Aircraft Accident Report
Crash During Takeoff of Carson Helicopters, Inc. Firefighting Helicopter Under Contract to the U.S. Forest Service
Sikorsky S-61N, N612AZ
Near Weaverville, California
August 5, 2008

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

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

The safety issues discussed in this report involve the accuracy of hover performance charts, USFS and Federal Aviation Administration (FAA) oversight, flight crew performance, accident survivability, weather observations at helispots, fuel contamination, flight recorder requirements, and certification of seat supplemental type certificates. Safety recommendations concerning these issues are addressed to the FAA and the USFS.

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Abbreviations and Acronyms

AC	advisory circular
ACO	aircraft certification office
agl	above ground level
C_P	power coefficient
C_T	thrust coefficient
CAR	Civil Air Regulations
CFR	*Code of Federal Regulations*
CHC	Canadian Helicopter Corporation
CHI	Carson Helicopters, Inc.
CHSI	Carson Helicopter Services, Inc.
CMRB	composite main rotor blade
CO	contracting officer
CRM	crew resource management
CVR	cockpit voice recorder
CWN	call when needed
DA	density altitude
DER	designated engineering representative
DO	director of operations
DoD	Department of Defense
DOI	Department of Interior
DOM	director of maintenance
EU	exclusive use

EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FCU	fuel control unit
FDR	flight data recorder
FSDO	flight standards district office
G	ratio of the force imposed by an object divided by the object's weight
GE	General Electric
H-36	Helispot 36
H-44	Helispot 44
HEMS	helicopter emergency medical services
HIGE	hover in ground effect
HOGE	hover out of ground effect
IA	initial attack
IHOG	Interagency Helicopter Operations Guide
kts	knots
lbs	pounds
LFS	large fire support
LZ	landing zone
MAP	mandatory availability period
min spec	minimum specification
msl	mean sea level
nm	nautical mile

NTSB	National Transportation Safety Board
N_G	gas generator speed
N_R	main rotor speed
NWS	National Weather Service
OAT	outside air temperature
OEI	one engine inoperative
OGE	out of ground effect
P/N	part number
PA	pressure altitude
PIC	pilot-in-command
PMA	parts manufacturer approval
PMI	principal maintenance inspector
POI	principal operations inspector
PRV	pressure regulating valve
PTRS	program tracking and reporting subsystem
Q	torque
RAWS	remote automatic weather station
RFM	rotorcraft flight manual
RFMS	rotorcraft flight manual supplement
SAFECOM	Aviation Safety Communiqué
SDR	service difficulty report
SHP	shaft horsepower

STC	supplemental type certificate
SVA	stator vane actuator
T_2	engine inlet air temperature
T_5	power turbine inlet temperature
U.S.C.	*United States Code*
USDA/USDI	U.S. Department of Agriculture/U.S. Department of the Interior
USFS	U.S. Forest Service
VFR	visual flight rules

Executive Summary

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

The National Transportation Safety Board 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 USFS and the Federal Aviation Administration (FAA).

Contributing to the accident was the failure of the flight crewmembers to address the fact that the helicopter had approached its maximum performance capability on their two prior departures from the accident site because they were accustomed to operating at the limit of the helicopter's performance.

Contributing to the fatalities were the immediate, intense fire that resulted from the spillage of fuel upon impact from the fuel tanks that were not crash resistant, the separation from the floor of the cabin seats that were not crash resistant, and the use of an inappropriate release mechanism on the cabin seat restraints.

The safety issues discussed in this report involve the accuracy of hover performance charts, USFS and FAA oversight, flight crew performance, accident survivability, weather observations at helispots, fuel contamination, flight recorder requirements, and certification of seat supplemental type certificates. Safety recommendations concerning these issues are addressed to the FAA and the USFS.

1. The Accident

1.1 History of the Flight

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

The helicopter was stationed at Trinity Helibase,[4] located about 7 miles northeast of Weaverville. According to the copilot,[5] following the morning briefing about 0830, the PIC completed the USFS-required performance load calculation forms using an array of predicted altitudes and temperatures, including the least favorable conditions expected to be encountered that day. The PIC performed the load calculations using the performance charts and the helicopter's empty weight provided by CHSI. All calculations were done using a fuel weight of 2,400 pounds (lbs) and a flight crew weight of 440 lbs, which the PIC derived by adding his weight to the copilot's weight. Thereafter, the pilots were unoccupied for most of the morning, although they heard rumors of a possible demand for water-dropping and hand crew[6] repositioning missions. The pilots were expecting a USFS inspector pilot to arrive later that day to give the PIC a flight evaluation in the S-61 for an additional mission qualification.[7]

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[1] All times in this report are Pacific daylight time unless otherwise noted.

[2] According to the U.S. Forest Service, a helispot is a natural or improved takeoff and landing area intended for temporary or occasional helicopter use.

[3] CHI and CHSI are separate legal entities and at the time of the accident, each company held its own Federal Aviation Administration (FAA)-issued operating certificates. However, both companies have the same president and share facilities in Grants Pass. In this report, the term Carson Helicopters is used to refer to both companies, and the acronyms CHI and CHSI are used if it is necessary to specify the legal entity. For more information about these companies, see section 1.17.1.

[4] According to the USFS, a helibase is a designated, permanent facility for helicopter operations.

[5] Unless otherwise noted, the information in this section was obtained from a September 16, 2008, postaccident interview with the copilot.

[6] A hand crew is a team of about 20 individuals that have been organized and trained and are supervised principally for operational assignments on a fire, typically using hand tools.

[7] The evaluation was for the addition of "fire suppression (helicopter attack)" to the list of mission types the PIC was qualified to perform for the USFS. For more information about the PIC's qualifications, see section 1.5.1.

