National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: December 27, 2010

In reply refer to: A-10-148 through -158 and A-06-18 (Reiteration)

The Honorable J. Randolph Babbitt
Administrator
Federal Aviation Administration
Washington, DC 20591

On August 5, 2008, about 1941 Pacific daylight time, a Sikorsky S-61N helicopter, N612AZ, impacted trees and terrain during the initial climb after takeoff from Helispot 44 (H-44),[1] located at an elevation of about 6,000 feet in mountainous terrain near Weaverville, California. The pilot-in-command, the safety crewmember,[2] and seven firefighters were fatally injured; the copilot and three firefighters were seriously injured. Impact forces and a postcrash fire destroyed the helicopter, which was being operated by the U.S. Forest Service (USFS) as a public flight to transport firefighters from H-44 to another helispot. The USFS had contracted with Carson Helicopters, Inc. (CHI), of Grants Pass, Oregon, for the services of the helicopter, which was registered to CHI and leased to Carson Helicopter Services, Inc. (CHSI), of Grants Pass.[3] Visual meteorological conditions prevailed at the time of the accident, and a company visual flight rules flight plan had been filed.

The National Transportation Safety Board (NTSB) determined that the probable causes of this accident were the following actions by Carson Helicopters: 1) the intentional understatement of the helicopter's empty weight, 2) the alteration of the power-available chart to exaggerate the helicopter's lift capability, and 3) the practice of using unapproved above-minimum specification torque in performance calculations that, collectively, resulted in the pilots relying on

[1] (a) The National Transportation Safety Board's full report, *Crash During Takeoff of Carson Helicopters, Inc., Firefighting Helicopter Under Contract to the U.S. Forest Service, Sikorsky S-61N, N612AZ, Near Weaverville, California, August 5, 2008*, Aviation Accident Report NTSB/AAR-10/06 (Washington, DC: National Transportation Safety Board, 2010) will be available online at <http://www.ntsb.gov/publictn/A_Acc1.htm>. (b) According to the U.S. Forest Service, a helispot is a natural or improved takeoff and landing area intended for temporary or occasional helicopter use.

[2] The safety crewmember was a USFS inspector pilot who was giving the pilot-in-command a flight evaluation in the S-61 and simultaneously acting as the required cabin safety crewmember.

[3] CHI and CHSI are separate legal entities, and at the time of the accident, each company held its own Federal Aviation Administration (FAA)-issued operating certificates. However, both companies have the same president and share facilities in Grants Pass. In this report, the term Carson Helicopters is used to refer to both companies, and the acronyms CHI and CHSI are used if it is necessary to specify the legal entity.

performance calculations that significantly overestimated the helicopter's load-carrying capacity and did not provide an adequate performance margin for a successful takeoff; and insufficient oversight by the USFS and the Federal Aviation Administration (FAA).

Contributing to the accident was the failure of the flight crewmembers to address the fact that the helicopter had approached its maximum performance capability on their two prior departures from the accident site because they were accustomed to operating at the limit of the helicopter's performance. Contributing to the fatalities were the immediate, intense fire that resulted from the spillage of fuel upon impact from the fuel tanks that were not crash resistant, the separation from the floor of the cabin seats that were not crash resistant, and the use of an inappropriate release mechanism on the cabin seat restraints.

Background

On the morning of the accident, the pilot-in-command (PIC) completed performance calculations to ascertain whether the helicopter could hover out of ground effect (HOGE) at the density altitudes that were expected. The USFS requires helicopters operating at helispots to have HOGE capability because a helicopter that cannot HOGE cannot make a vertical takeoff. Without HOGE capability, takeoff is only possible if a sufficient clear area exists for the helicopter to move forward while remaining in ground effect until translational lift is achieved. In completing the calculations, the PIC relied on weight documents and performance charts that had been altered by Carson Helicopters to give the appearance of higher payload capabilities; as a result, the pilots believed that the helicopter had the performance capability on the accident takeoff to HOGE with the manifested payload when, in fact, it did not.

During the accident takeoff and during the previous two takeoffs from H-44, the main rotor speed (N_R) decreased (drooped) while the engines were producing maximum power, with the most severe N_R droop occurring during the accident takeoff. The similarities between all three takeoffs indicated that, during each takeoff, the power required to maintain N_R exceeded the power available from the engines. This condition could have resulted from either a deficiency in power available due to engine malfunction or from excessive power demands associated with attempting to lift more weight than possible given the conditions.

The NTSB ruled out a deficiency in power available based on evidence from the cockpit voice recorder (CVR) sound spectrum study, which indicated that the engines were running at their topping (maximum) speed,[4] and evidence from teardowns and examinations, which indicated that both engines and their fuel control units (FCUs) were functioning normally throughout the accident flight.

The accident takeoff was unsuccessful because the helicopter was loaded with more weight than it could carry in a HOGE given the ambient conditions. The PIC was unable to maintain clearance from trees and terrain while attempting to gain enough airspeed to achieve effective translational lift.

[4] "Topping" refers to operating at the maximum gas generator speed limit, corresponding to the maximum power output of the engines.

During the two previous departures from H-44 on the day of the accident, the pilots had the opportunity to realize that the helicopter was not performing in a manner consistent with the load calculations. However, neither pilot called attention to the discrepancy between the predicted and actual performance of the helicopter or suggested postponing further flight until the discrepancy could be resolved. The USFS inspector pilot also had an opportunity to notice and comment on the helicopter's marginal performance but failed to do so.

Accuracy of Hover Performance Charts

The NTSB requested that Sikorsky prepare simulations of the takeoff using its GenHel helicopter simulation computer program. Sikorsky performed four simulations: two that used the performance data in CHI's Rotorcraft Flight Manual Supplement (RFMS) #8 with temperatures of 20° and 23° C, and two that used Sikorsky's predicted performance based on the U.S. Navy flight tests with temperatures of 20° and 23° C. The flightpaths computed using the RFMS #8 performance at 20° and 23° C show performance better than that which was actually achieved during the accident, as they depict the helicopter clearing the first tree struck by the helicopter's main rotor blade. The simulations using the Sikorsky prediction of performance at 20° and 23° C best matched the helicopter's actual performance. At 23° C, the rotor blade impacts the tree about 6 feet below the actual tree strike, and, at 20° C, the rotor blade impacts the tree about 4 feet above the actual tree strike.

