Crash of Skydive Quantum Leap de Havilland DHC-6-100, N203E Sullivan, Missouri July 29, 2006

AIRCRAFT ACCIDENT SUMMARY REPORT

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de Havilland DHC-6-100, N203E
Sullivan, Missouri
July 29, 2006

National
Transportation
Safety Board

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2008. ***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.**

Abstract: This report explains the July 29, 2006, accident involving a de Havilland DHC-6-100, N203E, registered to Adventure Aviation, LLC, and operated by Skydive Quantum Leap as a local parachute operation flight. The aircraft crashed into trees and terrain after takeoff from Sullivan Regional Airport, near Sullivan, Missouri. The safety issues discussed in this report relate to the inadequate protection provided by single-point restraints for parachutists. Included are safety recommendations addressed to the Federal Aviation Administration and the United States Parachute Association regarding this issue.

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ABBREVIATIONS

AC	**advisory circular**
CAMI	**Civil Aerospace Medical Institute**
CFR	*Code of Federal Regulations*
EMMA	**equalized maintenance for maximum availability**
FAA	**Federal Aviation Administration**
FSDO	**flight standards district office**
IAS	**indicated airspeed**
MEL	**minimum equipment list**
MMEL	**master minimum equipment list**
PMA	**parts manufacturer approval**
SB	**service bulletin**
TBO	**time between overhaul**
USPA	**United States Parachute Association**
UUV	**Sullivan Regional Airport**

Executive Summary

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. 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 (and photographic evidence showed) that, shortly after the airplane lifted off from the runway, flames emitted from the airplane's right engine. Witnesses reported that the airplane continued to fly low above the treetops before turning right and diving nose first into the ground.

The safety issues discussed in this report relate to the inadequate protection provided by single-point restraints for parachutists. Two safety recommendations to the Federal Aviation Administration and two to the United States Parachute Association are included.

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1. The Accident

On July 29, 2006, about 1345 central daylight time, a de Havilland DHC-6-100,[1] N203E, registered to Adventure Aviation, LLC, and operated by Skydive Quantum Leap as a local parachute operations flight, crashed into trees and terrain after takeoff from Sullivan Regional Airport (UUV), near Sullivan, Missouri. The pilot and five parachutists were killed, and two parachutists were seriously injured. The flight was operated under 14 *Code of Federal Regulations* (CFR) Part 91 with no flight plan filed. Visual meteorological conditions prevailed.

According to photographic evidence provided by a witness, the pilot taxied the airplane onto runway 24 from the intersecting taxiway, which is about 1,700 feet from the runway's west end, and began a takeoff roll to the west from that location, rather than using the runway's entire 4,500-foot length. Photographic evidence depicting the airport windsock shows that the airplane departed into a moderate headwind. Witnesses at the airport reported seeing the airplane take off and climb to about treetop height.[2] Several witnesses reported hearing a "poof" or "bang" noise and seeing flames and smoke coming from the right engine. One witness reported that, after the noise and the emergence of flames, the right propeller was "just barely turning." Photographic evidence shows that, at one point after the flames occurred, the airplane was about one wingspan (about 65 feet) above the runway. (See figure 1.) One witness estimated that the airplane climbed to about 150 feet.

Figure 1. Witness' photograph showing accident airplane above the end of runway 24 with smoke and flames visible from right engine. (Inset shows an enlarged view.)

[1] The DHC-6-100 was originally manufactured by de Havilland, but the type certificate is currently held by Viking Air Limited of Sidney, British Columbia, Canada.

[2] According to estimates from witnesses and other sources, the tree height ranged from 30 to 100 feet.

Witnesses reported that the airplane lost some altitude, regained it, and then continued to fly low above the treetops before turning to the right and disappearing from their view behind the treeline. Another witness in the backyard of a residence northwest of the airport reported that she saw the airplane flying straight and level but very low over the trees before it dived nose first to the ground. She and her father called 911, and she said that local emergency medical service personnel arrived within minutes. The airplane impacted trees and terrain and came to rest vertically, nose down against a tree behind a residence about 1/2 mile northwest of the end of runway 24. (An aerial map of the runway and accident site is shown in figure 2.)

Figure 2. Aerial map of UUV showing runway 24, the intersecting taxiway, and the accident site.

2. Investigation and Analysis

The airplane was powered by two Pratt & Whitney Canada PT6A-20, 550-horsepower engines equipped with three-bladed, single-acting, hydraulically operated, constant-speed, reversible Hartzell propellers with feathering[3] capabilities. Examination of the wreckage, including both engines and propellers, revealed that the right engine's compressor turbine disk was intact but that its attached blades[4] were fractured; the damage observed within the engine resulted in the loss of engine power. No evidence of any other preimpact conditions that would interfere with normal operations was found during examinations of the airplane, engines, propellers, and components.