In the late morning, the pilots participated with the Trinity helitack crew[8] in rappel training with a mock-up system on the accident helicopter. About 1320, the helicopter departed on a water-dropping mission with the copilot, who had previously been to the destination, acting as the pilot flying. The mission lasted for an entire fuel cycle, with the helicopter not returning to the helibase until the fuel was low, which comprised a fairly routine mission. About 1515, the helicopter landed at the helibase and was then refueled. The PIC and copilot ate lunch and discussed the PIC's upcoming flight evaluation.

About 1615, the USFS inspector pilot arrived at the helibase. After discussing the possibility of a hand crew repositioning mission later that day, the three pilots decided that, even if a mission was not assigned, they would still make a flight so that the PIC could complete his flight evaluation. The inspector pilot then gave the PIC an oral examination, querying him regarding operation of the S-61 and emphasizing the performance load calculations, which enable a pilot to determine the performance of the helicopter at specified combinations of pressure altitude (PA) and temperature.

About 1630, the helibase manager informed the pilots and the helitack crew of a request for a hand crew repositioning mission. Based on a forecast of lightning for the high mountainous areas that night, USFS management had decided to transport two hand crews from H-44, which has an elevation of 5,980 feet, to Helispot 36 (H-36), which has an elevation of 1,531 feet (see figure 1). The hand crews were conducting ground-based firefighting operations to suppress the Buckhorn fire, one of the fires in the Iron Complex fire system.[9] H-44 was located on the northern boundary of the Buckhorn fire near an actively burning area of timber. Neither the pilots nor the helitack crew had previously been to H-44.

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[8] Helitack (helicopter attack) is the use of helicopters to transport crews, equipment, and fire retardants or suppressants to the fire line during the initial stages of a fire. The term also refers to a fire crew trained to use helicopters for initial attack and to support the suppression of large fires through bucket drops and the movement of personnel, equipment, and supplies.

[9] A "complex" fire is two or more fires in the same area assigned to a single commander or unified command. The Iron Complex fire began on June 21, 2008, as a result of lightning and, at the time of the accident, covered about 100,000 acres in the Shasta-Trinity National Forest.

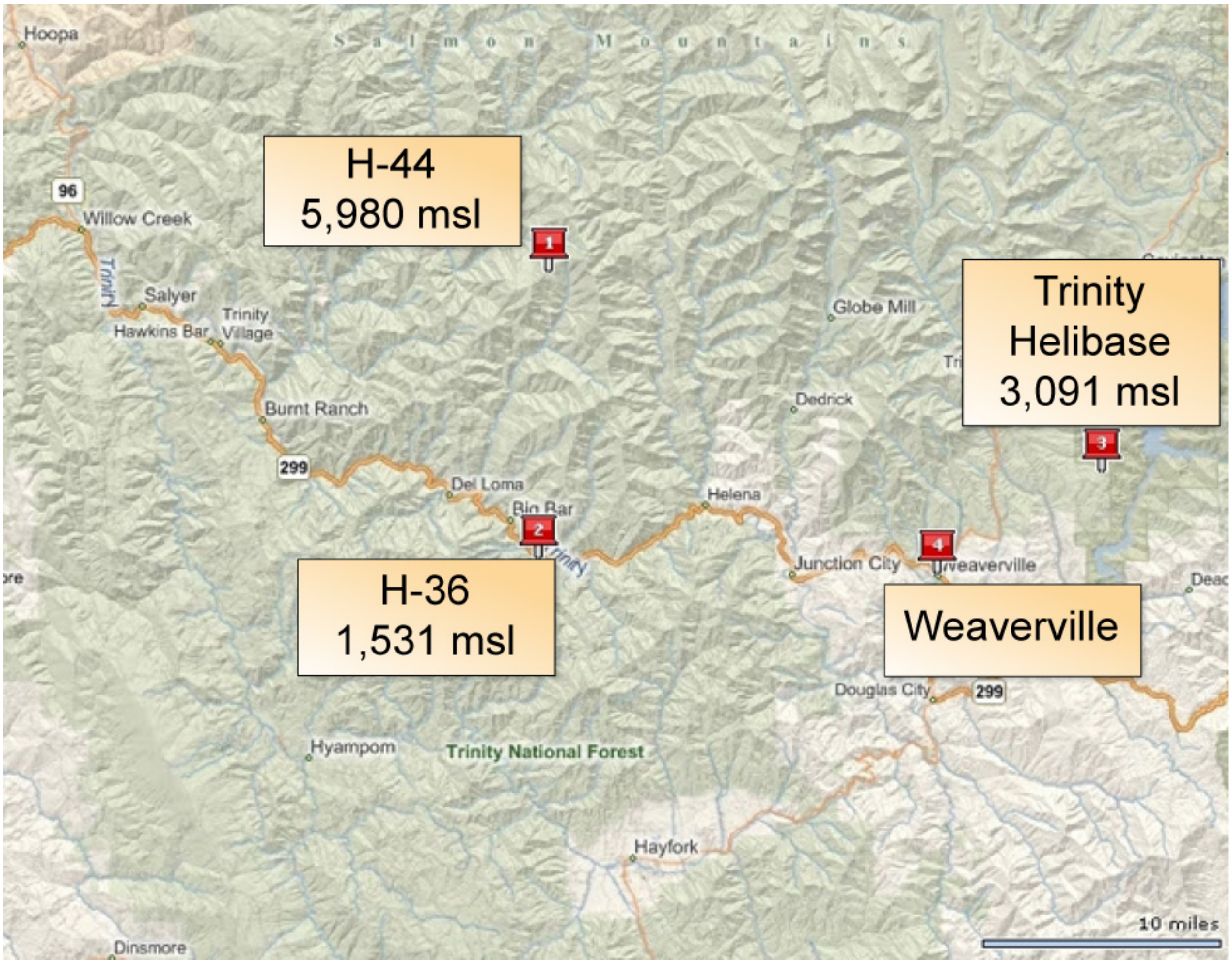

Figure 1. Map showing locations of H-44, H-36, and Trinity Helibase.

