

Recent reports of two accidents that resulted in serious injuries when the pilots performed excessive maneuvers during traffic-alert and collision avoidance system (TCAS) resolution advisories (RAs) suggest that while pilot educational efforts should continue to focus on the need to respond promptly and correctly to RAs, they also should emphasize that a gentle and smooth response is sufficient.

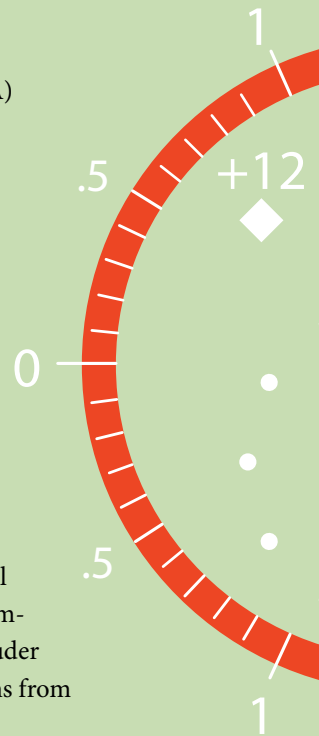
There is no need to panic when an RA is generated because enough time is available to carry out the recommended maneuver with normal control inputs. “Limit the alterations of the flight path to the minimum extent necessary to comply with the RA,” says the International Civil Aviation Organization (ICAO),¹ which requires “airborne collision avoidance system equipment” — that is, the RA-generating TCAS

II equipment — aboard large turbine airplanes in international commercial operations. ICAO also recommends that *all* aircraft be equipped with TCAS.

A brief description of how TCAS works might help in understanding how the system is intended to be used. Basically, TCAS obtains information about other aircraft up to 30 nm (56 km) away by transmitting interrogation signals that trigger replies from their altitude-encoding or selective-address transponders. The transponder replies yield information about the range, bearing and altitude of the other aircraft. From this information, TCAS computes the *closest point of approach* (CPA) for each aircraft, whether that point is within a programmed *protected volume* around the host aircraft and when the other aircraft, the *intruder*, will reach that point.

A traffic advisory (TA) is generated if the other aircraft will reach a CPA in the outer protected volume within a specific amount of time that varies from about 20 seconds below 1,000 ft to 48 seconds above Flight Level (FL) 200 (approximately 20,000 ft). A TA consists of an aural advisory — “traffic, traffic” — and a visual advisory, in which the symbol representing the intruder on the traffic display turns from white to amber.

A TA prompts the flight crew to use their traffic display as an aid in establishing visual contact with the intruder and to prepare themselves for a possible RA.

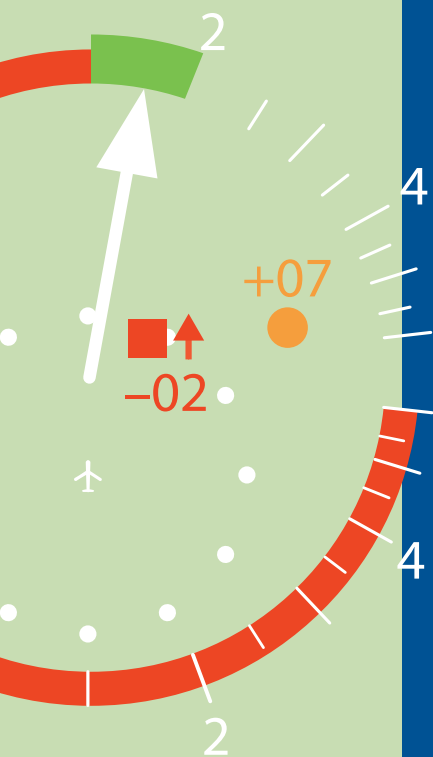


Easy Does It

BY MARK LACAGNINA

TCAS resolution advisories require rapid — but not radical — response.





Five-Second Margin

An RA is generated if the intruder continues to close and the CPA is projected to be within the inner protected volume of the host aircraft. Alert lead times range from about 15 seconds at 1,000 ft to 35 seconds above FL 200. (No RAs are issued below 1,000 ft.) The intruder’s symbol turns red on the traffic display, and an aural advisory to “climb,” “descend” or “adjust vertical speed, adjust” is issued. Red and green arcs appear on the RA display, typically built into the vertical speed indicator (VSI), to show the climb or descent rates that should be achieved or avoided.

