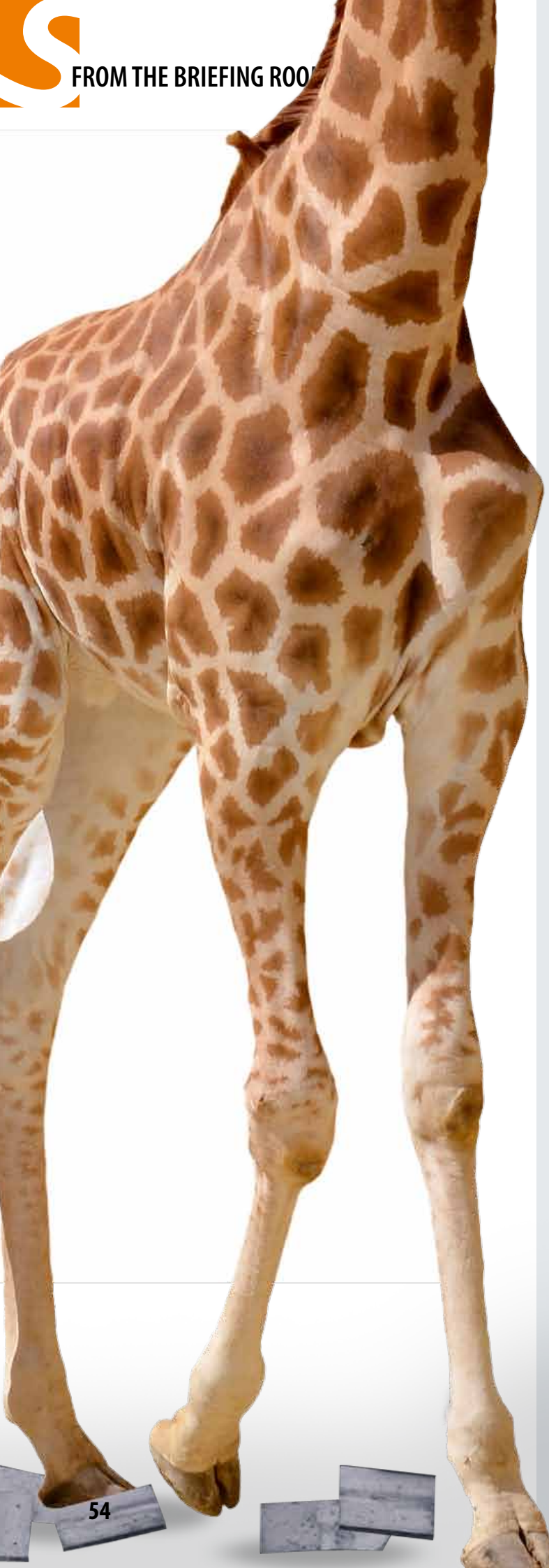


Unnecessary TCAS RAS caused by high vertical rates before level off

by Stanislaw Drozdowski, Captain Wolfgang Starke and First Officer Felix Gottwald

TCAS warns flight crews of an imminent risk of collision by generating Resolution Advisories (RAs) to the flight crew. However, monitoring conducted in core European airspace in 2011 and 2012 shows that roughly three out of four TCAS RAs are in level off geometries[1]. The causal factor in most of these RAs is a high vertical rate of climb or descent by one of the aircraft involved during the last 1000 feet prior to level-off when the adjacent level is occupied. This is despite ICAO publishing a recommendation in November 2008 to reduce the vertical rate to 1500 ft/min in the above situations.

In the first part of this article, TCAS expert and editor of EUROCONTROL's ACAS Bulletins Stanislaw Drozdowski explains why such RAs are generated. In the second part of the article, Wolfgang Starke and Felix Gottwald, both current commercial pilots and members of the German Air Line Pilots' Association Air Traffic Services Committee give the pilots perspective.

