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National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

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In reply refer to: A-87-96 through -98

Mr. T. Allan McArtor
Administrator
Federal Aviation Administration
Washington, D.C. 20591

The National Transportation Safety Board has completed its investigation and report of the midair collision between Aeronaves de Mexico (Aeromexico) flight 498, a DC-9-32, and a general aviation Piper PA 28-181, which occurred over Cerritos, California, on August 31, 1986. Aeromexico flight 498 was operating under instrument flight rules (IFR) destined for the Los Angeles International Airport on a scheduled passenger flight from Tijuana, Mexico. The PA-28 was climbing under visual flight rules (VFR) after departure from Torrance, California. The collision occurred about 8 miles beyond the point at which flight 498 crossed the boundary of the Los Angeles Terminal Control Area (TCA) near 6,500 feet mean sea level. Both airplanes fell to the ground within the city limits of Cerritos. Five houses were destroyed and seven other houses were damaged by airplane wreckage and postimpact fire. Fifty-eight passengers and 6 crewmembers on the DC-9, the pilot and 2 passengers on the PA-28, and 15 people on the ground were killed in the accident. 1/

The Safety Board's investigation determined that the Los Angeles Approach Arrival Radar Controller did not perceive the presence of the PA-28 and thus did not issue a traffic advisory to flight 498. The investigation also determined that the pilot of the PA-28 entered the TCA without the required communication or clearance from air traffic control (ATC), and that his airplane was not properly equipped for flight in the Los Angeles TCA inasmuch as the transponder did not have an altitude reporting (mode C) feature. Examination of recorded data from the Los Angeles Automated Radar Terminal System (ARTS) computer disclosed that the transponder replies from both airplanes were processed by the system and that the appropriate symbology representing the airplanes would have been displayed on the controller's scope; flight 498 would have been displayed as an analog beacon signal and an alphanumeric symbol with a full data block. Because the equipment setup used by the Los Angeles terminal radar controllers intentionally inhibited beacon signals from VFR aircraft, the analog beacon signal for the PA-28 would not have been presented and the airplane would have been discernible to the controller as a single alphanumeric symbol. It could not be established whether the symbol would have been supplemented by a primary radar return.

1/ For more information, read Aircraft Accident Report--"Aeronaves de Mexico, S.A., McDonnell Douglas DC-9-32, XA-JED, and Piper PA-28-181, N4891F Cerritos, California, August 31, 1986" (NTSB/AAR-87/07).

The Safety Board also is continuing its investigations of three other midair collision accidents that have occurred since the accident at Cerritos and that exemplify some concerns common to those raised by the Cerritos accident.

On January 15, 1987, Sky West flight 834, a Swearingen Metro operating as a scheduled passenger commuter, collided with a privately operated Mooney-20C over Kearns, Utah. Two crewmembers and six passengers on the Metro and two pilots aboard the Mooney were killed. The Safety Board's investigation determined that flight 834 was operating under IFR and was being vectored by the Salt Lake City approach radar controller for a landing at the Salt Lake City International Airport. Flight 834 was within the airspace defined by the Airport Radar Service Area (ARSA) when the collision occurred. The pilots aboard the Mooney were involved in training and had been operating from an uncontrolled airport south of Salt Lake City. Three circumstances in this accident were similar to the Cerritos accident: the pilot of the Mooney had not communicated with the approach controller before entering the ARSA, the controller was not aware of the presence of the Mooney when the flightpaths were converging even though an examination of the ARTS-recorded data showed that the airplane's beacon signal was processed for display, and the Mooney's transponder was not equipped for altitude reporting.

The second midair collision occurred on January 20, 1987, near Independence, Missouri. A U.S. Army U-21 airplane (Beechcraft King Air), en route to Fort Leavenworth, Kansas, was operating under IFR while level at 7,000 feet and was being controlled by a Kansas City approach controller. The U-21 collided with a Piper PA-31 airplane that was climbing en route under VFR after departure from Downtown Airport in Kansas City. The pilot of the PA-31 had not established communication with ATC after departure. Three persons were aboard each airplane and all were killed in the accident.

Unlike the Cerritos and Kearns accidents, this collision occurred outside of protected airspace where the intermix of VFR and IFR traffic is permitted and expected. Also, both aircraft were equipped with altitude reporting transponders and their beacon signals had been processed by the Kansas City ARTS computer. As in the other accidents, the controller did not detect the converging targets and consequently did not issue a safety alert or traffic advisory.

