2. Analysis

2.1 General

The flight crew was properly certificated and qualified in accordance with USFS contract requirements and FAA regulations.

No evidence was found of any pre-impact airframe structural or system failure.

The emergency response and rescue of the injured firefighters and copilot were timely, and they were transported as quickly as possible given the constraints associated with, and limited access to, the accident site.

The following analysis describes the helicopter's predicted and actual performance, and it examines the safety issues associated with USFS and FAA oversight of Carson Helicopters, the flight crew's performance during the two previous takeoffs from H-44, and accident survivability. Weather observations at helispots, fuel contamination, flight recorder requirements, and certification of seat STCs will also be discussed.

2.2 Preflight Performance Planning

On the morning of the accident, the PIC completed load calculation forms for the day's anticipated missions. The purpose of these calculations was to ascertain that the helicopter's gross weight remained at or below the maximum weight that would enable the helicopter to operate safely at the density altitudes expected. In completing the calculations, the PIC relied on weight and balance forms and RFMSs provided by CHSI and contained in a binder at Trinity Helibase. Specifically, the PIC obtained the helicopter's empty weight from the Chart C in the binder and used the performance charts from the copy of RFMS #8 in the binder. However, because these documents had been altered, the PIC's calculation of the payload that the helicopter could lift that day was incorrect, leading to a substantial overestimate of the payload capability.

2.2.1 Empty Weight of Helicopter

The accuracy of the PIC's calculation of the helicopter's gross weight was dependent on the accuracy of the helicopter's empty weight recorded on Chart C. As discussed in section 1.6.4, when the helicopter was weighed, Chart A and Chart B were prepared; Chart A identified all items installed on the helicopter at the time of the weighing, and Chart B recorded the weighing data. Equipment changes made between weighings were recorded on Chart C, which was based on the actual physical weighing of the helicopter documented in Chart B; if Chart B was erroneous, then Chart C would be incorrect.

The Chart C provided to the pilots was derived from the Grants Pass-prepared Charts A and B for the January 4, 2008, weighing, which were erroneous because they inaccurately indicated that the Fire King tank was installed when the helicopter was weighed. However, the

Fire King tank was not installed until March 25, 2008. Therefore, the empty weight of 12,408 lbs used by the PIC in determining the helicopter's performance capabilities was incorrect.

Based on a review of all available records and interviews of pilots, mechanics, and other personnel involved in the helicopter's operations during 2007 and 2008, NTSB investigators determined that the most recent accurate weighing documents for the helicopter were the Perkasie-prepared Charts A and B for the January 4, 2008, weighing and the Chart C dated March 25, 2008. Using these charts and accounting for the weight of equipment known to be installed or removed from that weighing to the time of the accident, the NTSB determined that the empty weight of the helicopter was 13,845 lbs, which was 1,437 lbs heavier than the empty weight of 12,408 lbs that CHSI provided to the accident helicopter's pilots.

Carson Helicopters acknowledged during the investigation that the helicopter's weight and balance documents were inaccurate and that the helicopter weighed more than the weight provided to the pilots on Chart C. However, the company disagreed with the NTSB's calculated empty weight of 13,845 lbs and proposed several different estimated empty weights, the most recent of which was 13,432 lbs. According to Carson Helicopters, the Chart A prepared on January 4, 2008, in Perkasie was incorrect because it did not include equipment that the Carson Helicopters president "personally recalled" seeing installed in the helicopter. As additional evidence that the Perkasie-prepared Chart A was incorrect, Carson Helicopters submitted a photograph of the helicopter taken on March 25, 2008, which it stated showed "dark seatbacks in the windows." However, the Carson Helicopters president's recollection is directly contradicted by the CHI DOM's statement that the Perkasie-prepared documents for the January 4, 2008, weighing, which he prepared, correctly showed the equipment installed in the helicopter. Also, visual examination of the photograph by NTSB investigators revealed dark areas in some of the windows; however, it was not possible to identify whether these areas were shadows, seatbacks, or other objects. Further, even if investigators could establish from the March 25, 2008, photograph that seats were installed, doing so would not definitively establish the number of seats installed in the helicopter on January 4, 2008.

The NTSB believes that it has used the most reliable information available to calculate the helicopter's empty weight at the time of the accident for the following reasons: the helicopter was actually weighed on January 4, 2008, in Perkasie, not in Grants Pass; the CHI DOM, who was present when the helicopter was weighed, stated that the weighing documents he prepared for the January 4, 2008, weighing were accurate; and the Perkasie-prepared weighing documents were consistent with the maintenance log entries for the installation of the Fire King tank and the rescue hoist. The NTSB concludes that, because Carson Helicopters provided an incorrect empty weight to the PIC, he overestimated the helicopter's load carrying capability by 1,437 lbs.

2.2.2 Takeoff Power Available Chart

Examination of the takeoff (5-minute) power available chart, RFMS #8 Figure 4, used by the PIC to perform the load calculations on the day of the accident revealed that it had been intentionally altered. The alteration consisted of pasting the graphical section of a 2.5-minute power available chart over the graphical section of the takeoff power available chart, while retaining the header and footer of the takeoff power available chart (including the FAA approval stamp). CHSI submitted the altered and incorrect chart to the USFS as part of its bidding process for the 2008 season and also distributed this altered chart to company pilots about 1 month before the accident, instructing them to discard the previous (correct) chart. In its party submission to the NTSB, Carson Helicopters acknowledged that the chart was altered, used in its bid package, and distributed to the company's pilots. The party submission stated that the company did not become aware of the altered chart or the incorrect weight documents until after the accident and that although it could not determine the "reason for the incorrect information," the "anomalies and irregularities appear to have originated from documents created or assembled by…Carson's Vice President of Operations," who was subsequently fired.

The alteration of the chart essentially indicated that 2.5-minute power was available for normal takeoff operations. Because the 2.5-minute power available chart provides the maximum power approved for use in an emergency when one engine fails, it reflects higher power capability than the takeoff power available chart, which provides the maximum power approved by the FAA for use on takeoff when both engines are operating. The USFS requires that the takeoff power available chart be used for load calculations because the additional power reflected in the 2.5-minute power available chart provides a safety margin of emergency reserve power. Therefore, the substitution of the 2.5-minute power available chart for the takeoff power available chart eliminated this safety margin. For example, when used to calculate a HOGE gross weight at 6,000 feet PA and 32° C, as the PIC did when performing his load calculations, the FAA-provided, correct RFMS #8 Figure 4 resulted in a maximum HOGE weight of 16,400 lbs, which was 1,200 lbs less than the 17,600 lbs obtained using the altered CHSI-provided figure. This safety margin of 1,200 lbs of emergency reserve power was eliminated by the alteration of the chart. The NTSB concludes that the altered takeoff (5-minute) power available chart that was provided by Carson Helicopters eliminated a safety margin of 1,200 lbs of emergency reserve power that had been provided for in the load calculations.

2.2.3 Use of Above-Minimum Specification Torque

The copilot reported that, when determining power available, only min spec torque (torque uncorrected for the positive torque margins determined by the engine power check) was used. However, review of the PIC's calculations revealed that he had used above-min spec torque. In the load calculation at 6,000 feet PA and 32° C, the PIC calculated a HOGE weight of 18,400 lbs, whereas if he had used min spec torque, the calculated HOGE weight would have been only 17,600 lbs. Using above-min spec torque equated to an additional 800-lb increase in the calculated HOGE weight capability over and above the errors previously identified.

According to Sikorsky, positive torque margins are not intended for use in performance planning since the additional performance provided by the above-min spec torque cannot be accounted for in the performance charts. Additionally, regarding engine performance, the USFS stated that, when any operator is on contract, "performance shall be obtained using minimum engine specifications and no more," and "if the engines are producing more power than the applicable charts calculate, then that would be considered a safety margin but could not and would not be allowed for HOGE computation." However, the CHSI DO stated that, "as long as an operator does not exceed the maximum horsepower rating for each engine, then actual available torque [above-min spec torque] for each engine can be utilized to convert to available horsepower for HOGE performance." Therefore, the PIC appears to have been following a company-approved procedure when he used above-min spec torque in performing the load calculations.

