



Log 2392

National Transportation Safety Board

Washington, D.C. 20594
Safety Recommendation

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In reply refer to: A-93-46 through -48

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Washington, D.C. 20594

The National Transportation Safety Board has endorsed and strongly supported Federal Aviation Administration (FAA) and industry programs to develop and implement an airborne collision avoidance system that will function independently of, and serve as a safety back-up to, the ground-based air traffic control (ATC) system. The development program began in the late 1960s and, after undergoing many evolutionary changes in system design and technology, culminated in the FAA's committal to the current version of the Traffic Alert and Collision Avoidance System (TCAS) in 1981. The Safety Board was also supportive of the phased installation program for the TCAS II, established by regulation in April 1990, which requires that all large air carrier airplanes be equipped with the TCAS II by December 30, 1993.

Since the installation of TCAS began in 1990, there have been some operational problems with the systems typical of those that could be expected during the early introduction of such equipment. Similar problems occurred during the introduction of the Ground Proximity Warning System (GPWS). The unacceptable nuisance alarm rate of the GPWS reduced pilot confidence in the system to the extent that proponents feared that alarms of real dangers would be ignored. However, changes in system logic and other improvements have nearly eliminated false and nuisance alarms, and GPWS has been very effective in reducing the rate of occurrence of controlled flight into terrain accidents for transport airplanes.

The Safety Board is aware of the concerns about TCAS that have been expressed by some air traffic controllers. Some of these appear to be well founded, although many might be attributed to the lack of a timely effort on the part of FAA air traffic management to train the ATC workforce adequately before the TCAS installation program began. The FAA has acknowledged this shortcoming and has initiated efforts to educate and train the controllers as to operational considerations that the TCAS system may create when flightcrews respond to resolution advisories (RAs). However, a Member of the Safety Board was a participant at a recent pilot/controller symposium on TCAS, which was held in Minneapolis, Minnesota, on January 26, 1993. During the course of this symposium, he learned that the FAA may not be providing the ATC workforce with a comprehensive program to explain the operational factors and characteristics of TCAS so that controllers, when performing

their duties, will be aware of those situations in which TCAS may provide flightcrews with an advisory or alert. Because of the potential for havoc that could be created by a controller who may not fully understand the ramifications of TCAS maneuvering, the Safety Board believes that the FAA should move aggressively to provide all radar certified controllers with a thorough and comprehensive formal briefing that, at a minimum, explains the operation of TCAS and the roles and responsibilities of flightcrews in responding to TCAS RA alerts. This training should be administered to all controllers on an annual basis.

Many of the early concerns were prompted as pilots received TCAS advisories about "phantom" targets. This problem was associated with a logic discrepancy in one version of the equipment, which has since been corrected. An additional problem has been nuisance alarms in certain areas where normal ATC traffic flow converging on parallel approaches or climbing or descending to assigned altitudes can produce unnecessary TCAS RAs. Again, this is a matter of fine-tuning the TCAS RA logic to achieve a better compromise between the time allotted for evasive maneuvers and the reduction in nuisance alarms. Such logic changes are planned for future retrofit.

The Safety Board believes that the problems have not detracted from the TCAS installation programs. More than 3,500 airplanes, about 65 percent of the air carrier fleet, are now equipped, and over 5 million hours have been flown by TCAS-equipped airplanes. More than 3,000 TCAS-generated advisories have been analyzed by an industry Separation Assurance Task Force. Although there is no way to state with certainty that a collision would have occurred in the absence of a TCAS alert, several pilots have attested to that possibility in Aviation Safety Reporting System (ASRS) reports.

The general success of the program notwithstanding, one problem that continues to be of concern to the Safety Board relates to the extent of training provided to flightcrews to prepare them for the proper response to a TCAS RA maneuver when that infrequent need arises.

On July 4, 1991, the Transportation Safety Board of Canada conducted an investigation of a near-midair collision incident that involved two United States commercial air carriers and an Air Canada Boeing B-767 approximately 15 miles east of London, Ontario. Canadian investigators learned that United Airlines flight 117 (UAL117), a Boeing B-737, and Air Canada flight 793 (ACA793) had departed from the Toronto/Lester B. Pearson International Airport. Both airplanes were on radar vectors for their climb southwest bound to flight level (FL) 280 with ACA793 about 15 miles in trail of UAL117. American Airlines flight 50 (AAL50), a McDonnell Douglas DC-10, was northeast bound at FL290.

