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National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: October 29, 1990

In reply refer to: A-90-156 through -159

Honorable Richard H. Truly
Administrator
National Aeronautics and Space Administration
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Washington, D.C. 20546

The National Transportation Safety Board has completed its third investigation of a pilot deviation[1] incident in which an astronaut flying a National Aeronautics and Space Administration (NASA), Northrup Talon, T-38A airplane descended below an altitude assigned by air traffic control (ATC) and conflicted with passenger-carrying jet airplanes. These incidents involved single-pilot operations in which the airplanes were flown under instrument flight rules (IFR) flight plans and were receiving ATC services. The Safety Board's investigation of these incidents has determined the need for NASA to implement appropriate corrective actions to ensure the safe operation of its T-38A airplanes in the National Airspace System (NAS). The Safety Board has also issued safety recommendations to the Federal Aviation Administration (FAA), addressing the need for improvements in air traffic controller performance and in the ATC conflict alert system.

Background

NASA maintains a fleet of 28 T-38A airplanes for use by astronauts in its Space Flight Readiness Training program. These airplanes are used for flight proficiency and as transportation to and from meetings and public appearances. The airplanes are operated from civil and military airports throughout the United States. There are currently 47 astronauts designated as either commanders or co-pilots of the space shuttle. This group of pilots is required to fly and remain current in the T-38A airplane. There are 48 other astronauts, known as Mission Specialists, who are scheduled to be aboard the shuttle but are not designated as pilots of it. Of these 48, 10 are qualified pilots who are maintaining military currency by flying the T-38A. The remaining 38 Mission Specialists are not designated pilots. There are a total of 57 pilot-astronauts in the T-38A program.

[1] Pilot deviation: The actions of a pilot that result in the violation of a Federal Aviation Regulation or a North American Aerospace Defense Command Air Defense Identification Zone tolerance.

Details of the Incidents

On May 15th, 1989, an incident occurred resulting in a near-midair collision (NMAC)[2] between NASA N92ONS (NASA 920) and a Pan American World Airways Airbus A-310, N806PA (Clipper 140). The incident occurred about 2 miles northwest of the Washington/Dulles International Airport, Washington, D.C., about 1841 local time. NASA 920 descended through an assigned altitude of 8,000 feet to an altitude of 7,000 feet after having acknowledged to the controller, "...down to eight." Clipper 140 had been assigned 7,000 feet. The captain of Clipper 140 stated that the T-38A passed about 250 to 500 feet directly in front of his airplane at the same altitude and that there was no time to take evasive action. The pilot of NASA 920 stated that he did not see Clipper 140 but expedited a climb to 8,000 feet after receiving a traffic advisory from ATC. The flightcrews of both airplanes stated that at the time of the incident they were flying between cloud layers. They described the weather as "very scuddy" with no clear horizon and a forward visibility of 1/2 mile. ATC-recorded radar data indicated that the minimum distance between the two airplanes was 100 feet vertical and 700 feet lateral. Clipper 140 had departed from the Washington/Dulles International Airport with 166 passengers and 10 crewmembers aboard and was en route to Paris, France. NASA 920 had originally departed from Ellington Field, Houston, Texas, with a refueling stop at Fort Campbell, Kentucky. NASA 920's destination was Andrews Air Force Base.

On September 17, 1989, about 1447 local time, NASA 923 descended below its assigned altitude of FL330 and conflicted with N812BJ, a Piper Cheyenne, at FL310. The incident occurred 55 miles northwest of El Paso, Texas, in visual meteorlogical conditions. The pilot was returning from an astronaut training activity at Edwards Air Force Base, California, and was en route to Ellington Field, Texas. Recorded radar data indicated that the aircraft passed each other with 1,400 feet of vertical and 3.1 miles of horizontal separation.[3] Neither flight reported visual contact with the other.