The simulation results are consistent with the different approaches taken by CHI and Sikorsky to determine the performance capability of the S-61N with CHI composite main rotor blades (CMRBs). The scatter in the data points from the August 2010 joint Sikorsky/CHI flight testing of an S-61A equipped with CHI CMRBs showed that even at the FAA-required wind speeds of 3 knots (kts) or less, the effects of wind on performance can be significant with headwinds improving performance and tailwinds or crosswinds decreasing performance. Sikorsky's prediction of the S-61N performance was based on data from extensive flight tests of a Navy VH-3A helicopter equipped with CHI CMRBs, adjusted to account for configuration differences between the VH-3A and S-61N. Sikorsky evaluated the baseline VH-3A test data conservatively, by taking into account data points collected at four wind azimuth angles, including those that produced a performance decrement due to a tailwind or crosswind. In their 2006 flight tests of an S-61N helicopter equipped with CHI CMRBs, CHI followed the FAA-accepted industry practice used to conduct hover performance testing and considered only the nose-into-the-wind (headwind) data points, which did not include a performance decrement due to an adverse wind azimuth, but may have included a performance increment due to a light (0 to 3 kts) headwind.

Based on analysis of the available meteorological data, the wind speed for the accident takeoff was estimated to be 2 kts or less, which was consistent with witness reports of calm or light winds with directions ranging from southeast to south-southwest and supported by photographs taken a few minutes after the crash that show a vertical column of smoke. These conditions are similar to those present during the August 2010 flight testing. The close match between the simulations using Sikorsky's performance prediction with the helicopter's actual performance suggests that Sikorsky's more conservative approach better defines the hover performance of the helicopter in a light and variable wind condition than does the standard approach that only considers nose-into-the-wind flight test points. Additionally, the relatively poor match of the accident takeoff simulations based on CHI's RFMS #8 performance charts with the helicopter's actual performance suggests that CHI's use of only nose-into-the-wind data points resulted in performance charts that overestimate the hover performance of the helicopter when winds are light and variable and wind azimuth is changing.

The hover performance charts published by helicopter manufacturers typically provide a means to adjust the zero-wind performance predicted by the charts for headwinds, but the charts do not provide for any adjustments due to tailwinds or crosswinds. When used by pilots to predict performance with winds reported to be "light and variable," these charts may not be accurate. The August 2010 flight test results indicated that, in light and variable winds, the HOGE capability of the S-61 helicopter can decrease by as much as 700 pounds (lbs) below the lifting capability defined by testing with even a 3-kt (or less) headwind. Because the wind direction in these conditions is "variable," it is likely that during hover the helicopter will not face into the wind at all times and that the adverse wind azimuths that produce the HOGE performance decrement could be encountered. Consequently, the zero-wind HOGE capability published in the performance charts cannot be guaranteed in light and variable wind conditions. The NTSB concludes that safety would be improved if the HOGE capability indicated by performance charts represented all conditions for which the charts are applicable, including light and variable wind conditions. Therefore, the NTSB recommends that the FAA require that the hover performance charts published by helicopter manufacturers reflect the true performance of the helicopter in all conditions for which the charts are applicable, including light and variable wind conditions.

Oversight

The FAA had an opportunity to discover the discrepancies in the accident helicopter's maintenance, performance, and weight and balance documents by performing an inspection when the helicopter was added to CHSI's 14 *Code of Federal Regulations* (CFR) Part 135 operations specifications on June 3, 2008, but inspectors failed to conduct such an inspection or to inspect any of the other three helicopters that were added to the certificate at the same time, even though this addition tripled the size of CHSI's fleet. The discrepancies with the accident helicopter's documents that could have been found included:

1. The weight documents indicated that a Fire King 900-gallon aerial liquid dispensing tank was installed on January 4, 2008; however, the maintenance logbook entry and the FAA Form 337[5] showed that the tank was not installed until March 25, 2008.
2. The weights on the weighing record were recorded to the nearest tenth of a pound; however, the scales used by Carson measured only to the nearest whole pound.
3. RFMS #6 and #7 were included in the helicopter's flight manual; however, the required maintenance logbook entries and FAA Form 337s documenting their installation had not been completed.

Additionally, the FAA missed the opportunity to identify discrepancies in the weight and balance documents of the other three helicopters added to CHSI's Part 135 certificate. It is likely

[5] A maintenance record entry is required by 14 CFR Part 43.9(a) for any alteration to an aircraft, and FAA Form 337 is required by 14 CFR Part 43.9(d) for a major repair or alteration.

that weight discrepancies would have been identified for all three helicopters, because, when these three helicopters were weighed by the USFS after the accident, discrepancies of 407 to 655 lbs were found between the helicopters' weight documents and their actual weights.

If these discrepancies had been detected, the FAA would have required CHSI to correct them, which likely would have prevented the accident. The NTSB concludes that the FAA's oversight of CHSI was inadequate, and effective oversight would have detected discrepancies in the accident helicopter's maintenance, performance, and weight and balance documents and required their correction before the helicopter was added to CHSI's Part 135 operations specifications.

Following the accident, the Portland Flight Standards District Office (FSDO) was made aware of the NTSB's concerns with Carson Helicopters' weight and balance documentation. The FSDO also received two letters from S-61 pilots who expressed concern about erroneous weights. The inspectors responded to the reports of erroneous weights by visiting CHSI's Grants Pass facility in October 2008. The recorded findings by the assistant principal maintenance inspector (PMI) stated that the inspectors were "unable to support a violation, as it appears that the weight and balance errors were inadvertent." The findings stated that the weight errors resulted from damaged scales and that the weight documents "were reviewed by inspectors with appropriate expertise and oversight for this area, with no significant discrepancies [found]." They additionally stated that "all flights with miscalculated weights were as public use operations and not under Part 135."

