National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: September 25, 2008

In reply refer to: A-08-71 and -72

The Honorable Robert A. Sturgell
Acting Administrator
Federal Aviation Administration
Washington, D.C. 20591

On July 29, 2006, about 1345 central daylight time, a de Havilland DHC-6-100, N203E, registered to Adventure Aviation, LLC, and operated by Skydive Quantum Leap as a local parachute operation flight, crashed into trees and terrain after takeoff from Sullivan Regional Airport, near Sullivan, Missouri.[1] The pilot and five parachutists were killed, and two parachutists were seriously injured. The flight was operated under 14 *Code of Federal Regulations* Part 91 with no flight plan filed. Visual meteorological conditions prevailed. Witnesses at the airport reported that, shortly after the airplane lifted off from the runway, flames emitted from the airplane's right engine. The airplane continued to fly low above the treetops before turning right and diving nose first into the ground.

The National Transportation Safety Board determined that the probable cause of this accident was the pilot's failure to maintain airspeed following a loss of power in the right engine due to the fracturing of compressor turbine blades for undetermined reasons. Contributing to some parachutists' injuries was the lack of a more effective restraint system on the airplane.

Accident Survivability

Only two of the seven parachutists survived the accident even though the airplane was equipped with parachutists' restraints and the cabin area in which all the parachutists were seated showed little crush intrusion. In fact, the crush damage observed on the wreckage showed that only the pilot was seated in a space subjected to nonsurvivable crush intrusion. Load analyses calculated during the investigation of the accident showed that the peak deceleration was between 6.6 G[2] and 19.7 G and that the final velocity was between 40.1 and 69.5 feet per

[1] For more information, see National Transportation Safety Board, *Crash of Skydive Quantum Leap, de Havilland DHC-6-100, N203E, Sullivan, Missouri, July 29, 2006*, Aircraft Accident Summary Report NTSB/AAR-08/03/SUM (Washington, DC: NTSB, 2008).

[2] One G is equivalent to the acceleration caused by the earth's gravity (32.174 feet/second^2).

second; these ranges fall within survivable limits outlined in the Safety Board's 1985 *General Aviation Crashworthiness Project* report.[3]

Because of the near-vertical orientation of the airplane at impact, most of the crash load forces were directed along the longitudinal axis of the airplane. As a result, the parachutists traveled primarily forward—toward the front of the cabin—during the crash sequence, and some of the parachutists entered the area of intrusion. The level of injury for each parachutist was affected by restraint use, surfaces impacted, and impacts received from other restrained and unrestrained parachutists in the cabin.

Single-Point Restraints in the Accident Airplane

The airplane's cabin was equipped with 20 sets of sidewall-mounted webbing restraint systems (10 sets on the left sidewall and 10 on the right) for parachutists.[4] This type of single-point restraint is designed to pass through the parachute harness, anchoring the parachutist to a single point on the airplane's sidewall using the sidewall-mounted seat tracks. The parachutists—three solo parachutists and two tandem pairs (one parachutist-in-command and one passenger parachutist per pair)—all sat facing aft at the time of the crash.[5] The three solo parachutists sat on the floor, and each tandem pair straddled one of two foam block benches in the forward cabin. All of the parachutists had restraints accessible from their seated locations.

Evidence of Parachutists' Restraint Use

One tandem pair sat straddling the foam block bench on the right side, and evidence suggests that each member of this pair likely used a restraint. The parachutist-in-command's seating position was the most forward (closest to the front of the cabin) of the parachutists seated on the right side of the airplane. His passenger-parachutist sat in close proximity and immediately aft of his position. Also, the close seated proximity of this pair suggests that they may have harnessed together before takeoff, although this would be inconsistent with company practice.

The parachutist-in-command did not survive the accident. Analysis of his injuries suggests that the loose, single-point restraint enabled considerable forward motion of his upper body and head, exposing him to large forces and allowing him to enter the intrusion area and impact surfaces there. Further, he was impacted by his tandem partner, who survived the accident. Analysis of her injuries, which were serious, suggests that she likely benefited from her

[3] For more information, see National Transportation Safety Board, *General Aviation Crashworthiness Project Phase III: Acceleration Loads and Velocity Changes of Survivable General Aviation Accidents*, Safety Report NTSB/SR-85/02 (Washington, DC: NTSB, 1985).

[4] A Federal Aviation Administration Form 337, dated April 17, 2000, indicated that 22 sets of seatbelt restraints for parachutists were installed. Only 20 sets were identified in the videos, the preaccident photographs, and the postaccident photographs. Whether or not the airplane ever contained additional restraints is unknown. The characteristics of the identified restraints appeared consistent with the descriptions provided on the Form 337.

