

Wrong reaction to "Adjust Vertical Speed" RAs

Editorial

ACAS operational monitoring programmes have shown that the TCAS RA display is occasionally misinterpreted by flight crews. Occurrences seem to be linked to the type of RA with the aural, 'Adjust Vertical Speed, Adjust'. This RA is posted either as an initial RA, or as a weakening RA which can follow a "Climb" or "Descend" RA.

"Adjust Vertical Speed" RAs are the most frequent RAs triggered by TCAS II. It is essential that these RAs are followed accurately.

This ACAS Bulletin, through explanations and illustration of actual events, seeks to address this operational issue. It shows clearly the flight crew responses which are expected, both to initial reduce vertical speed RAs, and to weakening RAs. In addition, it highlights the risks which can be associated with inaccurate responses to these RAs.

Finally, earlier Bulletins have emphasised the need to 'Follow the RA'. Amendment 12 to the ICAO PANS-OPS, Doc 8168, includes reinforced ACAS provisions which make this clear. Adherence to the PANS-OPS ACAS provisions will help ensure that the ACAS safety benefit is maximised.

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"Adjust Vertical Speed" as an Initial RA

TCAS II is designed to generate an "Adjust Vertical Speed" RA instead of a stronger "Climb" or "Descend" RA, whenever possible.

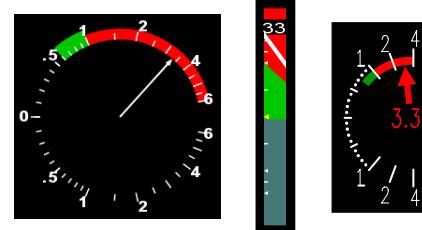
The objective is to solve a predicted risk of collision by a reduction of the current vertical speed, either in climb or in descent, while maximising compatibility with the ATC clearance. The reduction is associated with four different values: 0, 500, 1000 or 2000 fpm.

This type of RA is mainly issued when an aircraft is climbing or descending to level-off 1000 ft from another aircraft. It reinforces the controller's clearance and helps to ensure successful level-off at the cleared flight level. Operational monitoring in coordination with a major European airline has confirmed that 90% of RAs in 1000 ft level-off encounters were "Adjust Vertical Speed" RAs.

Example of Initial "Adjust Vertical Speed" RA

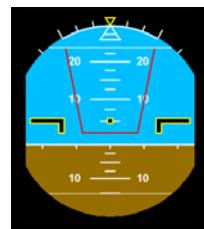
In the following example, the RA requires the flight crew of an aircraft climbing at 3300 fpm to reduce the rate of climb to no more than 1000 fpm.

RAs are often displayed on **Vertical Speed Indicators** (VSI). There are three types of VSIs: the dedicated instantaneous VSI, the vertical speed tape on the Primary Flight Display (PFD), and the semi-circular VSI on the PFD.



The vertical speeds to be **avoided** are displayed with a **red** area and the **required** ones with a **green** area. The reduction of rate of climb will put the vertical speed needle into the green area.

On some aircraft, RAs are displayed by a **pitch cue**, which corresponds to the required vertical speed, on the Electronic Attitude Display Indicator (EADI).



Only the pitches to be **avoided** are displayed with a **red** area (i.e. no green area). The reduction of rate of climb will put the current pitch marker outside the red trapezoid.

Note: the RA displays depicted in this bulletin have been slightly modified to aid clarity.

Misinterpretation of Initial "Adjust Vertical Speed" RAs

In the short period of 14 months, operational monitoring programmes have identified at least 12 events where the flight crew manoeuvred the aircraft opposite to the sense of an initial "Adjust Vertical Speed" RA (other possible occurrences are still to be confirmed). In these events, the flight crew of an aircraft cleared to level-off 1000 ft from another aircraft misinterpreted the RA and increased, rather than reduced, the aircraft's vertical speed.

