



National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: May 2, 2007

In reply refer to: A-07-35 through -37

Honorable Marion C. Blakey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On September 29, 2006, about 1657 Brasilia standard time,¹ a Boeing 737-800 (PR-GTD) operated by Gol Airlines of Brazil and an Embraer Legacy 600 business jet (N600XL) owned and operated by Excelsaire of Long Island, New York, collided in flight over the Amazon jungle approximately 100 nautical miles (nm)² southeast of Cachimbo Air Base, Brazil. The Boeing 737 was destroyed by in-flight breakup and impact forces; all 154 occupants were killed. The Embraer Legacy sustained damage to the left wing and left horizontal stabilizer, and the flight crew subsequently performed an emergency landing at Cachimbo Air Base. The two crew members and five passengers were not injured, and there was no further damage to the airplane. The Boeing 737 was operating as a scheduled domestic air carrier flight on an instrument flight rules (IFR) flight plan; the Embraer Legacy was operating under 14 *Code of Federal Regulations* (CFR) Part 91 and was also on an IFR flight plan. Visual meteorological conditions prevailed in the area at the time of the accident.

The investigation³ of this accident is ongoing; however, preliminary findings suggest that a critical safety issue exists regarding the loss of functionality of an aircraft's collision avoidance system (comprising a transponder⁴ and a traffic alert and collision avoidance system [TCAS]⁵)

¹ Unless otherwise indicated, all times are Brasilia standard time, based on a 24-hour clock.

² Unless otherwise indicated, all distances are nautical miles.

³ The investigation of this accident is being conducted by the Brazilian Aeronautical Accident Prevention and Investigation Center. Under the provisions of Annex 13 to the Convention on International Civil Aviation, the National Transportation Safety Board is participating in the investigation as a representative for the State of Registry and Operator of the Excelsaire-operated Embraer Legacy airplane and the State of Manufacture of the Boeing 737 and the avionics equipment in both airplanes.

⁴ A transponder reports a unique code that aids in radar identification and provides an accurate indication of an airplane's altitude. Currently, three types of transponders are used in aircraft: modes A, C, and S. Mode A transponders provide an enhanced radar return with a discrete beacon code to ground-based radars, mode C transponders provide enhanced radar returns with a discrete beacon code and encoded altitude data to ground-based radars, and mode S transponders provide the same functions as a mode C transponder in addition to incorporating a unique digital address for each mode S transponder and an air-to-air digital data link capability that allows mode S transponders on two aircraft to communicate with each other.

⁵ TCAS is anticollision equipment that is required by Federal Aviation Regulations to be installed on all turbine-powered airplanes of more than 33,000 pounds maximum certificated takeoff weight operating under 14 CFR Parts 121, 125, and 129 and on all airplanes with 10 to 30 seats that are operated under Parts 121, 129, and

and resulting cockpit warnings to flight crews. Flight data recorder (FDR) and cockpit voice recorder (CVR) information from both airplanes revealed no indication of any TCAS alert on board either airplane (both airplanes were equipped with mode S transponders and TCAS II⁶ computer units), no evidence of pre-collision visual acquisition by either flight crew, and no evidence of evasive action by either crew.

Background

The Boeing 737 departed Eduardo Gomes International Airport in Manaus, Brazil, about 1535 en route to Presidente Juscelino Kubitschek International Airport, Brasilia, Brazil. The flight plan filed requested flight level (FL) 370, or approximately 37,000 feet above sea level, as a cruise altitude and a routing via airway UZ6 to Brasilia VOR⁷ (BRS). The airplane was cleared as filed, and there were no anomalies in communication with or radar surveillance of the Boeing 737 throughout the flight.

The Embraer Legacy, on its delivery flight from the Embraer factory to Excelaire's base in New York, departed Professor Urbano Ernesto Stumpf Airport, São José dos Campos, Brazil, about 1451 with a planned stopover in Manaus. The filed flight plan included a routing via airway UW2 to BRS then via airway UZ6 to Manaus. After takeoff, the Legacy was issued a number of interim altitudes during climb, the last of which was to the initial cruise altitude of FL370.

About 1551, the Legacy flight crew performed a routine frequency change to air traffic control (ATC) at a point just south of Brasilia. Radar and radio communications indicate that the airplane was level at FL370 about this time. ATC acknowledged and instructed the crew to "ident," or provide an enhanced radar return from its transponder. ATC radar data indicates that the Legacy's transponder return was observed. At this time, the airplane was approximately 40 nm south of BRS. This was the last radio communication between the Legacy crew and ATC. About 1556, the Legacy passed BRS, continuing level at FL370. There is no record of a request from the Legacy crew, nor instruction from ATC, to change the cruise altitude. About 1602, when the airplane was about 30 nm north-northwest of BRS, the transponder return from the Legacy airplane was no longer observed on ATC radar and remained undetected by ATC radar until shortly after the collision. According to ATC radar data, other aircraft in the vicinity produced normal transponder returns.

135. In addition, aircraft operating under 14 CFR Part 91 Subpart K (fractional ownership programs) are also required to have TCAS. Title 14 CFR 91.221 requires that all aircraft with a TCAS installed have the system on and operating.