The NTSB concludes that the PIC followed a Carson Helicopters procedure, which was not approved by the helicopter's manufacturer or the USFS, and used above-min spec torque in the load calculations, which exacerbated the error already introduced by the incorrect empty weight and the altered takeoff power available chart, resulting in a further reduction of 800 lbs to the safety margin intended to be included in the load calculations. For further discussion of the role of the USFS in overseeing the load calculations, see section 2.4.1.

In summary, the PIC unknowingly used two separate pieces of erroneous information in his preflight load calculations: the empty weight and the power available chart. Additionally, the PIC followed a company procedure that was not approved by the USFS and used above-min spec power in performing the load calculations. For the PIC's load calculation at 6,000 feet PA and 32° C, these discrepancies resulted in overestimating the helicopter's maximum allowable payload by 3,437 lbs. (1,437 lbs for the incorrect empty weight + 1,200 lbs for the altered power available chart + 800 lbs for the use of above-min spec torque = 3,437 lbs.) Immediately before attempting the accident takeoff, the pilots referred to this incorrect load calculation that indicated that the helicopter had the capability to HOGE with a maximum payload of 2,552 lbs and compared this to the manifested payload of 2,355 lbs. Since the pilots estimated that the temperature was 12° to 13° below the 32° C temperature that the load calculation assumed and the manifested payload was about 200 lbs lighter than the load calculation allowed, they determined that the helicopter should have performance in excess of that predicted by the load calculation. Because of the incorrect load calculation, when initiating the accident takeoff, the pilots believed the helicopter was "good to go" with capability beyond that required to HOGE.

With correct information and using min spec torque, the load calculations would have indicated that at 6,000 feet PA and 32° C the helicopter could not carry any payload. Clearly, a correct load calculation would have deterred the pilots from attempting the accident takeoff with the manifested payload of 2,355 lbs. In fact, since the correctly calculated maximum allowable payload was less than zero (-845 lbs as shown in Table 7), in order to comply with USFS standards to carry a payload of 2,355 lbs, the weight of the helicopter needed to be reduced (via removing equipment or carrying less fuel) by a total of 3,200 lbs (845 + 2,355 = 3,200). The NTSB concludes that the incorrect information—the empty weight and the power available chart—provided by Carson Helicopters and the company procedure of using above-min spec torque misled the pilots to believe that the helicopter had the performance capability to HOGE with the manifested payload when, in fact, it did not.

When comparing the PIC's calculated maximum allowable payload of 2,552 lbs with the manifested payload of 2,355 lbs, the pilots made an additional error in failing to recognize that the inspector pilot's weight of 210 lbs was not included in the manifested payload. Catching this error and correcting for it would have resulted in an actual payload for the accident flight of 2,565 lbs (2,355 + 210 = 2,565), which would have exceeded the 2,552-lbs allowable payload calculation by 13 lbs. It is unlikely that catching this error would have deterred the pilots from attempting the takeoff, as they would still have believed that the helicopter had performance in excess of that predicted by the load calculation because they estimated that the actual temperature at H-44 was 12 to 13 degrees cooler than the 32° C used for the load calculation.

2.3 Actual Helicopter Performance

The actual performance characteristics of the helicopter during the accident takeoff from H-44 were determined from the sound spectrum study of the CVR recording. The study indicated that both engines reached topping (maximum N_G limit) about 22 seconds after power was applied and remained at that speed, without fluctuating, for the next 31 seconds until the CVR recording ended. Further, the study indicated that N_R decreased from a maximum speed of about 106.9 percent at the time power was applied to a final value of about 93.5 percent at the end of the CVR recording. This droop in N_R with the engines operating at topping indicates that the power required to maintain a constant N_R had exceeded the power available from the engines.

A comparison of the sound spectrum information from the accident takeoff to that from the helicopter's two previous successful takeoffs from H-44 reveals similar N_G and N_R speed characteristics during the initial portion of each takeoff. During both successful takeoffs, each engine accelerated up to topping and then remained at topping consistent with the N_G characteristics from the accident takeoff. Also, during both successful takeoffs, N_R initially decreased, decaying to a minimum of 101.5 and 101.4 percent, respectively, for the first and second takeoffs. However, unlike the accident takeoff, during the successful takeoffs, after less than 20 seconds at topping, N_R began to increase, and N_G began to decrease below topping as the helicopter achieved effective translational lift[119] and the aerodynamic efficiency of the rotor increased, enabling the engines to maintain the required N_R at a reduced torque and power.

The similarities in the engine and rotor speed characteristics between all three takeoffs indicate 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 weight in excess of the helicopter's capabilities given the conditions. The NTSB considered both possibilities.

2.3.1 Engine Power Available

The USFS requires engine power assurance checks to be performed every 10 flight hours to verify that an engine is producing at least min spec power. The accident pilots conducted the helicopter's most recent power assurance check on the day before the accident (about 3.5 flight hours before the accident), and the test indicated that both engines were producing above-min spec power.

According to the CVR transcript, during the first landing at H-36 on the day of the accident, the pilots performed a power check, and, following this check, the copilot commented, "Power's good." In addition, according to the CVR transcript, on the accident takeoff the copilot was calling out engine torque values up to 90 percent, indicating that he was looking at the engine torque gauges and likely would have noticed any indications that the helicopter was not performing as expected. Further, the torque values called out by the copilot match the torque that

[119] Translational lift refers to additional rotor performance gained from added inflow to the rotor. The replacement of turbulent, recirculating air as seen in a no-wind hover with "clean" air due to forward movement of the helicopter increases the rotor efficiency and thus increases the thrust produced at the same power.

would have been produced by normally operating engines. Finally, the copilot stated in a September 16, 2008, postaccident interview that the helicopter "had plenty of power."

The CVR sound spectrum study demonstrated that each engine was operating and stabilized at its maximum N_G (topping speed) during the accident takeoff and during the previous two takeoffs from H-44. According to GE, when a CT58-140 engine operates at topping speed, the FCU delivers maximum fuel flow to the engine, and only a reduction in the amount of airflow going through the power turbine could cause the engine to produce less than maximum power. Low airflow through the power turbine could be caused by two conditions: a contaminated compressor, resulting in airflow blockage due to buildup on the blades and reduced compressor efficiency, or a malfunction of the variable stator vane system, resulting in improper positioning of the stator vanes (vanes partially closed when they should be fully open).

If one engine had lost power due to compressor contamination, the torque produced by the affected engine would have decreased, and the pilots would have seen a torque needle split on the torque gauges in the cockpit. The CVR did not record any comments indicating a torque split, and it is clear from the copilot's comments during the accident takeoff that he was looking at the torque gauge. In addition to a torque split, another symptom of compressor contamination that would have been visible in the cockpit is high engine temperature readings. The CVR did not record any comments indicating that either pilot observed high engine temperature readings on the T_5 gauges during the accident takeoff.