These wrong reactions caused **altitude busts** and losses of standard ATC separation. However, a vertical distance was maintained between the two aircraft since the other flight crew received and followed "Climb" or "Descend" RAs.

The RA display of the aircraft involved in all of these events was either a vertical speed tape, or a semi-circular VSI on the PFD. However, a similar event has been recently identified involving an aircraft where an RA is displayed using a pitch cue on the EADI.

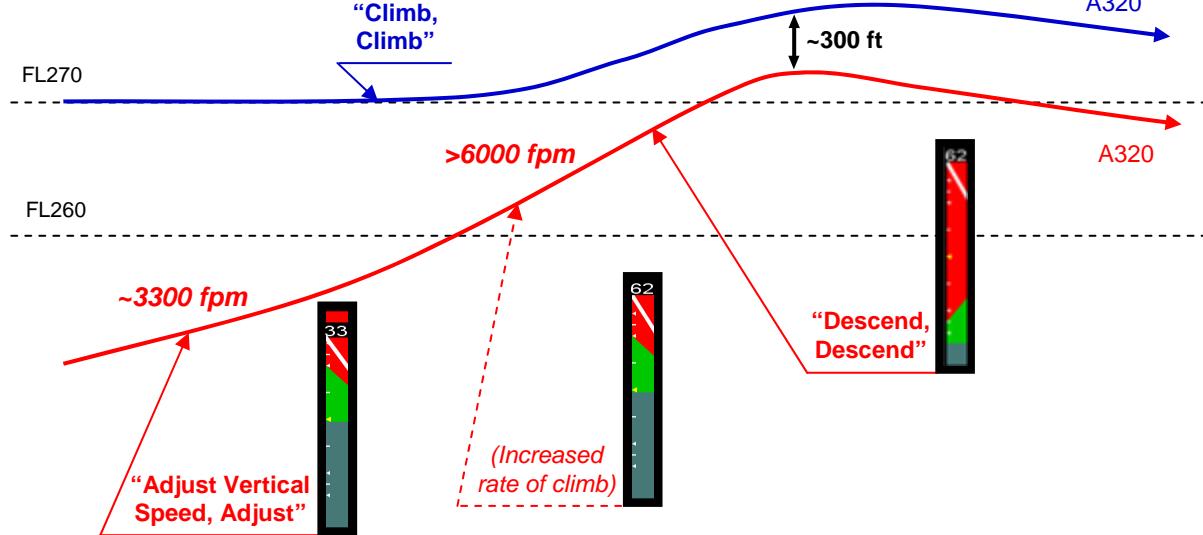
Event 1: Misinterpretation of Initial “Adjust Vertical Speed” RA

An A320 is level at FL270, heading South.

A second A320 is cleared to climb to FL260, heading North. Its rate of climb is about 3300 fpm. When passing through FL253, its TCAS triggers an initial “Adjust Vertical Speed” RA requiring a reduction in the rate of climb to 1000 fpm.

However, the flight crew misinterprets the RA and reacts opposite to it: the rate of climb is increased to more than 6000 fpm instead of being reduced. The closure rate increases between the two aircraft and the RA is strengthened to a “Descend” RA. The flight crew follows this second RA but the manoeuvre takes time to be effective.

As a result of the wrong reaction to the “Adjust Vertical Speed” RA, the climbing A320 busts its flight level by 1200 ft and the level A320 receives a “Climb” RA, which the flight crew follows. **The vertical distance is 300 ft with 0.8 NM.**