In the same document, the assistant PMI noted that "it is not the FAA's concern about what another agency allows within its contract bidding" and that "no violation could be found on actually using the inappropriate [performance] charts." He added that "the FAA had no safety involvement in substantiating any aspect of the bidding process; further the FAA has no regulation associated with this type of contracting."

In addressing the concerns raised after the accident, the FAA inspectors consistently asserted that, because CHSI primarily operated under contract to the USFS, the FAA was not responsible for the oversight of a majority of the company's operations. The NTSB recognizes that the FAA has no statutory authority to regulate public aircraft operations. However, during the time period after Carson Helicopters submitted its bid to the USFS on April 10, 2008, and before the contract went into effect on July 1, 2008, the accident helicopter was flown under Part 91, and, after it was added to CHSI's Part 135 operations specifications on June 3, 2008, could have been flown under Part 135, with the same discrepancies in maintenance, performance, and weight and balance documents that it had while flying under contract to the USFS. Additionally, the USFS postaccident weighing of other helicopters listed on CHSI's Part 135 operations specifications showed that these helicopters also had discrepancies in their weight and balance documents, and they also could have been flown under Part 91 or Part 135 prior to going on contract with the USFS.

Further, although the FAA has no regulatory authority over public aircraft operations, the agency has stated in FAA Order 8900.1, which provides guidance to FAA inspectors in performance of their official duties, that any aircraft certificated by the FAA is subject to the FAA's normal surveillance activities regardless of whether the aircraft is operating as a public or a civil aircraft. The order specifically states that if a public aircraft operation is being conducted with an aircraft that holds an airworthiness certificate, the operator's maintenance records are subject to review. The guidance in the order suggests that it is the FAA's intent for inspectors to provide continuing surveillance of the airworthiness aspects of any certificated aircraft regardless of whether it is engaged in civil or public flight operations. However, the FAA has limited mechanisms in place for its inspectors to conduct surveillance of operations that are conducted in locations outside their assigned geographic areas. In the case of CHSI, which, at the time of the accident, had six helicopters operating on USFS contracts in four states (two in California [including the accident helicopter], two in Montana, one in Utah, and one in Oregon), only 1 of the 43 activities conducted by FAA inspectors in 12 months before the accident was at a location outside of the Portland FSDO's geographic area. The NTSB is concerned that the FAA has not adequately addressed the unique oversight challenges presented by operators with aircraft, such as the accident helicopter, that operate part of the time as public aircraft and part of the time as civil aircraft.

The NTSB identified a similar lack of continuity in FAA oversight of a Part 135 operator in its investigation of the November 27, 2004, crash near Bamiyan, Afghanistan, of a CASA 212 airplane that was being operated by Presidential Airways under contract to the Department of Defense (DoD) in accordance with the provisions of Part 135.[6] The investigation revealed that the DoD attempted to provide for safe operations, just as did the USFS, through the issuance of a contract that required the operator to hold a Part 135 certificate and conduct operations in accordance with Part 135 regulations. However, although the FAA had approved Presidential Airways to conduct Part 135 operations in Afghanistan, it did not provide, and was not required to provide, personnel who could directly oversee the operations there. In a December 4, 2006, safety recommendation letter, the NTSB expressed its concern that the remoteness of operations in Afghanistan presented a unique oversight challenge that had not been adequately addressed by either the FAA or the DoD and issued companion Safety Recommendations A-06-77 and -78 to the FAA and the DoD, respectively, which asked the two agencies to coordinate to ensure that oversight of the DoD's civilian contractors was provided overseas. These two recommendations were classified "Closed—Acceptable Action" on January 11, 2008. This accident again demonstrates the need for continuous oversight of Part 135 operators regardless of the circumstances under which they are operating. The FAA currently has no procedures in place to ensure continuous oversight of Part 135 operators whose aircraft are under contract to the federal government for part of the year. Therefore, the NTSB recommends that the FAA develop and implement a surveillance program specifically for Part 135 operators with aircraft that can operate both as public aircraft and as civil aircraft to maintain continual oversight ensuring compliance with Part 135 requirements. Further, the NTSB recommends that the FAA take appropriate actions to clarify FAA authority over public aircraft, as well as identify and document where such oversight responsibilities reside in the absence of FAA authority.

[6] See *Controlled Flight Into Terrain, CASA C-212-CC, N960BW, Bamiyan, Afghanistan, November 27, 2004*, Aircraft Accident Brief NTSB/AAB-06/07 (Washington, DC: National Transportation Safety Board, 2006). <http://www.ntsb.gov/publictn/2006/AAB0607.pdf>.

Accident Survivability

Fuel Tanks

The four occupants seated on the left side of the helicopter and five of the nine occupants seated on the right side of the helicopter were fatally injured. According to their autopsy reports, the cause of death for all nine fatally injured occupants was blunt force trauma and thermal injuries. Because the intensive postcrash fire consumed the majority of the remains, the pathologist was unable to determine the extent of blunt force trauma that the fatally injured occupants sustained during impact. Therefore, it cannot be determined whether additional occupants survived the impact but were unable to successfully exit the helicopter due to unconsciousness or injury. However, the nature of the injuries sustained by the survivors, specifically their lack of debilitating injuries, suggests that additional occupants seated near them may have survived the impact. Had a postcrash fire not erupted so quickly, other occupants surviving the impact would have had more time to evacuate successfully or be rescued. The NTSB concludes that, without an immediate fire, additional occupants on board the helicopter would likely have survived the accident.

Inspection of the helicopter wreckage revealed that the postcrash fire consumed most of the helicopter's cabin and cockpit sections, including the cabin flooring, all fuel tank cells, and the lower fuselage structure. Because the postcrash fire consumed the fuel tanks, their respective fuel lines, and their supportive components, it was not possible to conclusively identify a failure mechanism responsible for the fire. However, witnesses reported that the fire erupted immediately after the crash, and one survivor reported that, when he regained consciousness, "there was fire and smoke throughout the cabin," and he was "soaked in fuel."