Postaccident disassembly of the engines revealed no evidence of any preimpact compressor malfunctions or failures. Witnesses stated that both engines continued to run after impact. The presence of soil throughout the engines also indicated that both engines were operating during the impact sequence. Metallurgical examination of the left engine's first-stage turbine wheel revealed that, after impact, it experienced a short duration over-temperature event that led to stress fracturing of the turbine blades.[120]

During an engine start, the variable stator vanes begin to open about 65 percent N_G and are fully open about 95 percent N_G. They remain fully open until N_G begins to decrease during a normal engine shutdown, reaching the fully closed position again as N_G decreases below 65 percent. A malfunction of the stator vane control system could result in a lower torque output or fluctuating torque output from the affected engine. The CVR transcript and sound spectrum study indicated that, during the accident takeoff, both engines reached 95 percent N_G several seconds before the copilot called out an engine torque value of 75 percent. This torque value matches the torque that would be expected from a normally operating engine and variable stator vane system at the engine N_G and atmospheric conditions present at the time. Furthermore, as the copilot called out torque values up to 90 percent, he never communicated indications of anomalous torque readings. This evidence indicates that both engines' variable stator vanes were fully open and functioning normally during the accident flight. Postaccident examination found the pilot valves and their respective stator vane actuators in the closed (retracted) position,

[120] The presence of soil deposits on the areas of intact blade coating and the absence of deposits on the areas of spalled blade coating indicated that the soil deposits occurred when the blades were intact. Because the soil ingestion occurred after ground impact, the over-temperature event also had to occur after impact.

indicating they functioned correctly after impact as the engines shut down. No contamination was found in either pilot valve.

Postaccident examination of the 3-D cams and the T_2 bellows' position adjusting screws offered additional evidence that the stator vane system operated normally throughout the accident flight and indicated that both T_2 bellows assemblies were intact and functioning during the flight. Metallurgical examination of the position adjusting screws found that both fractured due to overstress after weakening from exposure to high temperatures, indicating both T_2 bellows assemblies were intact until they were exposed to the heat of the postcrash fire.[121] Another indication that both T_2 bellows assemblies remained intact until exposure to the postcrash fire was the fact that neither 3-D cam was found in its full cold (low T_2) position, as would be expected if a position adjusting screw had failed during flight.[122] The NTSB concludes that the efficiency of the engines' compressors was not compromised, and the stator vanes functioned normally throughout the accident flight.

During disassembly and examination of the FCUs, contamination (fibrous 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 PRV. As discussed in section 1.18.3, a contaminated PRV can result in N_G power fluctuations, erratic operation, or slow acceleration of a CT58-140 engine. These malfunctions of the PRV can occur when considerable amounts of contaminants become lodged between the PRV's piston and its sleeve, restricting the piston's movement. The few contaminant particles found within each PRV from the accident helicopter were within the circumferential balance grooves of the piston, and no particles were found between the piston and sleeve of either unit. Additionally, the sound spectrum study demonstrated that both engines simultaneously increased up to their maximum N_G for all three takeoffs from H-44 and remained at this speed without fluctuating, indicating that the PRV pistons were functioning correctly and were not sticking. The NTSB concludes that the trace contaminants found within the FCUs did not affect their operation, and both FCUs functioned normally throughout the accident flight. For more information about fuel contamination, see section 2.7.2.

2.3.2 Helicopter Performance Capability

A helicopter's actual maximum HOGE weight varies depending on the power developed by the helicopter's engines and the meteorological conditions (PA, temperature, and wind). Determining the helicopter's weight margin by comparing the helicopter's gross takeoff weight to the maximum HOGE weight provides a direct measure of the performance capability that exists for a given takeoff. A helicopter with a negative weight margin (that is, gross weight greater than HOGE weight) cannot HOGE, and a takeoff is only possible if a sufficient clear area exists for the helicopter to move forward while remaining in ground effect until translational lift

[121] The heat from the postcrash fire weakened the position adjusting screws and caused the intact T_2 bellows to expand, putting pressure on the position adjusting screws, which then fractured because of their reduced strength.

[122] The left 3-D cam was found in its full hot (high T_2) position, indicating that, when the left T_2 bellows expanded due to exposure to heat from the postcrash fire, fuel pressure was still available to the T_2 servo valve. The right 3-D cam was found in a mid-range position, indicating that, when the right T_2 bellows expanded, no fuel pressure was available to the T_2 servo valve.

is achieved. If the weight margin is zero (gross weight equal to HOGE weight), the helicopter can HOGE but has no excess capability available for climbing vertically, maneuvering, or accelerating forward while maintaining altitude. A helicopter with a positive weight margin (gross weight less than HOGE weight) can HOGE and has excess capability available.

The NTSB's hover study used both the performance charts in RFMS #8 and the more conservative performance predicted by Sikorsky based on its 2008 flight tests of a VH-3A for the U.S. Navy to calculate the weight margins for all three H-44 takeoffs. The HOGE weights derived from both data sources were reduced by 100 lbs to account for the negative effect of the Fire King tank on hover performance. The HOGE weights were then compared to the helicopter's gross takeoff weight to determine the weight margin. See table 11 for the results of these calculations.

For the first H-44 takeoff at 6,106 feet PA, 29° C, a gross weight of 18,368 lbs, and both engines running at topping, the hover study calculated weight margins of 113 and -453 lbs using RFMS #8 and the Sikorsky prediction, respectively. This range of weight margin from slightly positive to negative indicates that the helicopter had little to no HOGE capability and that the first H-44 takeoff was only successful because the PIC was able to maintain clearance from trees and terrain while gaining enough airspeed to achieve effective translational lift. This situation is consistent with the reports of passengers on board the helicopter during this takeoff who commented that the helicopter felt "heavy, slow and sluggish" and noted that the flightpath took them below treetop level for "quite a while."

For the second takeoff at 6,106 feet PA, 27° C, a gross weight of 18,001 lbs, and both engines running at topping, the hover study calculated weight margins of 633 and 65 lbs using RFMS #8 and the Sikorsky prediction, respectively. The range of positive weight margins indicates that the helicopter had some HOGE capability on this takeoff.

For the accident takeoff at 6,106 feet PA, 23° C, a gross weight of 19,008 lbs, and both engines running at topping, the hover study calculated weight margins of 12 and -563 lbs using RFMS #8 and the Sikorsky prediction, respectively. This range of weight margin indicates that the helicopter had even less performance capability on this takeoff than it did on the first takeoff. The accident takeoff was not successful because the PIC was unable to maintain clearance from trees and terrain while attempting to gain enough airspeed to achieve effective translational lift.

The ambient temperature decreased for each successive takeoff from H-44, thus improving the helicopter's performance capability. However, the increase in the helicopter's weight for the third (accident) takeoff was greater than the benefits provided by the improving temperature scenario. Thus, the helicopter's weight margin improved slightly when comparing the first and second takeoffs but then decreased again on the accident takeoff.

The magnitude of the weight margins for all three H-44 takeoffs can be put into perspective by considering the margins that would have been provided if performance planning had been correctly accomplished. For example, on the accident takeoff, using the RFMS #8 and following the USFS-prescribed procedures with an accurate helicopter weight, the correct 5-minute performance chart, and the correct min spec torque, the weight of the helicopter should have been no greater than 17,000 lbs.[123] Comparing this weight to the actual maximum HOGE weight of 19,020 lbs yields a positive weight margin of 2,020 lbs, or 10.6 percent of the actual maximum HOGE weight. With this weight margin, the helicopter would have had significant excess capability available for climbing vertically, maneuvering, or accelerating forward while maintaining altitude. Positive weight margins were intended to provide a safety margin so that minor changes in engine performance, wind, temperature, and actual weight would not result in the loss of HOGE capability.

To further explore the helicopter's performance on the accident takeoff while operating near and below zero weight margin, the NTSB requested that Sikorsky prepare simulations of the takeoff using its GenHel helicopter simulation computer program. As described in section 1.16.7, Sikorsky performed four simulations: two using the performance data in RFMS #8 with temperatures of 20° and 23° C, and two using Sikorsky's predicted performance based on the U.S. Navy flight tests with temperatures of 20° and 23° C. Temperatures of 20° and 23° C were selected because, although analysis of the available meteorological data estimated an ambient temperature of 23° C for the accident takeoff, Carson Helicopters disagreed with this estimate and proposed a temperature of 20° C based on the copilot's statements as recorded on the CVR.

As shown in figure 14, the flightpaths computed using the RFMS #8 performance at 20° and 23° C show performance better than was actually achieved, 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 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 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

[123] This weight was calculated using the charts in RFMS #8 to determine a maximum HOGE weight for the accident conditions of 17,550 lbs and then subtracting the 550-lb USFS-required weight reduction.