The other midair collision still under investigation occurred on May 1, 1987, within the 20-mile outer area of the ARSA serving Orlando, Florida. The airplanes involved were a North American AT-6, which was returning to Executive Airport after completing a sky-writing session, and a Cessna 340 inbound to the Orlando International Airport. Although the AT-6 was operating under VFR, the pilot, in accordance with ARSA procedures, had established radio contact with an Orlando approach controller who subsequently assigned a discrete transponder code and identified the airplane's radar target. The AT-6 did not have mode C altitude reporting equipment. The Cessna 340 was operating under IFR and was also being controlled by the Orlando Approach Control. The pilot, the sole occupant of the AT-6, and all three occupants of the Cessna 340 were fatally injured.

The Safety Board's investigation determined that the Cessna was level at 3,000 feet and that the AT-6 had been cleared by the controller to descend from 10,000 to 1,500 feet. An analysis of the recorded ARTS data indicates that, for about 1 1/2 minutes before the collision, the AT-6 was almost directly overhead of, and following the same ground track as, the Cessna 340. The examination of impact damage to the airplanes corroborated other evidence that the collision occurred when the AT-6 descended onto the Cessna 340. The preliminary analysis of ARTS data shows that the transponder beacon replies from the AT-6 were intermittent and that the proximity of both airplanes caused mutual transponder reply interference, which affected the ARTS data processing and the controller's display. The controller did not discern the convergence of the two airplanes and did not effect traffic separation.

Examination of the circumstances of the four midair collision accidents described herein shows that:

> All of the accidents occurred in daylight visual meteorological conditions in which the pilots and other flight crewmembers were expected to remain vigilant and to see and avoid other airplanes.
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> All of the accidents involved at least one airplane being operated under IFR by a pilot who was directly communicating with an ATC terminal radar control (TRACON) facility. In all of the accidents, except the Orlando collision, the conflicting airplane was being operated under VFR and its pilot was not communicating with the ATC facility.
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> The Cerritos accident occurred within the confines of a TCA; the Kearns and Orlando accidents occurred within the confines of an ARSA; the Independence accident was in the vicinity of, but outside the boundary of, a TCA.
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> In both the Cerritos and the Kearns accidents, the pilots of the VFR aircraft had entered the designated airspace wherein special operating rules and pilot/equipment requirements are imposed (TCA and ARSA) without having established the requisite ATC communication.
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> All of the airplanes involved in these accidents were equipped with operating transponders. However, in three of the accidents, the airplane being operated under VFR did not have mode C altitude reporting capability.
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> In all of the accidents, the transponder replies from both airplanes had been processed by the ARTS computer and symbology representing the airplanes would have been displayed on the controller's scope. However, in the Orlando accident, the display was intermittent and the convergence of flightpaths was probably not discernible. In the other three accidents, flightpath convergence would have been discernible.
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> In all of the accidents, the radar controllers were not aware of the traffic conflict and no safety alerts or traffic advisories were issued.

Based on the above comparisons among the accidents, the primary issues of concern exemplified by these accidents are:

> The limitations of the see and avoid concept of collision avoidance.

The effectiveness of ATC Terminal Radar Controllers to detect and prevent conflicts between IFR and VFR airplanes near airports having TCAs and ARSAs.

Future developments to prevent midair collision accidents.

Limitations of See And Avoid

Clearly, the see and avoid concept of collision avoidance was not in itself adequate to prevent these four accidents. In two of the accidents (Kearns and Independence), the convergence of the airplanes was nearly head on. Although not yet completed, the Safety Board believes that these investigations might show that the pilots had marginal opportunity to see and avoid each other because of the relatively high closure rate of the airplanes, and the small area presented by the airplanes when viewed head on, combined with the human physical limitations for visual detection, recognition, and response. In the Orlando accident, an analysis of the geometry of the converging flightpaths, combined with the visibility envelope from the cockpit of the AT-6 and the cabin of the Cessna 340, indicates that the visual detection of the other airplane by either pilot would have been unlikely and perhaps impossible.

The limitations in the see and avoid concept of collision avoidance have long been recognized and acknowledged by the Safety Board and other aviation safety advocates. It has also been recognized that the risk of midair collisions is minimized when all airplanes within a given volume of airspace are provided separation by an ATC radar facility. While less effective than ATC-provided separation, midair collision avoidance is significantly improved when the pilots of airplanes operating in a see and avoid environment are alerted to the presence and location of potentially conflicting traffic. Thus, the issuance of safety alerts and traffic advisories to those airplanes communicating with an ATC radar controller and the intelligence that will be provided by the onboard Traffic Alert Collision Avoidance System (TCAS) are key elements in the future prevention of midair collision accidents.