[5] Video evidence indicated that two of the parachutists in the aft cabin initially faced forward during takeoff but later repositioned and sat on the floor facing aft.

restraint and from the impact attenuation achieved by having another person coupled to her back, acting as a barrier between her and the cabin crush intrusion. She was also likely not impacted by parachutists seated aft of her location because the parachutist seated on the floor directly aft of her location was restrained.

Like the tandem pair just described, the pair on the left side of the airplane sat straddling a foam block bench. Evidence suggests that at least one member of this pair likely used a restraint. The parachutist-in-command's seating position was the most forward of the parachutists seated on the left side of the airplane. His passenger-parachutist sat in close proximity and immediately aft of his position. As with the other tandem pair, the seated proximity of the members of this pair suggests that they may have harnessed together before takeoff.

Neither member of this pair survived. Although the parachutist-in-command was likely restrained (either independently or through his attached tandem partner), analysis of his injuries suggests that the loose restraint allowed him to be exposed to large forces and to impact the surfaces in the intrusion area. He was also impacted by his tandem partner. Although the partner, too, was likely restrained (likely to the sidewall) and likely benefited from the impact attenuation achieved by having another person coupled to her back, she was likely impacted by at least one of two likely unrestrained parachutists seated in the aft cabin. Analysis of her injuries suggests that they may have resulted from an impact by at least one other parachutist and from the failure of the loose, single-point restraint to adequately restrain her.

One of the three solo parachutists sat on the floor on the right side of the airplane just aft of the foam block bench. Although she used a restraint routed through the left-leg portion of her parachute harness, she did not survive the accident. Analysis of her injuries suggests that they likely resulted from the failure of the loose, single-point restraint to adequately restrain her and from the impact received from the likely unrestrained parachutist seated on the right side of the airplane aft of her position.

A second solo parachutist sat on the floor on the left side of the airplane and was likely unrestrained; he did not survive the accident. Analysis of his injuries suggests that, because he was seated a distance aft of the passenger-parachutist seated forward of his position on the left, he likely traveled a large distance before impacting her and/or a surface, resulting in high impact forces. Despite the attenuation of these forces through impacts with the other parachutist, he also likely traveled into the area of intrusion. Therefore, his lack of restraint use, along with a lack of support forward of his seating position, contributed to his fatal injuries.

A third solo parachutist sat on the floor in the aft cabin on the right side of the airplane (aft of the restrained solo parachutist) and was likely unrestrained; however, he survived the accident. Analysis of his injuries suggests that he impacted the restrained parachutist forward of his position on the right and possibly also the passenger-parachutist on the left. Colliding with other parachutists may have absorbed some of his impact energy, thus, reducing the forces experienced by his body during the crash. Also, he was not impacted by other parachutists because none were seated aft of his position.

Restraint Performance

Only one of the five parachutists who were likely restrained survived the accident. Historically, parachutists have fared poorly during parachute operations airplane crashes because they do not have the crash protection provided by typical aircraft passenger seat structures and passenger seatbelts. As a result of the Safety Board's investigation of several parachute operations accidents, the Board issued safety recommendations in 1994 regarding parachutists' seating and restraints.[6] In response to the recommendations, the Federal Aviation Administration (FAA) Civil Aerospace Medical Institute (CAMI), in conjunction with the Parachute Industries Association and the United States Parachute Association (USPA),[7] performed a series of dynamic sled tests to evaluate various types of restraint systems for parachutists and published a report on its findings.[8] The restraint systems evaluated included both single- and dual-point systems intended for aft-facing, floor-seated occupants. All of the systems tested were designed to pass through the parachute harness and attach to the aircraft floor.

Tests involving single-point restraint systems, such as those installed on the accident airplane, showed poor kinematics of the test dummies. The results of the sled test for one single-point restraint design,[9] which attached around the near side of the parachutist's back strap, noted the following:

> During the impact, the [dummy] slid forward significantly, then violently rotated counterclockwise about the center of the pelvis. The upper torso rotated forward to 40 degrees from vertical and the legs flailed about the vertical axis to a position 90 degrees from initial.

