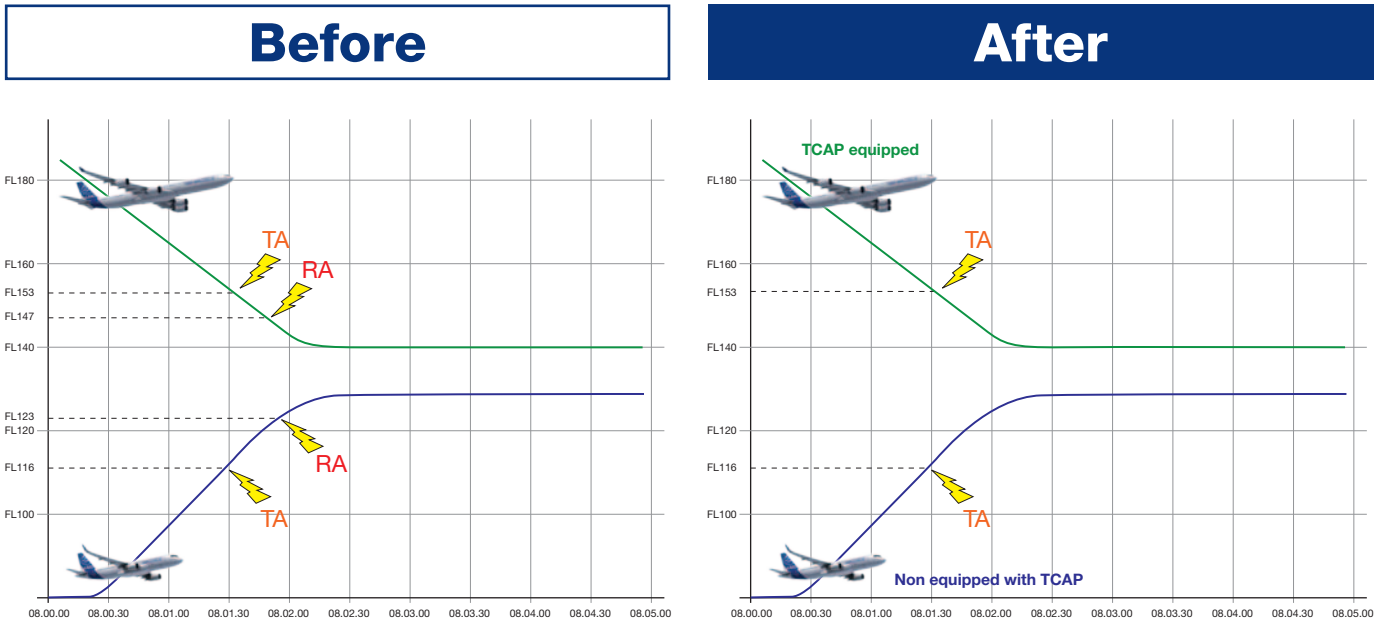


Figure 10
TCAP benefits on a double level-off encounter

Example 2: TA occurring during an altitude capture (in ALT*)

The aircraft is performing an altitude capture on the conventional 0.05g parabola capture profile (ALT* mode) when a TA occurs. The ALT*$_{TCAP}$ law automatically activates to quickly reduce the rate of descent, shortcutting the parabola with a vertical load factor of 0.15g (ALT* mode remains engaged).

The rate of descent is reduced to a vertical speed target between 1200ft/min and 1500ft/min depending on the aircraft's distance to the target flight level at the time of the TA till the end of the capture (fig. 9).

6. Expected Benefits

An operational and safety performance assessment was performed in the frame of the Single European Sky ATM Research (SESAR) project to assess the impact of the new Airbus TCAP solution, based on a large encounter model representative of operations in Europe.

The assessment showed that more than 95% of the 1000ft level-off RAs were avoided through the use of TCAP. Since 1000ft level-off RAs represent more than 55% of all RAs, the project concluded that TCAP may halve the overall number of RAs for an equipped aircraft.

Another observed relevant result was that only one aircraft of the encounter needs to be equipped with TCAP to allow RAs prevention on both aircraft (fig. 10).

7. Conclusion

With significant operational benefits such as more than 95% level-off RAs avoided, leading to an overall number of RAs cut by two without debasing safety, TCAP establishes as a promising standard.

These benefits will be associated to the following outcomes:

► For the crew: less stress due to a reduced number of RA situations,

► For ATC: less unnecessary traffic perturbations due to 'undue' avoidance manoeuvres.

The TCAP will also contribute to the crew workload alleviation: even though pilots still have to maintain awareness and vigilance over near by traffic, they will not have to reduce ROC/ROD as a precautionary measure. The pilots will just have to monitor the Auto Pilot or the Flight Director and to verify its reaction in accordance with their expectations.

This new TCAP altitude capture enhancement will be available on all Airbus Fly-By-Wire aircraft, including the A380 and A350, in the near future. The certification targets are anticipated between end 2011 and mid 2013, depending on the aircraft type.

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