The first segments of the mission were intended to position four Trinity helitack crewmembers at H-36 and the remaining five crewmembers at H-44, staging them to assist in transporting the hand crews from H-44. Five loads of 10 persons each were to be transported from H-44 to H-36. The helitack crewmembers, the pilots, and the inspector pilot all agreed on the mission plan. Before departure, the inspector pilot reviewed the PIC's load calculations. Of the four load calculations that the PIC completed earlier that day, the 6,000 foot PA at 32° C condition, which was the most similar to the conditions expected at H-44, gave an allowable payload[10] of 2,552 lbs.

About 1707, the helicopter departed with nine Trinity helitack crewmembers on board and the PIC acting as the pilot flying. The inspector pilot was conducting the PIC's flight evaluation while the mission was being executed and was also acting as the required safety crewmember.[11] The flight proceeded to H-44, and, upon arriving in the vicinity, the pilots

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[10] The allowable payload represents the amount of weight available for passengers and/or cargo.

[11] The USFS requires a safety crewmember on each passenger-carrying flight in a heavy (Type I) helicopter. The safety crewmember is usually a helitack crewmember, although any USFS-carded helicopter pilot is qualified

performed several orbits about 300 feet above ground level (agl) as their high reconnaissance of the H-44 landing zone (LZ) and surrounding area. During the orbits, the pilots discussed the approach, termination, and safety considerations for H-44, including the altitude, temperature, and wind. They agreed that all parameters fell within the bounds of the previously computed load calculations and, therefore, that the mission could be conducted safely. They did not land but continued to H-36, where four helitack crewmembers were to be staged. While en route, the pilots overflew H-36 by several miles because of confusion about the coordinates. After resolving the location issue, the pilots performed a high reconnaissance of the H-36 LZ.

Subsequently, the pilots conducted a low reconnaissance of H-36 and, about 1742, performed a power check just before landing. According to the cockpit voice recorder (CVR) transcript,[12] the copilot stated, “Power check–32 degrees there’s three knots [kts] showin’ eighty–okay power’s good.”[13] Following an uneventful landing, four helitack crewmembers disembarked to prepare for the firefighter transport mission. About 1751, the helicopter departed and returned to H-44. While en route, the PIC and the copilot discussed the helicopter’s fuel load with respect to the mission. Having completed numerous orbits for reconnaissance, combined with the indirect route to H-36, the helicopter had burned more fuel than the pilots anticipated. The pilots estimated that the helicopter had about 50 minutes of fuel remaining and calculated that, with the five loads of firefighters remaining, they might not be able to safely complete all of the trips with the current fuel load. The pilots also discussed the upcoming landing at H-44, and the copilot asked the PIC if the helicopter would be capable of hovering at H-44. The PIC responded that the helicopter had the performance capability to hover.

After arriving in the vicinity of H-44, the pilots performed a high reconnaissance and again confirmed that they would touch down in the area that the helitack crewmembers had staged for landing. Upon the first landing attempt, the helicopter encountered a brownout[14] near the LZ. The helicopter approached closer to the ground, and the dust became so severe that a helitack crewmember on the ground at H-44 requested that the pilots abort the landing. With the helicopter’s wheels lightly touching the ground, the PIC executed a go-around maneuver. Other smaller helicopters were called in to perform water drops on the LZ as a dust abatement procedure. On the second landing attempt, the PIC landed at a location about 100 feet south of the original spot on a comparatively dust-free rock outcrop.

The remaining 5 helitack crewmembers exited the helicopter and helped board the first load of 10 firefighters. Two helitack crewmembers that had been flown into H-44 about 1 hour earlier by a different helicopter had completed the passenger briefings and five load manifests, which accounted for the ground personnel at H-44 who needed transport to H-36. None of the manifests included the inspector pilot/safety crewmember, as he was already on board the helicopter. The helitack crewmembers and the pilots discussed the firefighter loads and

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for the position. The safety crewmember sits in the passenger cabin and performs duties such as assisting the passengers with fastening their restraints, relaying messages from the pilot to the passengers, and operating doors.

[12] The CVR recording began when the helicopter was inbound to H-36.

[13] According to the copilot, he was stating that the outside air temperature was 32° C, the airspeed was 3 kts, and the engine torques were 80 percent.

[14] Brownout conditions connote in-flight visibility restrictions due to dust or sand in the air generated by the helicopter’s own rotor downwash.

upcoming required shut-down time[15] of about 2053. According to the CVR transcript, while on the ground at H-44, the copilot asked the PIC if the helicopter would have "enough power" to depart vertically out of the LZ. The PIC responded, "Absolutely, yes."

About 1814, the helicopter departed. Fifty-foot trees were directly ahead of the LZ. According to ground witnesses, the departure path started vertically, then veered to the right and continued forward toward a natural depression in the trees. The CVR transcript indicated that, during the initial departure, the copilot announced, "seventy five percent torque," referring to the engine torque gauge indication, followed by, "everything looks good." As the takeoff continued, the copilot announced, "eight seven," again referring to the engine torque gauge, and then "one hundred and two percent power's good," referring to the main rotor speed (N_R). According to the sound spectrum analysis of the CVR recordings, the engines reached topping[16] about 30 seconds after the power began to increase and remained at topping for about 14 seconds, with the gas generator speeds (N_G) steady at 102 percent and 101.4 percent on the individual engines. As the N_Gs increased and topped out, the N_R gradually decayed, or "drooped," over about 51 seconds from 108.6 to 101.5 percent.[17] N_R then began to increase and stabilized about 103.2 percent. Within 2 seconds of the increase in N_R, both N_Gs decreased below their topping speeds. The CVR did not record any discussion by the pilots regarding the fact that the engines had reached topping.