On May 6, 1990, at 1647 local time, Memphis Air Route Traffic Control Center (ARTCC) cleared NASA 918 to descend from flight level (FL) 390 to FL370 near Paducah, Kentucky. NASA 918 acknowledged and read back what sounded like FL370 to the controller. However, the pilot descended below FL370 and conflicted with an Eastern Air Lines DC-9, flight 222, in level flight at FL350. The NASA pilot advised Safety Board investigators that he thought the controller said to descend to FL270, and the pilot said that he repeated to the controller, "flight level 270," after receiving the

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[2]An incident associated with the operation of an aircraft in which a possibility of collision occurs as a result of proximity of less than 500 feet to another aircraft, or an official report is received from an aircrew member stating that a collision hazard existed between two or more aircraft (Federal Aviation Administration definition).

[3]The minimum ATC separation is 2,000 ft vertical and/or 5 miles horizontal.

clearance. The incident occurred in visual meteorological conditions. Flight 222 was en route from Atlanta, Georgia, to Kansas City International Airport, Kansas. NASA 918 was en route from Wright-Patterson Air Force Base, Ohio, to Blytheville Air Force Base, Arkansas. Recorded radar indicated that the airplanes came within 1,500 feet vertically and 3 miles horizontally of each other. Neither flight crew reported that it had visual contact with the other.

The Safety Board has reviewed the FAA's records for other pilot deviations involving NASA T-38A aircraft. In addition to the incidents investigated by the Board, there were two incidents in 1986 and two in 1989 that involved altitude deviations. The Safety Board notes that all of these incidents, except one occurring in 1986, as well as the three that it investigated, involved deviations on descents below the assigned altitudes. NASA personnel said that they receive as many intermediate altitude assignments from ATC for climbs as they do for descents.

Investigation

For the three incidents cited, Safety Board investigators reviewed the pilots' training records, proficiency and instrument checks, the extent of recent flight experience, and medical evaluations. The pilots were fully qualified to fly the T-38A and met or exceeded the minimum training and operational standards established by NASA.

During personal interviews, the pilots of NASA 920 and 923 could not provide definitive reasons for their altitude deviations. Despite their acknowledgement by repeating the proper altitude clearances, the pilots continued their descents, inadvertently, to improper altitudes. Neither of the pilots had written their clearances on their "knee boards" because they said that they did not consider the clearances to be of sufficient complexity to warrant that action. When the Safety Board initially discussed these two incidents with NASA personnel, they were considering asking all T-38A pilots to write down altitudes and utilize a moveable cursor ("bug") on the air speed indicator as an altitude reminder. For example, if a flight received clearance to climb or descend to 7,000 feet, the pilot would read back the clearance verbatim while moving the airspeed marker to the .7 Mach[4] indices. Prior to the investigation of NASA 923, NASA suggested that its pilots use this technique.

The pilot of NASA 920 described his cockpit workload as "busy" and further commented that in the T38A, "with all you've got to do, it's real easy to not remember what altitude you're supposed to be going to." The pilots of NASA 920 and 923 stated that they believed the safety of the T-38A flight operation would be enhanced if the airplanes were equipped with an

[4] "Mach number" means the ratio of true airspeed to the speed of sound.

altitude alerting device,[5] similar to those used on aircraft in 14 CFR Part 121 and 135 operations.

In the investigation of the most recent incident involving NASA 918, the voice communication tape, which was recorded at the air traffic control facility, indicated that the air traffic controller cleared NASA 918 to descend to FL370 and not to FL270. Upon listening to this tape, particularly when investigators anticipated hearing the correct altitude, the pilot seemed to have read back "three seven zero." This could account for the controller's belief that the pilot correctly repeated his clearance to "three seven zero." However, after listening to the tape a number of times, the first syllable of the pilot's reply is actually indiscernible. The quality of the transmission from NASA 918, when compared with the quality of transmissions of other aircraft on the frequency, was much lower.