The fuel tanks installed in the helicopter met the standards used during the certification of the S-61N in 1961. The tanks were required by Civil Air Regulations (CAR) 7.420(b) to meet the emergency landing load limits in CAR 7.260 of 1.5 G upward, 4 G forward, 2 G sideward and 4 G downward.[7]

Because the fuel tanks only had to meet the requirements of CAR 7.420(b), they were not as crash-resistant as a fuel tank designed to the standards of 14 CFR 29.952, which requires load limits of 4 G upward, 16 G forward, 8 G sideward, and 20 G downward. Additionally, because they were located in the hull of the helicopter (beneath the passenger cabin floor), the fuel tanks contacted the ground immediately upon impact with the rocky terrain and experienced not only forces that likely exceeded their ultimate design limits of a 2 G side load and a 4 G downward load,[8] but also direct penetration from rocks and other aircraft structure. The impact likely resulted in a failure of the fuel tanks' fiberglass structure, penetration and tearing of the rubberized (flexible) fabric cells, and separation of fuel tank fittings, such as fuel lines and plumbing, allowing an unknown quantity of fuel to be released. The statement from one of the

[7] The letter "G" denotes the ratio of the force imposed by an object divided by the object's weight.

[8] The impact forces could not be determined because of the damage to the helicopter and the lack of recorded flight data that were needed to calculate the forces.

survivors that he was soaked in fuel confirms that the fuel system was compromised by the impact. The NTSB concludes that the postcrash fire likely originated from the ignition of the fuel that was released or spilled from the helicopter's fuel tanks when the left side of the helicopter impacted the ground.

The fire likely spread because of the helicopter's inclined orientation after impact (the nose was lower than the tail) and the slope of the terrain. Any spilled fuel would have run downhill from the fuel tanks and forward toward the area of the engines.

If the fuel tanks and lines on the helicopter had been compliant with the crashworthiness standards in 14 CFR 29.952, the amount of fuel spilled from the tanks likely would have been significantly reduced. Sikorsky is developing a crashworthy fuel system as an option that will be available as a retrofit for all variants of S-61 and H-3 helicopters. The crashworthy fuel system option is being developed with fuel bladders and break-away valves and will undergo the testing required to meet 14 CFR 29.952 standards. Because the current S-61 fuel system may not safely contain fuel in the event of an emergency high-impact landing or crash, which could lead to a postcrash fire, the NTSB recommends that the FAA require the installation of fuel tanks that meet the requirements of 14 CFR 29.952 on S-61 helicopters that are used for passenger transport.

Passenger Seats

NTSB investigators identified 57 percent of the mounting hardware used to secure the forward-facing passenger seats to the cabin floor and side walls. Of the identifiable seat mounting hardware, 68 percent had separated from their respective mounts during the helicopter's impact with the ground.[9] Of the 16 forward-facing seats in the cabin, 62.5 percent (10 seats) were occupied during the accident. Although investigators were unable to correlate the seats to the occupants that were killed, the percentage of identifiable seat hardware that separated from the floor loosely correlates to the percentage of seats that were occupied. The likelihood that a seat attachment will separate from the helicopter structure increases as the loads imposed on the attachment increase; the attachment loads will be much higher for those seats that are occupied than for those seats that are vacant. Therefore, it is most likely that the seats that separated from the floor when the helicopter impacted the ground were those that were occupied.

Additional evidence that the occupied seats separated during the impact was provided by the survivors' statements, which clearly indicated that the survivors' seats separated during the impact and that their upper bodies struck objects on their left sides. One survivor, who was unable to unfasten his restraint after the crash, stated that the seat came with him as he tried to evacuate the helicopter. The NTSB concludes that the majority of the cabin seats that were occupied during the crash separated from the floor during the helicopter's impact with the ground, subjecting the occupants to secondary impacts from other occupants and seats and hindering their ability to evacuate the cabin.

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[9] The 16 forward-facing seats (6 single seats and 5 double seats) were attached by 22 single-stud hold-down fittings on the seat legs and 22 single-pin hold-down fittings on the seat cross tubes. Of the 22 seat legs, 12 were identified in the wreckage; the stud fittings were separated from 6 of these. Of the 22 seat cross tubes, 13 were identified in the wreckage; the pin fittings were separated from 11 of these.

The cabin seats installed in the helicopter met the standards used during the certification of the S-61N in 1961. The seats and the structures to which they were attached were required to meet the load limits in CAR 7.260, which differ substantially from the current load limits in 14 CFR 29.561. In addition, 14 CFR 29.562 requires that new seat designs meet dynamic load criteria by absorbing energy during a crash. In comparison to seat installations that meet the load limits in CAR 7.260, seat installations that meet the higher load limits in 14 CFR 29.561 and the dynamic load criteria in 14 CFR 29.562 would be less likely to separate from their mounting structures during an emergency, high-impact landing, or crash and would provide energy absorbing protection to the occupants. The NTSB concludes that, if the accident helicopter had been equipped with seat installations that met the load limit requirements of 14 CFR 29.561, more occupants may have survived the accident because the seats likely would not have separated from their mounting structures. Further, energy absorbing seat systems that met the requirements of 14 CFR 29.562 would have provided additional occupant protection.

According to Sikorsky, substantial structural reinforcement of the S-61N cabin floor and sidewalls would be required in order to meet 14 CFR 29.561 and 29.562. However, designs that comply with portions of 14 CFR 29.561 and 29.562 would provide a substantial increase in occupant protection over CAR 7 seats. The FAA’s adoption of the current requirements of 14 CFR 29.561 and 29.562 came about because of improvements in the design of crashworthy cabin interiors. The crashworthiness improvements in seats and seat installation that have evolved since the CAR 7 requirements were written, for example, energy attenuating seats and more robust seat attachment fittings, have resulted in seats that provide improved occupant protection and would be less likely to separate from their mounting structure during an emergency high impact landing. Therefore, the NTSB recommends that the FAA require that S-61 helicopters that are used for passenger transport be equipped with passenger seats and seat mounting structures that provide substantial improvement over the requirements of CAR 7.260, such as complying with portions of 14 CFR 29.561 and 29.562.