⁶ Two versions of TCAS are currently in use: TCAS I (required on aircraft with 10 to 30 seats) detects nearby aircraft and provides flight crews with traffic advisories (TA); TCAS II (required on aircraft with more than 30 seats) provides TAs and, if nearby aircraft present a collision threat, issues resolution advisories (RA), which instruct pilots to climb or descend to avoid potential collision with another aircraft. Aircraft equipped with TCAS II also require at least one mode S transponder to provide the data communications needed to coordinate RAs with nearby aircraft.

⁷ VOR stands for very high frequency omnidirectional radio range.

About 1626, ATC attempted to contact the Legacy flight crew without success and continued trying to establish contact until about 1653. Beginning about 1648, the Legacy flight crew also made several unsuccessful attempts to contact ATC. Data from the FDR indicated that the Legacy crew did not perform any abnormal maneuvers during the flight. FDR information indicates that the airplane was level at FL370, on course along airway UZ6, and at a steady speed until the collision with the Boeing 737 at a point about 460 nm north-northwest of BRS, on airway UZ6.

CVR data from the Legacy airplane indicate that, during the crew's emergency descent to Cachimbo Air Base, the crew made a series of comments related to whether or not the TCAS was on.⁸ ATC radar data indicate that the transponder return for the airplane was again visible to ATC radar less than 30 seconds after these comments. About 2 minutes later, the crew made a comment related to setting the transponder to the emergency code (7700); ATC radar subsequently indicated the emergency code.

Discussion

Preliminary findings in the ongoing investigation indicate that, for reasons yet to be determined, the collision avoidance system in the Legacy airplane was not functioning at the time of the accident, thereby disabling the system's ability to detect and be detected by conflicting traffic. In addition, CVR data indicate that the flight crew was unaware that the collision avoidance system was not functioning until after the accident.

For a TCAS-equipped aircraft to provide a flight crew with collision avoidance information, the TCAS unit and the transponder must be turned on, and the transponder cannot be selected to the STANDBY mode (that is, powered but not transmitting data).⁹ If the transponder is not turned on and responding to interrogations, the aircraft's TCAS cannot display information about potentially conflicting aircraft nearby nor can it provide instructions to the crew to resolve impending collision threats. Failures of the TCAS computer unit itself can also occur; however, these failures only affect the TCAS-equipped aircraft's ability to detect nearby aircraft. The aircraft containing the inoperative TCAS unit remains visible to other aircraft as long as its transponder remains operative. The consequences of a TCAS unit failure are magnified, however, when the transponder is inoperative¹⁰ because not only is TCAS information lost on the affected aircraft, but also that aircraft will not be visible to other airborne

⁸ According to the collision avoidance system logic, the accident flight crew should have received a white "TCAS OFF" warning on the flight display while the transponder was set to STANDBY. About 2 minutes after impact (at 1959:13.5), the first officer questioned whether TCAS was on, the captain confirmed it was not and, immediately afterwards, the transponder signal returned to ATC radar returns. Therefore, there is evidence that the flight display warning was available to the crew but not noticed and acted upon until after impact.

⁹ TCAS-equipped aircraft interrogate transponders in nearby aircraft to determine the relative position of these aircraft and determine whether they are a potential collision hazard. If the transponder is not on or is on but selected to the STANDBY mode, it will not respond to TCAS interrogations and the aircraft in which it is installed cannot be detected by TCAS nor will the aircraft be visible to ground-based radar interrogation.

¹⁰ Despite the multiple reasons that a transponder would not respond to interrogations (including a failure of the transponder, the flight crew's failure to turn the transponder on, or an inadvertent deactivation of the transponder), the functional consequence to the collision avoidance system is the same and the affected aircraft will not be visible to other airborne collision avoidance systems or ground-based air traffic controllers.

collision avoidance systems. Regardless of whether the transponder has failed or the TCAS has become inoperative, a flight crew's ability to mitigate the risk of collision is significantly degraded if the collision avoidance system becomes inoperative and the failure is not quickly and reliably brought to the crew's attention, as this accident demonstrates.

In the Legacy airplane involved in the accident, the only notification the pilots likely received regarding the loss of TCAS functionality was a small, static text message on the pilots' flight display¹¹ that read "TCAS OFF" in white lettering. In the event of a TCAS failure, the warning "TCAS FAIL" would illuminate in amber; the type of text message varies depending on the reasons for the loss of function. Loss of transponder functionality is indicated by a small message on the radio management unit that reads "ATC FAIL" or "STANDBY." In the event of loss of transponder functionality, the "TCAS OFF" or "TCAS FAIL" message will also be displayed (again, depending on the reasons for the loss of function). The collision avoidance system does not require pilots to acknowledge or cancel these warnings. National Transportation Safety Board investigators' preliminary survey of a number of transport-category aircraft found that annunciations of TCAS and transponder failure were consistent with those used on the Legacy airplane.