After UAL117 reported level at FL280, the controller advised the flightcrews of UAL117 and AAL50 of the other's position. The airplanes were on converging, opposite-direction tracks, the distance between them was 12 miles, and the altitude separation was the required minimum of 1,000 feet. Both flightcrews acknowledged the traffic information, and the flightcrew of UAL117 acquired visual contact with AAL50. The radar controller later observed from mode C transponder returns that AAL50 had initiated a descent from FL290, and about the same time, the flightcrew of AAL50 reported they were descending as a result of a TCAS alert. The controller advised the

flightcrew of AAL50 that they had passed UAL117, that there was no traffic above them, and that they should return to and maintain FL290.

During the occurrence, AAL50 had descended to FL283, conflicting with UAL117. While at this altitude, AAL50 passed within 300 feet of vertical and 2 miles of lateral separation of UAL117. AAL50 also passed within 3 miles of lateral separation of ACA793, which was climbing through FL250 for its assigned altitude of FL280.

It was learned that after the flightcrew had been advised of UAL117, a voice was heard in the cockpit. When the captain inquired as to what was said, he was advised that the voice had been a TCAS announcement. There was a second TCAS announcement, and the captain noticed that there was an RA indicated by a lighted red segment in the lower portion of the VSI.¹ He thought he heard "DESCEND, DESCEND" and initiated a descent of approximately 500 feet per minute (fpm). The crew thought that the time between the second TCAS announcement and the start of descent was about 7 seconds.

The captain reported that he had difficulty understanding the TCAS aural alerts because the volume was too low. He also recalled that there was no lighted green zone on the RA/VSI and that, while in the descent, the TCAS information displayed on the HSD² indicated the threat target altitude to be 600 feet below. The rest of the flightcrew believed that the first aural alert was a "TRAFFIC TRAFFIC" traffic advisory (TA) and that the second alert was a "MONITOR VERTICAL SPEED" RA. Because the first officer was busy getting flight publications out of his bag, he immediately looked outside of the cockpit to see the traffic and did not notice the HSD or RA/VSI indications. The second officer confirmed that the lower half of the captain's RA/VSI contained a red-light zone. None of the flightcrew recalled hearing a "CLEAR OF CONFLICT" announcement. It was also learned that although the first officer had experienced a TCAS RA on a previous flight, the captain had never before experienced an in-flight TA or RA alert.

A review of the ATC radar plots indicated that the flightpath of UAL117 in relation to AAL50's flightpath should have resulted in the initial display of a nonintruding target and then in the generation of a traffic RA, a preventive "MONITOR VERTICAL SPEED" RA, and a "CLEAR OF CONFLICT"

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- 1 The VSI (vertical speed indicator) displays the airplane's vertical speed and is modified to indicate the vertical rate that must be achieved to maintain safe separation from the threatening aircraft. The RA display contains segmented red and green lights around the vertical speed scale. Compliance with the RA requires flying to keep the VSI needle out of the red segments.
 - 2 The HSD (horizontal situation display) on the airplane involved in this incident displayed the relative heading, distance, and altitude of TCAS traffic along with the primary navigational information.

advisory. The Canadian investigators found no evidence to support the conclusion that the crew had received anything other than the correct aural traffic and RAs. In addition, the lack of a "CLEAR OF CONFLICT" aural advisory would be inconsistent with the normal operation of TCAS, and it was likely that this aural alert was generated but not noticed by the crew.

On March 29, 1992, a McDonnell Douglas DC-9 and a Boeing B-757, both operated by Northwest Airlines, departed the Detroit Metropolitan Airport. The airplanes, while operating in instrument meteorological conditions, came within 0.3 miles of a midair collision over the northern shore of Lake Erie. Both airplanes were TCAS equipped.

Both airplanes were on crossing flightpaths and level at 10,000 feet prior to the incident. When the airplanes were about 3.5 miles apart, the radar controller at the Detroit ATC facility instructed the flightcrew of the B-757 to climb and maintain 13,000 feet. The copilot responded to the climb clearance and inquired, "...do you show traffic our 10 o'clock 2 to 3 miles?" The controller's response was, "yes sir climb and maintain 13,000." The controller then instructed the flightcrew of the DC-9 to turn left to a heading of 050°. The DC-9 flightcrew responded that they were turning to the assigned heading and also advised, "...we're climbing for traffic avoidance." The controller replied, "OK sir that traffic is climbing also, he is out of ten five [10,500 feet] maintain ten [thousand]." The flightcrew responded to a TCAS RA presentation by climbing straight ahead.