One of the firefighters on board the helicopter during the departure from H-44 reported that "the helicopter felt heavy, slow and sluggish" and that his eye level was "approximately five to eight feet below the treetops for quite a while." Another firefighter on board reported that, as the helicopter lifted off, "it seemed very slow" and "took a little bit to get up above the tree line."

The pilots continued to H-36, performed a reconnaissance, and landed. The helitack crewmembers escorted the firefighters away from the helicopter and unloaded their equipment. About 1829, the helicopter departed, and, during the takeoff, the copilot did not announce engine torque. While en route to H-44, the PIC and copilot discussed the diminishing fuel supply again. They calculated that the required shut-down time would be approaching in about 2 hours 20 minutes and agreed that they would have to get more fuel amid the remaining trips between H-44 and H-36. According to the CVR transcript, as the flight approached H-44 for the second pickup, the pilots were told by ground personnel at H-44 that the wind was "real light out of the south" and that the weight of their next load was 2,405 lbs. The copilot commented that this weight was "well below" their previously determined payload capability.

After landing at H-44, 10 firefighters boarded, and the helicopter departed about 1843. The CVR transcript indicated that, during the departure, the copilot stated, "power's good showing one oh three[18]–ninety percent torque." The sound spectrum analysis of the CVR

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[15] The USFS does not permit flights below 1,000 feet agl during the period of darkness, which is defined as the period falling between 30 minutes after official sunset and 30 minutes before official sunrise. On the day of the accident, sunset was about 2023, equating to a required shut-down time of about 2053.

[16] "Topping" refers to operating at the maximum gas generator speed limit, corresponding to the maximum power output of the engines. For more information about topping, see section 1.6.2.1.

[17] According to the copilot, the typical N_R for beginning a takeoff was 106 percent, and it was not uncommon for N_R to droop to 105 or 104 percent during takeoff.

[18] According to the copilot, he was referring to an N_R of 103 percent.

recordings indicated that the engines reached topping about 16 seconds after the power was applied and remained at topping for about 18 seconds, with N_Gs steady at 101.9 percent and 101.4 percent on the individual engines. As the N_Gs increased and topped out, N_R gradually drooped from 108.7 to 101.4 percent over about 39 seconds. N_R then began to increase and stabilized briefly about 103.1 percent before continuing to increase. Within 2 seconds of the increase in N_R, both N_Gs decreased below their topping speeds as they did on the first takeoff from H-44. Again, the CVR did not record any discussion by the pilots regarding the fact that the engines had reached topping.

The flight to H-36 was uneventful. While on the ground at H-36, the pilots decided to refuel at Trinity Helibase before transporting the remaining three loads of firefighters. About 1854, the helicopter departed, and, during the takeoff, the copilot did not announce engine torque. While en route to the helibase, the PIC and copilot discussed the quantity of fuel that should be added. The copilot remarked that, if they refueled the forward and aft tanks to the top, the helicopter would then have 2,500 lbs of fuel. He further remarked that, with that fuel load, the helicopter’s allowable payload would be 2,552 lbs, which was more than the 2,400 lbs that the helitack crewmembers had been loading that day. He estimated that, after refueling, the helicopter would burn about 400 lbs en route to H-44, which would give them an additional margin.

Upon landing at the helibase about 1905, the pilots shut down the helicopter, and the fuel truck driver began refueling while two mechanics performed a routine visual inspection. While the helicopter was being refueled, the inspector pilot informed the PIC that he had passed the flight evaluation. Additionally, the inspector pilot spoke with the pilots about staying on board the helicopter and continuing to act as the required safety crewmember to aid in the timely completion of the mission before dark. Doing so would eliminate the need to locate a helitack crewmember to act as safety crewmember and the time to brief that person on the mission. They agreed that the inspector pilot would remain on the helicopter as the safety crewmember.

Both mechanics reported that, during their inspection, they noted a layer of ash on the leading edges of the main rotor blades and around the engine inlets. One mechanic stated that both engine intakes were covered in ash, but the compressors’ first stage stators were clean. He further stated that the amount of ash on the blades was more than he had seen previously during this particular fire but was equivalent to what he had seen when the helicopter was working on other fires. He began wiping the blades with a rag, which easily removed the ash, leaving the wiped area of the blades free of debris. The mechanic stated that, while he was wiping the blades, he asked the PIC how the helicopter was running, and the PIC replied that it was operating well.

The other mechanic reported that he had asked the copilot if any problems existed with the helicopter, and the copilot replied, “she is flying great.” The mechanic stated that, as he began to wipe the ash from the engine inlets, the PIC asked the two mechanics to finish their work so that the helicopter could depart since the required shut-down time was nearing. They stopped wiping the ash off the blades and inlets and finished preparing the helicopter for flight.

About 1923, the helicopter departed for H-44, and, during takeoff, the copilot did not announce engine torque. According to the CVR transcript, at 1930:33, the pilots were told by ground personnel at H-44 that the wind was “the same out of the south about three to five,” and the pilots agreed that the LZ and approach would be the same as before. During the approach, the copilot told the PIC that the outside air temperature (OAT) gauge was reading 20° C, and the PIC replied, “so it’s gotten cooler.” The copilot stated that the helicopter would have “quite a bit of performance with the drop in temperature.” About 1936, the helicopter landed, and a helitack crewmember asked the pilots if he should get another helicopter to aid in the transportation, as dark was nearing. The copilot responded that they should be able to complete the mission. The helitack crewmember then informed the pilots that the manifested weight of the firefighters and cargo being boarded was 2,355 lbs.

After the pilots were notified of the manifested weight, the copilot stated that the performance load calculation indicated a maximum payload of 2,552 lbs at 32° C. He added that the temperature was 12 to 13 degrees cooler and their payload 200 lbs less than calculated. Both pilots restated that they were indeed 200 lbs lighter than the previously calculated maximum payload,[19] and the copilot confirmed that the helicopter was “good to go.”