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. Further, the fact that both simulations (20° and 23° C) using RFMS #8 performance charts clear the tree whereas both simulations using Sikorsky's performance prediction impact the tree indicates that the effect on performance of a 3° C temperature difference is of considerably less magnitude than the effect of a change in the direction of a light wind.

Further, the simulations clearly illustrate that, on the accident takeoff, the power required from the engines to climb and maintain N_R exceeded the power available, not as a result of a power loss due to engine malfunction but due to excessive power demands associated with attempting to lift more weight than possible in a HOGE given the ambient conditions. On the basis of this and other evidence (as detailed in section 2.3.1), the NTSB concludes that both engines were operating normally throughout the accident flight. The NTSB also concludes that 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 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 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.

2.4 Oversight

2.4.1 Role of USFS

During his carding inspection of the accident helicopter in June 2008, the USFS maintenance inspector had an opportunity to examine the helicopter's weight and balance records, maintenance logbooks, and the helicopter itself. However, USFS procedures required only that the maintenance inspector verify and record certain discrete items, such as the date of the helicopter's last weighing, its equipped weight, and its bid weight. No requirements existed to review, as part of the carding process, a helicopter's Charts A, B, and C or to examine the maintenance logbooks for entries recording equipment installations and removals. If this review and crosscheck had been completed during the carding inspection, the maintenance inspector may have detected the same inconsistencies found by NTSB investigators after the accident. Specifically, he may have discovered that the Fire King liquid tank and snorkel (weighing 1,090 lbs) were not installed during the last weighing on January 4, 2008, as Chart A indicated because the maintenance records showed that the tank was not installed until March 25, 2008, about 3 months after the weighing.

Following the accident, the USFS weighed the entire Carson Helicopters fleet and found that 9 of the 10 helicopters under contract were over the weight listed on their corresponding Chart Cs. The 9 helicopters were overweight by amounts ranging from 34 to 1,004 lbs, with an average of 495 lbs. Thus, the weight irregularities were not confined to the accident helicopter but were systemic of the majority of Carson Helicopters' fleet. Several months after the postaccident weighings, the USFS terminated both Carson Helicopters contracts based on the operator's "failure to comply with contract terms and conditions." One of the contract violations identified was that 7 of the 10 helicopters weighed "more than their equipped weight as bid." Another violation was that when using the helicopters' actual weights (as determined by the postaccident weighings) and the nonaltered RFMS #8 Figure 4, only 5 of the 10 helicopters would have been qualified to bid on the solicitations because the others would not have met the contractual payload requirements.

NTSB investigators reviewed the weight documentation CHI provided in its 2008 bid proposal to the USFS. On the Chart Bs for 8 of the 11 helicopters CHI offered, including Chart B for the accident helicopter, the scale readings were recorded to the nearest tenth of a lb, even though the scales used were only capable of measuring to the nearest lb. In addition, the differences in weight between the left main gear weight and the right main gear weight on these eight helicopters were all exactly 80 lbs. These findings indicate that the weights documented for each landing gear were likely computed mathematically to result in a predetermined, desired total helicopter weight. The NTSB concludes that the lower-than-actual empty weights recorded by Carson Helicopters on the Chart B weighing records for the accident helicopter and 8 of Carson's other 10 helicopters created the appearance of higher payload capabilities; at their actual weights, the accident helicopter and 5 of the other helicopters would not have met the contractual payload specifications.

Historically, S-61 operators bid on USFS contracts using performance numbers derived from the 2.5-minute power available charts. In 2006, the USFS changed the policy because it determined, through consultations with GE, Sikorsky, and the FAA, that those charts were solely intended for OEI operations. Thereafter, the use of 2.5-minute power available charts was prohibited for contract bidding or for load calculations, and operators were to use only the takeoff power available charts. One month after that decision, CHI protested this ruling, stating that the 2.5-minute power available chart did not specifically indicate that it was intended for OEI operations only. According to the USFS, no change was made as a result of CHI's protest.[124]

As indicated, USFS policy stated the 2.5-minute power available chart was not to be used for bidding or load calculations, and Carson Helicopters was aware of the policy because it submitted a protest against the policy. Although Carson Helicopters has stated it does not know where the altered performance chart originated, the NTSB notes that the alteration benefited Carson Helicopters in meeting contractual requirements by giving the appearance of higher payload capabilities, as did the use of low helicopter empty weights.

Because the USFS uses load carrying capacity as a criterion for evaluating and awarding contracts, it must ensure that the weight and performance charts the bidders submit are accurate and applicable. As previously discussed, the USFS only attempted to verify the weights of Carson Helicopters' aircraft after the accident, at which time the majority were found to be over their contract weights. Also, even though the USFS was aware that Carson Helicopters was opposed to its decision regarding use of the 2.5-minute power available chart, the USFS did not scrutinize the performance charts Carson Helicopters submitted in its bid packages. Careful examination of the charts would likely have led the USFS to detect the same inconsistencies found by NTSB investigators after the accident.

The load calculations the PIC performed on the day of the accident used charts from RFMS #6, #7, and #8. CHSI claimed that these RFMSs were appropriate for use with the accident helicopter as configured at the time of the accident. However, no maintenance record entries or FAA Form 337s existed for installation of the STCs associated with RFMS #6 and #7, and, although a maintenance record and FAA Form 337 existed for installation of the hoist STC associated with RFMS #8, the hoist was only partially installed at the time of the accident. Further, when queried by NTSB investigators after the accident, the FAA stated that none of these RFMSs were appropriate for use with the helicopter as it was configured at the time of the accident. According to the FAA, the RFMS for the Carson composite main rotor blade STC (RFMS CH-03) was applicable, and, since its performance section stated, "No Change," the appropriate performance charts for use with the helicopter as it was configured at the time of the accident were those in the original Sikorsky RFM. The USFS's lack of awareness concerning the RFMSs before the accident hindered its ability to provide effective oversight.

The USFS had opportunities during its review of CHI's bid package and its carding inspection of the accident helicopter to discover that the company was using improper weight and performance charts for contract bidding and for actual load calculations but failed to detect

[124] Carson Helicopters continues to maintain that the use of these charts is permissible for dual-engine operation, stating in its May 28, 2010, party submission to the NTSB that, "in contrast to other twin engine helicopter models, the Sikorsky [RFM] does not state that the 2.5 minute chart can only be used for emergency use or single engine operations."

these discrepancies. During the bid package review, the power available chart used by Carson to demonstrate the helicopter's performance capability should have received specific scrutiny by the contracting officer because the USFS was aware that Carson opposed its policy of not allowing use of the 2.5 minute charts for bidding; however, this did not occur. Also, during the bid package review, the contracting officer failed to notice that the Part 135 certificate submitted by CHI was actually in the name of CHSI. During the carding inspection, a comparison by the USFS maintenance inspector of the entries on the Chart C with the maintenance logbook entries would have shown that the 1,090-lb Fire King tank was checked off as on the helicopter when it was weighed on January 4, 2008, but not shown by the maintenance logbook entry and the Form 337 as being installed until March 25, 2008. If the maintenance inspector had noted this conspicuous error, he could have required Carson to weigh the helicopter in his presence and verify that it met the contract requirements; however, this did not occur. Further, the USFS missed a last opportunity to detect that Carson was violating approved procedures when, on the day of the accident, the inspector pilot failed to notice that the PIC was using above min-spec torque in completing the load calculations. (The inspector pilot's performance is further discussed in section 2.4.1.1.)

Had these discrepancies been detected, the USFS would have required CHI to correct them, which could have prevented the accident. The NTSB concludes that the USFS's oversight of Carson Helicopters was inadequate, and effective oversight would likely have identified that Carson Helicopters was using improper weight and performance charts for contract bidding and actual load calculations and required these contractual breaches to be corrected.