It was learned that after the captain of the B-757 was issued an ATC clearance and had initiated the climb to 13,000 feet, he received a TCAS RA to descend; however, he believed that the controller's acknowledgement of traffic, in conjunction with the instruction to climb, took precedence over the TCAS RA and therefore elected to continue the climb. Consequently, the flights were deprived of the safe separation that should have been provided by TCAS. In fact, because the DC-9 was climbing also in response to TCAS, the airplanes came closer than they would have if they had not been TCAS equipped.

Most recently, on August 30, 1992, a near-midair collision occurred involving a Boeing B-767 and a McDonnell Douglas DC-9, both operated by USAir. USAir flight 1081 (the B-767), which was TCAS equipped, was northbound at FL288, and USAir flight 1934, which was not TCAS equipped, was eastbound at FL280. Both aircraft were receiving ATC services from controllers at the Washington Air Route Traffic Control Center. When the airplanes were approximately 6 miles apart and on converging courses, a TCAS TA was presented to the flightcrew of USA1081. That flightcrew, who had misunderstood their assigned radio frequency, was attempting to reestablish communications with the appropriate controller when the advisory was presented. When the range between the two airplanes decreased to approximately 4.5 miles, TCAS issued an RA. Because of the vertical separation that existed, the RA was issued as a preventative measure only, advising the flightcrew not to change their vertical speed (not to descend). However, after the RA was received, the flightcrew of USA1081 initiated a 3,500 fpm descent and advised ATC that they were taking evasive action to avoid a midair collision. As a result of their action, the airplanes passed

within 100 feet of vertical separation and 0.6 miles of horizontal separation.

Safety Board investigators learned that the captain of USA1081, the nonflying pilot, reported receiving a TA concerning an intruder that he perceived to have been displayed as at the same altitude. Based on the TCAS TA display, the captain initiated a visual search for the intruder and sighted USA1934. The captain then recalled receiving a TCAS RA; however, he could not recall either the aural announcement or the information displayed on the TCAS indicator. Believing that the traffic was at the same altitude, he initiated evasive action while maintaining visual contact with the other airplane. This action was taken approximately 10 seconds after the RA was issued and when the airplanes were about 3 miles apart. The flightcrew of USA1934 saw their company airplane and did not take any evasive action, nor did they believe it was required. Therefore, the Safety Board concludes that the action taken by the captain of USA1081 was taken as a result of his sighting of the traffic, not as a result of the TCAS RA, and was in fact counter to the advisory presented by TCAS.

The Safety Board believes that these incidents exemplify the potentially serious consequences that might result when flightcrews respond to ATC instructions that are in direct conflict with TCAS commands or when flightcrews respond based on a visual assessment of traffic position rather than adhering to TCAS aural alerts and commands, or when they respond inappropriately to an RA. The Safety Board concludes that these actions are particularly hazardous when TCAS commands are coordinated between two TCAS-equipped aircraft. Improper actions by either flightcrew could create, rather than avoid, a potential midair collision. Also, the Safety Board believes that flightcrews, after receiving a TCAS alert, often initiate an avoidance maneuver to an altitude at a rate greater than that necessary to clear the conflict. The resulting altitude excursion can create a cascading effect, thereby conflicting with other aircraft that initially were not a threat. These actions also can seriously disrupt air traffic controllers' separation efforts and necessitate their resolving any resultant conflicts.

The Safety Board is aware that the FAA is anticipating the approval and implementation of a software change to TCAS beginning in early 1993. This program change will make TCAS more compatible with existing ATC procedures and pilot expectations of the National Airspace System (NAS). Current TCAS RAs allow 5 seconds for the pilot to recognize the nature of the alert and 3 seconds for the pilot to establish the rate of climb or descent necessary to maneuver. Although these thresholds will not be changed, there are specific instances in which the RA will be modified. For example, there are occasions when an RA will be presented to flightcrews of aircraft that are in apparent conflict but, because of ATC clearances, the conflict will be resolved without flightcrew RA compliance. This can occur when a climbing or descending aircraft is approaching its clearance altitude with the other aircraft in level flight, although the adequate 1,000 foot separation standard will be maintained. Under such conditions the TCAS system is functioning as intended; however, the system is not able to incorporate the controller issued altitude and the resultant action of the flightcrew. In essence, the TCAS system is not able to predict that the 1,000 foot

separation standard has been assured.