Passenger Restraints

Carson Helicopters installed and the USFS approved a rotary buckle on the passenger seats in the S-61N helicopter. The three surviving firefighters’ unfamiliarity with this type of buckle significantly hindered their ability to release their restraints when they attempted to evacuate the cabin under emergency conditions. The accident flight was the first time they had used a rotary buckle, and they all experienced difficulty in releasing their restraints. They had previously only used a lift-latch buckle similar to those on commercial airline flights and on other USFS aircraft.

Instead of simply requiring the occupant to lift a latch on a buckle, the rotary restraint required between 9.7 and 14.2 lbs of force to rotate the face of the buckle in either direction to release the buckle. In addition, the buckle face needs to be rotated past 30° because the release mechanism does not function when rotated less than 30°. The majority of the buckles found in the wreckage were still buckled.[10]

[10] Of the 15 buckles found in the wreckage, 10 had the lap belt and both shoulder harnesses engaged.

Because operation of a rotary buckle may not be intuitive, passengers attempting to release this type of restraint during an emergency may be confused and unable to do so. An FAA study[11] found that nonpilots could only apply about 6 lbs of force to a rotary-style release mechanism, whereas pilots could apply almost double that force, or over 12 lbs.[12] The study also found that flight crewmembers who were familiar with rotary restraints and experienced with the motion and the application of force were able to apply greater forces to the rotary restraints. Conversely, nonpilots who rarely, if ever, saw rotary restraints and were inexperienced with their operation had greater difficulty with the application and force required to release the restraints.

The rotary-release mechanism used in the accident helicopter was not like other restraints commonly used by the firefighters. Although the firefighters received a preaccident briefing that described how to operate the rotary restraint, the surviving firefighters had never used the rotary restraints before the accident and became confused with its release when the accident occurred. A lack of operational experience with a mechanical device such as a rotary restraint can make it difficult for an individual to instinctively operate the device under stressful conditions because of unfamiliarity with its required direction of action and application of force. The NTSB concludes that the surviving firefighters were unable to release the rotary restraints under emergency conditions because they were unfamiliar with the rotary-release mechanism.

Had the firefighter's restraints been equipped with a common lift-latch release mechanism, the release of the restraints may have been more intuitive. The USFS has already added to its contractual requirements that heavy-transport helicopters be equipped with lift-latch release restraints. However, other operators of transport-category helicopters may have passenger seats equipped with rotary-release restraints. Therefore, the NTSB recommends that the FAA require operators of transport-category helicopters to equip all passenger seats with restraints that have an appropriate release mechanism that can be released with minimal difficulty under emergency conditions.

Compatibility of Passenger Seats and Restraints

The USFS required CHI to install an "FAA approved shoulder harness integrated with a seat belt with one single point" release mechanism for each passenger seat because 14 CFR 29.785(c) states that "each occupant's seat must have a combined safety belt and shoulder harness with a single-point release." Although this regulation applied to rotorcraft certificated with seats that met 14 CFR Part 29, the USFS interpreted this regulation to mean that the installation of a shoulder harness on any seat with only a lap restraint would be an improvement to the crashworthiness of the seats. CHI complied with this contractual requirement by replacing the original two-point lap belts on the passenger seats with four-point restraints, attaching the shoulder harness to the lower cross tube of the non-locking folding seatbacks. However, when

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[11] D.B. Beringer, "An updating of data regarding the forces pilots can apply in the cockpit, Part II: Yoke, rudder, stick, and seatbelt-release forces," in *Proceedings of the Human Factors and Ergonomics Society 52nd Annual Meeting, September 22–26, 2008, New York, NY* (Santa Monica, CA: Human Factors and Ergonomics Society, 2008), pp. 64-68.

[12] The study compared 5th percentile pilots to 5th percentile nonpilots. The 5th to 95th percentile is an anthropometric range employed by ergonomists and designers to accommodate the largest range of the population. Essentially the 5th to 95th percentile encompasses the 4-foot-11-inch female to the 6-foot-2-inch male.

installing the four-point restraints, CHI failed to complete FAA Form 337 as required for a major alteration and failed to document the installation in a maintenance logbook.

The installation of a shoulder harness should provide additional protection for the occupant; however, because the seatback folded forward, the shoulder harness provided no safety improvement for the occupant beyond that which was provided by the lap belt only. As the seatback folded forward during longitudinal loads, the shoulder harness moved with the seatback, thereby providing no upper body protection for the seat occupant. In fact, adding a shoulder harness to the seatback increased the overturning moment of the seat[13] and increased the compression loads on the occupant's spine. Typically, the installation of a shoulder harness is an improvement to occupant protection; however, in this case, the shoulder harness installation actually increased the risk of injury to the occupant.

Although CHI did not submit FAA Form 337 with structural substantiation data for the installation of the four-point restraints in the accident helicopter, the investigation revealed that CHI did have structural substantiation data prepared for the installation of four-point restraints on several other S-61N helicopters. CHI provided two reports prepared by the same designated engineering representative (DER) (a handwritten report dated July 12, 2006, and a formalized document dated September 18, 2008) that contained the same calculations but differed in that the 2006 report did not acknowledge that the seatbacks folded, while the 2008 report did. The DER's analysis of the shoulder harness installation as presented in both reports found that the seat structure itself was sufficiently strong for the installation of the shoulder harness on the S-61N CAR 7 seat (the seat could support the restraint loads at the restraint attachment to the seat) and determined that the harness attachment points on the seat were sufficiently strong for the installation of shoulder restraints on a seat that was previously equipped with only lap belts. However, the DER's analysis did not consider the integrity of the seat attachment to the floor, the relationship of the shoulder harness to the seat, the interaction between the occupant and the seat and restraint, or the geometry of the shoulder harness attached to a folding seatback.