The NTSB notes that the USFS has made a number of changes in response to this accident investigation, including validating the weight of each aircraft awarded a contract and instituting checks to determine that contractors are in full compliance with the contract during the contract award period. Although the NTSB is encouraged that the USFS has already implemented changes as a result of the accident, the NTSB believes that further oversight improvements are necessary.

The NTSB previously identified a similar lack of effective USFS oversight of its contractors during its investigation of the in-flight breakups of three firefighting aircraft. In an April 23, 2004, safety recommendation letter, the NTSB recognized that the USFS did not have the infrastructure in place to provide independent oversight of the continuing airworthiness and maintenance programs for its air tanker fleet and issued Safety Recommendations A-04-29 through -31 to the USFS. These recommendations, respectively, asked that the USFS develop maintenance and inspection programs specifically for aircraft used in firefighting operations, require the use of these programs by its contractors, and conduct appropriate oversight to ensure the programs were followed. Since these recommendations were issued, the USFS has made substantial progress towards their implementation. Safety Recommendation A-04-31 was classified "Closed—Acceptable Action" on February 13, 2007, and Safety Recommendations A-04-29 and -30 are currently classified "Open—Acceptable Response." The findings from this investigation demonstrate the need for the USFS to address its oversight of firefighter transport operations in a manner comparable to that of the air tanker fleet.

An underlying reason for the USFS's failure to provide effective oversight may have been its belief that its requirements for all contractors who transport passengers to hold a

Part 135 certificate and comply with their operations specifications and all portions of Part 91 would ensure a greater margin of safety. However, once an aircraft is under contract to the USFS, it operates as a public aircraft and is not subject to FAA oversight of those operations. Therefore, the USFS cannot rely on the FAA to ensure its contractors are in continuous compliance with Part 135 and must take responsibility for overseeing the safety of public firefighting flights such as the accident flight. Further, the USFS acknowledged that, at times, its contractors may not be able to fully comply with Part 135 regulations because of firefighting mission-specific requirements. For example, helitack crews routinely rappel from the helicopter to the ground, and hazardous materials are often carried on firefighter transport missions; neither of these operations would be allowed on a Part 135 flight. Thus, no FAA safety standards exist that can be applied to determine how these operations should be conducted. The NTSB concludes that, although the USFS attempted to provide for safe operations by contractually requiring that the operator comply with Part 135, these requirements without effective oversight were not adequate to ensure safe operations. Therefore, the NTSB recommends that the USFS develop mission-specific operating standards for firefighter transport operations that include procedures for completing load calculations and verifying that actual aircraft performance matches predicted performance, require adherence to aircraft operating limitations, and detail the specific Part 135 regulations that are to be complied with by its contractors. In addition, the NTSB recommends that the USFS require its contractors to conduct firefighter transport operations in accordance with the mission-specific operating standards specified in Safety Recommendation A-10-159. Further, the NTSB recommends that the USFS create an oversight program that can reliably monitor and ensure that contractors comply with the mission-specific operating standards specified in Safety Recommendation A-10-159.

2.4.1.1 Role of USFS Inspector Pilot

The USFS inspector pilot who was evaluating the PIC reviewed the load calculations the PIC had prepared but apparently did not notice that the PIC had used above-min spec torque when completing the load calculations, a procedure that the USFS does not allow. If the inspector pilot had noticed this improper procedure and required the PIC to correct the load calculations, the allowable payload for the 6,000 foot PA and 32° C condition would have been reduced by 760 lbs, which may have reduced the actual payload manifested for the accident takeoff.

During the first and second takeoffs from H-44, the inspector pilot had an opportunity to notice the helicopter's marginal performance. Although the inspector pilot was seated in the cabin facing rearward, he could see out the side windows and observe the helicopter's height above the ground. Therefore, he had the opportunity to note the same indications of marginal performance reported by the firefighters on board the helicopter during the first takeoff from H-44, such as the helicopter feeling "heavy, slow and sluggish" and being "below the treetops for quite a while." However, according to the CVR transcript, he never questioned the PIC about the helicopter's performance. Given the inspector pilot's extensive flight experience of over 11,500 hours of flight time in turbine helicopters, it is difficult to understand why the inspector pilot did not notice the helicopter's marginal performance and express concern about it. However, although the inspector pilot had prior experience evaluating pilots in the S-61, he did not hold an SK-61 type rating, had never flown as PIC of an S-61, and did not have an approval on his USDA/USDI Interagency Helicopter Pilot Qualification Card for the S-61.

The USFS does not require PIC time, a type rating, or carding for USFS inspector pilots in each type of helicopter in which they perform evaluations. According to the USFS, a type rating is not required for inspector pilots because they never act as PIC during evaluations. Further, the content of a USFS evaluation is significantly different from that of an FAA evaluation in that the inspector pilots do not reevaluate the tasks that the FAA typically evaluates, and the USFS evaluations do not determine competency to act as a pilot. The inspector pilot's primary function is to ensure that a pilot is competent in demonstrating his/her abilities for "special use" operations, which include USFS-specific missions such as long-line vertical reference and water/retardant delivery. Specifically, on the day of the accident, the inspector pilot was evaluating the PIC on his ability to perform passenger-transport missions in a fire environment.

Although the inspector pilot was not expected to duplicate an FAA evaluation, he was tasked with performing a mandatory evaluation of the PIC in a helicopter with which he was unfamiliar. He had received no specific training from the USFS in the performance of S-61 load calculations or in normal operating procedures for this helicopter. It is evident from the fact that the inspector pilot failed to notice the PIC's incorrect usage of above-min spec torque that his lack of knowledge specific to S-61 load calculations hampered his ability to perform an adequate evaluation of the PIC. Additionally, familiarity with normal operating procedures for the S-61 would have aided him in identifying that the helicopter was being operated in an unsafe manner on the first two takeoffs from H-44. The NTSB concludes that the USFS's inadequate training of the inspector pilot led to the inspector pilot's failure to correct the PIC's improper usage of above-min spec torque and contributed to the inspector pilot's failure to identify the helicopter's marginal performance on the first two takeoffs. If the inspector pilot had received specific training in S-61 performance calculations and operating procedures, his ability to perform an adequate evaluation of the PIC would have been enhanced, and he might have detected the unsafe practices that occurred during the previous departures from H-44 (reaching topping) and intervened before the accident occurred. Therefore, the NTSB recommends that the USFS provide specific training to inspector pilots on performance calculations and operating procedures for the types of aircraft in which they give evaluations.

2.4.2 Role of the Federal Aviation Administration

During the year before the accident, Portland FSDO inspectors recorded 43 actions in the FAA's PTRS for the CHSI Part 135 certificate. Of those actions, 13 were related to operational activities, 16 were related to maintenance, and 14 were related to avionics. Although many of the PTRS entries did not contain detailed information, leaving it unclear as to precisely what transpired during the inspections, the quantity of PTRS entries indicates that CHSI received significantly more than the minimum required surveillance of one visit per year from each principal inspector. However, despite the recorded surveillance, the FAA inspectors did not identify the discrepancies in maintenance, performance, and weight and balance documents that were revealed after the accident.

About 2 months before the accident, on June 3, 2008, the accident helicopter and three other S-61N helicopters were added to CHSI's Part 135 operations specifications, which tripled the number of helicopters on the certificate. When an aircraft is added to the operations specifications of a Part 135 operator, the operator must demonstrate that the aircraft conforms to its original type design or properly altered condition, meets all additional operational regulations applicable for intended use, and is in condition for safe flight. Typically, an FAA inspector conducts an inspection of the aircraft and its records to verify that it meets all Part 135 requirements; however, there is currently no FAA procedure requiring such an inspection. The accident helicopter was never at CHSI's main base in Grants Pass, Oregon, and no PTRS records were found indicating that Portland FSDO inspectors had seen the accident helicopter. Additionally, review of the PTRS records revealed no entries indicating that any of the other three S-61N helicopters that were added to CHSI's certificate on June 3 received an inspection by an FAA inspector to verify that they met all the Part 135 requirements before they were added to the certificate. If such an inspection had been performed on the accident helicopter, at least some of the discrepancies in maintenance, performance, and weight and balance documents that were revealed after the accident could have been found. The discrepancies that could have been found included:

1. The Chart C indicated the Fire King tank was installed on January 4, 2008; however, the maintenance logbook entry and the Form 337 showed the tank was not installed until March 25, 2008.
2. The weights on the Chart B 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 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 on June 3, 2008, because they did not inspect any of these helicopters before they were added to the certificate. It is likely weight discrepancies would have been found with 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' Chart C weights and their actual weights.