1- Source: Analysis of downlinked RA messages for SESAR project 4.8.3

The TCAS experts point of view

by Stanislaw Drozdowski

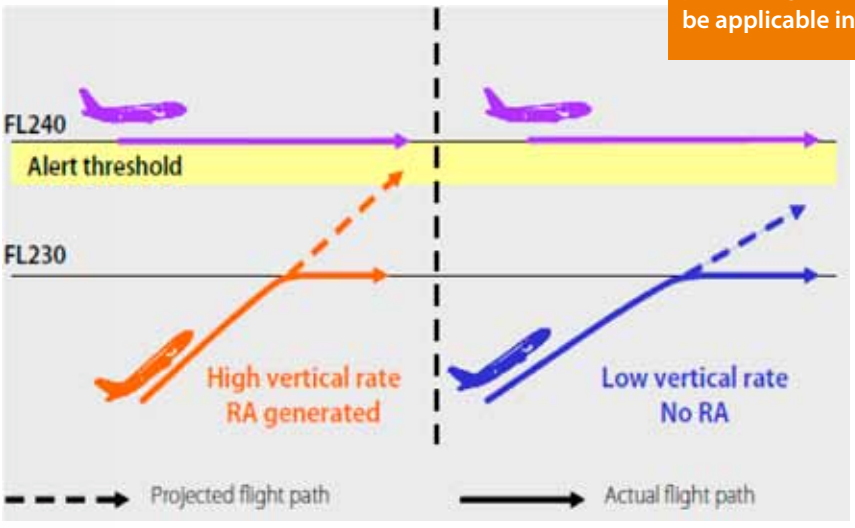
Stan is a Senior ATM Expert at EUROCONTROL HQ in Brussels, working in the area of ground and airborne safety nets. He focuses on current operational issues as well on enhancements to existing systems. Before joining EUROCONTROL, Stan worked as an ATM system engineer with Northrop Grumman in Baltimore (USA) and as an en-route air traffic controller in Poland and New Zealand.

The performance of modern aircraft allows pilots to climb and descend with high vertical rates. While this can provide operational benefits (i.e. fuel or time savings), it can become problematic when aircraft continue to climb/descend with a high vertical rate close to their cleared level when the adjacent level is occupied or another aircraft is descending/climbing towards the adjacent level.

TCAS RAs due to high vertical rates before level-off

TCAS will issue an RA when it calculates a risk of collision based on the closing speed and vertical rates. A high vertical rate before level-off may cause the TCAS logic to predict a conflict with another aircraft even when appropriate ATC instructions are being correctly followed by each crew. This is because TCAS does not know aircraft intentions – autopilot or flight management system inputs are not taken into account because TCAS must remain an independent safety net.

If, simultaneously, another aircraft is approaching an adjacent level, the combined vertical rates make RAs even more likely. The majority of all RAs occur within 2000 feet before level-off at the cleared level. TCAS will typically generate: an "Adjust vertical speed, adjust" RA (in version 7.0) which requires a reduction of the vertical rate as indicated on the flight instruments; or a "Level off, level off" RA (in version 7.1) which requires a reduction of the vertical rate to 0 ft/min (i.e. a level-off). In extreme cases, involving very high vertical rates TCAS may diagnose that insufficient time remains to assure safe separation by a reduction in vertical rate and instruct a crossing RA, announced in the cockpit as "Maintain vertical speed, crossing maintain".



Always follow the RA

Pilots and controllers sometimes judge these RAs as operationally not required and refer to them as "nuisance" RAs. However, in real time the pilot cannot (and should not) assess whether the RA is in fact operationally required. Once an RA has been issued it must be followed without delay and it takes precedence over any ATC instructions.

Therefore, it is best to avoid approaching the cleared level with a high vertical rate when the pilot is aware of another aircraft at the adjacent level – based on ATC traffic information, observation on the TCAS traffic display or as a result of a Traffic Advisory (TA). In this way the occurrence of nuisance RAs can be minimised.