At 1940:46, the PIC began to increase the power for takeoff. At 1940:47, the copilot stated, “okay, just nice and smooth here.” At 1941:03, he stated, “okay there’s seventy five–there’s eighty,” and then, at 1941:06, “there’s eighty five,” all of which were engine torque readings. About 4 seconds later, he stated, “there’s ninety showin’ ah hundred and three percent,” referring to an engine torque reading of 90 percent and an N_R reading of 103 percent. About 9 seconds later, he informed the PIC that N_R had decreased to 100 percent and was drooping. The CVR recording ended 20 seconds later at 1941:39.

Sound spectrum analysis of the CVR recording indicated that the engines reached topping 22 seconds after power was applied and remained at topping until the end of the recording, with N_Gs steady at 102.1 percent and 101.5 percent on the individual engines. Between 1940:46 and 1941:31, the N_R drooped from 106.9 to 95.0 percent and remained there for about 3 seconds. At 1941:34, about 5 seconds before the end of the recording, the N_R started to droop again, reaching a final value of 93.5 percent.

Ground witnesses stated that, as the helicopter began to lift off, the rate of climb appeared very slow, and the helicopter’s movement was labored. One witness stated that the takeoff was at “extremely slow speed and low altitude,” while another witness stated that the helicopter was “moving extremely slow, inconsistent with the last two departures.” The witnesses reported that the helicopter began to move forward in a nose-low configuration and drift sideways to the right. The helicopter continued to move forward and then began losing altitude as it continued down slope. One witness described the takeoff as follows:

> After a vertical ascension of about 20 feet, the helicopter began to move forward and about 40 feet to the right. As the helicopter continued forward toward a section of lower trees, the belly of the fuselage contacted trees; it appeared as though the helicopter would fit between trees, though the main rotor blades were

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[19] The payload was actually 13 lbs heavier than the previously calculated maximum payload. The manifested weight of 2,355 lbs plus the inspector pilot’s weight of 210 lbs equaled 2,565 lbs.

> not high enough to clear the trees. Debris began to fly from the surrounding trees and the helicopter settled into the vegetation.

The helicopter collided with the trees and subsequently impacted the down sloping terrain, coming to rest on its left side. (See figure 2 for an aerial view of H-44 and N612AZ's departure path.) Almost immediately after the impact, witnesses saw smoke and fire coming from the wreckage. One witness reported that both engines continued to run for about 30 seconds after the helicopter impacted the ground.

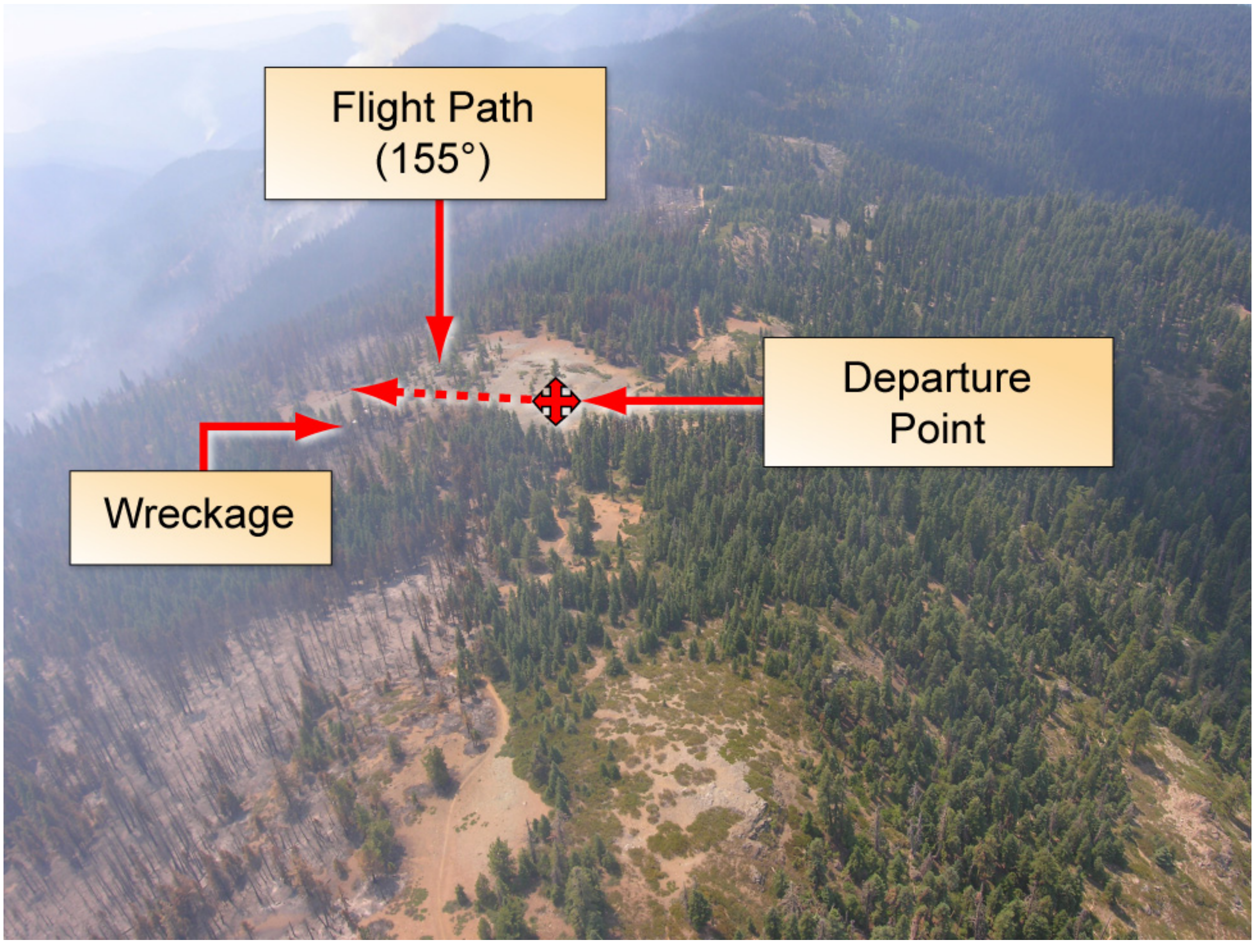

Figure 2. Aerial photograph of H-44. Red dashed arrow shows approximate departure path of helicopter.