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 Part 135 operations specifications, 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. 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 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 Chart C 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 POI 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 Chart Cs "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 POI 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 March 2009, a team consisting of the principal inspectors assigned to CHSI at the time of the accident performed the initial phase of a "compliance audit" at the CHSI facilities. The team's report on this inspection included no adverse findings. It is not surprising that the report did not reveal the irregularities found during the NTSB's investigation, because by the time the inspection was conducted, CHSI had already had 7 months to correct them.

In addressing the concerns raised after the accident, the FAA inspectors consistently asserted that, since 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 the year prior to 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 DoD in accordance with the provisions of 14 CFR Part 135. 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, that 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.

2.5 Flight Crew Performance

When a helicopter reaches topping, it is at maximum power with no power in reserve; any increase in required torque will result in a drooping (slowing down) of the N_R. Even though N_R remained sufficiently high during the first two takeoffs from H-44 to allow these takeoffs to succeed, the topping of the engines indicated that the helicopter was laboring to fly and was close to its absolute performance capability.

During the two previous departures on the day of the accident, the pilots had the opportunity to realize that the helicopter was overweight or at least that it was not performing in a manner consistent with the load calculations. The N_G gauges would have shown that the engines were being operated in excess of the flight manual takeoff N_G limit of 100 percent (shown on the N_G gauges as a red line) and were at topping power. Additionally, the droop in N_R would have been audible to the pilots and visible on the triple tachometer. Nonetheless, neither pilot mentioned that the engines were at topping, even though the load calculations showed that they should have been well below the helicopter's maximum performance capabilities. Further, 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 PIC had accumulated the majority of his experience flying helicopters in the logging and firefighting industries. As revealed by the comments of other S-61 pilots, the operating procedures are significantly different when carrying logs or water than when carrying passengers. In both logging and water-dropping missions, the pilots do not routinely rely on load calculations. In logging, the operation of flights is driven by the maximum power capabilities of the helicopter as indicated by the torque gauges, and pilots consistently load the helicopter until it reaches its maximum performance capability, knowing that they can jettison the load and instantaneously decrease the power required to hover or climb. During water-dropping missions, the pilot verifies the helicopter's available power before arriving at a dip site. The pilot increases power by increasing collective until the N_R begins to droop, then notes the engine torque attained and uses it as a reference. When at the dip site and pumping water into the tank, the pilot monitors the torque gauges, and when the torque reaches about 10 percent below the reference torque, the pilot shuts off the pump and departs. If the N_R begins to droop on departure, the pilot jettisons some of the water and continues the mission. The PIC was very experienced in these types of operations and likely knew and accepted operating at the limit of the helicopter's performance.

Throughout the accident flight, the copilot referred to the load calculations repeatedly and queried the PIC about whether the helicopter could perform under the ambient conditions. Additionally, the copilot diligently read aloud the cockpit gauge indications (torque and N_R) during the departures from H-44, while these callouts were not made on the other takeoffs from lower altitudes. These actions may indicate that the copilot was concerned about the helicopter's performance limitations despite the load calculations that indicated that the helicopter should have been well within its capabilities. However, during the copilot's interview, he stated that "everything was normal" on the first two H-44 takeoffs and that the performance of the helicopter was as expected. The copilot was also experienced in water-dropping operations and, when interviewed, described the same procedures for picking up water as the other S-61 pilots.

The NTSB concludes that the pilots likely recognized that the helicopter was approaching its maximum performance capability on the two prior departures from H-44 but elected to proceed with the takeoffs because they were accustomed to performing missions where operating at the limit of the helicopter's performance was acceptable.

As a result of the lessons learned from this accident, the USFS added two new tasks—a HOGE Power Check Task and a Special Use Passenger Transport Task—to its pilot carding evaluations to determine whether pilots possess the skills and knowledge to properly perform a HOGE power check before landing at or departing from helispots located in confined areas, pinnacles, or ridgelines. The task objectives state that, when transporting passengers, HOGE power must be available, or the mission cannot be conducted. As specified in these tasks, a before takeoff HOGE power check is performed by ascending vertically to and maintaining an OGE hovering altitude and then descending vertically back to the ground. Performing this check demonstrates that the power required does not exceed the power available and thus ensures that the helicopter's performance is sufficient to safely complete the takeoff. If the pilots had performed a HOGE power check before attempting the first H-44 takeoff, they would have determined that HOGE power was not available, which would likely have led them to acknowledge that the helicopter was not performing in a manner consistent with the load calculations and to take action to address the discrepancy. The NTSB concludes that the performance of a HOGE power check before takeoff from helispots located in confined areas, pinnacles or ridgelines would increase flight safety.

In its party submission to the NTSB, the USFS stated that its inspector pilots are now required to evaluate helicopter pilots on their performance of these two tasks during flight evaluations. However, the NTSB believes a pilot's ability to properly perform a HOGE power check should not only be evaluated by inspector pilots, but should also be a standard operating procedure performed by pilots flying for the USFS before every takeoff carrying passengers from helispots located in confined areas, pinnacles, or ridgelines. Therefore, the NTSB recommends that the USFS require a HOGE power check to be performed before every takeoff carrying passengers from helispots in confined areas, pinnacles, and ridgelines.

2.6 Accident Survivability

2.6.1 Fuel Tanks

The four survivors were seated on the right side of the helicopter. Although briefly knocked unconscious, the surviving firefighters regained consciousness and quickly evacuated the cabin through a right-side pop out window. Because the surviving firefighters were not immobilized by their injuries, they were able to evacuate the burning cabin before succumbing to the smoke and fire. Additionally, the right-side occupants had an increased chance of survival compared to the left-side occupants because the helicopter impacted the ground on its forward left side. The occupants seated on the left side sustained the brunt of the impact in addition to secondary impacts from occupants and cabin seats falling on top of them. While the firefighters and the copilot on the right side experienced similar impact forces, they did not strike the left-side wall of the fuselage and were not struck by seats and occupants.

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 CAR 7.420(b) to meet the emergency landing load limits in CAR 7.260, which differ substantially from the current emergency landing load limits in 14 CFR 29.561[125] as shown in table 12:

Table 12. Ultimate load requirements in CAR 7.260 versus 14 CFR 29.561.

Ultimate Loads				
Regulation	**Forward**	**Sideward**	**Upward**	**Downward**
CAR 7.260	4 G	2 G	1.5 G	4 G
14 CFR 29.561	16 G	8 G	4 G	20 G

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. 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,[126] 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 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.

[125] Title 14 CFR 29.561 replaced CAR 7.260 on December 3, 1964. At that time, the load requirements in the two regulations were similar. The load requirements were increased to their current level on March 13, 1996.

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

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 N612AZ 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.

2.6.2 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.[127] 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.

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

[127] 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.

14 CFR 29.561 (as shown in table 12). 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.

2.6.3 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.[128]

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

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

study[129] 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. [130] 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.

2.6.4 Leather Gloves Worn In Flight

The USFS required that all persons traveling in helicopters wear flame-resistant gloves.[131] The firefighters on board the accident helicopter were wearing firefighting leather gloves made of medium-weight leather, which are more rigid than the thin Nomex flight gloves that flight crewmembers wear during flight. Although the survivors reported that they did not remove their leather gloves during their numerous attempts to release their restraints, investigators found it significantly easier to release the rotary restraints with their bare hands than when wearing the same type of leather gloves worn by the survivors. The inflexibility of the

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[129] 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.