The DER explained to NTSB investigators that he was not approving the installation of the restraints; rather, he was approving data in support of the installation. However, the reference documents listed in the DER's second report included FAA guidance (Advisory Circular [AC] 21-34, "Shoulder Harness—Safety Belt Installations"), which recommended that the entire assembly be considered during a retrofit installation of a shoulder harness. Specifically, the AC recommended that, when conducting a strength evaluation for the installation of shoulder harnesses, the following should be accomplished: review the installation for false security or possible occupant injury due to shoulder harness geometry, review the integrity of rear seat leg attachments to the floor relative to loads introduced by the shoulder harness, and conduct a special evaluation of the entire seat strength when the upper end of the shoulder harness is attached in a manner that applies restraint loads to the seatback. The DER failed to consider that the installation of a shoulder harness on a non-locking folding seatback does not enhance occupant protection. Although the DER may not have been aware that the seatbacks folded when he prepared his report in 2006, he was clearly aware of this fact when he prepared his report in 2008 because he mentioned it in the report. Also, the DER did not follow the recommended

[13] With a rigid seatback, the increase in overturning moment would be even greater.

shoulder harness geometry that was illustrated in the AC. Because the shoulder harness attachment to the seatback was below the shoulder level of the occupant, it was contrary to the AC's recommendation of a shoulder harness attachment elevation angle of 0° to 30° above the occupant's shoulder level and, therefore, did not achieve the most favorable angle for the distribution of loads to the seat occupant in an accident.[14] The NTSB concludes that the DER's failure to follow FAA guidance materials resulted in his approval of a shoulder harness installation that did not improve occupant protection, and in fact, increased the risk of injury to the occupant.

Because Carson Helicopters failed to submit a Form 337 for the installation of the shoulder harnesses in the accident helicopter, the FAA had no opportunity before the accident to review and approve the DER's work. However, after the accident, when the CHSI PMI found that four of the other helicopters listed on CHSI's Part 135 certificate were also altered by the installation of shoulder harnesses to the folding seatbacks, he requested that the Seattle Aircraft Certification Office (ACO) conduct an evaluation of the "adequacy of this alteration." The ACO's review found that "the structural substantiation was correct in its determination that the shoulder harness installation met the regulatory requirements." The review failed to acknowledge that the DER did not adhere to FAA guidance, which recommends that the entire assembly be considered during a retrofit installation of a shoulder harness. The NTSB concludes that the FAA disregarded its own guidance and condoned the installation of a shoulder harness that did not improve safety, and, in fact, increased the risk of injury to the occupant. Therefore, the NTSB recommends that the FAA require that AC 21-34 be used to evaluate all shoulder harness retrofit installations and to determine that the installations reduce the risk of occupant injury.

Fuel Filtering on Sikorsky S-61 Helicopters

During disassembly and examination of the FCUs, contamination (fiberglass and organic particles) was found in each unit. The majority of the contamination was found on the fuel filter screens of the FCUs; however, trace amounts were found within each unit's pressure regulating valve (PRV). No evidence exists that this contamination affected engine performance. On the contrary, the evidence from the CVR sound spectrum indicates that the engines were running at their topping speed and that, consequently, the FCUs were providing the maximum fuel flow possible to the engines. Nonetheless, the presence of a minimal amount of contamination in the accident helicopter's FCUs indicates that the filters in the fuel supply system do not adequately filter contaminants from the fuel.

The NTSB conducted additional research regarding the effects of contamination within the fuel supply system on engine performance. The NTSB found that flight crews of S-61 helicopters have detected and reported the following discrepancies with General Electric (GE) CT58-140 engines from 1996 to the present: engine torque split, slow engine acceleration, or a reduction in engine power in the affected engine. No reports exist of a simultaneous degradation in performance of both engines as a result of fuel contamination.

[14] The attachment of the shoulder harness to the bottom of the seatback resulted in an installation that increased the compression loads on the occupant's spine.

In all cases except one, the flight crew detected and successfully managed the engine performance degradation and safely landed the helicopter. The single case in which FCU contamination was cited as a contributing factor in an accident occurred in Canada on December 16, 2002, when an S-61N landed hard on a road.[15] In this accident, the FCU contamination was identified as one of three engine anomalies that prevented the No. 2 engine from producing sufficient power for the helicopter to maintain flight after a loss of power from the No. 1 engine due to a mechanical failure.

During examination of the FCUs removed from an SH-3H helicopter involved in a July 17, 2009, accident,[16] NTSB investigators found that the filter in each FCU had trapped trace amounts of debris, but not enough to restrict fuel flow and cause the filter to bypass fuel. However, contamination with dimensional characteristics larger than 40 microns was found within the left engine's FCU, indicating that the contamination bypassed the 40-micron FCU filter element. A possible explanation for how the contamination got into the FCU is that the main filter's bypass valve was not completely seated (sealed) and allowed an unknown quantity of fuel to bypass the filter during engine operation. According to the operator, the SH-3H did not have any engine or FCU problems before or during the accident. The fact that contamination larger than 40 microns in this FCU did not result in engine problems provides evidence that the FCU can reliably function with some contamination.

A review of the S-61 airframe and the GE CT58-140 engine fuel control system showed that contamination may originate from several sources, such as the engine-driven dynamic (centrifugal) filter, the fuel tank, or the environment during the fueling process. The most likely source of fiberglass and organic material (soil) that was found in the FCU teardowns is the fuel tank. Each fuel tank contained a fiberglass collector can. An NTSB material analysis of a sample from an exemplar fiberglass collector can determined that the collector can was likely the source of the fiberglass. The organic material (soil) was likely introduced into the tanks during the refueling process. Metal particles may originate from the dynamic (centrifugal) filter, although no evidence of contamination from this source was found in the accident helicopter's FCU teardowns.

The NTSB believes that the airframe and engine fuel supply filtering system could be enhanced to minimize the amount and size of debris in the fuel supplied to the FCU and the pilot valve. The investigation revealed that the servo valves, the PRV within the FCU, and the pilot valve within the stator vane system can jam due to metal and fiberglass contamination with particles greater than 10 microns.

On January 15, 2010, Sikorsky released an Alert Service Bulletin that requires the replacement of the forward and aft fuel system 40-micron fuel filter elements with 10-micron

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[15] See *Loss of Engine Power/Collision with Tree, Hayes Helicopter Services Limited, Sikorsky S-61N (Shortsky) Helicopter C-FHHD, Lake Errock, British Columbia, 16 December 2002*, Report Number A02P0320 (Gatineau, Quebec, Canada: Transportation Safety Board of Canada, 2002). <http://www.tsb.gc.ca/eng/rapports-reports/aviation/2002/index.asp>.