Effectiveness of Air Traffic Control

The Safety Board has recognized that positive control of all aircraft in all airspace is not presently practical. In fact, the Safety Board has recently expressed its concern that the safety inherent in the ATC system may be derogated by continual increases in traffic operations within the system. Nonetheless, the circumstances of past midair collision accidents and the analyses of near midair collision reports conclusively show that the highest midair collision risk is associated with flight under VFR.

On this basis, the Safety Board repeatedly has advocated that the National Airspace System be designed so that air carrier aircraft operate in an environment wherein all aircraft are provided ATC separation to the maximum practical extent from takeoff to landing. In the late 1960s and early 1970s, the Safety Board recommended establishment of designated climb and descent corridors to join major airports with a stratum of upper level airspace wherein all aircraft would be subject to ATC. This concept was not totally accepted but was partially satisfied by the establishment of the Positive Control Area (PCA), TCAs, and ARSAs. The pilots of all aircraft in those areas must communicate with the appropriate air traffic controller. Furthermore, airplanes operating in the PCA and in 9 of the 23 present TCAs must be equipped with altitude reporting transponders. However, a gap remains between the top of the TCA (which is typically at 7,000 feet above ground level) and the floor of the PCA (at 18,000 feet mean sea level), through

which the air carrier aircraft must climb and descend. During visual meteorological conditions, this airspace can be freely transited by aircraft that are operating under VFR and thus are not participating in the ATC system. It is in such airspace, where a mix of IFR and VFR aircraft exists, that the pilots of all airplanes must still rely heavily on the see and avoid concept.

The segregation of air carrier aircraft operating under IFR in the PCA and TCAs has proven to be effective in collision prevention in the high altitude en route environment and in the immediate area of the major airports. In fact, the collision between flight 498 and the PA-28 over Cerritos is the only collision of which we are aware that has occurred in the protected airspace of a TCA; we are unaware of any collisions in the PCA.

The prevention of midair collision accidents in the PCA, TCAs, and ARSAs can be largely attributed to the positive separation, safety alerts, and traffic advisories provided by controllers to aircraft operating in these designated airspaces. The ability of controllers to provide these services is contingent upon their awareness of all the airplanes in the contained volume of airspace as effected by the required pilot-to-controller communication. The probability that a controller will be aware of those aircraft that intrude into TCA or ARSA airspace is undoubtedly reduced when such communication does not exist. In fact, the Safety Board believes that a controller might be more inclined to overlook a potential conflict involving an unidentified VFR target without a displayed altitude within the bounds of a TCA or ARSA than he or she would if the conflicting targets were in airspace where a VFR/IFR mix is expected. Unreported VFR targets without a displayed altitude within the depicted horizontal boundary of a TCA or ARSA are common and are normally associated with aircraft above or below the altitude bounds, which thus do not threaten controlled airplanes within the TCA or ARSA. The Safety Board believes that such logic might apply to the Cerritos and Kearns accidents. If the theory is valid that controllers "overlook" VFR targets whose altitudes are unknown, the probability of awareness would likely increase if all aircraft in the vicinity of the TCA or ARSA were equipped with mode C altitude reporting transponders.

The Safety Board believes that the FAA must act to reduce the number of unauthorized VFR aircraft intruding into TCAs and ARSAs. Thus, the Safety Board was pleased when the FAA established a special task group in September 1986 as a result of the Cerritos accident. In reviewing the design and procedures pertaining to TCAs, the task group examined such factors as size, shape, traffic count, complexity, number and type of flight infractions, procedures, past enforcement action, and general TCA performance. As a result of the review, the task group made 40 recommendations, which were subsequently consolidated into 39 action items approved by the FAA Administrator.

The action items included the initiation of changes to simplify design of the TCA boundaries, to expand the airspace, to improve pilot education programs, to strengthen enforcement actions against violators, and to apply more stringent requirements to pilots and aircraft entering TCAs. Several of these actions are included in the Notice of Proposed Rulemaking (NPRM) issued on June 11, 1987, "Terminal Control Area (TCA) Classification and TCA Pilot and Equipment Requirements." The NPRM describes rulemaking to simplify TCA design, to require altitude reporting transponders in aircraft operating in all TCAs, and to enlarge the applicable volume of airspace around major airports.

