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Midair Collisions Prompt Recommendations For Improvement of ATC Radar Systems

The U.S. National Transportation Safety Board said that air traffic control radar systems should track all primary (no-transponder) aircraft targets and conspicuously display the targets on controllers' radar scopes. The recommendation was generated by investigations of two fatal accidents involving the failure of controllers to see primary targets and to warn pilots of conflicting traffic.

FSF Editorial Staff

Investigations of two midair collisions in the United States have shown deficiencies of air traffic control (ATC) radar systems in tracking aircraft and displaying aircraft targets on controllers' plan-view displays (commonly called radar scopes), according to the U.S. National Transportation Safety Board (NTSB).[1]

The collisions involved a Cessna 525 CitationJet and a Cessna 172N Skyhawk on April 4, 1998, over Marietta, Georgia; and a Boeing CH-47D Chinook helicopter and a Beech J35 Bonanza on Feb. 11, 1998, near Morgan Hill, California.

"In both cases, fatalities resulted from collisions between transponder-equipped aircraft receiving radar-traffic-advisory service (the CitationJet and the CH-47D) and aircraft that were neither in contact with ATC nor operating a transponder to enhance their visibility to radar (the Skyhawk and the Bonanza)," said NTSB. (The accident report said that the transponder in the Bonanza was operating on the visual flight rules code 1200 and that radar returns from the aircraft were "erratic."[2])

Both collisions occurred in daylight, visual meteorological conditions.

Targets for all four aircraft were displayed on controllers' radar scopes. NTSB said that the Skyhawk and the Bonanza appeared as primary targets; the CitationJet and the CH-47D appeared as combined primary targets and secondary targets.

A primary target is displayed on a controller's scope when energy transmitted by a ground-based ATC radar antenna is reflected back to the antenna by the exterior surfaces of an aircraft. The primary target is combined with a secondary target when an operating transponder aboard an aircraft transmits

information — such as "identity" (the selected transponder code) and altitude — in response to interrogations by signals from a ground-based radio transmitter-receiver that functions simultaneously with the primary radar antenna.[3]

NTSB said that combined primary targets and secondary targets are displayed conspicuously on controllers' radar scopes; primary targets alone are displayed less conspicuously.

"[Primary-only targets for] aircraft not equipped with an operating transponder are much less conspicuous and are presented only as bright spots that illuminate approximately every four seconds when the radar antenna passes the targets," NTSB said. "The spots then fade away within one [second] to two seconds."

The collision between the CitationJet and the Skyhawk occurred in airspace controlled by Atlanta Terminal Radar Approach Control (Atlanta TRACON). The collision between the CH-47D and the Bonanza occurred in airspace controlled by Bay TRACON.

"Recorded radar data from Atlanta TRACON and Bay TRACON showed that primary targets for the non-transponder aircraft were detected by the radar systems before the collisions, indicating that it was possible for the controllers involved to have detected the potential conflicts and provided advisories to the pilots of the transponder-equipped aircraft," said NTSB. "In both cases, the controllers reported that they did not see any conflicting non-transponder targets.

"Both controllers also stated that they routinely configure their displays to show primary targets and that if they had noticed a potential traffic conflict, they would have provided an advisory to the other aircraft involved."[3]

"Recorded radar data … showed that primary targets for the non-transponder aircraft were detected by the radar systems before the collisions, indicating that it was possible for the controllers involved to have detected the potential conflicts and provided advisories to the pilots of the transponder-equipped aircraft," said NTSB.

NTSB said, in its factual accident report, that the collision between the CitationJet and the Skyhawk occurred at 1034 local time.[5] The CitationJet departed about 1030 from Dekalb-Peachtree Airport, eight miles (13 kilometers) northeast of Atlanta, Georgia, for an instrument flight rules flight to Harrisburg, Pennsylvania. Three passengers were aboard the aircraft for the private business flight.

The pilot, 53, had an airline transport pilot certificate and a type rating that authorized him to fly the CitationJet without a copilot. The pilot had approximately 1,825 flight hours, including 86 flight hours in type.

After takeoff from Runway 34, the pilot was told by an Atlanta TRACON controller to fly a heading of 280 degrees and to climb to 3,000 feet. The pilot at 1033 was told to fly a heading of 360 degrees and to climb to 14,000 feet.

The Skyhawk departed at 1025 from Mathis Airport in Cumming, Georgia, which is about 22 nautical miles (41 kilometers) north-northeast of Atlanta. The aircraft was being operated under U.S. Federal Aviation Regulations Part 91 as a power-line-patrol flight.