TCAS incidents, such as those cited earlier in this letter, strongly suggest that current TCAS training standards for commercial airline flightcrews are inadequate. During a review of TCAS training provided to air carrier flightcrews, Safety Board staff noted that, for initial TCAS training, most airlines rely on classroom study, videotape presentations, computer-based instruction, and written tests. However, none of this training requires the use of simulators or other types of interactive devices that would provide the pilot experience in responding to RAs. Also, recurrent training appears to be very limited and, of more concern, no time limit has been established from initial training to first TCAS flight. The Safety Board is aware that FAA Advisory Circular 120-55, dated October 23, 1991, describes acceptable methods for TCAS training, including the use of simulators; however, because this document is not regulatory in nature, there is no requirement for compliance. The Safety Board believes that because TCAS is interactive by design, rapid and correct display interpretation is essential for immediate and proper pilot response. Therefore, a variety of TCAS encounter scenarios should be developed that would require dynamic interpretation and maneuvering response by the pilot. This training should be accomplished in a simulator. These scenarios should be administered, at a minimum, during initial and recurrent training, to ensure the highest level of flightcrew proficiency. The Safety Board does not believe that complete TCAS installations or the use of complicated TCAS algorithms in the simulator would be required to achieve this objective.

The Safety Board believes that the use of flight recorders would provide a more complete and accurate account of flightcrew reactions to TCAS RAs and would be beneficial for accident prevention purposes. Specifically, such records would prove to be beneficial to all pilots, air traffic controllers, and the FAA as a means to readily identify those operational and technical issues which may need to be addressed and corrected. On July 11, 1988, the FAA issued a final rule³ that revised the flight data recorder (FDR) and cockpit voice recorder (CVR) requirements for a broad category of airplanes and rotorcraft operated by air carriers and commuters, as well as select aircraft operated in general aviation. Prior to issuance of the rule changes, FAA and Safety Board staff met to discuss the feasibility of recording all TCAS targets, traffic alerts, and RAs. The Safety Board staff expressed the view that recording all TCAS information might saturate the flight recorder system and, as an alternative, suggested that TCAS RAs and sensitivity level selections be recorded. The FAA concurred with the Safety Board's position and included them as recommended parameters if additional FDR recording capacity is available.

The Safety Board recognizes that the introduction of new technology into an operational environment may require a period of transition and adjustment to accommodate unforeseen occurrences. Such has been the case with TCAS. The Safety Board also believes that FDRs have proven to be extremely

³ Federal Register/ Vol.53, No. 132 / July 11, 1988 14 CFR Parts 23, 25, 27, 29, 91, 121, 125, and 135

successful in determining flightcrew responses to hazardous situations. As a result, many changes have been made to operating procedures that have substantially contributed to enhanced flightcrew performance. At present, the investigation of TCAS incidents is limited to available ATC radar data, readout of existing FDR parameters, and statements of observations and actions from the flightcrews. The Safety Board believes that in order to comprehensively evaluate flightcrew and TCAS performance and operational characteristics, the existing criteria for future FDR parameter recording should be modified to require that specific TCAS parameters be included.

The Safety Board commends the FAA for its accomplishments in the TCAS program and believes that the implementation of the following safety recommendations will contribute to the improvement of both flightcrew and TCAS operational performance and safety. Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

Amend 14 CFR Parts 121, 125, and 129 to require Traffic Alert and Collision Avoidance System (TCAS) flight simulator training for flightcrews during initial and recurrent training. This training should familiarize the flightcrews with TCAS presentations and require maneuvering in response to TCAS visual and aural alerts. (Class II, Priority Action)(A-93-46)

Amend 14 CFR Parts 121, 125, and 135, Appendix B or D, as appropriate, to include Traffic Alert and Collision Avoidance System (TCAS) resolution advisories and TCAS sensitivity level settings as mandatory recording parameters for future flight data recorders (FDR) and current FDR installations that have the capacity for these additional parameters. (Class II, Priority Action)(A-93-47)

Immediately provide all radar certified controllers with a thorough and comprehensive formal briefing that explains the operations of the Traffic Alert and Collision Avoidance System (TCAS) and the roles and responsibilities of flightcrews in responding to TCAS resolution advisory (RA) alerts. This briefing should be administered to all air traffic controllers on an annual basis. (Class II, Priority Action)(A-93-48)

Chairman VOGT, Vice Chairman COUGHLIN, and Members LAUBER, HART, and HAMMERSCHMIDT concurred in these recommendations.



By: Carl W. Vogt
Chairman