The Safety Board generally endorses these actions and recognizes that the optimization of TCA design is a complex problem. The Safety Board will continue to monitor the FAA actions to achieve an appropriate final rule.

The FAA actions appear, however, to address the problem as it relates to TCAs only. The Safety Board believes that the Kearns accident shows that the hazard of unauthorized intrusion equally applies to ARSAs. In fact, the airports within ARSAs may accommodate a greater mix of air carrier and general aviation aircraft than those airports within TCAs. The Safety Board acknowledges that many of the action items pertaining to TCAs will have an inherent effect on the knowledge of pilots flying in and around ARSAs as well. The Safety Board believes that the FAA should implement positive actions to track, identify, and take appropriate enforcement action against pilots who intrude without the required ATC communication into ARSAs as well as TCAs. Furthermore, the Safety Board believes that airplanes operating in the ARSA should be equipped with transponders with an altitude reporting capability. The knowledge of the airplane's altitude will significantly enhance the ability of the radar controller to perceive and resolve flightpath conflicts.

While acknowledging that the excellent record of midair collision prevention within the PCA and TCAs is a tribute to controller performance, the Safety Board also recognizes that controllers occasionally need help. Thus, the prevention of collisions between two aircraft operating under IFR in airspace controlled by en route and terminal radar control facilities is partly attributable to the enhancements in the ATC system during the last 12 years, specifically the implementation of conflict alert logic into the en route and many terminal facility computer systems.

Even when controllers have communicated with pilots and established the identification of airplanes under their direct control, they occasionally miss a developing flightpath conflict, perhaps because of distraction caused by other control duties or high workload. Such occurrences sometimes result in a compromise of standard separation — a controller operational error. Undoubtedly, many operational errors and more serious compromises of separation between IFR airplanes have been prevented because the conflict alert feature at the control station alerted the controller to the developing situation.

Until recently, the conflict alert logic in both en route and terminal control facilities was effective only between aircraft of which the controller was aware, that is, the controller had accepted a hand-off of the aircraft from an adjacent ATC facility, or the controller had taken specific action to enter the aircraft into the ATC tracking environment. The conflict alert logic is based upon the system's knowledge of the aircraft's position, altitude, and predicted track, data that usually are determined by the aircraft's transponder replies and the ATC computer. In the en route environment, a controller can enter the aircraft's reported altitude into the system. Unless the controller enters the aircraft's reported altitude in the en route environment, and in all cases in the terminal environment, the conflict alert feature will only include airplanes with transponders and the associated mode C altitude reporting equipment.

The Safety Board is aware that the FAA is presently evaluating an enhancement to the en route radar control computer system in the Houston Air Route Traffic Control Center (ARTCC). This enhancement incorporates the additional computer processing requirement and software logic changes to permit conflict alert between aircraft equipped with transponders having an altitude reporting function, irrespective of the controller's previous awareness of the aircraft. Thus, the conflict alert signal will activate to bring a controller's attention to a convergence of any mode C-transponder equipped VFR aircraft with an aircraft under his or her control, in that way permitting positive separation or issuance of safety alerts and traffic advisories. The Safety Board is aware that the FAA plans to incorporate this enhancement into all ARTCCs when the new

"host" computer is introduced in the near future. The Safety Board is concerned, however, that there is no similar plan to incorporate a VFR intruder conflict alert feature into the TRACON facilities. The Safety Board has been advised that such an enhancement will not be available until the next generation ATC system, the Advanced Automation System (AAS), is implemented in the late 1990s.

Future Developments Needed

Except in those environments where all aircraft are known to the controller, are under radar control, and are subject to the computation of the ATC system conflict alert feature, the prevention of midair collisions in the National Airspace System depends entirely on human performance. Primary collision avoidance depends on the pilot's ability to see and avoid other airplanes with all the inherent limitations of see and avoid. The risk of collision is reduced when the pilots are operating within the ATC system and are communicating with a radar controller. However, collision prevention between aircraft operating within the ATC system and non-participating VFR aircraft is still contingent upon human performance — the controller's observation of the pending conflict. The Safety Board believes that the four accidents described herein are evidence that a system that relies on perfect human performance without automated backup does not provide a sufficient level of safety.