1.2 Injuries to Persons

Table 1. Injury chart.

Injuries	Flight Crew	Other Crew	Firefighters	Other	Total
Fatal	1	1	7	0	9
Serious	1	0	3	0	4
Minor	0	0	0	0	0
None	0	0	0	0	0
Total	2	1	10	0	13

1.3 Damage to Aircraft

The helicopter was destroyed by impact forces and the postcrash fire.

1.4 Other Damage

Trees along the wreckage path were damaged by impact forces and the postcrash fire.

1.5 Personnel Information

1.5.1 The Pilot-in-Command

The PIC, age 54, held an airline transport pilot certificate with a rotorcraft-helicopter rating and type ratings for BV-234 and SK-76 helicopters. Additionally, he held type ratings for BV-107 and SK-61 helicopters at the commercial level.[20] The SK-61 rating was issued on June 21, 1993. The PIC's most recent second-class medical certificate was issued on March 20, 2008, with no limitations.

According to CHSI, the PIC had a total flight time of 20,286 hours, 8,166 of which were accumulated in S-61 helicopters. He held a U.S. Department of Agriculture/U.S. Department of Interior (USDA/USDI) Interagency Helicopter Pilot Qualification card,[21] which had an expiration date of May 31, 2009. The card indicated that the PIC was approved for five types of missions (mountain flying, external load [sling], retardant/water-dropping, long-line vertical reference, and snorkel), all of which were permitted in S-61 helicopters. During the flight legs

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[20] BV-234, BV-107, SK-76, and SK-61 are helicopter type designations used by the Federal Aviation Administration on pilot certificates for Boeing Vertol 234, Boeing Vertol 107, Sikorsky S-76 series, and Sikorsky S-61 series helicopters, respectively.

[21] Pilots are required by the USFS to have a current interagency card showing qualifications for the mission to be performed; each qualification card has an annual expiration date. The card qualifications are the primary criteria used to select a pilot for a given mission.

before the accident, the PIC underwent a flight evaluation for the addition of the mission fire suppression (helitack) to his USDA/USDI card, which would qualify him to transport firefighting personnel to and from the fire line.

The PIC received his initial flight training in the U.S. Army from 1974 to 1978. After his discharge, he began employment as a pilot with Columbia Helicopters, Inc., Aurora, Oregon, where he worked for 14 years performing logging, firefighting, passenger-transport, and precision long-line operations. From 1993 to 1994, he performed logging operations at Rocky Mountain Helicopters, Provo, Utah, where he received his type rating in the S-61. The pilot began working for CHI in December 1994 and did not fly outside of work.

The PIC's most recent annual flight evaluation for PIC in the S-61 was conducted on June 23, 2008, by the CHSI chief pilot. The PIC satisfactorily completed the evaluation, which encompassed demonstration of current knowledge and competency (14 *Code of Federal Regulations* [CFR] 135.293), as well as demonstration of operational procedures (14 CFR 135.299).

The PIC's previous duty rotation ended on July 6, 2008, equating to a 25-day break until the beginning of his duty period on August 2. According to CHSI records, during the preceding 90 and 30 days, the PIC had flown approximately 25 and 15 hours, respectively. During the 4 days before the accident, the pilot was on duty for 14, 14, 12, and 12 hours, respectively. During that time, he flew 4 hours on August 2 and did not fly again until the morning of the accident.

1.5.2 The Copilot

The copilot, age 44, held a commercial pilot certificate with rotorcraft-helicopter and instrument helicopter ratings; he received his SK-61 type rating on May 10, 2005. His most recent second-class medical certificate was issued on May 12, 2008, with no limitations.

The copilot reported that he had a total flight time of about 3,000 hours, 1,100 of which were accumulated in S-61 helicopters. He held a USDA/USDI Interagency Helicopter Pilot Qualification card, which had an expiration date of July 31, 2009. The card indicated that he was approved for seven types of missions (mountain flying, external load [sling], retardant/water-dropping, long-line vertical reference, fire suppression [helitack], reconnaissance and surveillance, and snorkel), all of which were permitted in S-61 helicopters.

The copilot received his initial flight training in the U.S. Army from 1991 to 1995. He subsequently served in the U.S. Army National Guard until 2007 as a pilot flying UH-60, UH-1H, and OH-58 helicopters. The copilot was hired by CHI in May 2002 and had no prior experience in the S-61. He worked at CHI for 4 years performing logging, firefighting, and passenger-transport operations. From August 2006 to October 2006, he was employed at Arctic Air Service, Astoria, Oregon, where he conducted offshore Part 135 passenger-transport operations. He returned to CHI in October 2006.

The copilot's most recent annual flight evaluation for the position of second-in-command in the S-61 was conducted on November 29, 2007, by the Federal Aviation Administration

(FAA) principal operations inspector (POI) for CHSI. He satisfactorily completed the evaluation, which included demonstration of current knowledge and competency as well as demonstration of operational procedures.

The copilot's previous duty rotation ended on July 23, 2008, equating to a 6-day break until the beginning of his duty period on July 30. According to CHSI records, during the preceding 90 and 30 days, the copilot had flown approximately 65 and 25 hours, respectively. During the 5 days before the accident, the copilot was on duty for 14, 14, 14, 12, and 12 hours, respectively. During that time, he flew 2 hours on July 31, 4 hours on August 2, and did not fly again until the morning of the accident.