The pilot, 44, had a commercial pilot certificate, a flight instructor certificate and an airframe-and-powerplant mechanic certificate. He had approximately 13,959 flight hours; his time in type was not reported.

The company that hired the pilot for power-line-patrol services said that the company's contract with the pilot required that he fly with an observer aboard the aircraft.

"[A company representative said that] the observer was required for safety reasons, so the pilot could fly the airplane and the observer [could] look at the lines," said the report.

An observer was not aboard the Skyhawk when the accident occurred.

About 1034, the Skyhawk pilot established radio contact with the ATC tower at Dobbins Air Force Base. The pilot initially transmitted his aircraft's call sign.

The controller said, "Seven Whiskey Delta, Dobbins Tower."

The pilot said, "Good morning, sir, Seven Whiskey Delta, Cessna one seventy."

The controller told the pilot that his last transmission was "cut out" — that is, blocked by a radio transmission from another aircraft.

"No further transmissions were received from the [Skyhawk pilot], and the controller was unable to re-establish contact," said the report.

The CitationJet was being flown north and the Skyhawk was being flown south when the aircraft collided over a residential area.

"According to radar data, the CitationJet had vacated 3,000 feet MSL [mean sea level] and was at 3,400 feet MSL, at 1034, when a primary target merged with the radar target of the CitationJet," the report said. "In addition to the loss of radio contact with the CitationJet, the radar-data block on the controller's display depicted 'coast,' indicating that radar contact was lost."

All the aircraft occupants were killed; no one on the ground was injured. Most of the CitationJet wreckage came to rest in a residential yard.

"The horizontal stabilizer, elevators and the top one-fourth, approximately, of the vertical stabilizer [had] separated from the airplane," the report said. "The separated portion of the empennage was found about one mile [1.6 kilometers] southeast of the main wreckage."

The report said that black tire marks were found on the leading edge of the CitationJet's vertical stabilizer.

"Additionally, blue paint that was similar to the blue paint of the Cessna 172 was found transferred to the leading edge of the portion of the horizontal stabilizer that remained attached to the vertical stabilizer," said the report.

The Skyhawk struck trees and then struck the ground approximately a half mile (0.9 kilometer) southeast of the CitationJet. The Skyhawk's left-main wheel was found about 1,600 feet (488 meters) from the main wreckage. The nose-landing-gear upper-strut housing, which was found with the main wreckage, had an indentation that matched an indentation on the leading edge of the CitationJet's left-horizontal stabilizer.

The Skyhawk's transponder was damaged severely by fire. The transponder function switch was in the "off" position.

"An interview was conducted with the [Skyhawk] pilot's son, who stated [that] he had flown often with his father," the report said. "The son stated that because of the type [of] flying involved [in power-line patrol], it was his father's practice to leave the transponder in the 'off' position during normal flight, until he approached airspace in which he needed the transponder. At that point, he would turn on the transponder, prior to entering the airspace."

The report said that, because the Skyhawk was being flown within 30 nautical miles (56 kilometers) of William B. Hartsfield Atlanta International Airport, the pilot was required to have " an operating transponder."[6] (The collision occurred 22 nautical miles [41 kilometers] north of the Hartsfield Atlanta airport; the airport is seven miles [11 kilometers] south of Atlanta.)

A cockpit-visibility study showed that the pilots could have seen each other's aircraft for up to 35 seconds before the collision.

"The aircraft had an approximate closure rate of 300 knots, with an angular difference in their headings [of] about 52 degrees," the report said. "The [cockpit-visibility study] plots the relative position of the aircraft in the opposing airplane's windscreen. The plots indicated that the Cessna 172 was either behind the CitationJet center windscreen post, based on a single-eye position, or to the right of the center-windscreen post from 35 seconds prior to the closest radar position of the two aircraft.

"The plots indicate that the CitationJet was visible, based on a single-eye position, in the lower-left quadrant of the [Skyhawk] pilot's windscreen between 35 [seconds] and five seconds prior to the closest radar position of the two aircraft."

Recorded ATC radar data showed a series of primary targets that began near the Skyhawk's departure point and ended when they intersected the CitationJet's radar targets.

"A trail of primary targets commenced approximately two miles [3.7 kilometers] southwest of the Mathis Airport, [the Skyhawk's] home base, and extended to the southwest in a curving path that intersected the flight path of [the CitationJet] over Marietta," said the report.

The controller told investigators that the primary targets associated with the Skyhawk were not observed on the radar scope; therefore, a traffic advisory was not issued to the CitationJet pilot.

A cockpit-visibility study showed that the pilots could have seen each other's aircraft for up to 35 seconds before the collision.