The pilot of NASA 918 reported during the Board's interview that he does not write down assigned altitudes or use the "bug" on the air speed indicator. When the pilot of NASA 918 listened to the recording of the voice communication tape, he expressed genuine surprise at the clarity of the controller's transmission instructing him to descend to FL370. He said that in the aircraft the transmission "sounded like 270." When the controller realized that NASA 918 had descended below FL370, he instructed the pilot to maintain FL370. The pilot said that he recalled the controller telling him to maintain an altitude but that the transmission was indistinct. He thought that the controller wanted him to go to FL370, but he wasn't sure. He then leveled off and asked the controller if he should climb back to FL370. When there was no response from the controller, he said that he slowly started a climb back to FL370.

Frequent comments received during interviews with NASA pilots described various problems associated with the communication equipment installed in the T-38A fleet. The Safety Board believes that the equipment is outdated and far from state-of-the-art. The UHF and VHF communication radios have only a single frequency selection capability. The Safety Board determined that simultaneous use of the UHF and VHF communication radios was a normal operating procedure for the pilots of NASA 920 and NASA 923. When the Safety Board investigated the most recent incident involving NASA 918, it learned that all NASA's astronaut pilots had been briefed not to use the radios simultaneously during periods of increasing workloads, such as in high-traffic terminal areas. The Board believes that such a practice is prudent and fully supports this change.

The Safety Board attempted to determine what, if any, human and/or operational factors contributed to the descents below assigned altitudes. High workload situations contribute to human errors. The pilot of NASA 920 was recleared by the Indianapolis Air Route Traffic Control Center (ARTCC),

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[5]Altitude alerting device: When a pilot receives an altitude clearance, the altitude is set in the altitude alert device. When the aircraft approaches the preselected altitude, an aural and visual alert is presented to the pilot.

via the preferential routing of the FINKS ONE STAR to the ARMEL VORTAC and then direct to Andrews. This required the pilot to locate and become familiar with the standard terminal arrival route (STAR). If the pilot had properly preplanned his flight, he would have filed the standard arrival routing and would not have been burdened with this extra workload while in flight. (The information for standard arrival routes into Andrews AFB was published and was available). As the flight was descending into the Washington terminal area, the pilot attempted to receive the Andrews automatic terminal information service (ATIS) but experienced difficulty in doing so on both the VHF and UHF frequencies. Subsequently, NASA 920 received several clearances from ATC, including heading changes to 030, 050, and 090 degrees, and then direct to the Armel VORTAC, descent clearances to 12,000 and 8,000 feet, a speed reduction to 250 knots, and a transfer of communications to Washington approach control, which, according to the pilot technique in use at that time, included both a VHF and UHF frequency change. The pilot was also required to fly the T-38A manually, without the aid of an autopilot, and navigate, while communicating with ATC. In contrast, the pilot of NASA 923, who made the same type of error as the pilot of NASA 920, commented that his workload was "light" and that it was a "beautiful day to fly."

In 1987, one of NASA's T-38A's was struck by lightning and was landed while on fire. Subsequent to this event, NASA developed and proposed an equipment improvement program for the T-38A fleet which included an electronic flight instrument system with weather display capability, an altitude alert, improved navigation and communication hardware, improved cockpit ergonomics, and other enhancements. NASA named this program the T-38A Avionics Upgrade. The Safety Board understands that in January 1991 a single T-38A will be configured as a prototype for this program, and subsequent to a period of evaluation, a decision will be made on whether or not to purchase the equipment for the rest of the fleet.

Recommendations

The Safety Board recognizes that in any human endeavor, errors are inevitable, but that they must be minimized. The Safety Board believes that NASA must implement changes to its T-38A flight program to reduce the potential for human error. NASA should also recognize and correct factors that contribute to the cause of such errors before other dangerous situations are created.

The Safety Board believes that NASA's use of the T-38A is unique. The T-38A is a high-performance airplane capable of supersonic speeds. Moreover, it is the only tactical-type airplane used extensively in the NAS that has a second crewmember seat that is not required to be occupied by a qualified crewmember on most flights. Although the military operates single seat fighter airplanes in the NAS, these flights are, for the most part, in groups of two or more. Most of the other IFR flights operating in the same environment as NASA 920, 923, and 918 include two or three cockpit crewmembers. In addition, these other airplanes are, by design, inherently more stable than the T-38A, equipped with autopilots, dual radio frequency

selection capability, flight directors, and altitude alerters, all of which enhance safety.

