WHAT'S GOING ON UP THERE?

ASSESSMENT OF PILOT COMPLIANCE WITH TCAS RA

TCAS Resolution Advisories are not everyday events for pilots, but dealing with them is part of the job. So how many RAs are flown correctly? **Stanislaw Drozdowski** and **Mateusz Michalski** report on a study of nine million flight hours, with some concerning results.

KEY POINTS

- **Anecdotal evidence suggests that pilot responses are often neither prompt nor accurate. To obtain a wider view on the quality of pilot response, we performed an assessment using radar data.**
- **Only 38% of RAs were classified as "followed", and 58% of all RAs were flown in the opposite direction or not followed.**
- **The percentage of RAs followed 12 seconds after the RA improved markedly. But almost a third of RAs were not flown correctly and the proportion of excessive reactions doubled.**
- **Although the assessment using radar data comes with some limitations, it clearly indicates that the level of pilot compliance with TCAS resolution advisories is low.**
- **Aircraft operators should monitor carefully crew performance, to understand what influences performance, and take corrective measures as necessary.**

The development and implementation of the Traffic alert and Collision Avoidance System (TCAS) was driven by aviation accidents. When there is a risk of collision, TCAS will issue a Resolution Advisory (RA) telling pilots how to change or limit the vertical rate to avoid a collision, so a prompt and accurate pilot response to all RAs is particularly important. While pilot responses are typically only assessed in serious incidents, anecdotal evidence suggests that pilot responses are often neither prompt nor accurate. To obtain a wider view on the quality of pilot response, we decided to perform an assessment using radar data.

The radar data for this assessment was gathered in core European airspace over a period of 12 months. An aircraft's transponder downlinks Mode S radar messages providing details of RAs and RA termination on each radar interrogation, as well as details of the threat aircraft. These messages – RA downlink messages – were used for this study.

The assessment of pilot compliance with TCAS RAs using radar data comes with certain limitations. Firstly, radar data is subject to surveillance delays (due to radar rotation) – any downlinked event occurred up to three seconds before the time of downlink. Secondly, the aircraft's altitude and vertical rate may be inaccurately determined by the ATC system tracker. In order to deliver optimal display performance of radar data to air traffic controllers, the ATC system tracker software makes assumptions regarding the estimated position of tracks and approximates the data accordingly. Finally, for some RAs, Mode S downlink messages do not provide all the details required for the assessment.

Ideally, the assessment of pilot compliance with RAs should be conducted based on airborne recordings (Flight Data Recorders or dedicated TCAS recorders), which provide a level of detail that is not available from ground-based systems. Aircraft operators regularly assess compliance of their crews. However, they typically do not share the results of their studies. While results coming from individual carriers may be occasionally available, that does not provide a system-wide view.

How many RAs are happening up there?

In the first step of our study, we examined the frequency of RAs. The radar data consisted of over nine million flight hours and contained 1,022 encounters (events in which at least one aircraft received an RA) and 1,373 RAs, i.e., an RA occurred every 6,567 flight hours, making an RA an infrequent event.

In the majority of encounters (84%), only one aircraft involved in the encounter received an RA. This was because of one of two reasons: the threat aircraft was not TCAS equipped, or the geometry of the conflict required an RA for just one aircraft.

Low? High? Or everywhere?

Most RAs occurred above FL180 (67%). The distribution of initial corrective RAs (i.e., RAs requiring a change of aircraft's vertical rate) by altitude is shown in Figure 1.

What type of RAs are occurring up there?

When two aircraft are converging horizontally and with high vertical rates (i.e., climbing or descending towards their cleared levels 1000 feet apart), TCAS may trigger an RA even though the ATC separation is correctly applied. This is because TCAS calculates a risk of collision based on the closing speed and vertical rates. Therefore, high vertical rates while approaching the cleared level may cause the TCAS logic to predict a conflict with aircraft at the adjacent level. In these cases, TCAS will