[130] 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.

[131] (a) Chapter 72, Exhibit 01, of the Forest Service Handbook 6709.11, states that gloves (flame-resistant fabric or leather, USFS–approved) are required personal protective equipment for rotorwing air travel. (b) *Health and Safety Code Handbook*, FSH 6709.11 (Washington, DC: U.S. Department of Agriculture, U.S. Forest Service, 1999), p. 70-13.

firefighters' occupational leather gloves made the operation and release of the restraints difficult and cumbersome. The NTSB concludes that the leather gloves worn by the firefighters decreased their dexterity, hampering the release of their restraints after the crash. Therefore, the NTSB recommends that the USFS review and revise policies regarding the type and use of gloves by firefighting personnel during transport operations, including, but not limited to, compatibility with passenger restraints and opening emergency exits.

2.6.5 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 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 occupants; however, because the seatbacks folded forward, the shoulder harness provided no safety improvement for the occupants 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[132] 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, because of the DER's failure to consider the entire seating system design, the shoulder harness installation actually increased the risk of injury to the occupant.

The NTSB concludes that the USFS contract requirement for Carson Helicopters to install shoulder harnesses on the passenger seats did not provide improved occupant protection because Carson Helicopters installed the shoulder harnesses on seats with non-locking folding seatbacks. Therefore, the NTSB recommends that the USFS review and revise its contract requirements for passenger transport by aircraft so that the requirement to install shoulder harnesses on passenger seats provides improved occupant crashworthiness protection consistent with the seat design.

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 DER (a handwritten report dated July 12, 2006, and a formalized document dated September 18, 2008)

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

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 (AC 21-34, "Shoulder Harness—Safety Belt Installations"), which recommended 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 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.[133] 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 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

[133] 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.

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.

2.7 Other Related Issues

2.7.1 Weather Observations at Helispots

No weather observations were available at H-44 other than a rudimentary wind indicator consisting of ribbons tied to several trees about 5 to 6 feet agl near the LZ. The CVR indicated that the pilots were told the wind was 3 to 5 kts out of the south before their third landing at H-44. However, as previously mentioned, meteorological analysis, supported by witness statements and photographs, determined that the wind was calm for the accident takeoff.

The CVR indicated that, as the helicopter approached H-44 for the last landing before the accident takeoff, the copilot stated that the OAT was 20° C. The CVR also indicated the pilots were referring to an OAT gauge reading of 20° C while discussing the helicopter's performance capability before the accident takeoff. However, the NTSB's approach and landing study calculated a temperature on the ground at H-44 of 22° C, which was within 1° of the 23° C temperature determined by meteorological analysis. Although more accurate wind and temperature readings taken at H-44 and available to the pilots immediately before the accident likely would not have changed the outcome, this accident highlights the importance of accurate recorded data—including weather data—in all aspects of high-altitude, heavy-helicopter operations. Although substantial safety margins are incorporated into performance calculations, this accident demonstrated that these safety margins may be significantly eroded by a variety of errors or omissions. For example, the calculated takeoff weight may be inaccurate because of math errors, an extra passenger that is boarded, or less-than-expected fuel burn. Another source of potential error is insufficient or inaccurate meteorological information, such as temperature, pressure altitude, and wind direction and speed. As highlighted in both this and previous investigations, small differences in temperature and wind values can have a significant effect on a helicopter's performance capability.[134] The hover study quantified the magnitude of the changes in the helicopter's HOGE capability with small changes in temperature and wind to be an 80-lb decrease in lifting capability for each 1° C increase in temperature and a 30-lb increase in lifting capability for each 1-kt increase in headwind.

Although it is unlikely that the availability of more accurate weather data would have prevented this accident, accurate information about all factors that affect the takeoff performance of a helicopter must be available if expected safety margins are to be maintained. The USFS already uses a standard manifest form that is routinely completed by helitack crewmembers for each flight. This form could be revised to provide a place to record basic weather information, and helitack crewmembers could be trained to obtain and record the information as part of their

[134] The May 30, 2002, helicopter accident on Mount Hood, Oregon, described earlier in this report illustrated that, when a helicopter is operated close to the power available/power required margin, extremely small atmospheric changes or pilot control inputs can become the determining factor in power required and maintaining HOGE capability.

preflight duties. Weather observations by a trained ground crew could provide independent, accurate, and recorded weather information.

Basic weather instrumentation capable of reading wind, temperature, and pressure is currently available at low cost, and helitack crewmembers could be taught during their annual training to use this instrumentation to obtain and disseminate weather information to flight crews. The NTSB concludes that making accurate basic weather information available to flight crews operating at remote helispots would increase flight safety. Therefore, the NTSB recommends that the USFS require that helispots have basic weather instrumentation that has the capability to measure wind speed and direction, temperature, and pressure and provide training to helitack personnel in the proper use of this instrumentation. Further, the NTSB recommends that the USFS modify its standard manifest form to provide a place to record basic weather information and require that this information be recorded for each flight.

2.7.2 Fuel Contamination

Although trace amounts of fiberglass and other contaminants were found in the PRVs of the accident helicopter's FCUs, 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 and the severe contamination found in other FCUs that did result in engine performance anomalies indicate 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 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.

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.[135] 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.

A review of the GE CT58-140 engine control system and its fuel supply system showed that many factors can affect the power output of the engine. Contamination within the engine fuel supply system is one potential factor. Depending on the size and material characteristics of the contamination, a malfunction with either the FCU or the pilot valve (a component of the

[135] Transportation Safety Board of Canada, Report Number A02P0320.

stator vane system) could result in a degradation of engine performance similar to that seen in the previously discussed discrepancy reports.

A review of SAFECOM and SDR reports identified several events in which an FCU was replaced as the corrective action for an engine discrepancy, but these reports do not track the component history or examination findings. While the reported events confirm that FCUs are typically replaced when a GE CT58-140 engine power discrepancy is reported, they do not provide any supportive information regarding the cause of the failure or malfunction that led to the event.

During examination of the FCUs removed from an SH-3H helicopter involved in a July 17, 2009, accident,[136] 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. 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 fuel filter elements on all S-61A/D/E/L/N/NM/R/V model helicopters. The bulletin states the following:

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

> 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.

2.7.3 Flight Recorder Systems

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, N_G, and T_5 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[137] 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. 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.[138] 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.

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

[138] NTSB/AAR-09/07.

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. Therefore, the NTSB reiterates Safety Recommendation A-06-18.

On February 9, 2009, the NTSB issued Safety Recommendation A-09-11, asking the FAA to require that all existing turbine-powered, nonexperimental, nonrestricted-category aircraft that are not equipped with an FDR and are operating under Parts 91, 121, or 135 be retrofitted with a crash-resistant flight recorder system. (For more information about this recommendation, see section 1.18.8.3.) This recommendation is currently classified "Open—Acceptable Response." As a turbine-powered, transport-category aircraft listed on CHSI's Part 135 operations specifications, the accident helicopter would be covered by this recommendation. The NTSB notes that the accident that prompted issuance of Safety Recommendation A-09-11 involved a midair collision between two helicopters.[139] This accident and the September 27, 2008, accident that prompted the reiteration of Safety Recommendation A-06-17 also involved helicopters. These accidents provide additional support for Safety Recommendation A-09-11 and demonstrate the need for flight recorders on helicopters as well as on airplanes.

The NTSB believes that the USFS should not wait for the FAA to require the installation of flight recorders but should take action now. Therefore, the NTSB recommends that the USFS require all contracted transport-category helicopters to be equipped with a CVR and an FDR or a cockpit image recorder with the capability of recording cockpit audio, crew communications, and aircraft parametric data.

2.7.4 Certification Issue with STC SR02327AK

After the accident, on December 5, 2008, 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

[139] NTSB/AAR-09-02.