2.1 Loss of Power in One Engine

Microscopic examination of the right engine's fractured compressor turbine blades revealed features consistent with overload. Additional damage was observed in engine sections beyond the compressor turbine section along the engine's gas path. Also, several of the right engine's compressor turbine blade tips were missing. The overload fractures on the blades in the compressor turbine section and the damage beyond that section were consistent with mechanical damage caused by separated compressor turbine blade tips migrating within the engine. Because no preimpact anomalies were observed in engine areas forward of the damaged compressor turbine along the engine's gas path, there is no evidence that an ingested object, such as a bird or debris, initiated the overload events in the compressor turbine section.[5] Therefore, the initial blade separation originated within the compressor turbine section. However, because several separated compressor turbine blade tips were not located for examination, the source of the initial event or condition that precipitated the overload events could not be determined.

The airplane's maintenance records indicate that the left and right engines had accumulated 5,829 hours and 6,493 hours since overhaul, respectively (15,155 hours and 17,264 hours since new, respectively), which far exceeded the manufacturer's recommended time between overhaul (TBO) period of 3,600 hours, as stated in Pratt & Whitney Canada Service Bulletin (SB) 1803R1, "Turboprop Engine Operating [TBOs] and Hot Section Inspection Frequency."[6] However, Federal regulations do not require operators of aircraft

[3] Feathering means to rotate the propeller blades so that the blades are parallel to the line of flight (streamlined to the airflow) to reduce the drag caused by the blades and prevent further damage to an engine that has stopped operating.

[4] The compressor turbine blades were Federal Aviation Administration (FAA) PMA (parts manufacturer approval) blades manufactured by Doncasters, Inc., Turbo Products Division.

[5] In addition, the engine's intake port is at the rear of the engine and is designed with a mesh-screen cover, further reducing the likelihood of an ingestion of objects or birds during flight.

[6] Further, SB 1803R1 specifically excludes engines that have been used in parachute jump operations from eligibility for the manufacturer's program for extending TBOs. Pratt & Whitney Canada reported that it had no documentation indicating that the operator requested to participate in the TBO extension program.

operated under 14 CFR Part 91 to comply with manufacturers' recommended TBOs specified in SBs or service information letters.

In developing TBOs, manufacturers analyze the cumulative effects of various stresses placed on different components over time. Based on this analysis, manufacturers determine a schedule of maintenance and inspection that they believe will provide an acceptable level of safety. Overhauling an engine within the manufacturers' recommended TBO increases the likelihood that potentially catastrophic conditions that may otherwise be undetectable will be discovered and corrected. Therefore, the Safety Board concludes that, although damage to the accident airplane's right engine precluded determination of the initial event that precipitated the overload fracturing of the compressor turbine blades, and although the operator was not required to comply with the engine manufacturer's SBs, it is possible that the initiating fracture event within the engine resulted from a condition that could have been detected and corrected during an engine overhaul performed within the manufacturer's recommended TBO.

Because most parachute jump operators function under Part 91 and thus, are not required to comply with TBOs, the Safety Board in its 2008 *Special Investigation Report on the Safety of Parachute Jump Operations*,[7] issued Safety Recommendation A-08-63 on September 16, 2008, that asked the Federal Aviation Administration (FAA) to do the following:

> Require parachute jump operators to develop and implement Federal Aviation Administration-approved aircraft maintenance and inspection programs that include, at a minimum, requirements for compliance with engine manufacturers' recommended maintenance instructions, such as service bulletins and service information letters for time between overhauls and component life limits.[8]

In addition, to help operators implement effective maintenance and inspection quality assurance programs, on September 16, 2008, the Safety Board issued Safety Recommendation A-08-64 that asked the FAA to do the following:

> Develop and distribute guidance materials, in conjunction with the United States Parachute Association [(USPA[9])], for parachute jump operators to

7 National Transportation Safety Board, *Special Investigation Report on the Safety of Parachute Jump Operations*, Special Investigation Report NTSB/SIR-08/01 (Washington, DC: NTSB 2008).

8 Safety Recommendation A-08-63 is classified "Open—Await Response."

9 The USPA is a voluntary organization made up of about 31,000 individual members and about 270 operator members, also called "group members" or "drop zones." USPA supports and promotes safe skydiving through parachuting training, rating, and competition programs and distributes safety information through printed publications and its website.