[16] More information regarding this accident, NTSB case number WPR09TA353, is available online at <http://www.ntsb.gov/ntsb/query.asp>.

fuel filter elements on all S-61A/D/E/L/N/NM/R/V model helicopters. The bulletin states the following:

> Due to instances of contaminants being found in the fuel control pressure regulating valves, the potential existed for possible seizures of the fuel control pressure regulating valves. Installation of the 10-micron fuel filter elements would reduce the potential of larger contaminants reaching the engine, ultimately reducing the risk of sticking or seizure of the fuel control pressure regulating valves.

The NTSB concludes that the 10-micron airframe fuel filters will reduce the risk of sticking or seizure of a PRV or pilot valve, which could result in the degradation of engine performance during a critical phase of flight. Therefore, the NTSB recommends that the FAA require operators of Sikorsky S-61 helicopters with GE model CT58-140 engines to install 10-micron airframe fuel filters.

Certification Level of Seat Supplemental Type Certificates

After the accident, on December 5, 2008, supplemental type certificate (STC) SR02327AK was issued to CHI for installation of a sidewall-mounted, energy-attenuating seat manufactured by Martin Baker in the S-61. Although these seats were not installed in the accident helicopter, the NTSB reviewed the engineering data submitted by CHI to the FAA in order to determine whether this STC would provide additional occupant protection over the original CAR 7 seats installed in the accident helicopter. Although the seat itself was designed to meet the higher ultimate static forces in 14 CFR 29.561 and the dynamic forces associated with energy attenuation defined in 14 CFR 29.562, the support structure for the seat attachment to the fuselage only met the load requirements in CAR 7.260. The Martin Baker seat was designed to withstand 10 G of lateral loads in the inboard and outboard directions and was dynamically tested to 30 G; however, the certification loads for the seat support structure were equivalent to 4 G forward, 4 G downward, 1.5 G upward, and 2 G sideward. Therefore, the energy-attenuating seats installed in accordance with this STC do not provide sufficient occupant protection because if the seat does not stay attached to the sidewall, it cannot provide the appropriate protection at which it was tested.

While the STC itself does not contain any reference to the seat installation having energy- or crash-attenuating qualities, the Instructions for Continuing Airworthiness that accompany the STC contain numerous references to the "Martin Baker crash attenuating seat." Another S-61 operator, which recently replaced the original seats in several of its S-61 helicopters with the Martin Baker seats in accordance with the STC, believed that the installation of the seats had resulted in a substantial improvement in occupant protection. The NTSB concludes that the CHI STC for installing side-mounted seats is misleading because it refers to the installation of the Martin Baker crash-attenuating seats, yet the total seat system does not provide occupant protection beyond the CAR 7.260 requirements. Therefore, the NTSB recommends that the FAA require CHI to put a conspicuous notification on the title page of the Instructions for Continuing Airworthiness that accompany its STC for installing side-mounted seats indicating that the installation does not provide enhanced occupant protection over that provided by the originally installed seats and meets CAR 7.260 standards. Further, the NTSB recommends that the FAA require all applicants for STC seat installations in any type of aircraft to put a conspicuous notification on the title page of the Instructions for Continuing Airworthiness that accompany the STC indicating whether the installation provides enhanced occupant protection over that provided by the originally installed seats and the certification standard level met by the seating system.

When CHI applied to the FAA for STC SR02327AK, it provided a DER-prepared certification plan to establish the certification basis for the proposed change, in accordance with the guidance in AC 21.101. Although the stated intent of AC 21.101 is to "enhance safety" through the incorporation of the latest requirements in the certification basis for changed products, the FAA did not require CHI to comply with any requirements beyond the certification level of the original seats. Instead, the FAA accepted CHI's argument (as presented by the DER in the certification plan) that compliance with the current requirements in 14 CFR 29.561 and 29.562 would not substantially increase safety and was an economic burden.

As previously mentioned, the NTSB recognizes that it may be difficult to design seating systems for the S-61 that meet the full intent of 14 CFR 29.561 and 29.562, because it may require substantial structural reinforcement of the cabin floor and sidewalls. However, designs that comply with portions of 14 CFR 29.561 and 29.562 would provide a substantial increase in occupant protection over CAR 7 seats, contrary to CHI's argument. The retrofit of a seat in an older transport-category helicopter provides an opportunity to improve its crashworthiness. However, when it issued STC SA02327AK to CHI, the FAA did not use the new installation to substantially improve occupant protection because it did not require CHI to comply with critical requirements beyond the certification level of the original seats (CAR 7.260), such as the support structure for the seat attachment to the fuselage. The NTSB concludes that the FAA missed an opportunity to require crashworthy improvements in an older transport-category rotorcraft when it issued an STC to CHI for installing side-mounted seats without requiring incorporation of any requirements beyond the certification level of the original seats (CAR 7.260). Therefore, the NTSB recommends that the FAA require STC applicants to improve the crashworthiness design of the seating system, such as complying with portions of 14 CFR 29.561 and 29.562, when granting STC approval for older transport-category helicopters certificated to CAR 7.260 standards.

Flight Recorder Systems

The helicopter was equipped with a Penny & Giles Multi-Purpose Flight Recorder that combined a CVR and a flight data recorder (FDR) in one self-contained unit. The solid-state unit was capable of recording 2 hours of digital cockpit audio and at least 25 hours of flight data. The CVR operated properly; however, the FDR did not. Although NTSB investigators were able to extract N_R and engine operating parameters from the CVR sound spectrum analysis, an operating FDR would have provided a direct recording of N_R, as well as engine torque, gas generator speed, and turbine inlet temperature for each engine. Additionally, an operating FDR would have provided parameters such as airspeed, altitude, and flight control positions that would have allowed a precise reconstruction of the helicopter's takeoff flightpath. The NTSB concludes that an operating FDR would have provided detailed information about the accident scenario and thus would have aided the NTSB in determining the circumstances that led to this accident.