Figure 1: Altitude distribution for first corrective RAs

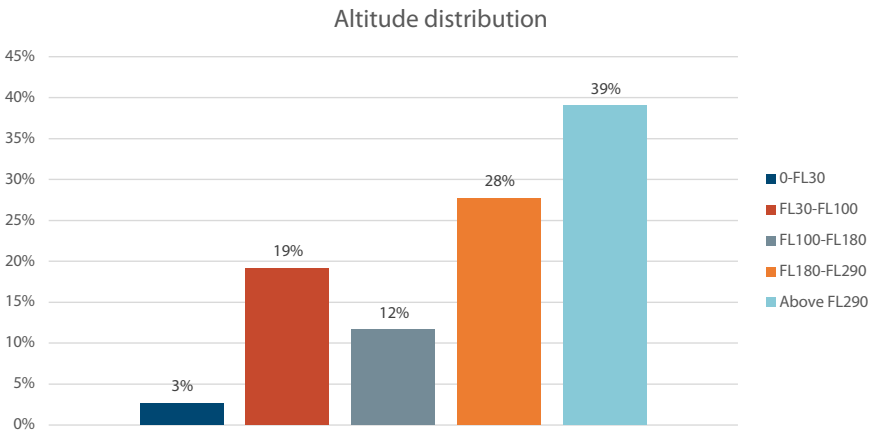
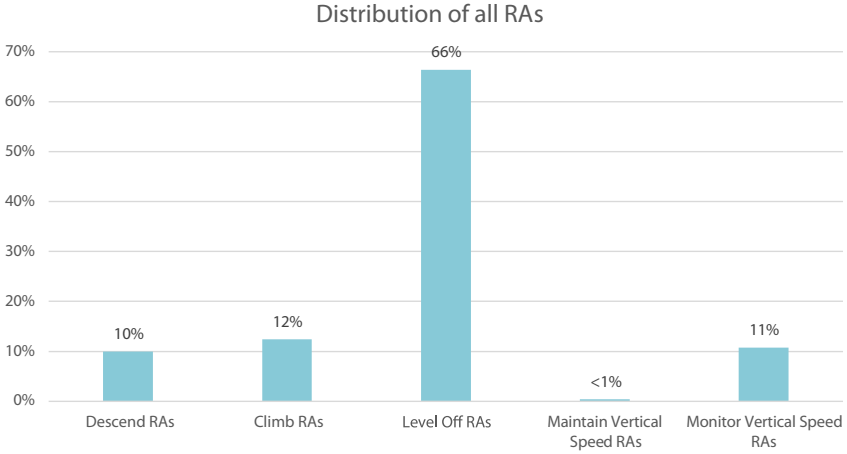


Figure 2: All first RAs taken into the assessment



issue a Level Off RA, instructing the pilot to reduce the vertical rate to 0 ft/min. In congested European airspace this is a common scenario, so quite predictably Level Off RAs top the list of all RAs (66%). The distribution of all recorded RAs is shown in Figure 2.

So, what is really going up there? Do pilots follow RAs?

A simple answer is "not quite". ICAO standards assume the pilot will start response to an RA within five seconds. Depending on the vertical rate at the time when the RA was issued, it may take the pilot more than five seconds to reach the rate required by the RA. Given that, and the limitations of the radar data, only RAs with duration longer than eight seconds were initially evaluated.

In line with the IATA/EUROCONTROL guidance material (IATA/EUROCONTROL, 2020), the pilot responses were categorised as follows:

- Followed: when the required vertical rate was achieved within eight seconds after the RA.
- Not followed (too weak response): when any change was not sufficient to meet the vertical rate required by the RA. Too weak a response carries a risk that the required vertical spacing will not be achieved.
- Opposite: when the achieved vertical rate was in the opposite vertical direction to the required rate.
- Excessive: when the achieved vertical rate exceeded the required value. Any excessive responses increase the risk of a follow-up conflict (with another aircraft) and are disruptive to ATC.

The overall picture is not very encouraging (see Figure 3) with only 38% classified as "followed". More than half (58%) of all RAs were flown in the opposite direction or not followed.