> assist those operators in implementing effective aircraft inspection and maintenance quality assurance programs.[10]

2.2 Pilot Performance of Emergency Procedures

According to section 3.1 of the emergency procedures of the airplane's flight manual, which was found in the wreckage, the emergency procedures for an engine failure during takeoff include, in part:

> If engine failure occurs above V_{mc} [minimum control speed[11]] and a decision is made to continue the take-off, proceed as follows: … Maintain heading by applying rudder and lowering wing against the live engine as necessary and lower nose to hold desired airspeed. … Advance power levers. … Power lever of failed engine - IDLE. … Propeller lever of failed engine - FEATHER. … Hold 71 knots IAS[12] if flaps at 30°; … 83 knots IAS if flaps at 0°. … When clear of obstacles, the flaps should be retracted in increments and the airspeed increased appropriately per the above schedule in order not to lose altitude during retraction. Best single engine rate of climb is achieved with flaps 0° at 83 knots IAS.

The emergency procedures to configure a multiengine airplane for climb following a loss of engine power during takeoff are generally considered "memory items," which are procedures that a pilot must execute immediately from memory rather than first using a checklist. However, evidence showed that the accident pilot failed to effectively perform most of those procedures. For example, as the photograph in figure 1 illustrates, the airplane's rudder was not deflected and its wings were not banked toward the operating engine. Witnesses' descriptions of the flight indicated that the pilot instead allowed the airplane to drift to the right (toward the inoperative engine)[13] before it nose-dived into the ground.

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[10] On September 16, 2008, the Safety Board also issued Safety Recommendation A-08-69 that asked the USPA to do the following: "Work with the Federal Aviation Administration to develop and distribute guidance materials for parachute jump operators to assist operators in implementing effective aircraft inspection and maintenance quality assurance programs." Safety Recommendations A-08-64 and A-08-69 are each classified "Open—Await Response."

[11] According to FAA definitions, V_{mc} is the minimum airspeed at which the airplane could remain controllable with its critical engine inoperative; for twin-engine airplanes, the critical engine is the engine in which a failure would have the most adverse effect on directional control. On the DHC-6-100 airplane, which has engines that both rotate in conventional, clockwise rotation as viewed from the pilot's seat, the left engine is the critical engine.

[12] Knots IAS stands for knots indicated airspeed, which is the speed of the airplane as shown on the airspeed indicator on the cockpit control panel.

[13] A turn toward an inoperative engine can degrade climb performance. See National Transportation Safety Board report AAR-79-10 for information about a similar accident involving a DHC-6-300 airplane. This report stated, in part, "expected climb performance can be degraded by ... turns into the failed engine, by failure to minimize drag by inducing a sideslip or not maintaining correct speeds, and by turns away from the headwind."

The information provided by witnesses, the nose-down attitude of the wreckage, and the crush damage to the forward fuselage of the airplane are consistent with an uncontrolled descent due to an aerodynamic stall. Further, the filaments of the stall warning light, recovered from the wreckage, were found stretched, which is consistent with the light having been illuminated at impact.

According to a performance assessment provided by the airplane's current type-certificate holder, given the weather conditions at the time of the accident, airport altitude, and calculated weight for the accident airplane, the airplane should have been capable of a positive single-engine climb rate of about 300 feet per minute if the pilot had configured the airplane properly according to the published procedures by feathering the propeller on the failed engine and attaining the recommended airspeed.

However, according to the *Airplane Flying Handbook*, published by the FAA, factors such as "engine and propeller wear, or poor technique in airspeed, bank angle, and rudder control," among others, can reduce actual rate-of-climb performance.[14] Several performance-reducing factors were present during the accident flight: the accident airplane's engines were thousands of hours beyond the manufacturer's recommended TBO, and photographic evidence indicates that the pilot used poor technique by not banking the airplane or using rudder control to maintain airspeed as prescribed in the airplane's emergency procedures. Therefore, the Safety Board concludes that, although engine wear would likely have prevented the accident airplane from obtaining its maximum published single-engine climb performance, the pilot's failure to maintain airspeed, according to the technique specified in the published emergency procedures following the loss of power in one engine, negated any possibility of continued, controlled flight that could have allowed for a return to the airport or other suitable landing area. Because the pilot did not effectively configure the airplane for continued single-engine flight, the airplane could not sustain a climb; therefore, the pilot's only other available option would be to maintain a controllable airspeed and perform a controlled descent. However, the airplane's descent was not controlled; the pilot allowed the airplane's airspeed to decay to the point of aerodynamic stall.

In the Safety Board's 2008 special investigation report on parachute operations,[15] the Board identified several parachute operations accidents in which the pilots were deficient in maintaining airspeed and properly executing emergency procedures. As a result, the Safety Board issued Safety Recommendation A-08-65 on September 16, 2008, that asked the FAA to do the following:

> Require parachute jump operators to develop initial and recurrent pilot training programs that address, at a minimum, operation- and aircraft-specific weight and balance calculations, preflight inspections,

[14] See U.S. Department of Transportation, Federal Aviation Administration, *Airplane Flying Handbook*, FAA-H-8083-3A (Washington, DC: FAA, 2004): Ch. 12, p. 12-10.