The RA alert time includes a margin of five seconds for crew response. “For TCAS to provide safe vertical separation, initial vertical speed response is expected within five seconds of when the RA is displayed,” says U.S. Federal Aviation Administration Advisory Circular (AC) 120-55B, *Air Carrier Operational Approval and Use of TCAS II*.

“Satisfy RAs by disconnecting the autopilot, if necessary, using prompt, positive control inputs in the direction and with the magnitude TCAS advises,” the AC says. “To achieve the required vertical rate (normally, 1,500 fpm climb or descent), first adjust the aircraft’s pitch using the suggested guidelines [Table 1]. Then, refer to the VSI and make all necessary pitch adjustments to place the VSI in the green arc.

“Excursions from assigned altitude, when responding to an RA, typically should be no more than 300 to 500 ft to satisfy the conflict.”

‘Excessive Maneuver’

Table 1 shows that the recommended initial pitch adjustment is 5 to 7 degrees when airspeed is below 200 kt. On Oct. 3, 2005, a cabin crewmember was seriously injured when an Embraer 170 was pitched 14 degrees in response to an RA.

The U.S. National Transportation Safety Board (NTSB) report on the accident is based on a limited investigation and provides relatively few details.² The airplane was being

operated by Shuttle America as United Express Flight 7627 from Montreal to Washington Dulles International Airport with 41 passengers, two cabin crewmembers and two flight crewmembers. The first officer was the pilot flying.

The 170 was southbound at 3,000 ft in visual meteorological conditions (VMC) and about to turn right base for Runway 01R at Dulles when the airport traffic controller advised the flight crew of northbound traffic ahead at 2,500 ft. The controller told the Embraer crew to fly a southwesterly heading. “About the same time, the airplane’s [TCAS] alerted the crew to the traffic and issued [an RA] to climb the airplane,” the report said.

Recorded flight data indicate that the first officer increased the pitch attitude to 14 degrees nose-up, resulting in a peak vertical acceleration of +2.0 g — that is 2.0 times standard gravitational acceleration. NTSB said that the “excessive maneuver” was the probable cause of serious injuries, including a broken leg, sustained by a cabin crewmember. The 170 was not damaged.

The report said that if the first officer had followed pitch guidance on his primary flight display while responding to the RA, a vertical acceleration of only +0.75–1.25 g would have resulted.

Roller Coaster

Injuries were more numerous on Nov. 16, 2006, when a Boeing 757-200 was maneuvered excessively during an RA over the East China Sea.

Recommended Initial Reaction to ‘Climb’ or ‘Descend’ RA	
Airspeed	Pitch Adjustment
0.80 Mach	2 degrees
250 KIAS below 10,000 ft	4 degrees
Approach below 200 KIAS	5 to 7 degrees

RA = traffic-alert and collision avoidance system resolution advisory; KIAS = kt indicated airspeed

Source: U.S. Federal Aviation Administration

Table 1



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A flight attendant suffered a broken leg when this Embraer 170 pulled 2 g during an excessive RA maneuver.

The 757, operated by Far Eastern Air Transport as Flight EF306, was en route from Taipei, Taiwan, to Jeju Island, South Korea, according to the report by the Aviation Safety Council (ASC) of Taiwan.³

The 757 departed from Taipei at 0041 coordinated universal time (UTC; 0841 local time) with 129 passengers, six cabin crewmembers and two flight crewmembers. The captain was the pilot flying.

The 757 was northbound in VMC at FL 390 and about 100 nm (185 km) from the destination at 0202 UTC when the flight crew was told by a controller at the Incheon (South Korea) Area Control Center to descend to FL 310. The 757 crew turned on the cabin seat belt sign before beginning the descent.

A Boeing 777 operated by Thai Airways was southbound at FL 340 on the same airway. TAs were generated aboard both aircraft when they were 12 nm (22 km) apart and 48 seconds from the projected CPA.

The 757 was descending through 34,052 ft at about 1,900 fpm when the TA was generated. Two seconds later, the controller said, “Far Eastern 308, stop, uh, immediately clear descend.”

The controller explained to investigators that he had “lost awareness of the converging traffic for a minute” while he concentrated on identifying another aircraft on his radar display. When he returned his attention to the 757 and 777, he saw that they were about 13 nm (24 km) apart and that the 757 was at a higher altitude, and “instinctively” told the 757 crew to stop their descent.

While issuing that instruction, he saw that the 757’s displayed altitude was 33,800, “so I thought that the urgent situation was over, and I instructed [the 757 crew] to descend more quickly.” He

also told the 777 crew to immediately turn right to a heading of 270 degrees.