The T-38A, as currently configured and operated by NASA, is a high-workload airplane. The cockpit is small thereby posing problems for ergonomic design considerations. When the airplane is flown at high altitudes, the controls are quite sensitive, and the pilot must devote much attention to control of the airplane. If flying when thunderstorms are present, the lack of weather radar increases the workload. The radios and their respective controls are positioned at various locations throughout the cockpit. The substandard quality of the radio reception and transmissions causes pilots to have to strain to understand air traffic control instructions; occasionally, the pilots must request that the instructions be repeated. The simultaneous use of the UHF and VHF radios appears to be the result of the diminished level of confidence that pilots have in their airplane's aged communication equipment, in particular, the UHF radio. If the radios were equipped with dual frequency selectors, a frequency could be tuned ahead of time or a pilot could return to the last assigned frequency by operating a simple switch. This dual selection capability can have a positive effect on reducing cockpit workload. Nearly all turbojet airplanes flying in today's civil aviation environment are equipped with communication radios that have dual frequency selection capability. If a route is changed, the location of the map storage areas on the T-38A requires the pilot to turn his head and reposition his entire body in order to retrieve the item needed. A routine task, such as reviewing a book of STARS, requires two hands and is difficult without the use of an autopilot. All of these situations increase a pilot's workload, and, for a single-pilot operation without an autopilot, the workload is increased to an even greater extent.

The crew concept utilizing multiple flight crewmembers serves two purposes. It reduces workload by allowing one pilot to fly the aircraft and the other to handle communications and/or record clearances, set and verify navigation equipment, complete checklists, and perform other required cockpit duties. By reducing the workload, fewer mistakes are made that have to be corrected. The crew concept also serves as a redundant feature for the recognition of errors after they have occurred.

Just as the use of an additional flight crewmember helps to reduce workload and serves as a redundant feature for error correction, other items that are in daily use in commercial aviation fleets perform the same tasks, such as autopilots, and advanced navigation and flight instrumentation systems. Altitude alerters, on the other hand, serve primarily as a redundant reminder. All of these items enhance safety. The T-38A has none of these.

The Safety Board believes that the most recent incident would not have occurred if NASA 918 had been equipped with better radios or had a second crewmember aboard who may have questioned the pilot's response to the ATC altitude assignment. The pilot stated that the controller's transmission sounded like "270," that he was surprised at the clarity of the controller's transmission on the tape recording, and that he didn't clearly

hear the controller's transmission when instructed to maintain FL370. The pilot's transmission, which intended to confirm the assigned altitude of FL370, was of substandard quality. The pilot of NASA 920 also experienced difficulty receiving the ATIS on both UHF and VHF radios.

The Safety Board believes that the incident involving NASA 923 could have been prevented by the addition of either an altitude alerter or a crewmember occupying the second seat. The incident involving NASA 920 also could have been prevented by a reduced workload or a second person in the cockpit to assist the pilot.

The Safety Board believes that the primary reason that so many of NASA's T-38A altitude deviations were on descents rather than climbs is because of a fatigue factor. Because the T-38A is a high-workload airplane, the Safety Board believes that a type of short-term fatigue may develop, which results in a decreased amount of attention available for all of the tasks associated with controlling the airplane, navigating, and communicating with ATC. Consequently, descents at the end of a flight, coupled with short-term fatigue produce a higher probability that human error will occur. If the second seat is occupied by another pilot or mission specialist, the descent below assigned altitudes probably would be recognized and corrected before a dangerous situation develops. For flights conducted in high-density terminal environments, the addition of a second flight crewmember becomes even more critical, especially when instrument meteorological conditions are forecast. The Safety Board notes that the use of an autopilot is an asset to reducing cockpit workload. However, NASA has advised Safety Board investigators that the use of an autopilot in the T-38A is inconsistent with the training objectives of its Space Flight Readiness Training program. Flying the airplane manually provides desirable pilot training because the "hands-on" feel of the T-38A is similar to that of the space shuttle. Therefore, NASA has not included an autopilot in the T-38A Avionics Upgrade.