The best compliance was achieved for Level Off RAs (40% followed), but also approximately 40% of Level Off RAs were flown in the opposite direction (i.e., the vertical rate was increased rather than reduced). For Climb and Descend RAs, pilot responses were classified in the range of 20-25% as

Figure 3: Pilot compliance with first RAs – 8 seconds or longer

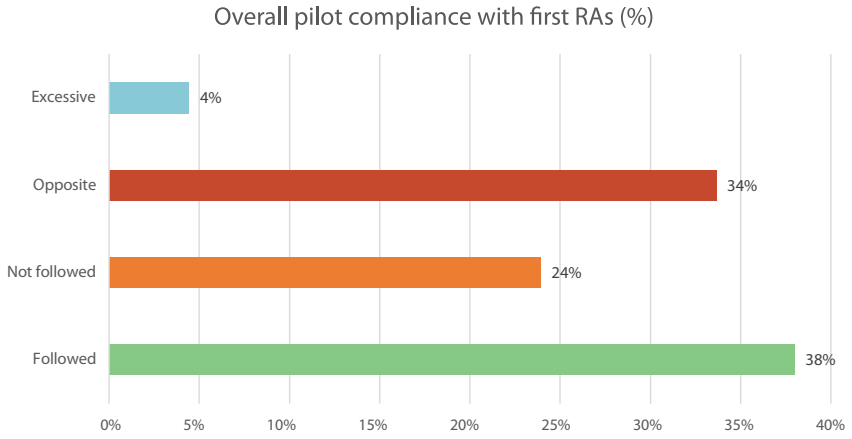
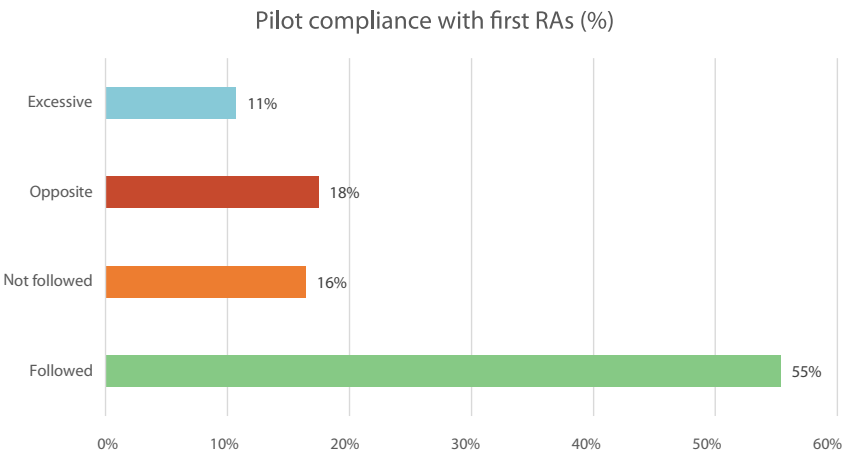


Figure 4: Pilot compliance with RAs – 12 seconds or longer



followed; however, 57-65% of these RAs were not followed correctly and 6-20% were flown in the opposite direction.

Given the poor level of response determined at eight seconds after the initial RA (or more precisely, eight seconds after the RA has been downlinked to the ground system, so up to 11 seconds after the RA), pilot responses were further assessed at 12 seconds after the RA, provided the RA lasted longer than 12 seconds. Initial RAs with a duration shorter than 12 seconds were disregarded. The expectation was that these responses would show an improvement associated with the time frame extension, thus giving the pilots more time to respond and achieve the required vertical rate. Indeed, as shown in Figure 4 the percentage of RAs followed improves markedly. Still, almost a third of RAs are not flown correctly. Interestingly, the proportion of excessive reactions doubled.

What happens if RAs are not followed?

In cases where the initial RA will not provide sufficient vertical spacing, the RA will be modified to either increase the vertical rate or reverse the vertical sense of the initial RA. For strengthening or reversal RAs, prompt and correct pilot responses are particularly important. On the other hand, if the collision avoidance logic determines that the response to the initial RA will provide sufficient vertical spacing, the initial RA will be weakened to limit any unnecessary altitude deviation.