Using only static text messages to indicate a loss of collision avoidance system functionality is not a reliable means to capture pilots' attention because these visual warnings can be easily overlooked if pilots' attention is directed elsewhere in the flight environment. The Safety Board notes that the notifications for other critical aircraft system failures that could result in catastrophic consequences generally use both aural alerts and conspicuous visual alerts, such as the use of a salient color (which can help draw a pilot's attention to a significant abnormal situation)¹² and perceptible movement (provided by a flashing light or text message). These warnings also require the flight crew to acknowledge that the annunciation has been detected. Because the silent and static annunciation accompanying loss of the collision avoidance system on most airplane types can be easy to miss, the Safety Board is concerned that pilots may not be quickly alerted or aware that the TCAS and/or transponder are not functioning, leading to their aircraft not being detectable to other TCAS-equipped aircraft and a potential accident. Although loss of a transponder during IFR operations can be detected by ATC, in many circumstances, this is not a reliable method to ensure the integrity of the collision avoidance system because of normal limitations in radar or communication coverage.¹³

¹¹ In the accident Legacy airplane, if a separate TCAS display (a box covering approximately 1/3 of the display) is being presented on the multifunction display, a similar small text message will also be displayed in this box. Use of the TCAS display box is at crew discretion, and FDR data for the Legacy indicates that it was not being displayed at the time of the accident.

¹² Title 14 CFR 23.1322 requires that cockpit warning lights be colored red to indicate a hazard that may require immediate corrective action and amber to indicate the possible need for future corrective action. In the Legacy accident airplane, the "TCAS OFF" warning appears in white lettering.

¹³ For example, radar coverage is typically limited in remote areas, below certain altitudes, in oceanic airspace, and especially near nontowered fields. In addition, verbal warnings may not be timely because they depend on a controller noting and properly assessing the situation before making a two-way radio transmission, which is subject to coverage limitations, blocking, misunderstanding, etc.

Federal Aviation Regulations require that all aircraft equipped with TCAS must have the TCAS unit operational, thereby helping to ensure that the safety benefits these systems provide in mitigating the risk of midair collision are realized. However, it is also imperative that when a failure of these systems occurs that flight crew attention is rapidly captured so that actions can be taken to mitigate this failure. The Safety Board is aware that the Federal Aviation Administration (FAA) and avionics manufacturers are currently planning new designs for collision avoidance systems that will provide increased functionality compared to the current systems and will enhance safety once they are incorporated. The Board is concerned, however, that, similar to the current systems, the new system designs will lack an aural alert that quickly notifies flight crews in the event that collision avoidance system functionality is lost. Therefore, the Safety Board believes that the FAA should require, for all aircraft required to have TCAS installed and for existing and future system designs,¹⁴ that the airborne loss of collision avoidance system functionality, for any reason, provide an enhanced aural and visual warning requiring pilot acknowledgment. This is an important consideration for the development of runway incursion collision avoidance systems, as well. Without aural and visual warning requiring pilot acknowledgement, there would be a loss of runway incursion avoidance system functionality if a system on an individual aircraft were to fail or be inadvertently turned off. Therefore, the Board believes that the FAA should evaluate the feasibility of providing enhanced aural and visual warnings for future systems that may provide ground collision avoidance functionality. If feasible, require that future design criteria include such warning functionality.

Until such upgrades in warning systems can be implemented, all pilots who use transponders and TCAS units can benefit from a greater awareness of issues regarding pilot verification and monitoring of transponder and TCAS status. This consideration applies not only to pilots with TCAS units but also to the large population of general aviation pilots without TCAS units who, through a failure to activate a transponder in flight, could inadvertently compromise collision protection and violate regulatory flight requirements in congested airspace. Therefore, the Safety Board believes that the FAA should (a) inform all pilots who use transponders or transponder/TCAS units about the circumstances of this accident and the lack of a conspicuous warning to indicate the loss of collision protection resulting from a compromise in functionality of either the transponder or TCAS unit and (b) ask all pilots who use transponders or transponder/TCAS units to become familiar with the annunciations currently used to indicate failure or lack of active functionality of these components.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

Require, for all aircraft required to have a traffic alert and collision avoidance system installed and for existing and future system designs, that the airborne loss of collision avoidance system functionality, for any reason, provide an enhanced aural and visual warning requiring pilot acknowledgment. (A-07-35)

¹⁴ The Safety Board acknowledges that for TCAS-equipped aircraft, warnings concerning the loss of transponder function on the ground would be useful for ground collision avoidance systems based on transponder output.

Evaluate the feasibility of providing enhanced aural and visual warnings for future systems that may provide ground collision avoidance functionality. If feasible, require that future design criteria include such warning functionality. (A-07-36)

Inform all pilots who use transponders or transponder/traffic alert and collision avoidance system (TCAS) units about the circumstances of this accident and the lack of a conspicuous warning to indicate the loss of collision protection resulting from a compromise in functionality of either the transponder or TCAS unit and ask all pilots who use transponders or transponder/TCAS units to become familiar with the annunciations currently used to indicate failure or lack of active functionality of these components. (A-07-37)

Chairman ROSENKER, Vice Chairman SUMWALT, and Members HERSMAN, HIGGINS, and CHEALANDER concurred with these recommendations.

[Original Signed]

By: Mark V. Rosenker
Chairman