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.

3. Conclusions

3.1 Findings

1. The flight crew was properly certificated and qualified in accordance with U.S. Forest Service contract requirements and Federal Aviation Administration regulations.
2. No evidence was found of any pre-impact airframe structural or system failure.
3. The emergency response and rescue of the injured firefighters and copilot were timely, and they were transported as quickly as possible given the constraints associated with, and limited access to, the accident site.
4. Because Carson Helicopters provided an incorrect empty weight to the pilot-in-command, he overestimated the helicopter's load carrying capability by 1,437 pounds.
5. The altered takeoff (5-minute) power available chart that was provided by Carson Helicopters eliminated a safety margin of 1,200 pounds of emergency reserve power that had been provided for in the load calculations.
6. The pilot-in-command followed a Carson Helicopters procedure, which was not approved by the helicopter's manufacturer or the U.S. Forest Service, and used above-minimum specification torque in the load calculations, which exacerbated the error already introduced by the incorrect empty weight and the altered takeoff power available chart, resulting in a further reduction of 800 pounds to the safety margin intended to be included in the load calculations.
7. The incorrect information—the empty weight and the power available chart—provided by Carson Helicopters and the company procedure of using above-minimum specification torque misled the pilots to believe that the helicopter had the performance capability to hover out of ground effect with the manifested payload when, in fact, it did not.
8. The efficiency of the engines' compressors was not compromised, and the stator vanes functioned normally throughout the accident flight.
9. The trace contaminants found within the fuel control units (FCU) did not affect their operation, and both FCUs functioned normally throughout the accident flight.
10. Both engines were operating normally throughout the accident flight.
11. The accident takeoff was unsuccessful because the helicopter was loaded with more weight than it could carry in a hover out of ground effect given the ambient conditions.
12. Safety would be improved if the hover-out-of-ground-effect capability indicated by performance charts represented all conditions for which the charts are applicable, including light and variable wind conditions.
13. The lower-than-actual empty weights recorded by Carson Helicopters on the Chart B weighing records for the accident helicopter and 8 of Carson's other 10 helicopters

created the appearance of higher payload capabilities; at their actual weights, the accident helicopter and 5 of the other helicopters would not have met the contractual payload specifications.

14. The U.S. Forest Service's oversight of Carson Helicopters was inadequate, and effective oversight would likely have identified that Carson Helicopters was using improper weight and performance charts for contract bidding and actual load calculations and required these contractual breaches to be corrected.
15. Although the U.S. Forest Service attempted to provide for safe operations by contractually requiring that the operator comply with 14 *Code of Federal Regulations* Part 135, these requirements without effective oversight were not adequate to ensure safe operations.
16. The U.S. Forest Service's inadequate training of the inspector pilot led to the inspector pilot's failure to correct the pilot-in-command's improper usage of above-minimum specification torque and contributed to the inspector pilot's failure to identify the helicopter's marginal performance on the first two takeoffs.
17. The Federal Aviation Administration's oversight of Carson Helicopter Services, Inc. (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 14 *Code of Federal Regulations* Part 135 operations specifications.
18. The pilots likely recognized that the helicopter was approaching its maximum performance capability on the two prior departures from Helispot 44 but elected to proceed with the takeoffs because they were accustomed to performing missions where operating at the limit of the helicopter's performance was acceptable.
19. The performance of a HOGE power check before takeoff from helispots located in confined areas, pinnacles, or ridgelines would increase flight safety.
20. Without an immediate fire, additional occupants on board the helicopter would likely have survived the accident.
21. 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.
22. 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.
23. If the accident helicopter had been equipped with seat installations that met the load limit requirements of 14 *Code of Federal Regulations* (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.

24. The surviving firefighters were unable to release the rotary restraints under emergency conditions because they were unfamiliar with the rotary-release mechanism.
25. The leather gloves worn by the firefighters decreased their dexterity, hampering the release of their restraints after the crash.
26. The U.S. Forest Service contract requirement for Carson Helicopters to install shoulder harnesses on the passenger seats did not provide improved occupant protection from injury because Carson Helicopters installed the shoulder harnesses on seats with non-locking folding seatbacks.
27. The designated engineering representative's failure to follow Federal Aviation Administration guidance materials resulted in his approval of a shoulder harness installation that did not did not improve occupant protection, and in fact, increased the risk of injury to the occupant.
28. The Federal Aviation Administration 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.
29. Making accurate basic weather information available to flight crews operating at remote helispots would increase flight safety.
30. The 10-micron airframe fuel filters will reduce the risk of sticking or seizure of a pressure regulating valve or pilot valve, which could result in the degradation of engine performance during a critical phase of flight.
31. An operating flight data recorder would have provided detailed information about the accident scenario and thus would have aided the National Transportation Safety Board in determining the circumstances that led to this accident.
32. The Carson Helicopters, Inc., supplemental type certificate 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 Civil Aviation Regulations 7.260 requirements.
33. The Federal Aviation Administration missed an opportunity to require crashworthy improvements in an older transport-category rotorcraft when it issued a supplemental type certificate to Carson Helicopters, Inc., for installing side-mounted seats without requiring incorporation of any requirements beyond the certification level of the original seats (Civil Aviation Regulations 7.260).

3.2 Probable Cause

The National Transportation Safety Board determines 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 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 U.S. Forest Service and the Federal Aviation Administration.

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.

4. Recommendations

4.1 New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following safety recommendations to 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)

> 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)

As a result of this investigation, the National Transportation Safety Board makes the following safety recommendations to the U.S. Forest Service:

> Develop mission-specific operating standards for firefighter transport operations that include procedures for completing load calculations and verifying that actual aircraft performance matches predicted performance, require adherence to aircraft operating limitations, and detail the specific Part 135 regulations that are to be complied with by its contractors. (A-10-159)

> Require its contractors to conduct firefighter transport operations in accordance with the mission-specific operating standards specified in Safety Recommendation A-10-159. (A-10-160)

> Create an oversight program that can reliably monitor and ensure that contractors comply with the mission-specific operating requirements specified in Safety Recommendation A-10-159. (A-10-161)

> Provide specific training to inspector pilots on performance calculations and operating procedures for the types of aircraft in which they give evaluations. (A-10-162)

> Require a hover-out-of-ground effect power check to be performed before every takeoff carrying passengers from helispots in confined areas, pinnacles and ridgelines. (A-10-163)

> Review and revise policies regarding the type and use of gloves by firefighting personnel during transport operations, including but not limited to, compatibility with passenger restraints and opening emergency exits. (A-10-164)

> Review and revise your contract requirements for passenger transport by aircraft so that the requirement to install shoulder harnesses on passenger seats provides

improved occupant crashworthiness protection consistent with the seat design. (A-10-165)

Require that helispots have basic weather instrumentation that has the capability to measure wind speed and direction, temperature, and pressure and provide training to helitack personnel in the proper use of this instrumentation. (A-10-166)

Modify your standard manifest form to provide a place to record basic weather information and require that this information be recorded for each flight. (A-10-167)

Require all contracted transport-category helicopters to be equipped with a cockpit voice recorder and a flight data recorder or a cockpit image recorder with the capability of recording cockpit audio, crew communications, and aircraft parametric data. (A-10-168)

4.2 Previously Issued Recommendation Reiterated in this Report

The National Transportation Safety Board reiterates the following safety 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)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Adopted: December 7, 2010

5. Appendixes

Appendix A: Investigation and Public Hearing

Investigation

The National Transportation Safety Board (NTSB) was notified about the accident on the morning of August 6, 2008. NTSB investigators arrived on-scene on August 7. Former Board member Kitty Higgins accompanied the investigative team.

Parties to the investigation were the Federal Aviation Administration, U.S. Forest Service, Carson Helicopters, Inc./Carson Helicopter Services, Inc., General Electric, Sikorsky Aircraft Corporation, and BAE Systems.

Public Hearing

No public hearing was held for this accident.