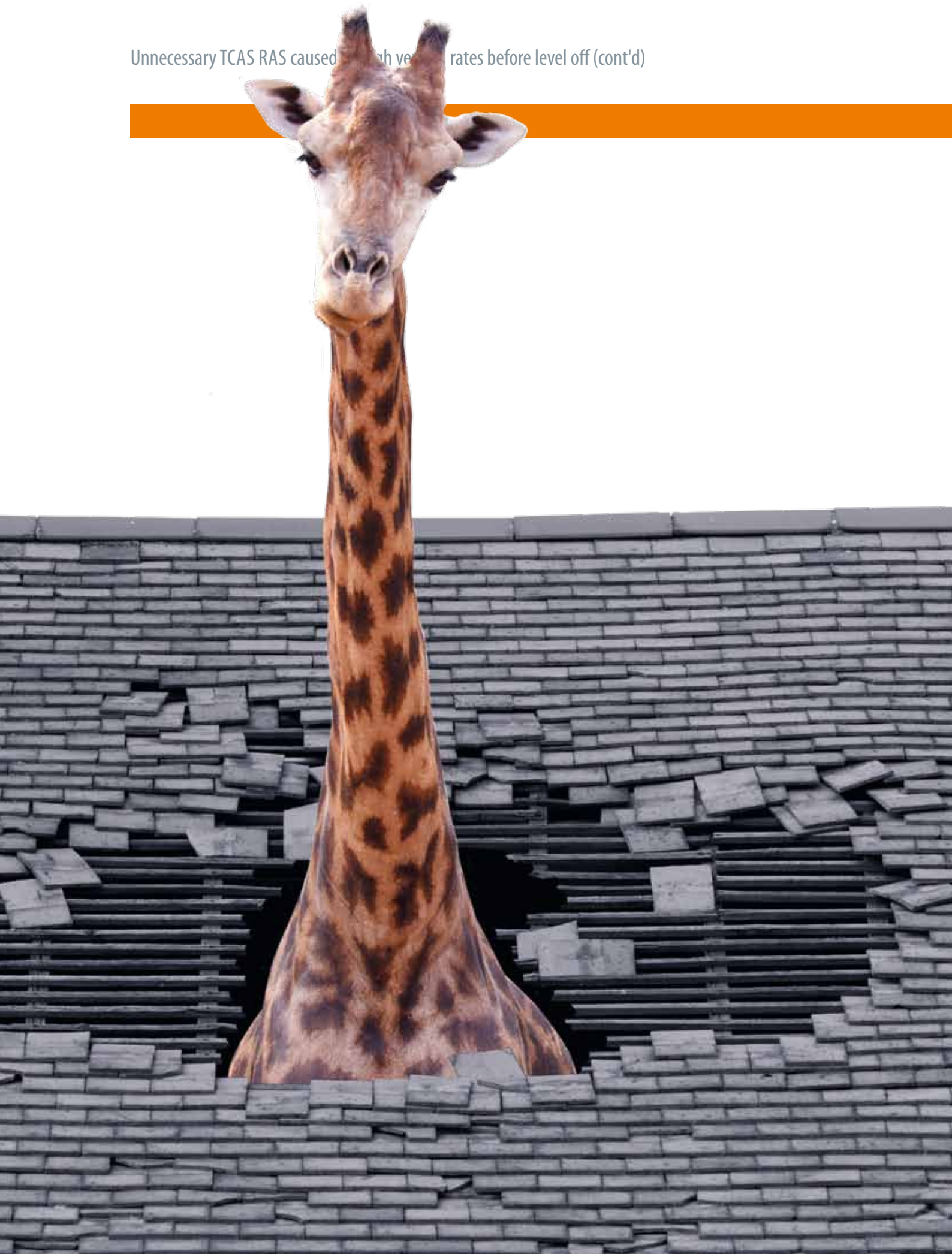
ICAO recommendation

In order to reduce the number of RAs caused by high vertical rates before level-off, ICAO in November 2008 published a provision recommending the reduction of vertical rates to 1500 ft/min or less in the last 1000 feet before level-off, when the pilot is made aware of another aircraft at or approaching an adjacent flight level, unless instructed by ATC to maintain a certain vertical rate. Some States have published or are considering publishing similar or even more restrictive measures to be applicable in their airspace.