The report said that the controllers' handbook "directs controllers to provide radar traffic advisories, considered an 'additional service,' on a workload-permitting basis."[7]

The collision near Morgan Hill, California, occurred at 1527 local time.[8] The CH-47D was being flown as the lead aircraft in a two-helicopter formation flight. The helicopters were operated by the California Army National Guard and were on a training mission. The accident helicopter had the call sign Schooner 14; the other helicopter had the call sign Schooner 44.

The helicopters took off at 1505 from Monterey (California) Peninsula Airport. A pilot, a copilot and two flight engineers were aboard Schooner 14. The pilot, 52, had 3,495 flight hours, including 686 flight hours in type. The copilot, 35, had 1,158 flight hours, including 920 flight hours in type.

"Both military pilots in Schooner 14 met Army currency requirements, and both had passed a standardization check ride in the same make and model aircraft within the preceding 12 months," said the report.

Before takeoff, the pilot-in-command of Schooner 14 told the copilot and the two flight engineers to look for traffic and to advise him if they saw any conflicting traffic.

"The pilot-in-command's preflight briefing instructed all crewmembers to be alert for possible conflicting traffic and to

promptly advise him of their observations," the report said. "This has been a standard portion of the preflight briefing, and the crewmembers had received the same instructions on previous flights."

The Bonanza departed at 1510 on a personal flight from Reid-Hillview of Santa Clara County Airport in San Jose, California. The pilot, 80, had a commercial pilot license and 6,165 flight hours.

Both helicopters were being flown at 2,500 feet, on a heading of 004 degrees and at an indicated airspeed of 115 knots. The pilot of Schooner 14 said that the helicopters were being flown about 500 feet (153 meters) below scattered clouds.

The pilot of Schooner 44 said that he was flying the helicopter approximately 450 feet (137 meters) behind Schooner 14 and slightly to the right of Schooner 14.

The pilot of Schooner 14 received radar traffic information service from Monterey Approach Control and operated the helicopter's transponder on a code assigned by Monterey Approach. The collision occurred about two minutes after the helicopter was handed off by Monterey Approach to Bay TRACON.

Recorded radar data showed that, when the collision occurred, the helicopter's ground track was north-northeasterly and the airplane's ground track was northwesterly.

The controller said that he did not see the primary target of the Bonanza on his radar scope.

"When investigators asked why he did not notice the conflict, the controller replied, 'Because I was busy,'" the report said. "The controller's workload at the time of the accident was described by his supervisor as moderate. …

"When investigators asked why he did not notice the conflict, the controller replied, 'Because I was busy,'" the report said. "The controller's workload at the time of the accident was described by his supervisor as moderate."

"[The controller] recalled working six different aircraft at the time he was handed Schooner 14. Most of that traffic was in the northern portion of his sector, while Schooner 14 and another VFR [visual flight rules] aircraft were in the southern area."

The crewmembers of Schooner 14 said that they did not see the Bonanza. The report did not say whether a cockpit-visibility study was conducted during the investigation.

The Bonanza was seen by crewmembers in the trailing helicopter before the collision.

"At least two of the crewmembers in Schooner 44 reported first seeing the Beech approach their formation from the right about three [seconds] to five seconds before the collision occurred," the report said. "They stated that neither aircraft made any perceptible changes in heading or altitude before the collision."

The Bonanza struck the helicopter's right rear fuselage. The right wing separated, and the Bonanza descended to the ground 19 nautical miles (35 kilometers) southeast of Reid-Hillview Airport. The pilot was killed.

The helicopter was substantially damaged. None of the occupants was injured. The pilot declared an emergency and conducted a precautionary landing about two statute miles (three kilometers) southeast of where the Bonanza struck the ground.

As of October 1999, NTSB had not completed the investigations of the two midair collisions. Nevertheless, NTSB said that preliminary findings of the investigations show that primary targets are not displayed conspicuously on controllers' radar scopes by automated radar terminal systems (ARTS).[1,9,10]

"Increasing primary targets' visibility to controllers is essential to enhancing flight safety," said NTSB.

NTSB in June 1999 made the following recommendation to the U.S. Federal Aviation Administration (FAA):

> "Modify all variants of [ARTS] software to automatically track primary radar targets that have characteristics consistent with aircraft in flight and tag them with a persistent track symbol that will be continuously displayed to controllers. Further, this feature should be incorporated into all future [FAA] terminal radar data processing systems."

