



TCAS AND STCA - NOT JUST ANAGRAMS

By Stanislaw Drozdowski

Stanislaw Drozdowski is an ATM Expert at EUROCONTROL HQ in Brussels, working in the area of ground and airborne safety nets. Previously, he worked as a system engineer with Northrop Grumman and as an Air Traffic Controller in Poland and New Zealand.

INTRODUCTION

Pilots and controllers are provided with a set of automated tools (safety-nets) to alert them to imminent loss of separation. These are Short Term Conflict Alert (STCA) in ground ATC systems and Traffic Alert and Collision Avoidance System (TCAS)¹.

Implementation details of STCA vary widely between ATC systems. They include different algorithms, warning times and type of alerts. STCA does not provide controllers with advice on how to resolve a conflict - this decision is always made by the controller.

TCAS, in contrast, operates according to uniform, world-wide ICAO standards. TCAS produces vertical collision avoidance advice in the form of Resolution Advisories (RAs) which pilots are required to follow. TCAS is widely considered to be the last resort safety net against mid-air collisions.

TCAS and STCA operate in a similar time scale and, therefore, are sometimes in "competition"; avoiding actions required from pilots by TCAS and controllers may differ. This can cause confusion at a time when prompt action and a clear distribution of responsibility between pilots and controllers is most needed.

The aim of this article is to recap the basics of TCAS operation and to raise controller awareness, so the potential interactions between TCAS and STCA can be better understood.

TCAS - HISTORY AND CURRENT STATUS

The development and implementation of airborne collision avoidance systems was very much driven by aviation accidents. The first conceptual research was initiated in 1956 after a mid-air collision over the Grand Canyon. The 1978 collision between a Boeing 727 and a Cessna 182 over San Diego led the FAA to start the development of airborne collision avoidance systems.

Eight years later, another mid-air collision occurred over California - a DC-9 collided with a Piper. Following this accident, the phased-in mandate of TCAS began in the USA. This was followed by a world-wide mandate.

In Europe, from 1 January 2005, all civil fixed-wing turbine-engined aircraft with a maximum take-off mass over 5,700 kg, or capable of carrying more than 19 passengers, must be equipped with TCAS II version 7.0. Additionally, many state and business aviation aircraft are also equipped.

The initial implementation of TCAS (known as TCAS I) only gave information about surrounding traffic and did not provide any collision avoidance advisories. The capability to produce collision avoidance advisories was added to the next version of TCAS (known as TCAS II). TCAS III, the future-generation system which will produce horizontal avoidance advice, has also been foreseen. However, due to the



TCAS limitation in horizontal tracking, the TCAS III system will remain in the area of theoretical development for many years to come.

TRAFFIC ADVISORIES AND RESOLUTION ADVISORIES

Two types of alert can be issued by TCAS II - TA (Traffic Advisory) and RA (Resolution Advisory). TAs are intended to assist the pilot in the visual acquisition of the conflicting aircraft and prepare the pilot for a potential RA.

If a risk of collision is established, an RA will be generated. Broadly speaking, RAs tell the pilot the range of vertical speed at which the aircraft should be flown during the RA. The visual indication of these rates is shown on the flight instruments. It is accompanied by an audible message indicating the intention of the RA.

Some RAs simply tell the pilot to initiate a climb or descent ("Climb, climb" or "Descend, descend"). However, the majority only require a reduction or continuation of the aircraft's current vertical speed (respectively, "Adjust vertical speed, adjust" or "Monitor vertical speed").

¹ TCAS II version 7.0 is the only commercially available implementation of the ICAO standard for ACAS (Airborne Collision Avoidance System). For the purpose of this article, the terms TCAS and ACAS should be considered as synonymous.

It needs to be pointed out that TCAS works independently of the aircraft navigation or flight management systems. While assessing threats it does not take into account the ATC clearance, pilot's intentions or autopilot inputs. RAs seek to achieve collision avoidance by establishing safe vertical separation (300 - 700 feet), rather than restoring a prescribed separation.

Every second, the effectiveness of an RA is evaluated and, if necessary, the RA may be strengthened, weakened, or reversed. For example, an initial RA may require a descent, but once a safe vertical separation has been established, the RA may weaken (i.e. require the pilot to reduce the vertical speed that has been established to comply with the initial RA). This serves to minimize the possibility of a large diversion from the flight path. Conversely, if a safe vertical separation is not established as the result of the initial RA, the RA will strengthen (i.e. it will require an increase of vertical speed), or will reverse its direction (from climb to descent or vice-versa).

Typically, for "Climb" and "Descend" RAs a rate of at least 1500 feet per minute is required. That may increase if the RA is strengthened. Other RAs may require a reduction of vertical rate (to between 2000 and 500 feet per minute or to level-off). A pilot should respond to the initial RA within 5 sec., and within 2.5 sec. to reversed and strengthened RAs.