The above is based on the text that first appeared in Issue 15 of EUROCONTROL's ACAS Bulletin. These bulletins discuss real-life TCAS events in order to spread the lessons learned and encourage best practice by pilots and controllers. Issue 15 is dedicated to Unnecessary RAs due to high vertical rates before level-off and can be accessed on the EUROCONTROL website and on SKYbrary.

http://www.skybrary.aero/bookshelf/books/1804.pdf

Unnecessary TCAS RAS caused [illegible] rates before level off (cont'd)



The pilot point of view

by Wolfgang Starke and Felix Gottwald

Following on from the first part of the article, why do pilots sometimes only fly shallow descents and sometimes approach their cleared flight level with a high and sometimes inappropriate vertical rate, knowing that there is traffic separated by just 1000 feet? To answer these questions we need to understand how the climb and descent phases are flown by pilots, and how the autopilot/flight director (AP/FD) systems on board the aircraft operate.

Climb profile

In modern aircraft fuel burn reduces significantly with increasing altitude. At the same time, true airspeed increases and the speed of the aircraft over the ground is higher. In order to achieve the most economic flight profile, the Standard Operating Procedures (SOPs) of most airlines require pilots to apply full climb thrust while adjusting the indicated airspeed (IAS), or at higher altitudes the Mach number, by increasing the pitch of the aircraft. This results in aircraft always flying their maximum available climb rate at the optimum speed.

- Asking pilots to maintain a low rate or reduce their vertical speed will either lead to a reduction in engine thrust or higher airspeeds. Both situations result in a non-optimal flight profile.

- Asking pilots to increase their vertical speed or maintain up to a higher flight level will require them to trade off an aircraft's indicated airspeed against vertical speed. Such a trade-off is possible for short-term manoeuvring like following a TCAS RA, but the available climb rate after the manoeuvre will be significantly reduced for a period longer than the manoeuvre itself. Additionally, ATCOs are unaware of the speed of the aircraft relative to its minimum climb speed.

All of the above has one common consequence: higher and more economic cruise altitudes will be reached later into the flight, which increases the amount of fuel used and the flight time. Nowadays pilots rarely carry significant additional fuel for economic reasons so the increased fuel burn at lower altitudes could limit their options later in the flight. Longer flights also mean higher cost for maintenance, air crew salaries etc.

Wolfgang is a Bombardier Dash 8-Q400 line training captain with Air Berlin. He has previously flown Boeing 737-NG and classic aircraft. Wolfgang is a member of the Air Traffic Services and Airport and Ground Environment committees of the Vereinigung Cockpit (German Air Line Pilots' Association) and IFALPA (International Federation of Air Line Pilots' Associations).

Felix is an MD-11 first officer with Lufthansa Cargo. He has previously flown the A320 series aircraft. Felix is a member of the Air Traffic Services committee of the Vereinigung Cockpit (German Air Line Pilots' Association) and IFALPA (International Federation of Air Line Pilots' Associations). He is also an IFALPA representative to the IFATCA Technical Operations Committee.

Descent profile

Practically all aircraft now operating within European airspace feature vertical navigation (VNAV) functions in their flight management systems (FMS). These VNAV paths are calculated at certain airspeeds with the engine thrust at flight idle. This is a simplified version of the climb case, engine thrust is kept constant while indicated airspeed is adjusted by changes in the aircraft's pitch.

Increasing the vertical speed of an aircraft during the descent when the engines are at idle leads to an increase in airspeed. This is only possible up to the maximum allowed airspeed, although increasing the descent rate further can be achieved to a certain extent by using speed brakes - usually in the form of lift spoilers on the upper surface of the wings. But speed brakes also disturb the very sensitive aerodynamic properties of the wing, wasting a lot of the aircraft energy, energy that had previously been generated by burning fuel. And of course, passenger comfort may be affected by the noise and airframe vibration which can occur with speed brake deployment.