Like the test sled configuration, the accident airplane's configuration provided no support for the upper body, enabling each restrained parachutist's upper body to rotate toward the front of the airplane during the impact sequence. As in the test findings, some of the parachutists in the accident airplane who used the single-point restraints experienced harmful movement, such as

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[6] On February 17, 1994, the Safety Board issued Safety Recommendation A-94-16, which asked the Federal Aviation Administration (FAA) to do the following: "In conjunction with industry, the United States Parachute Association, and the Civil Aerospace Medical Institute, develop and test universal restraint systems capable of providing adequate protection to parachutists similar to that provided for seated passengers." The FAA responded on March 26, 1999, that testing identified possible improvements in restraining parachutists and that it is not possible to provide the same level of protection afforded to occupants in seats. Because the FAA's actions met the intent of the safety recommendation, the Safety Board classified it "Closed—Acceptable Action" on January 4, 2000. The full text of the safety recommendation letter (which references several accidents), is available on the Board's website at <http://www.ntsb.gov/Recs/letters/1994/A94_16_19.pdf>.

[7] On February 17, 1994, the Safety Board also issued Safety Recommendation A-94-22, which asked the USPA to do the following: "Participate in the design, development, and testing of a universal restraint system that would provide adequate protection for parachutists seated on an aircraft floor." The USPA participated, as requested, in CAMI's restraint testing. Therefore, the Board classified the safety recommendation "Closed—Acceptable Action" on June 5, 2001.

[8] U.S. Department of Transportation, Federal Aviation Administration, Civil Aerospace Medical Institute, *Evaluation of Improved Restraint Systems for Sport Parachutists*, DOT/FAA/AM-98/11 (Washington, DC: DOT/FAA, 1998).

[9] The tested design anchored the parachutist tautly to the floor, whereas the accident airplane's restraints anchored the parachutists loosely to the sidewall.

large translational and rotational motion. Lack of support for the upper body and head, slack in the restraints, and any restraint and/or harness stretch during the accident sequence enabled forward motion of each restrained parachutist into the region of intrusion and/or into other parachutists. These types of issues contributed to the severity of the injuries sustained by the five parachutists who were likely restrained. Based on the results of CAMI's past testing and the serious and fatal injuries sustained by some of the restrained parachutists in this crash, the Safety Board concludes that a single-point restraint system is not sufficient to provide adequate restraint for parachutists. The Board further concludes that more parachutists may have survived, and injuries may have been reduced, if more effective restraints had been used.

The results of the CAMI tests revealed that dual-point restraint systems were superior to single-point restraints.[10] However, the CAMI tests for the dual-point restraints were conducted with the restraints mounted to the floor and attached symmetrically to the parachute harness system. The accident airplane, which had sidewall attachment tracks, was not configured for a symmetrical, dual-point system; other common seating arrangements on parachute operations aircraft likely also have attachment configurations that differ from the symmetrical dual-point design tested by CAMI. Although the absence of test data specific to the accident airplane's configuration precludes a determination of the optimal dual-point restraint design for that airplane, the Safety Board concludes that testing could identify the best method for dual-point restraint for the accident airplane's configuration and for the configurations of other airplanes commonly used in parachute operations. Therefore, the Safety Board believes that the FAA should conduct research, in conjunction with the USPA, to determine the most effective dual-point restraint systems for parachutists that reflects the various aircraft and seating configurations used in parachute operations.

In addition, the Safety Board notes that FAA Advisory Circular (AC) 105-2C, *Sport Parachute Jumping*, is an established source of guidance containing suggestions for improving the safety of parachute jump operations, including information for operators about modifying aircraft for parachute operations. However, AC 105-2C contains little information about restraint systems beyond the statement that "seatbelts must be provided to each person, and their installation must be approved." Therefore, the Safety Board believes that, once the most effective dual-point restraint systems for parachutists are determined, the FAA should revise AC 105-2C to include guidance information about these systems.

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

> Conduct research, in conjunction with the United States Parachute Association, to determine the most effective dual-point restraint systems for parachutists that reflects the various aircraft and seating configurations used in parachute operations. (A-08-71)
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> Once the most effective dual-point restraint systems for parachutists are determined, as requested in Safety Recommendation A-08-71, revise Advisory

[10] The results also concluded that survival may be improved by providing head support, by anchoring the restraint at a specific point, and by bracing in a specific manner for impact.

Circular 105-2C, *Sport Parachute Jumping*, to include guidance information about these systems. (A-08-72)

The Safety Board also issued two safety recommendations to the United States Parachute Association.

In response to the recommendations in this letter, please refer to Safety Recommendations A-08-71 and -72. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our Tumbleweed secure mailbox procedures. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

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

[*Original Signed*]

By: Mark V. Rosenker
Acting Chairman