The surrounding traffic is shown to the pilots on a TCAS traffic display. The display purpose is to provide the crew with general traffic awareness and it must not be used for self-separation as TCAS horizontal tracking is limited. TCAS can track up to 30 aircraft but its

range is limited to 14 NM.

RAs will only be generated against aircraft that have their Mode S or Mode C operational. If both aircraft are TCAS equipped, the RAs will be coordinated through the Mode S link (i.e. TCAS will ensure that the RAs on each aircraft are issued in the opposite sense). Also, TCAS is designed to deal with multi-aircraft encounters.

TCAS has much better "knowledge" of surrounding traffic than any ground radar system. Every second, it interrogates the Mode C and Mode S transponders of nearby aircraft. Based on the replies received, TCAS will calculate the time needed to reach the Closest Point of Approach (CPA) between the two aircraft. For Mode S equipped aircraft, altitudes are processed by TCAS in 25-foot increments.

In contrast, Air Traffic Controllers see the traffic picture on their radar screens updated every 5-12 seconds (so the traffic picture is always "historic") and the altitudes are presented in 100-foot increments. Having much more current and precise information than is available to ATC, TCAS is normally better positioned to provide effective last-resort collision avoidance.

TCAS operates on relatively short time scales. The maximum generation time for a TA is 48 sec. before the CPA. For an RA the time is 35 sec. The time scales are shorter at lower altitudes (where aircraft typically fly slower). Unexpected or rapid aircraft manoeuvre may cause an RA to be generated with much less lead time. It is possible that an RA will not be preceded by a TA if a threat is imminent.

An RA will be generated only if the

intruder aircraft transponder is transmitting altitude. Otherwise, only a TA can be generated. Aircraft without an operating transponder will not be detected by TCAS. Moreover, TCAS RAs will be suppressed when stall or ground proximity warnings are generated in the cockpit and descent RAs are not issued close to the ground.

COMPLYING WITH RAs

Pilots are required to immediately comply with all RAs, even if the RAs are contrary to ATC clearances or instructions.

If a pilot receives an RA, he/she is obliged to follow it, unless doing so would endanger the aircraft. Complying with the RA, however, will in many instances cause an aircraft to deviate from its ATC clearance. In this case, the controller is no longer responsible for separation of the aircraft involved in the RA. This is why the pilot is obliged to report the RA to ATC as soon as possible.

When the pilot reports an RA, controllers are not allowed to modify the aircraft flight path until the pilot reports returning to the current air traffic control clearance. Traffic information may be provided as appropriate. Controllers, however, should take into account that traffic information may distract or confuse the pilot.

Currently, the pilot report is the only source of information available to the controllers to notify them that an aircraft is deviating from the ATC clearance. However, due to a high level of workload in the cockpit, pilot reports of an RA are often delayed or fragmented.

TCAS will announce a "Clear of Conflict"

message when the aircraft diverge horizontally. Following that message, pilots are required to return to their last clearance or instruction and report this action to ATC.

TCAS - STCA INTERACTIONS

Both TCAS and STCA operate in a similar time scale. Alerts are independently generated by both systems and - as no connection exists between them - they are not coordinated. An STCA alert will most likely prompt the controller to issue an avoiding instruction. Controllers must remember that, depending on the time to the CPA, TCAS might have already identified the conflict and issued or be about to issue an RA.

Although, as mentioned above, pilots are specifically mandated to follow RAs and ignore ATC instructions during the RA, everyday experience shows that in some cases pilots will choose to follow the controller's instructions rather than the RA, or will hesitate, delaying a prompt reaction to the RA and jeopardizing collision avoidance.

It is a natural reaction for controllers to take action to restore the separation when they recognize a hazardous situation. In the majority of cases, a vertical instruction will restore the separation quicker than a horizontal one. However, controllers should remember that when two aircraft are in close proximity, a TCAS RA might have already been issued or be about to be issued and any ATC vertical instruction may contradict the RA and unnecessarily confuse the pilot. If, for whatever reason, the pilot decides to follow ATC rather than the RA, that would further

deteriorate the spacing between the aircraft.

Until the RA has been reported by the pilot, the controllers cannot know whether the situation is being resolved by TCAS. If controllers are not aware of an RA, and if they are providing the aircraft with instructions for avoiding action, horizontal instructions are more appropriate as they will not adversely affect any vertical manoeuvre required by TCAS RAs.

UNNECESSARY ALERTS?