[15] See NTSB/SIR-08/01.

> emergency and recovery procedures, and parachutist egress procedures for each type of aircraft flown.[16]

In addition, the Safety Board issued Safety Recommendation A-08-66 on September 16, 2008, that asked the FAA to do the following:

> Require initial and recurrent pilot testing programs for parachute jump operations pilots that address, at a minimum, operation- and aircraft-specific weight and balance calculations, preflight inspections, emergency and recovery procedures, and parachutist egress procedures for each type of aircraft flown, as well as competency flight checks to determine the pilots' competence in practical skills and techniques in each type of aircraft.[17]

As noted in the emergency procedures, the propeller configuration is also a factor in the accident airplane's single-engine climb performance; the propeller of the inoperative engine should be feathered. Although the accident airplane was equipped with a propeller autofeathering system designed to automatically feather the propeller of an underpowered engine, the system was deactivated.[18] With the system deactivated, the pilot would need to manually position the propeller-control lever of the failed engine to the "feather" position to feather the propeller blades. Because of the impact damage to the cockpit propeller-lever controls, it was not possible to determine their preimpact positions. However, postaccident examination of the right propeller assembly revealed that the blades were at high angles at impact, which is consistent with a feather or near-feather condition. Also, the autofeather system had been inoperative since the operator acquired the airplane in 2001, and its deactivated status was placarded in the cockpit; therefore, the pilot (who also operated Skydive Quantum Leap) was likely aware of the discrepancy. Further, the airplane was originally certificated without an autofeather system, and the airplane's published emergency procedures, which were available to the pilot in the cockpit, correctly indicated the procedure for feathering the propeller without the autofeather system. Therefore, the Safety Board concludes that, although the airplane's autofeather system, had it been operative, would have helped the pilot promptly feather

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[16] In addition, to help operators implement effective pilot training programs, on September 16, 2008, the Safety Board issued Safety Recommendation A-08-67 that asked the FAA to "[r]evise the guidance materials contained in Advisory Circular 105-2C, *Sport Parachute Jumping*, to include guidance for parachute jump operators in implementing effective initial and recurrent pilot training and examination programs that address, at a minimum, operation- and aircraft-specific weight and balance calculations, preflight inspections, emergency procedures, and parachutist egress procedures." Also, on September 16, 2008, the Safety Board issued Safety Recommendation A-08-70 that asked that the USPA do the following: "Once Advisory Circular (AC) 105-2C has been revised to include guidance for parachute jump operators in implementing effective initial and recurrent pilot training and examination programs that address, at a minimum, operation- and aircraft-specific weight and balance calculations, preflight inspections, emergency procedures, and parachutist egress procedures, distribute this revised AC to your members and encourage adherence to its guidance." Safety Recommendations A-08-65, A-08-67, and A-08-70 are each classified "Open—Await Response."

[17] Safety Recommendation A-08-66 is classified "Open—Await Response."

[18] The accident airplane was modified with a propeller autofeather system, which, according to the airplane's flight manual, is designed to "automatically feather the propeller of an underpowered engine when a decrease in torque to 13 [to] 11 [pounds per square inch] is detected … ." Examination of the airplane at the accident site, however, revealed that the autofeather system switch was placarded "DEACTIVATED."

the propeller of the inoperative engine, there is insufficient evidence to suggest that the inoperative autofeather system was a factor in the accident.

2.3 Intersection Takeoff Considerations

The pilot elected to perform the departure from an intersection location that left only 1,700 feet of the 4,500-foot runway available; photographic evidence shows that the airplane, at one point, was above the runway and near the departure end with flames and smoke visible on the right engine. Because the airplane had already achieved a speed above V_{mc} when the engine lost power, the pilot's decision to continue the flight was appropriate, according to the published emergency procedures for the airplane, regardless of available runway. However, page 12-18 of the FAA's *Airplane Flying Handbook* points out that a loss of engine power during takeoff is a critical emergency because altitude and time are minimal and that "it is paramount [for the pilot] to maintain airplane control and comply with the manufacturer's recommended emergency procedures." According to the airplane flight manual, the emergency procedures for configuring the airplane are to be performed if "a decision is made to continue the takeoff." A decision to discontinue a takeoff and land the airplane following a loss of engine power at an airspeed above V_{mc} would be up to the discretion of the pilot based, in part, on the pilot's assessment of available runway.