In most instances, increasing the rate of descent causes an aircraft to be at a much lower altitude than planned at a given distance from the destination airport. Similar to the climb, the consequence will again be prolonged flight times, increased fuel burn and higher operating costs. Additionally, both the risk of having a bird strike and noise abatement issues increase at lower altitudes.

The pilot point of view (cont'd)

Nevertheless, increasing descent rate is possible most of the time, but pilots may have difficulty making speed reductions if required to maintain high rates of descent whilst doing so.

Timing the start of the descent

As already mentioned, the aircraft's descent profile is planned using idle thrust. Therefore it is not always possible to increase the rate of descent to the rate requested by ATC. If ATC keeps an aircraft at high altitudes and the pilots are not allowed to initiate the descent in time, or are only instructed to do so at a low vertical rate, the descent rate required for the remaining track miles to the destination will become more and more problematic. This can result in one of two scenarios; the pilots are required to descend at the maximum rate, or they are unable to descend without flying additional track miles. In the later scenario, on top of fuel burn and flight time penalties, the additional track miles will be flown closer to the ground and near an airport, so the margin for error is reduced and the chance of receiving a TCAS RA is increased!

A good question is why do pilots not programme a little "reserve" into their FMS to cater for unexpected ATC constraints? To be honest, operationally this would be a good idea. However, as descents work well most of the time, planning to be at lower altitudes earlier than necessary would be less efficient than descending at high rates or even additional track miles from time to time.

Level-off procedure – influence of the autopilot/flight director

ICAO recommends that the vertical rate be reduced to not more than 1500 feet per minute during the last 1000 feet altitude prior level-off. If followed, this would reduce the number of unnecessary RAs during level-off quite significantly. But not all operators have yet incorporated this guidance into their SOPs. So why do pilots not always follow this recommendation?

Part of the answer lies with today's autopilot/flight director (APFD) design. These systems fly the aircraft in the most economical manner and, by doing so, will use the maximum available climb rate for a given speed. However, as a flight would be highly uncomfortable if a high rate of climb transitioned to level flight too quickly, autopilots have an altitude capture or altitude acquire mode. This mode is based on a predetermined g-load, typically in the range of 0.25 to 0.3g, during level off. The point relative to the level-off at which the altitude acquire mode starts to operate is dependent on the vertical rate of the aircraft. At low vertical rates, such as 1000 ft/min, the altitude acquire mode will typically start to reduce the vertical rate between 300 and 100 feet before level-off. At very high vertical rates, such as 6000 ft/min, the reduction in the vertical rate should be expected to start more than 1000 feet before level off.

Generally modes such as the altitude acquire work well; nevertheless they do have one significant safety issue in common. Whenever pilots try to modify their aircraft flight path once altitude acquire mode is active, it is likely to drop out if already engaged, which in turn may well lead to a level bust. To prevent aircraft from overshooting their cleared flight level, many airline SOPs restrict the use of VS mode near to level-off. These SOPs render pilots unable to reduce a high vertical rate whilst keeping the automatics engaged. Although IFALPA (International Federation of Airline Pilots' Associations) is calling for a consequent improvement in the design of modern autopilots, this change has not been made yet.

A version of this specific to Airbus aircraft is the so-called "Alt. Star trap" (a star symbolises the altitude capture mode in Airbus-speak). Once the autoflight system has captured the level-off altitude, it maintains the climb rate and there is no way for the pilot to change the aircraft's mode to reduce the vertical rate – the crew are "trapped" in the altitude capture mode. One possibility is flying the aircraft manually, which is hardly ever practiced during the en-route stages of a flight. The other is to select a new altitude, change to vertical speed mode, reselecting the original altitude and hope all goes well within the few seconds before the Autopilot overshoots the cleared level. But such non-standard actions increase the likelihood of errors and reduce safety margins.