Event 2: Correct reactions to Initial “Adjust Vertical Speed” RAs

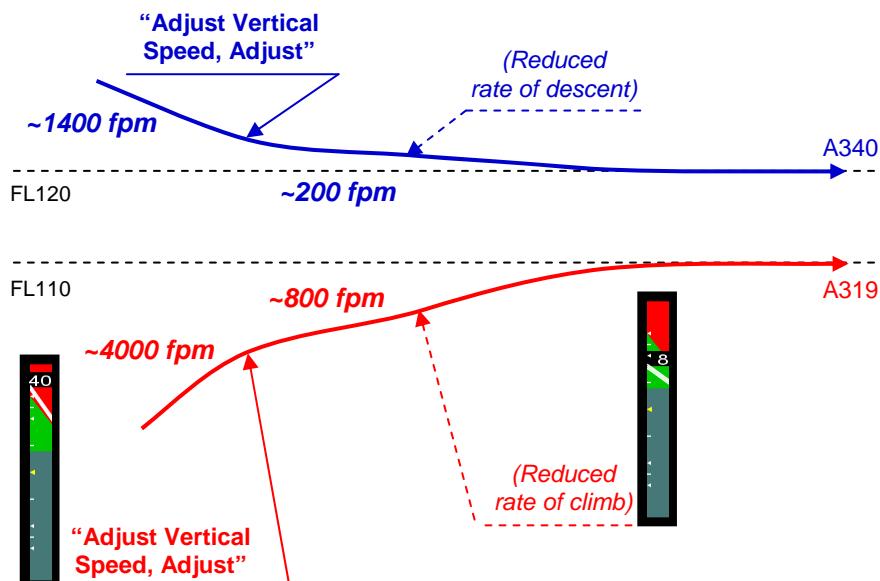
An A340 on approach is descending from FL140 to FL120 with a moderate vertical speed (about 1400 fpm).

An A319 is climbing on departure to FL110 with a high vertical speed (about 4000 fpm).

The aircraft are converging and will pass 0.1 NM apart but at cleared flight levels separated by 1000 ft.

The simultaneous horizontal and high rate of vertical convergence causes TCAS II to trigger “Adjust Vertical Speed” RAs before the aircraft have levelled off at their cleared flight levels:

- the A340 is required to reduce its rate of descent to 1000 fpm;
- the A319 is required to reduce its rate of climb to 2000 fpm.



The flight crews correctly follow these RAs, reducing their vertical speed below the maximum value required by TCAS II.

As a result, both aircraft continue to climb and descend with reduced vertical speeds. Then they level off at their cleared flight level; there is no disruption to ATC.

If the flight crew had correctly reduced the rate of climb as required by TCAS, simulations show that not only would the climbing A320 have levelled off correctly, but that the level A320 would not have received an RA.

Investigation of this incident revealed that **two factors** combined to contribute to misinterpretation of the RA :

- the RA display on the vertical speed tape is small and could be difficult to interpret and to follow
- the “Adjust Vertical Speed, Adjust” aural message does not specify the sense of the required manoeuvre

Several occurrences have been identified by operational monitoring programmes.

“Adjust Vertical Speed” as a Weakening RA

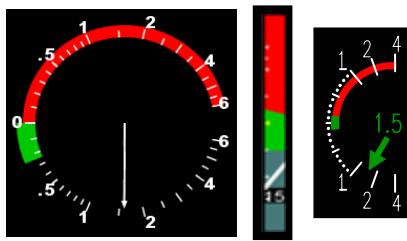
This RA is generated after a “Climb” or a “Descend” RA, when a safe vertical distance has been achieved. It prompts the flight crew **to stop the climb or descent** to minimise the overall vertical deviation from the cleared flight path.

The objective is **to improve compatibility with ATC by avoiding excessive deviations from clearance**, which could potentially generate subsequent conflicts.

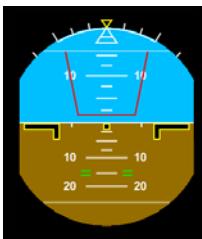
Example of Weakening “Adjust Vertical Speed” RA

In the following example, the “Adjust Vertical Speed” RA prompts the flight crew to level-off after a reaction to a “Descend” RA.

On a VSI, the vertical speed needle is outside the **red** area. Flying the aircraft to put the vertical speed needle into the **green** area will achieve a level-off.



On an EADI, the current pitch marker is outside the **red** trapezoid area. Flying the aircraft to put the current pitch marker on the bottom line of the **red** trapezoid will achieve a level-off.