Another example of TCAS - ATC interactions is the so-called "nuisance" or "unnecessary RA". Often, pilots and controllers report that they have encountered an RA that was not really necessary and the separation would have been maintained without the RA. As TCAS does not know the ATC clearance or pilot's intentions, an RA will be produced based on the extrapolation of the aircraft's trajectory. These "unnecessary" RAs usually occur in cases of fast climbing or descending aircraft just before the cleared level is reached. To minimize the likelihood of unnecessary RAs, a recommendation has been issued to the pilots to reduce the vertical rates one flight level before the level-off.

Many controllers see these RAs as a nuisance. However, it must be remembered that they can be qualified as "unnecessary" or "nuisance" only in hindsight. As we know very well, traffic situations can develop quickly and unexpectedly. Some alerts that initially appeared unnecessary, in many cases "saved the day".

To minimize the likelihood of these

RAs, controllers are advised to provide traffic information to aircraft climbing or descending above or below other aircraft. That should increase crews' situational awareness and may prompt the pilot to reduce the vertical speed. Also, controllers may want to apply a horizontal off-set to avoid level-offs above/below another aircraft. That is especially important if both aircraft are climbing and descending, as the combined vertical rate would increase the chance of RAs being generated.

FORTHCOMING CHANGES

There are two important forthcoming changes in the TCAS area to which we would like to draw readers' attention.

First, an amendment to ICAO regulations is pending that will require pilots to report only those RAs requiring a deviation from ATC clearance. We will inform the readers when this change comes into effect.

The second change concerns updates to TCAS logic that would produce reversal RAs in cases when the intruder aircraft is not following the RAs. Additionally, it has been identified that a significant proportion of the most common RAs (i.e. "Adjust vertical speed, adjust") are flown incorrectly. Several factors that contribute to these incorrect pilot reactions have been identified. Despite efforts made, this problem seems to be difficult to address through training and, therefore, changes to TCAS logic are currently under investigation that will replace this RA with another, more intuitive one. When this work, expected to take a couple years, nears completion, we will provide an update to our readers.

² To address this problem, an automatic downlink of RAs to controller working position is under investigation.

POINTS TO REMEMBER

- Pilots are required to follow RAs. ATC instructions/clearances must be ignored once the RA has been issued.
- Controllers will not know about RAs until notified by the pilot.
- An RA may or may not command the pilot to deviate from the current ATC clearance.
- For avoiding action, horizontal instructions are more appropriate as they will not adversely affect any vertical manoeuvre required by TCAS RAs.
- Traffic information and horizontal offset may reduce the likelihood of "unnecessary RAs".

ADDITIONAL SOURCES OF INFORMATION:

ACAS II Training Brochure

http://www.eurocontrol.int/ra-download/Library/ACAS_training_ver20.pdf

EUROCONTROL ACAS bulletins

http://www.eurocontrol.int/msa/public/standard_page/ACAS_ACAS_Safety.html#Bulletins

FAA's Introduction to TCAS II version 7.0 brochure

<http://www.arinc.com/downloads/tcas/tcas.pdf>

EUROCONTROL Safety Nets page

<http://www.eurocontrol.int/safety-nets>

REMINDERS**ICAO Doc. 4444****ATC vs. TCAS...**

15.7.3.3 Once an aircraft departs from its clearance in compliance with a resolution advisory, the controller ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the resolution advisory. The controller shall resume responsibility for providing separation for all the affected aircraft when:

- a) the controller acknowledges a report from the flight crew that the aircraft has resumed the current clearance; or
- b) the controller acknowledges a report from the flight crew that the aircraft is resuming the current clearance and issues an alternative clearance which is acknowledged by the flight crew.

15.7.3.2 When a pilot reports a manoeuvre induced by an ACAS resolution advisory (RA), the controller shall not attempt to modify the aircraft flight path until the pilot reports returning to the terms of the current air traffic control instruction or clearance but shall provide traffic information as appropriate.

PHRASEOLOGY**FOR AVOIDING ACTIONS...**

12.4.1.8 e) **TURN LEFT (or RIGHT) IMMEDIATELY HEADING (three digits) TO AVOID (UNIDENTIFIED) TRAFFIC (bearing by clock-reference and distance).**

12.4.1.8 f) **TURN LEFT (or RIGHT) (number of degrees) DEGREES IMMEDIATELY TO AVOID (UNIDENTIFIED) TRAFFIC AT (bearing by clock-reference and distance).**

REPORTING RA...

12.3.1.2 r) ... after modifying vertical speed to comply with an ACAS resolution advisory... **[callsign] TCAS CLIMB (or DESCENT).**

12.3.1.2 z)... when unable to comply with a clearance because of an ACAS resolution advisory... **[callsign] UNABLE, TCAS RESOLUTION ADVISORY.**

12.3.1.2 x) ... after returning to clearance after responding to an ACAS resolution advisory **[callsign] TCAS CLIMB (or DESCENT) COMPLETED (assigned clearance) RESUMED.**