Pilot and controller errors

Of course, it is not always the system design which makes things worse; sometimes pilots just forget to reduce the vertical rate. But imagine the workload when approaching busy terminal areas like those around London, Paris or Frankfurt. Often pilots have to focus on other things, knowing that the

autopilot capture mode is not perfect, but still will capture the cleared level. And there are also occasions where the controller instructs a vertical rate RA. A year ago, one of us travelled on the flight deck jump seat after a duty. When climbing through approximately FL210, ATC informed us about a company Boeing 737 levelling off 1000 feet above our cleared level of FL220. At the same time TCAS first gave a traffic advisory (TA), quickly followed by an RA instructing us to descend. At the time climb rate was about 1000 ft/min. We heard later that the company 737 received an RA to reduce vertical speed (an "Adjust vertical speed, adjust" RA) – a high rate being flown at the specific request of ATC!.

Communicating each other's intentions

Of course, mistakes do happen again and again and we will never able to change that. Yet, in aviation we have to find ways to mitigate the risks! Controllers and pilots are both experts in our very special jobs - pilots should not try to make adjustments to traffic separation, nor should ATCOs try to "fly airplanes". In our view, if a modern aircraft needs to be at a certain position at a certain airspeed or altitude, then it is better for a clearance to state exactly this requirement rather than make the sort of aircraft control request - such as "descend xxx with a rate of yyyy ft/min" which might suit older aircraft better. A clearance pilots love to hear is "be there at this altitude with that speed" because then we can do our job by manoeuvring our aeroplane efficiently to achieve that objective. Besides, this is current ICAO provision of PANS-ATM.

If as a controller you still need to instruct a defined vertical rate for separation, please always stick to ICAO and tell us when the specified vertical speed is no longer required. Otherwise we are not able to plan ahead, which is a prerequisite for safe flying.

Teamwork for ATC and pilots is best accomplished when both parties know each other's plan. For this we have to keep up proper communications and make sure our respective intentions are known. This allows everyone to do their job well.

EDITORIAL NOTE

See HS12 (Winter 2011) for more detail on this: http://www.skybrary.aero/bookshelf/books/1417.pdf

TCAP – A solution to reduce nuisance RAs?

In an effort to reduce the number of unnecessary preventive TCAS RAs to 'Adjust Vertical Speed' during the approach to level off, Airbus have developed the TCAS Alert Prevention (TCAP) system for Airbus A380 and A350 aircraft.

Recent data indicates that between 50 and 75 per cent of all such 'nuisance' RAs are caused by high vertical rates in geometries when one or sometimes two proximate aircraft are about to level off. To reduce these RAs, ICAO recommends reducing the vertical speed to less than 1500 fpm during the last 1000 feet prior to level off. However, even up to date autoflight systems fail to achieve this recommendation. So prior to level off, pilots may (if permitted by their SOPs) decide to change their flight guidance mode to manually reduce vertical speed. From a safety point of view this is potentially hazardous, as it can increase the chances of overshooting the cleared level.

TCAP is an enhancement of the autoflight system which ensures a reduction of vertical speed prior to level off to prevent these TCAS from nuisance RAs. TCAS itself is not changed by TCAP because it is merely an enhancement to the autoflight system. TCAP prerequisites are necessary to allow TCAP to automatically reduce the vertical speed after receiving a TCAS TA which has resulted from a proximity which may subsequently lead to an unwanted TCAS RA.

Pilots who have used TCAP certainly appreciate it, but TCAP can only be seen as a first step to improve modern autoflight systems. In fact, IFALPA have had a policy since 2010 that pilots should not be required to interfere with the normal autoflight system process for achieving level capture to prevent unwanted TCAS RAs as a result of an excessive vertical speed.

Whilst the possible disruption to air traffic control will be reduced as the numbers of nuisance RAs decrease, the real solution is for all autoflight systems to reduce the vertical speed as level off is approached to a value which does not even produce a TCAS TA. In other words, the system should be compatible with the ICAO recommendation and automatically reduce vertical speed to 1500 ft/min or less during the last 1000 feet prior to level off.