Excessive deviations due to lack of reaction to weakening RAs

From the introduction of TCAS II, operational monitoring programmes have highlighted that a significant proportion of deviations from clearance in response to RAs are excessive.

Analysis showed that some flight crews did not respond to weakening RAs, and maintained the vertical rate required by the initial RA until the “Clear of Conflict”. They then returned to the initial clearance. Disregarding the weakening RA often causes an unnecessarily large deviation, which has occasionally induced a conflict with a third aircraft.

The current TCAS II (i.e. version 7) addressed this issue on VSI and vertical speed tape RA displays by adding a green area to the indication of the weakening RA. The aural annunciation was also changed from “Monitor Vertical Speed” to “Adjust Vertical Speed, Adjust”. These changes are designed to encourage flight crews to react correctly to weakening RAs.

Nonetheless, in 2002, about 30% of deviations were still greater than 600 ft (and some more than 1000 ft). Although a few of them were indeed necessary, a very large proportion were not.

Event 3: Weakening “Adjust Vertical Speed” RA not followed

A Fokker 100, cleared to descend to FL110, levels off at the cleared flight level.

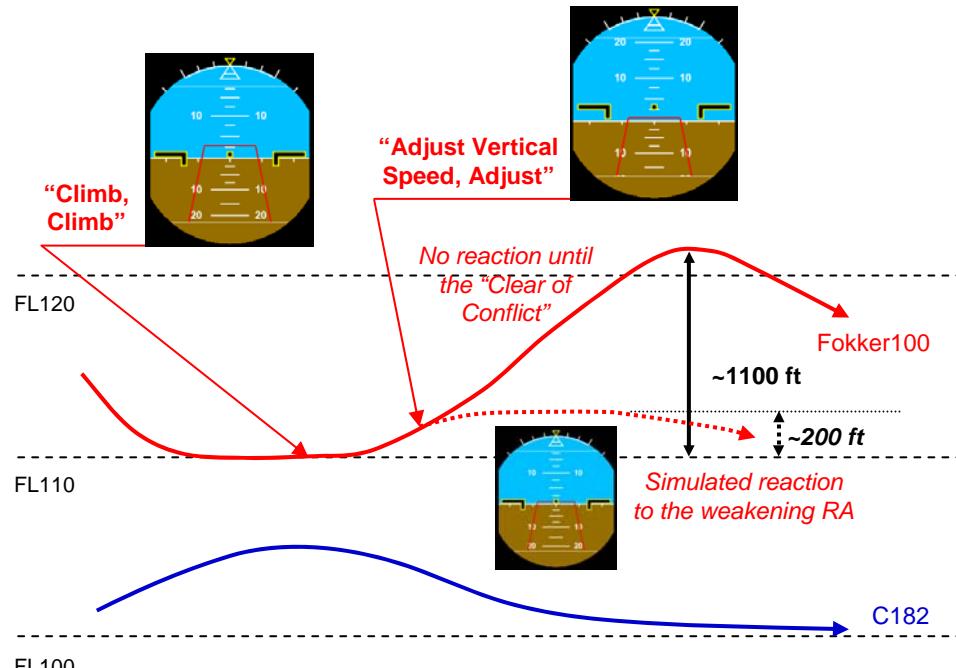
A C182, on an opposite route, is cleared to climb to FL100. However, it busts its flight level by 700 ft before starting to descend back to FL100.

Due to the horizontal convergence and the small vertical distance between the aircraft, the Fokker 100 receives a “Climb” RA, which the flight crew follows.

10 seconds after the “Climb” RA, a weakening “Adjust Vertical Speed” RA is generated since a safe vertical distance has been achieved and the aircraft are diverging vertically.

However, the flight crew **continues to climb** and only stops climbing once the “Clear of Conflict” is issued.

This excessive deviation was unnecessary and resulted in **an eventual deviation of 1100 ft**. Although not the case here, it could have generated a subsequent conflict.