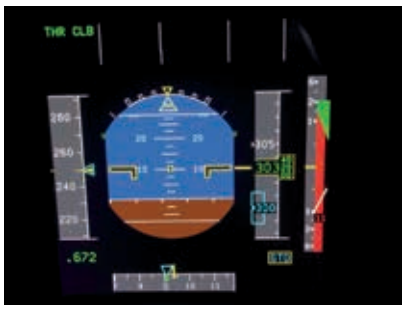
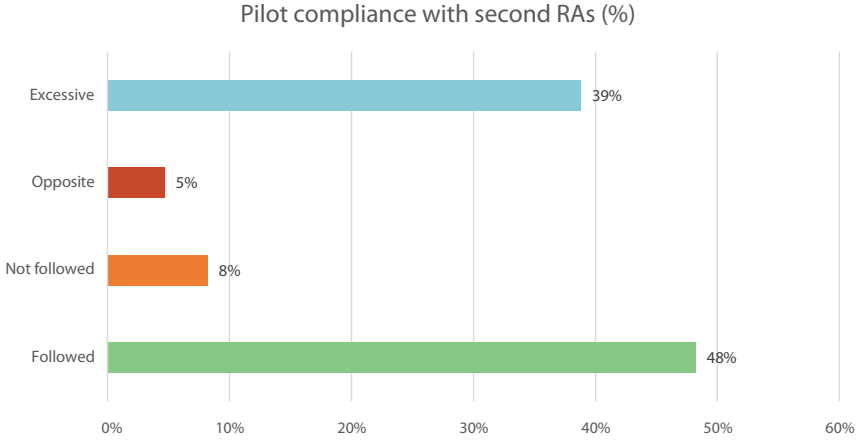


Figure 5: Pilot compliance with second RAs - 8 seconds or longer



Secondary RAs were issued in 171 cases (12% of all RAs) and most of them (over 81%) were weakening RAs. Almost a fifth of RAs were strengthened or reversed and half of them were not followed or were flown in the opposite direction. This is particularly concerning. Globally, the compliance with the second RA is much better than with the first RA (48% vs 38%; see Figure 5).

Some RAs are not followed, but does that make a difference?

The study has revealed that a significant proportion of RAs are not flown correctly. Is this just a procedural breach or does it degrade safety? Unfortunately, the study could not determine whether safety is degraded if pilots do not follow RAs correctly. However, it is reasonable to conclude that any incorrect responses to RAs in critical circumstances may lead to a collision. Such circumstances cannot be assessed until after the event.

The study found a number of cases where, in the absence of correct pilot response, vertical separation at the closest point of approach was significantly reduced. However, these cases could not be used to give quantitative assessments because they were not frequent enough to draw statistically significant conclusions. Moreover, the achieved vertical separation was affected by additional factors, including: pilot responses to modified RAs; manoeuvres of the other aircraft in the encounter; in case of Level Off RAs (which are typically issued when the aircraft are still separated) any degradation of separation is difficult to detect.

"The level of pilot compliance with TCAS resolution advisories is low. These results are in line with anecdotal evidence from various sources."

Conclusions

Although the assessment using radar data comes with some limitations (which could be overcome if less readily available airborne data were used), it clearly indicates that the level of pilot compliance with TCAS resolution advisories is low. These results are in line with anecdotal evidence from various sources.

Prompt and correct responses are particularly important for reversal and strengthening RAs. Unfortunately, in over half of the cases pilots did not react correctly to these RAs. This again emphasises the need for aircraft operators to monitor carefully crew performance, to understand what influences performance, and take corrective measures as necessary.

References

EUROCONTROL (2020). *The assessment of pilot compliance with TCAS RAs, TCAS mode selection and serviceability using ATC radar data.* Edition 1.0. October 2020. Available at: https://www.skybrary.aero/bookshelf/books/5842.pdf

IATA/EUROCONTROL (2019). *Guidance material: Performance assessment of pilot compliance to traffic alert and collision avoidance system (TCAS) using Flight Data Monitoring (FDM).* Edition 2. November 2020, Available at: https://bit.ly/3k5HOmA

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Note: Since the report on pilot compliance with TCAS RAs has been published, EUROCONTROL have received several comments. To address these comments, the study is being expanded to provide the view on pilot compliance with different granularity and using another assessment approach. Once the update is ready, it will be published on SKYbrary.

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