Because the accident airplane's airspeed and altitude at the time that the engine problem could have first been detected is not known, precise estimates of runway requirements to land the accident airplane following the loss of power cannot be determined. However, available witness and photographic information and performance information provided by the airplane's current type-certificate holder indicate that had the entire 4,500-foot runway been used, the airplane could have been landed straight ahead on the remaining runway following the loss of engine power but it might have overrun the end of the runway before coming to a stop within the airport boundary. The Safety Board concludes that the pilot's decision to use only 1,700 feet of the available runway diminished the margin of safety during takeoff because it eliminated the option of discontinuing the takeoff and performing a straight-ahead, emergency landing on the runway.

2.4 Operator Information

2.4.1 General

Skydive Quantum Leap was corporately owned and operated by the accident pilot since November 1993 and carried an estimated 10,000 to 12,000 parachutists per year, with a maximum of about 15,000 parachutists carried in 1 year. The accident airplane, which was owned by a limited liability company controlled by the accident pilot, was the operator's only airplane. Although the accident flight carried revenue parachutists, it was operated under Part 91 because 14 CFR 119.1(e) (6) exempts nonstop parachute operations flights conducted within a 25-mile radius of the departure airport from the rules that govern air carriers and other commercial operators.

The accident pilot, age 42, held an airline transport pilot certificate with a rating for multiengine land airplanes and commercial privileges for single-engine land airplanes. He held a first-class airman medical certificate, issued June 8, 2006, with no restrictions. On his application for the medical certificate, the pilot reported that he had accumulated 6,000 total civilian flight hours, with 400 hours accumulated in the previous 6 months. The pilot was properly certificated and qualified to perform the parachute operations flight, and there was no evidence that any physiological or other impairment affected his performance.

2.4.2 Maintenance Program for the Airplane

The operator used an independent maintenance facility to perform maintenance and inspections on the airplane, which was maintained under an equalized maintenance for maximum availability (EMMA) controlled inspection program.[19] According to the airplane's maintenance logbooks, its most recent inspection was an EMMA check number 16[20] completed on May 21, 2006, at an airframe total time of 37,434 hours.

Although evidence indicates that the operator followed the EMMA program for inspecting the airplane at the prescribed intervals, the operator did not repair all the discrepancies observed during the inspections. For example, the mechanic who performed the most recent EMMA inspection recalled that the operator had not wanted him to repair the airplane's inoperative autofeather system, so the mechanic ensured that the system was deactivated and that a "DEACTIVATED" placard was placed in the cockpit near the autofeather switch. Because the operator did not have an FAA-approved minimum equipment list (MEL) for the airplane, the operator was not authorized to dispatch the airplane with any inoperative equipment.[21] Further, an FAA-approved MEL, if the

[19] The EMMA inspection program was designed to use work cards to inspect airplanes in 5 delineated areas during 48 checks that take place every 125 flight hours. Special cards are included to address routine inspections, airworthiness directives, corrosion inspections, and items affected by calendar rather than flying hours.

[20] According to the EMMA inspection record, the number 16 inspection work cards specify a detailed grouping of tasks designed to inspect a wide variety of listed items on the airplane, such as specific airframe and powerplant items; electrical, hydraulic, and fuel system items; and communication and navigation system items, among others. The tasks include inspecting the specified items for security, condition, freedom of movement, cleanliness, corrosion, function, and operability, and the cards specify the removal, reinstallation, and/or replacement of items, as indicated.

[21] According to 14 CFR 91.213, no person may take off in a turbine-powered airplane with inoperative instruments or equipment installed unless an FAA-approved MEL exists for that airplane and the airplane has within it a letter of authorization from the local flight standards district office (FSDO) authorizing its operation under the MEL. A review of records on file at the St. Louis, Missouri, FSDO revealed that the operator had no letter of authorization or MEL on file for the accident airplane.

Figure 3. Preaccident photograph of accident airplane interior showing both foam block benches and some left-side restraints (view from left-side cargo door, looking forward); photograph provided by a relative of the pilot.

operator had obtained one for the airplane, would have limited operation of the airplane to a maximum of 10 consecutive calendar days with an inoperative autofeather system.[22]

The airplane had been modified from its original configuration to accommodate parachute operations; these modifications included the removal of the original cabin seats and installation of parachutists' restraints attached to the sidewalls of the cabin. Examination of the wreckage revealed that the accident airplane's cabin configuration differed from that which was specified in the FAA's records for the airplane. For example, according to an FAA Form 337,[23] dated October 5, 2000, the airplane was modified with two straddle benches, which, according to the information provided by the designer, are structural, metal benches that attach to the seat attachment points. However, the straddle benches described in the Form 337 were not observed in the wreckage; instead, two solid foam blocks, each measuring about 5 to 6 feet long and 15 to 18 inches tall and wide, were in the airplane. Each solid foam block served as a seating bench that extended aft from the forward cabin, parallel to each exterior cabin wall. The position of the two foam block benches allowed space for a center aisle and space between each bench and sidewall. (See figure 3 above.)