1.5.3 The Inspector Pilot

The inspector pilot, age 63, held a commercial pilot certificate with rotorcraft-helicopter and airplane single- and multi-engine land ratings. Additionally, he held a flight instructor certificate with a helicopter rating. The inspector pilot held no type ratings. His most recent second-class medical certificate was issued on November 14, 2007, with the limitations that he must wear corrective lenses and possess glasses for near and intermediate vision.

The inspector pilot was initially approved as an interagency inspector pilot on October 12, 2005. His most recent evaluation was on April 23, 2008, and included emergency procedures, night operations, and global positioning system familiarization. On the inspector pilot's last application for a medical certificate, he indicated that his total aeronautical experience consisted of about 12,100 hours, 11,537 of which were accumulated in turbine helicopters. The inspector pilot had given evaluations in the S-61 and provided three CHSI pilots with their USDA/USDI cards in the 2 months before the accident. The inspector pilot had never flown as PIC in an S-61.

1.6 Aircraft Information

The Sikorsky S-61N helicopter is a transport-category, dual-engine helicopter that requires two pilots by type certification.[22] The accident helicopter was manufactured in 1965 and was originally equipped with metal main rotor blades, which were replaced in 2007 with composite main rotor blades manufactured by CHI. As shown in figure 3, the helicopter was equipped with a Fire King 900-gallon aerial liquid dispensing tank.[23]

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[22] A type certificate is the FAA's approval of the design of a specific aircraft, engine, or component. The type certificate data sheet lists limitations and information required for type certification, including airspeed limits, weight limits, and minimum crew.

[23] For further information about the composite main rotor blades and the tank, see section 1.6.3.

Figure 3. Photograph of accident helicopter.

The accident helicopter was owned by CHI, which purchased it from Canadian Helicopter Corporation (CHC) on June 20, 2007, and leased it to CHSI. The helicopter was flown to the CHI facilities in Perkasie, Pennsylvania, on July 10, 2007, where it underwent maintenance and reconfiguration. According to CHI personnel, the reconfiguration involved changes to the landing gear, seats, cargo hook, interior, and removal of overwater equipment.[24] For several months thereafter, the helicopter was used to perform flight testing for a Goodrich rescue hoist installation and was granted an experimental special airworthiness certificate from December 20 to 27, 2007, for this purpose.

On December 31, 2007, the helicopter was equipped with a SkyConnect Tracker automated flight following system, an aircraft tracking system consisting of a transceiver and an antenna that transmitted the helicopter's position, speed, and direction to a satellite network about every 2 minutes.

Following various other missions, the helicopter returned to the CHI Perkasie facilities on June 18, 2008, where it underwent routine maintenance and reconfiguration, including the installation of additional passenger seats as required by the USFS contract. USFS personnel

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[24] No documentation of these changes was found in the helicopter's maintenance records.

inspected the helicopter in Perkasie on June 26, 2008,[25] and approved it to proceed to its assigned location of Trinity Helibase. The helicopter departed Perkasie on June 28, 2008, and after a cross country flight conducted under the provisions of 14 CFR Part 91, it arrived in Redding, California, on June 30, 2008. On July 1, 2008, it was flown to Trinity Helibase where it went under contract to the USFS.

Review of the helicopter's maintenance records revealed that, as of the end of the day before the accident (August 4, 2008), the helicopter had accumulated 35,396.4 flight hours. Using data from the SkyConnect system and the CVR recording, it was determined that the helicopter was flown about 3.5 additional hours before the accident, equating to a total operating time of about 35,400 hours.

1.6.1 Airframe Fuel System

The helicopter was equipped with three fuel tanks: a forward tank, a center auxiliary tank, and an aft tank. During normal operations, the forward tank supplied fuel to the No. 1 engine, and the aft tank supplied fuel to the No. 2 engine. All three fuel tanks were located in the hull of the helicopter beneath the passenger cabin floor in watertight compartments composed of three aluminum-ribbed cavities with bulkheads between them. Each fuel tank comprised a rubberized fabric cell, which was installed within a fiberglass liner that attached to structure inside the fuel tank compartment.

Pressurized fuel was supplied from each fuel tank via two electrically operated fuel booster pumps through a mixing chamber, fuel manifold, airframe fuel filter, and then to the engine fuel supply system. The forward and aft fuel tanks each contained a fiberglass collector can, and each can housed two fuel booster pumps. The fuel booster pumps drew fuel in through a mesh strainer and then discharged the fuel from their outlet ports through hoses to the mixing chamber. After the mixing chamber, the fuel flowed through the airframe fuel manifold into a 40-micron airframe fuel filter and then to its respective engine.

The helicopter was equipped with two independent airframe fuel filters, one for each engine. Each airframe fuel filter contained a cleanable 40-micron filter element, which incorporated corrugations designed to collect any contaminants in the fuel. According to the CHSI maintenance program, the airframe fuel filters were inspected and cleaned every 150 hours (Phase 3 inspection). The last Phase 3 inspection was accomplished on July 11, 2008, at an aircraft total time of 35,355.2 hours, or about 45 flight hours before the accident.

1.6.2 Engine Information

The accident helicopter was equipped with two CT58-140 engines, manufactured by General Electric (GE). The CT58-140 engine is an axial-flow turboshaft engine with output power of 1,500 shaft horsepower (SHP) at the 2.5-minute rating; 1,400 SHP at the 5-minute or takeoff rating; and 1,250 SHP at the maximum continuous rating.[26] The major sections of the

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[25] For further information about the USFS inspection, see section 1.17.2.3.

[26] Rated 2.5-minute power is the approved SHP that can be used for a period of not over 2.5 minutes after the failure of one engine of a multiengine rotorcraft. Rated takeoff power is the approved SHP that can be used for a

engine include a ten-stage compressor, an annular combustor, a two-stage gas generator turbine, and a single-stage power turbine. Gases from the combustor drive both the gas generator turbine, which drives the compressor, and the power turbine, which provides the output power of the engine. The power turbine is considered to be a free turbine because it is not mechanically connected to the gas generator turbine and can therefore rotate independently in the gas stream.