The report said that the controller had failed to use standard phraseology that required use of the term “correction” between the instruction to “stop” and the instruction to “descend.” The controller also used the wrong call sign — 308, rather than 306.

Confusion Reigns

The 757 captain did not thoroughly understand the controller’s radio transmission but believed that he had been told to “stop descent.” He engaged the autopilot altitude-hold mode, and the 757 leveled at 33,800 ft. The report said that if the captain had continued the descent, there would have been no conflict.

The captain’s attention then was drawn to the TA depicted on his traffic display. “I noticed that the color of the traffic symbol turned from white to amber then red very quickly,” he told investigators. The TA changed to an RA to descend.

At the same time, a coordinated RA to climb was generated aboard the 777. The distance between the aircraft was 9 nm (17 km), and the projected time to CPA was 35 seconds. The 777 crew responded promptly and correctly to their RA.

The 757 first officer erroneously told the controller that they were responding to a “TCAS climb” RA. The controller did not understand the transmission and replied, “Roger, now descend. Descend.” The first officer said, “Negative. We follow TCAS.”

The report indicated that the 757 captain’s initial response to the RA was in accordance with the TCAS manufacturer’s recommendation that “a prompt, smooth pitch change of 2 degrees to 6 degrees should be sufficient to resolve

nearly all conflicts.” The report said that a pitch change of 2 degrees would have resulted in a descent rate of about 1,600 fpm, which would have been adequate to resolve the conflict.

The captain told investigators, “When the RA aural tone ‘descend, descend’ was issued, I followed the TCAS red T-bar on the ADI [attitude director indicator] and pushed down the aircraft smoothly.

“Then, I looked outside [and saw] a flying object approaching rapidly in front of us. So, I pushed down the aircraft hard to avoid the traffic.”

‘Bounced ... and Dropped’

Recorded flight data indicated that the 757’s pitch angle changed from +4 degrees to –18 degrees in four seconds. “The maximum vertical acceleration [was] –1.06 g,” the report said. Descent rate peaked at 12,000 fpm (Figure 1).

The report indicated that the captain’s recovery also was excessive, resulting in a peak vertical acceleration of +2.58 g for two seconds as the 757 was leveled at FL 310.

“When the occurrence happened, some passengers were bounced up to the cabin ceiling and dropped onto seat backs, handrails or cabin equipment,” the report said. Unsecured cabin equipment, including a duty-free cart that was being moved to the galley by cabin crewmembers, became projectiles.

Four passengers sustained serious injuries. One seated near the rear of the cabin “bounced up several times and suffered an intracranial hemorrhage,” the report said, noting that she also was struck by the duty-free cart. A nearby passenger suffered broken ribs and hemothorax, an accumulation of blood in the chest cavity. A

Boeing 757 Response to RA



RA = resolution advisory generated by traffic-alert and collision avoidance system; ATC = air traffic control

Source: Aviation Safety Council of Taiwan

Figure 1

passenger returning from the lavatory to his seat “was bounced up and also encountered impact by the duty-free cart”; his injuries included a compound fracture of the left humerus, or upper arm bone. A passenger seated near the front of the cabin “encountered an impact with the ceiling and seat arm”; her injuries included fractured ribs, a fractured clavicle and hemothorax.

“The other 10 injured passengers and six cabin crewmembers sustained minor injuries such as contusions, sprains and abrasions,” the report said, noting that none of the injured passengers had their seat belts fastened.

After the accident, the crew declared an emergency and landed on Jeju Island without further incident at 0228. Damage to the 757 consisted of three broken armrests and a punctured ceiling panel. No structural damage was found.

Based on the findings of the accident investigation, the ASC recommended that “all operators review their training programs to ensure

that they contain the necessary training for flight crews to recognize and respond effectively to TCAS advisories.”

The report said that the training should include theory and simulator practice. “The flight crew should have an understanding of how TCAS works. This includes an understanding of the alert thresholds, expected response to TAs and RAs, proper use of TCAS-displayed information, phraseology and system limitations.”

Notes

1. ICAO. *Procedures for Air Navigation Services, Aircraft Operations*.
2. NTSB. Accident report no. NYC06LA002. June 30, 2008.
3. ASC. Final Report: *Far Eastern Air Transport Flight EF306, Boeing 757-200/Thai Airways International Public Company Ltd. Flight TG659, Boeing 777-300; A TCAS Event in Narrow Collision Avoidance at an Altitude of 34,000 Ft. and 99 NM South of Jeju Island, Korea, on November 16, 2006*. Aug. 15, 2008.