Simulations indicate that if the Fokker 100 flight crew had followed the weakening RA, the deviation would have been approximately 200 ft.

Airline operational feedback on initial "Adjust Vertical Speed" RAs

A major European airline is routinely monitoring flight crew responses to RA indications. It has identified an issue related to the "Adjust Vertical Speed" RAs.

- **About 4% of initial responses are wrong and opposite to the RAs;**
- **Most of the errors are quickly corrected but a few serious events have occurred.**

Some contributing factors have been identified by this operator:

- Only "Climb" and "Descend" RA scenarios are exercised on its flight simulators. An "Adjust Vertical Speed" RA can only be generated subsequently, depending upon the pilots' reactions;
- The aural "Adjust Vertical Speed, Adjust" does not specify the direction of the manoeuvre required;
- Interpretation of the RA display on the vertical speed tape of the PFD is less intuitive than the pitch cue.

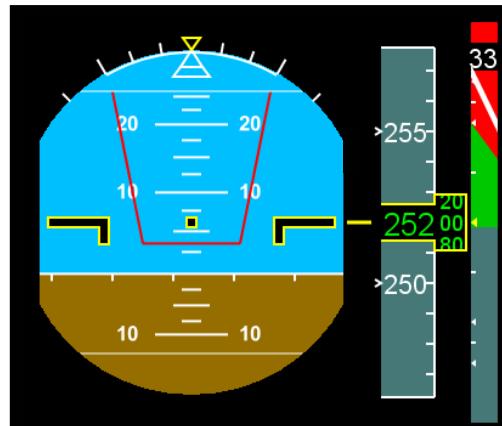
This experience is shared by some other major European airlines.

Advantages of a combined VSI and EADI RA display

The RA display on the PFD vertical speed tape is reported to be sometimes difficult to interpret. This seems to have been the case in some initial "Adjust Vertical Speed" RAs, as noted in this Bulletin. A problem of interpretation may also exist for "Increase Climb"/"Increase Descent" RAs or "Maintain Vertical Speed" RAs.

On the other hand, the RA display on the EADI can also be difficult to interpret in the case of a weakening RA, due to the absence of a green area. In addition, it does not inform the flight crew of the vertical speed required by the RA.

Nonetheless, many aircraft operators and pilots consider that the RA display using pitch cue on the EADI is superior to other types of RA displays.



However, an RA display on both the EADI and the vertical speed tape could improve the interpretation by flight crews of "Adjust Vertical Speed" RAs, and other types of RA. This figure shows a possible combined RA display on both the EADI and the vertical speed tape.

Conclusion

"Adjust Vertical Speed" RAs can be misinterpreted. As a consequence, a number of opposite manoeuvres have occurred, and excessive deviations from clearance have also taken place.

Two factors contributing to the misinterpretation of "Adjust Vertical Speed" RAs have been identified:

- the aural message "Adjust Vertical Speed, Adjust" does not specify the sense of the required manoeuvre;
- the RA display on the vertical speed tape and on the semi-circular VSI on the PFD may sometimes be difficult to interpret.

Therefore, it is necessary to observe carefully the RA display when manoeuvring, bearing in mind that an "Adjust Vertical Speed" RA **always requires a reduction of the vertical speed**.

Aircraft operators and training organisations should ensure that "Adjust Vertical Speed" RAs:

- are explained clearly in ACAS training courses, together with the expected pilot response;
- are included in flight simulation scenarios.

It is essential that **pilots follow these RAs accurately**, both when issued as an initial RA, (the most frequent RA issued) and as a weakening RA.

Prompt and accurate response to :

- an initial "Adjust Vertical Speed" RA will maximise safety, help to minimise the severity of the RA encounter, and improve compatibility with ATC;
- a weakening "Adjust Vertical Speed" RA will minimise any ATC disruption, and help to prevent any potential subsequent conflict.

"Adjust Vertical Speed" RAs always require a reduction of the vertical speed

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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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