The Safety Board believes that through appropriate scheduling, NASA's 38 mission specialists, who are not pilots, could be designated to fly in the rear seat of the T-38A as flight crewmembers for all T-38A flights. These specialists are required to maintain a level of currency and proficiency in the airplane and are trained to perform specific duties. These duties include: (1) the retrieval and briefing of weather information, flight planning and briefing of the T-38A mission; (2) operating communications and navigation equipment; (3) monitoring the progress of the flight and advising the pilot concerning altitudes and airspeeds; and (4) providing checklist challenge and response when appropriate. In the current program, after these individuals receive 200 hours of total time in the second seat of the T-38A or other high performance airplanes similar to the T-38A, they are required to fly an average of 4 hours per month; the pilots are required to fly about 15 hrs per month in the T-38A. The three incidents that the Safety Board has investigated could have been averted by a second crewmember. The Safety Board therefore believes that NASA should encourage the use of a second flightcrew member for all T-38A flights operating in the NAS and require, pending workload reducing avionics

upgrades, the use of an additional flightcrew member for all T-38A flights in selected high density terminal airspace.

Although the pilots of NASA 920, 923, and 918 did not believe that the altitude clearances were of a sufficiently complex nature to warrant writing them down, the Safety Board believes that such action would have served as a reinforcement and reminder of the clearance limit. The Safety Board believes that NASA should immediately institute a requirement that its pilots write down all ATC clearances that incorporate altitude restrictions or a change in altitude. This policy should be strictly adhered to until altitude alerters become standard equipment in the T-38A's.

The Safety Board believes that NASA should consider its T-38A Avionics Upgrade to be a basic safety necessity, especially since it is currently projecting that the T-38A will meet its requirements until the year 2010. The Safety Board believes that the specific improvements included in this upgrade will significantly enhance the overall operational safety of the Space Flight Readiness Training program, and that NASA should expedite the final approval and implementation of the T-38A Avionics Upgrade.

Finally, the Safety Board believes that it is a prudent practice for all pilots to review and use preferential routes, including STARS, for all instrument flight rules flights. The use of these routes will reduce the need for rerouting by ATC which can increase the pilot's workload. The Safety Board believes that NASA should therefore require T-38A pilots to file preferential routes including STARS, if they exist, for flights within the NAS.

Therefore, the National Transportation Safety Board recommends that the National Aeronautics and Space Administration:

> Expedite the final approval and implementation of the T38A Avionics Upgrade. This program should include, as a minimum, the following state-of-the art equipment: an altitude alert feature, navigation and communication hardware, and an electronic flight instrument system with weather radar display capability. (Class II, Priority Action) (A-90-156)
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> Encourage the use of a second flightcrew member for all T-38A flights operating in the National Airspace System (NAS) and require, pending workload reducing avionics upgrades, the use of an additional flightcrew member for all T-38A flights in selected high density terminal airspace. (Class II, Priority Action) (A-90-157)
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> Require T-38A pilots to write down all air traffic control clearances that incorporate altitude restrictions or a change in altitude. (Class II, Priority Action) (A-90-158)

Require T-38A pilots to file preferential routes including standard terminal arrival routes (STARS), if they exist, for flights within the National Airspace System. (Class II, Priority Action) (A-90-159)

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "...to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any action taken as a result of its safety recommendations. Therefore, it would appreciate a response from you regarding action taken or contemplated with respect to the recommendations in this letter. Please refer to Safety Recommendations A-90-156 through -159 in your reply.

KOLSTAD, Chairman, COUGHLIN, Vice Chairman, and LAUBER, BURNETT and HART, Members, concurred in these recommendations.

By: James L. Kolstad
Chairman