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[22] For FAA approval, a MEL must be no less restrictive than the FAA's master minimum equipment list (MMEL) for that aircraft. According to the MMEL for DHC-6-series airplanes, the autofeather system is considered a "Category C" item, which means that it must be repaired within 10 consecutive calendar days, excluding the day the malfunction was recorded in the aircraft maintenance record or logbook.

[23] An FAA Form 337 is used as part of the field approval process for approving a major repair or alteration of an aircraft. An applicant wishing to perform a major repair or alteration must submit to the local FSDO a completed FAA Form 337 that identifies the aircraft by serial number, describes the intended modification, and includes any applicable engineering drawings and/or other data, such as a flight manual supplement, pertinent to the change. FSDO inspectors review the submitted information, and, depending on the scope and complexity of the proposed modification, the FSDO may approve the proposed modifications as presented, request more data and support from the applicant, or forward the data to the aircraft certification office for further review.

A review of the airplane's maintenance records revealed that the removal of the straddle benches was not documented. Although there is no evidence this undocumented configuration or the inoperative autofeather system contributed to the accident, such discrepancies are not consistent with FAA airworthiness requirements; therefore, the operator should not have dispatched the accident airplane until the discrepancies were resolved.

One method by which the FAA can detect and require an operator to correct aircraft airworthiness discrepancies is through direct surveillance visits to the operator. However, a review of FAA Program Tracking and Reporting Subsystem data and Safety Performance Analysis System data showed no record of FAA inspectors conducting any maintenance or operations surveillance visits to the operator.[24] The Safety Board notes that, in the absence of surveillance, the operator was able to repeatedly dispatch the airplane in an unairworthy condition and that, had an FAA inspector observed the discrepancies, the airplane likely would have been grounded until the repairs were made. Therefore, the Safety Board concludes that greater FAA surveillance of the operator would have discouraged improper aircraft maintenance procedures, such as dispatching the airplane with an inoperative autofeather system and an undocumented cabin seating configuration.

In fact, the Safety Board's 2008 special investigation[25] identified a number of parachute operations airplanes that had open maintenance discrepancies at the time that they crashed. As a result, the Safety Board issued Safety Recommendation A-08-68 on September 16, 2008, that asked the FAA to do the following:

> Require direct surveillance of parachute jump operators to include, at a minimum, maintenance and operations inspections.[26]

[24] The records did show three FAA contacts with the operator related to the operator's airspace waiver requests.

[25] See NTSB/SIR-08/01.

[26] Safety Recommendation A-08-68 is classified "Open—Await Response."

3. Safety Issues

3.1 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 space where the pilot was seated was subjected to nonsurvivable crush intrusion. The airplane's nose,[27] cockpit, and cabin were crushed aft to an area immediately forward of the second window in the cabin passenger compartment. (See figure 4.)

Figure 4. Photograph of the crush damage on the fuselage (right wing removed from wreckage).

The survival of the two parachutists indicates that the forces generated during the crash sequence were survivable. Several sources of information, such as witness estimates of the airplane's height above the ground (ranging from 50 to 150 feet) at the onset of the dive, estimates of vertical speed derived from the airplane's vertical speed indicator at the accident site, the extent of crush damage observed on the wreckage, and the depth of the ground impact crater, were used when performing various load analyses. These analyses showed that the peak deceleration was between 6.6 G[28] and 19.7 G and that final velocity was between 40.1 and 69.5 feet per second; these ranges fall within survivable limits outlined in the Safety Board's 1985 *General Aviation Crashworthiness*

[27] The airplane's nose is not structural; it is constructed of balsawood and composite materials.

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

Project report.[29] In addition, the cabin area in which all of the parachutists were seated was aft of the area of direct crush intrusion observed on the airplane.

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.

3.1.1 Single-Point Restraints in the Accident Airplane

According to preaccident photographs of the airplane's interior and to information recovered from two onboard video cameras worn on the helmets of two of the parachutists, the airplane's cabin was equipped with 20 sets of sidewall-mounted webbing restraint systems for parachutists (10 sets on the left sidewall and 10 on the right).[30] 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.

3.1.2 Parachutists' Seating Locations, Restraint Use, and Injuries

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.[31] The three solo parachutists sat on the floor, and each tandem pair straddled one of the foam block benches in the forward cabin. (See figure 5 on the following page.) According to company practice, this seating arrangement was typical. The foam block benches allow easier harnessing for the tandem pairs by enabling a more upright seated position than provided by the airplane's floor. According to company practice, tandem pairs usually harness together about 2 to 5 minutes before jumping from the airplane.