On the other hand, at least three of the accidents described herein (Cerritos, Kearns, and Independence) would probably have been prevented had the TRACON been equipped to provide a conflict alert signal to bring the controller's attention to a conflict with a VFR non-participating aircraft. This presumes also that both aircraft were equipped with the requisite mode C altitude reporting transponder.

The Safety Board strongly believes that air carrier airplanes should be protected from collision with each other and with general aviation airplanes and that such protection should be automated and redundant. The level of redundancy needed will only be provided when independent airborne and ground based systems are fully developed, certified, and required.

The Safety Board has been recommending that an airborne collision avoidance system be developed and required for air carrier aircraft since 1969. Most recently, following its investigation of a collision between a Wings West Airlines Beech 99 and a general aviation Rockwell Commander near San Luis Obispo, California, on August 24, 1984, the Safety Board restated these views in safety recommendations 2/ that acknowledged the FAA's progress in the development and certification of the TCAS. The Safety Board believes that a TCAS aboard the Aeromexico DC9, combined with a mode C transponder on the Piper, would have prevented the Cerritos accident. Furthermore, the Independence accident probably would have been prevented if the U-21 had been so equipped. Such military aircraft are likely to be equipped with TCAS when it is certified and available for installation.

The Safety Board has been told that the TRACON facility ARTS computers could be expanded by adding processing capacity to include VFR mode C intruder conflict alert logic. The Safety Board realizes that the procurement of the additional processors would probably infringe on other FAA priorities and may be viewed as an interim measure

2/ For more information, see Aircraft Accident Report--"Midair Collision of Wings West Airlines Beech C-99 (N639921) and Aesthetec, Inc., Rockwell Commander 112TC, N112SM, near San Luis Obispo, California, August 24, 1985" (NTSB/AAR-85/07).

to the ultimate installation of the AAS. Nevertheless, the Safety Board believes that the risk of midair collisions in the terminal area will increase with projected increases in traffic and that such interim measures must be taken promptly if catastrophic accidents are to be prevented during the next 10 to 12 years.

Since airborne TCAS and ground based conflict alert systems are both contingent upon an airplane's operating mode C altitude reporting transponder, the Safety Board believes that transponders with mode C should be required for all aircraft sharing airspace with those air carrier aircraft for which TCAS will be required, particularly when TCAS is installed aboard air carrier aircraft. This could be largely accomplished by imposing a requirement for this equipment as a requisite for operations near airports served by the air carriers, in particular around those airports protected by TCAs and ARSAs.

Finally, the Safety Board believes that the circumstances of the Orlando accident are probably rare, that is, the occurrence of mutual interference of transponders for a period of time long enough to mask a developing collision conflict. Nonetheless, the accident illustrates the serious consequences of this phenomenon. The Safety Board believes that this problem will be solved when the Discrete Address Beacon (mode S) transponder is introduced. The Safety Board realizes that the FAA is moving forward with the implementation of mode S and will continue to monitor the progress of that program.

Therefore, as a result of these accidents and a review of the FAA's ongoing activities, the Safety Board reiterates the following recommendations to the FAA:

A-85-64

Expedite the development, operational evaluation, and final certification of the Traffic Alert and Collision Avoidance System (TCAS) for installation and use in certificated air carrier aircraft. (A-85-64)

A-85-65

Amend 14 CFR Parts 121 and 135 to require the installation and use of Traffic Alert and Collision Avoidance System (TCAS) equipment in certificated air carrier aircraft when it becomes available for operational use.

In addition, the Safety Board recommends that the FAA:

Implement procedures to track, identify, and take appropriate enforcement action against pilots who intrude into Airport Radar Service Areas (ARSAs) without the required Air Traffic Control (ATC) communications. (Class II, Priority Action) (A-87-96)

Require transponder equipment with mode C altitude reporting for operations around all Terminal Control Areas (TCAs) and within Airport Radar Service Areas (ARSAs) after a specified date compatible with implementation of Traffic Alert and Collision Avoidance System (TCAS) requirements for air carrier aircraft. (Class III, Longer Term Action) (A-87-97)

Take expedited action to add visual flight rules conflict alert (mode C intruder) logic to Automated Radar Terminal System (ARTS) computers as an interim measure to the ultimate implementation of the Advanced Automation System (AAS). (Class III, Longer Term Action) (A-87-98)

BURNETT, Chairman, GOLDMAN, Vice Chairman, and LAUBER, NALL, and KOLSTAD, Members, concurred in these recommendations.

By: Jim Burnett
Chairman