FAA in August 1999 made the following response to the recommendation:[11]

> "All [ARTS] IIIE and [ARTS] IIE with input from digital Airport Surveillance Radar (ASR) Model 9 [ASR-9] currently have this capability. All ARTS IIAs are being converted to ARTS IIEs, with program completion scheduled for April 2000. ARTS IIEs that do not have this capability will have it when an ASR-11 is installed.
>
> "The Micro En Route Automated Radar Tracking System currently places a symbol over primary targets. [FAA] is studying the effects primary target symbology will have on capacity. This study should be completed by November 1999. [NTSB will be informed] of the

FAA's course of action on this safety recommendation when the study is completed."♦

References and Notes

1. U.S. National Transportation Safety Board (NTSB). *Safety Recommendation A-99-46*. June 8, 1999.

2. NTSB factual accident report LAX98FA086A.

3. U.S. Federal Aviation Administration (FAA). *Aeronautical Information Manual* (*AIM*). Change 3 (July 15, 1999): 1–2–2.

4. The *AIM*, section 4–1–14, said that pilots receiving air traffic control (ATC) radar traffic information service "are advised of any radar target observed on the radar display which may be in such proximity to the position of their aircraft or its intended route of flight that it warrants attention. This service is not intended to relieve the pilot of the responsibility for continual vigilance to see and avoid other aircraft."

5. NTSB factual accident report ATL98FA060A.

6. U.S. Federal Aviation Regulations (FARs) Part 91.215(b)(2) requires that aircraft have an operating altitude-reporting transponder when being operated below 10,000 feet and within 30 nautical miles of an airport listed in FARs Part 91 Appendix D. As of Oct. 15, 1999, FARs Part 91 Appendix D listed 33 U.S. airports.

7. FAA publication 7110.65L, *Air Traffic Control*, section 2–1–1, said, "The primary purpose of the ATC system is to prevent a collision between aircraft operating in the system and to organize and expedite the flow of traffic. In addition to its primary function, the ATC system has the capability to provide (with certain limitations) additional services. The ability to provide additional services is limited by many factors, such as the volume of traffic, frequency congestion, quality of radar, controller workload, higher-priority duties, and the pure physical inability to scan and detect those situations that fall in this category." The "Controller/Pilot Glossary," which is included both in *Air Traffic Control* and in the *AIM*, said that additional services include "traffic advisories; vectors, when requested by the pilot … to avoid observed traffic; … [and] advisories that traffic is no longer a factor." The glossary said, "The controller has complete discretion for determining if he/she is able to provide or continue to provide a service in a particular case."

8. NTSB factual accident report LAX98FA086A.

9. The *AIM* "Pilot/Controller Glossary" defines the automated radar terminal system (ARTS) as "the generic term for the ultimate in functional capability afforded by several automation systems. Each differs in functional capabilities and equipment. ARTS plus a suffix roman numeral denotes a specific system [e.g., ARTS II]. A following letter indicates a major modification to that system [e.g., ARTS IIA]. In general, an ARTS displays … aircraft identification, flight plan data, other flight-associated information — e.g., altitude, speed — and aircraft-position symbols in conjunction with [the controller's] radar presentation."

10. The Atlanta TRACON and the Bay TRACON both had ARTS IIIA. The *AIM* "Pilot/Controller Glossary" said that ARTS IIIA "detects, tracks and predicts primary as well as secondary radar-derived aircraft targets. This more sophisticated computer-driven system upgrades the existing ARTS III system by providing improved tracking, continuous data recording and fail-soft capabilities."

11. Letter from FAA Administrator Jane E. Garvey to NTSB Chairman James E. Hall, Aug. 5, 1999.

Further Reading from FSF Publications

FSF Editorial Staff. "Factors in Near Midair Collisions Show Controller-Pilot Interdependence." *Airport Operations* Volume 25 (May–June 1999): 1–8.

Krause, Shari Stamford. "Collision Avoidance Must Go Beyond 'See and Avoid' to 'Search and Detect.'" *Flight Safety Digest* Volume 16 (May 1997): 1–7.

Pope, John A. "Limitations of See-and-Avoid Concept Cited in Fatal Midair Collision." *Flight Safety Digest* Volume 13 (March 1994): 1–9.

Mellone, V.J.; Frank, S.M. "The U.S. Air Traffic Control System Wrestles with the Influence of TCAS." *Flight Safety Digest* Volume 12 (November 1993): 1–8.

Pope, John A. "Midair Collision — The Links in a Chain." *Accident Prevention* Volume 49 (March 1992): 1–6.

Crockett, Doug. "Crew's Eyes Remain the Key to Midair Collision Avoidance." *Accident Prevention* Volume 48 (December 1991): 1–5.

Huang, Shung C. "Near Midair Collisions, Operational Errors and Pilot Deviations." *Flight Safety Digest* (Volume 10): 22–24.

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