All of the parachutists had restraints accessible from their seated locations. According to company practice, all parachutists are restrained before the airplane moves; however, no specific instructions are provided to parachutists regarding which restraint to use or how tightly to fasten it. Parachutists typically route the restraints through the vertical (main lift) webbing or the leg webbing of their parachute harnesses.

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29 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).

30 An FAA 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. It is unknown if these additional restraints were present at some time. The characteristics of the identified restraints appeared consistent with the descriptions provided on the Form 337.

31 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.

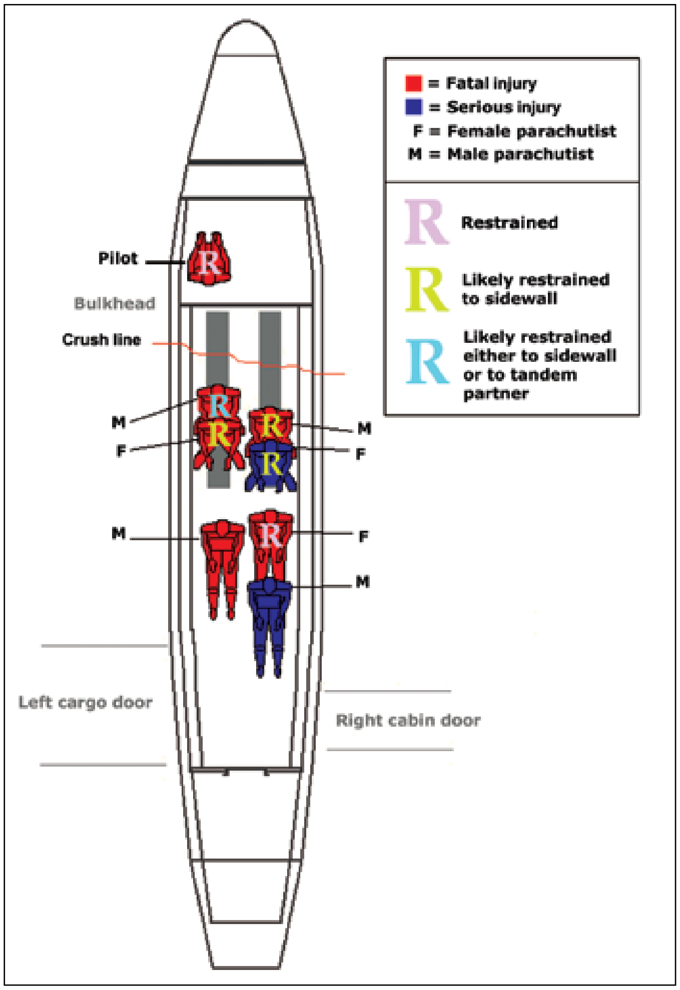

Figure 5. Seating diagram showing the approximate preaccident locations of the parachutists and the pilot with respect to the crush-intrusion line.

3.1.2.1 Tandem pair seated on the right

One tandem pair sat straddling the foam block bench on the right side. The parachutist-in-command wore a tandem parachute, and his 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; she wore a tandem passenger harness with no parachute. Analysis of postaccident restraint damage evidence, including a break in the attachment track at the normally installed location of one restraint and the pulled appearance of the attachment pin of a second restraint that was also missing one side, suggests that each member of this pair likely used a restraint. Also, the close proximity of this pair while seated on the foam block bench, as observed from an onboard video, 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. His injuries included a cervical fracture, bilateral rib fractures, and blunt chest trauma, suggesting 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. His tandem partner, however, survived the accident. Her injuries, which were serious, included a cervical fracture, multiple minor lumbar spinal fractures, and a right clavicle fracture. She likely benefited from her 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.

3.1.2.2 Tandem pair seated on the left

Like the tandem pair just described, the pair on the left side of the airplane sat straddling a foam block bench. The parachutist-in-command wore a tandem parachute, and his 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; she wore a tandem passenger harness with no parachute. Analysis of postaccident restraint damage, including elongation deformation of the attachment ring on one restraint, suggests that at least one member of this pair likely used a restraint. Although a second restraint showed damage, that damage did not clearly indicate use. 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) his injuries, which included blunt pelvic trauma, suggest 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. Her injuries, which included bilateral pelvic fractures, kidney and liver lacerations, multiple lower extremity fractures, and multiple fractures of the lumbar spine, may have resulted from an impact from at least one other parachutist and from the failure of the loose, single-point restraint to adequately restrain her.