The NTSB notes that, while the accident helicopter was not required to have an FDR installed, it would have been required to have an FDR or a cockpit image recorder had the FAA implemented Safety Recommendations A-06-17 and -18. Safety Recommendation A-06-17 asked the FAA to require, among other things, that transport-category rotorcraft manufactured before October 11, 1991, operating under 14 CFR Parts 91 and 135 be equipped with either a CVR and an FDR or a cockpit image recorder. When the NTSB issued this recommendation, it stated that transport-category helicopters should be equipped with flight recorders[17] to gather data critical to diagnosing safety deficiencies in the passenger-carrying helicopter fleet. The accident helicopter was a transport-category rotorcraft manufactured in 1965, and, although it was operating as a public aircraft at the time of the accident, it was listed on CHSI's Part 135 operations specifications. Further, the USFS contract required its contractors to operate in accordance with their operations specifications and with Part 91. On November 29, 2006, the NTSB classified Safety Recommendation A-06-17 "Open—Unacceptable Response," and, on November 13, 2009, the NTSB reiterated the recommendation following its investigation of a September 27, 2008, accident involving a transport-category helicopter manufactured in 1988 that was not equipped with an FDR or a CVR.[18] This accident provides additional support for Safety Recommendation A-06-17, as it again demonstrates the need for flight recorders on all transport-category rotorcraft.

Safety Recommendation A-06-18 asked the FAA not to permit exemptions or exceptions to the flight recorder regulations that allow transport-category rotorcraft to operate without flight recorders and to withdraw the current exemptions and exceptions that allow transport-category rotorcraft to operate without flight recorders. This recommendation was issued, in part, to address 14 CFR 135.152(k), which allows an exception to the FDR requirement for certain rotorcraft models manufactured before August 18, 1997. The S-61N is one of the models listed in section 135.152(k). Therefore, although the accident helicopter was listed on CHSI's Part 135 operations specifications, it was not required to be equipped with an FDR. On November 26, 2009, the NTSB classified Safety Recommendation A-06-18 "Open—Unacceptable Response" pending FAA removal of the exceptions in section 135.152(k). The NTSB continues to believe that the FAA should not permit exemptions or exceptions to the flight recorder regulations that allow transport-category rotorcraft to operate without flight recorders and should withdraw the current exemptions and exceptions that allow transport-category rotorcraft to operate without flight recorders. Thus, the NTSB reiterates Safety Recommendation A-06-18.

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

> Require that the hover performance charts published by helicopter manufacturers reflect the true performance of the helicopter in all conditions for which the charts are applicable, including light and variable wind conditions. (A-10-148)

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[17] The term "flight recorders" refers to all crash-protected devices installed on aircraft, including, but not limited to, FDRs, CVRs, and onboard image recorders.

[18] See *Crash During Approach to Landing of Maryland State Police Aerospatiale SA365N1, N92MD, District Heights, Maryland, September 27, 2008*, Aircraft Accident Report NTSB/AAR-09/07 (Washington, DC: National Transportation Safety Board, 2009). < http://www.ntsb.gov/publictn/2009/AAR0907.pdf >.

Develop and implement a surveillance program specifically for 14 *Code of Federal Regulations* (CFR) Part 135 operators with aircraft that can operate both as public aircraft and as civil aircraft to maintain continual oversight ensuring compliance with 14 CFR Part 135 requirements. (A-10-149)

Take appropriate actions to clarify Federal Aviation Administration (FAA) authority over public aircraft, as well as identify and document where such oversight responsibilities reside in the absence of FAA authority. (A-10-150)

Require the installation of fuel tanks that meet the requirements of 14 *Code of Federal Regulations* 29.952 on S-61 helicopters that are used for passenger transport. (A-10-151)

Require that S-61 helicopters that are used for passenger transport be equipped with passenger seats and seat mounting structures that provide substantial improvement over the requirements of Civil Air Regulations 7.260, such as complying with portions of 14 *Code of Federal Regulations* 29.561 and 29.562. (A-10-152)

Require operators of transport-category helicopters to equip all passenger seats with restraints that have an appropriate release mechanism that can be released with minimal difficulty under emergency conditions. (A-10-153)

Require that Advisory Circular 21-34 be used to evaluate all shoulder harness retrofit installations and to determine that the installations reduce the risk of occupant injury. (A-10-154)

Require operators of Sikorsky S-61 helicopters with General Electric model CT58-140 engines to install 10-micron airframe fuel filters. (A-10-155)

Require Carson Helicopters, Inc., to put a conspicuous notification on the title page of the Instructions for Continuing Airworthiness that accompany its supplemental type certificate for installing side-mounted seats indicating that the installation does not provide enhanced occupant protection over that provided by the originally installed seats and meets Civil Air Regulations 7.260 standards. (A-10-156)

Require all applicants for supplemental type certificate (STC) seat installations in any type of aircraft to put a conspicuous notification on the title page of the Instructions for Continuing Airworthiness that accompany the STC indicating whether the installation provides enhanced occupant protection over that provided by the originally installed seats and the certification standard level met by the seating system. (A-10-157)

Require supplemental type certificate (STC) applicants to improve the crashworthiness design of the seating system, such as complying with portions of 14 *Code of Federal Regulations* 29.561 and 29.562, when granting STC approval for older transport-category rotorcraft certificated to Civil Air Regulations 7.260 standards. (A-10-158)

Also, the National Transportation Safety Board reiterates the following previously issued recommendation to the Federal Aviation Administration:

> Do not permit exemptions or exceptions to the flight recorder regulations that allow transport-category rotorcraft to operate without flight recorders, and withdraw the current exemptions and exceptions that allow transport-category rotorcraft to operate without flight recorders. (A-06-18)

The NTSB also issued 10 safety recommendations to the USFS. In response to the recommendations in this letter, please refer to Safety Recommendations A-10-148 through -158 and A-06-18 (Reiteration). 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 secure mailbox. 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).

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in these recommendations.

[Original Signed]

By: Deborah A.P. Hersman
Chairman