3.1.2.3 Three solo parachutists

One parachutist sat on the floor on the right side of the airplane just aft of the foam block bench on which a tandem pair was seated. She was in a semi-reclined position with her parachute leaning against the end of the foam block bench. According to video evidence, she appeared to have restraint webbing routed through the left-leg portion of her parachute harness. Although she was restrained, she did not survive the accident. Her injuries, which included a fracture at the base of the skull and a thoracic spine fracture, 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.

Another parachutist, according to video evidence, initially looked out the left side cargo door but, after the engine noise changed (which was audible on the video), sat on the floor on the left side of the airplane and appeared to lean backward against his parachute in a semi-reclined position. There was no evidence that he used a restraint, and he did not survive the accident. His injuries, which included closed head trauma, blunt chest trauma, and blunt abdominal trauma, suggest 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.

Another parachutist, according to video evidence, initially leaned toward the left cargo door but, after the engine noise changed, eventually sat on the floor in the aft cabin on the right side of the airplane (aft of the restrained solo parachutist). There was no evidence that he used a restraint; however, he survived the accident. His injuries, which were serious and included a concussion, multiple thoracic and lumbar spinal fractures, complete spinal cord injury, and blunt chest trauma, suggest 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.

3.2 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.[32] In response to the recommendations, the FAA's Civil Aerospace Medical Institute (CAMI), in conjunction with the Parachute Industries Association and the USPA,[33] performed a series of dynamic sled tests to evaluate various types of restraint systems for parachutists and published a report on its findings.[34] The restraint systems evaluated included both single-point systems 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

[32] On February 17, 1994, the Safety Board issued Safety Recommendation A-94-16, which asked the 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 Safety Recommendation AS-94-16, 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>.

[33] 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 Safety Recommendation A-94-22 "Closed—Acceptable Action" on June 5, 2001.

[34] See 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).

test for one single-point restraint design,[35] 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 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.

Load calculations indicate that this accident was survivable for some parachutists; yet only two parachutists survived the crash. As stated previously, had the parachutists been securely restrained in their seating positions, all of the parachutists would have been away from the areas of major crush and intrusion. 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.[36] 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. The Safety Board also believes that the USPA should work with the

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

[36] 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.

FAA to conduct research 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 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. Further, the Safety Board believes that, once the most effective dual-point restraint systems for parachutists are determined, the USPA should educate its members on the findings and encourage them to use the most effective dual-point restraint systems.

4. Conclusions

4.1 Findings

1. Although damage to the accident airplane's right engine precludeded termination of the initial event that precipitated the overload fracturing of the compressor turbine blades, and although the operator was not required to comply with the engine manufacturer's service bulletins, it is possible that the initiating fracture event within the engine resulted from a condition that could have been detected and corrected during an engine overhaul performed within the manufacturer's recommended time between overhauls.

2. Although engine wear would have likely prevented the accident airplane from obtaining its maximum published single-engine climb performance, the pilot's failure to maintain airspeed, according to the technique specified in the published emergency procedures following the loss of power in one engine, negated any possibility of continued, controlled flight that could have allowed for a return to the airport or other suitable landing area.

3. Although the airplane's autofeather system, had it been operative, would have helped the pilot promptly feather the propeller of the inoperative engine, there is insufficient evidence to suggest that the inoperative autofeather system was a factor in the accident.

4. The pilot's decision to use only 1,700 feet of the available runway diminished the margin of safety during takeoff because it eliminated the option of discontinuing the takeoff and performing a straight-ahead, emergency landing on the runway.

5. Greater Federal Aviation Administration surveillance of the operator would have discouraged improper aircraft maintenance procedures, such as dispatching the airplane with an inoperative autofeather system and an undocumented cabin seating configuration.

6. Based on the results of the Civil Aerospace Medical Institute's past testing and the serious and fatal injuries sustained by some of the restrained parachutists in this crash, a single-point restraint system is not sufficient to provide adequate restraint for parachutists.

7. More parachutists may have survived, and injuries may have been reduced, if more effective restraints had been used.

8. 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.

4.2 Probable Cause

The National Transportation Safety Board determines 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.

5. Recommendations

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)
>
> Once the most effective dual-point restraint systems for parachutists are determined, as requested in Safety Recommendation A-08-71, revise Advisory Circular 105-2C, *Sport Parachute Jumping*, to include guidance information about these systems. (A-08-72)

The National Transportation Safety Board recommends that the United States Parachute Association:

> Work with the Federal Aviation Administration to conduct research to determine the most effective dual-point restraint systems for parachutists that reflects the various aircraft and seating configurations used in parachute operations. (A-08-73)
>
> Once the most effective dual-point restraint systems for parachutists are determined, as requested in Safety Recommendation A-08-71, educate your members on the findings and encourage them to use the most effective dual-point restraint systems. (A-08-74)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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