The No. 1 (left) and No. 2 (right) engines had accumulated total times of about 22,323.3 and 32,438.6 hours, respectively, at the time of the accident and had accumulated 1,016.4 and 238 hours since overhaul, respectively, at the time of the accident.

Various instruments were installed in the accident helicopter's cockpit to monitor engine performance. Dual-pointer engine torque gauges and triple-needle tachometers were installed in the pilot and copilot sections of the instrument panel. Each torque gauge (Q) had two needles labeled "1" and "2" for the No. 1 and No. 2 engine torque readings, respectively, and the markings on the gauges were incremented at 5-percent intervals. Each tachometer had three needles labeled "1," "2," and "R" for the No. 1 and No. 2 engine power turbine speed readings and the N_R in percent, respectively, and the markings on the gauges were incremented at 2-percent intervals (see figure 4). Additionally, the center section of the instrument panel housed two N_G gauges and two power turbine inlet temperature (T_5) indicators, one each for the No. 1 and No. 2 engines. The N_G gauges were marked with red lines at 100 percent and 102 percent for the 5-minute (takeoff) power limit and the 2.5-minute power limit, respectively.

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period of not more than 5 minutes for takeoff operation. Rated maximum continuous power is the approved SHP for unrestricted periods of use.

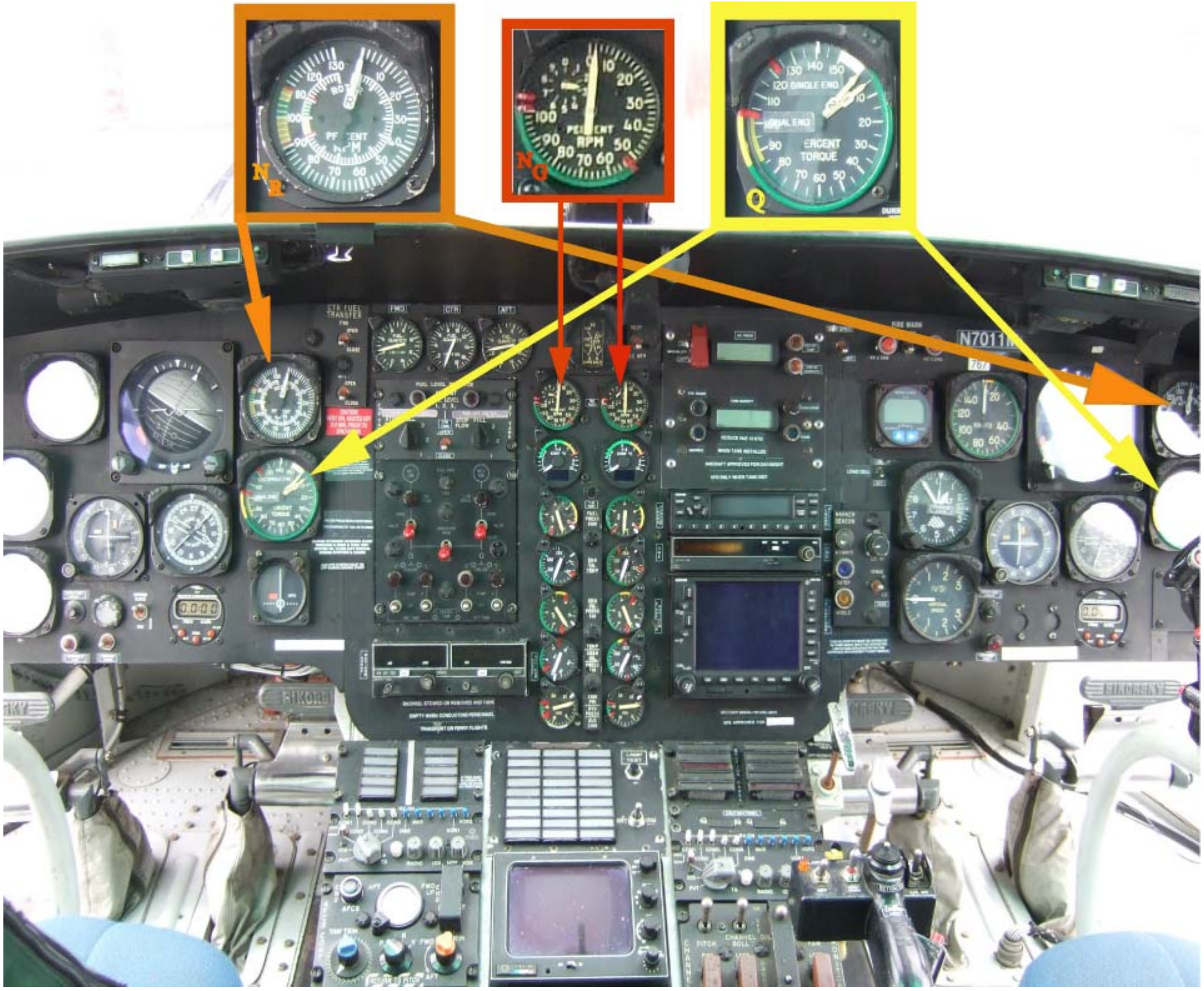

Figure 4. Photograph of exemplar instrument panel, tachometer, N_G gauge, and torque gauge. The tachometer, N_G gauge, and torque gauge are labeled N_R, N_G, and Q, respectively.

1.6.2.1 Explanation of Topping

According to GE, when a CT58-140 engine is operating at its topping (maximum N_G) speed, the fuel control unit (FCU) is delivering maximum fuel flow to the engine, and the engine is producing the maximum amount of power available under the existing ambient conditions.

As explained in the FAA's *Rotorcraft Flying Handbook*,[27] when the pilot raises the helicopter's collective pitch control, the pitch angle of all main rotor blades increases, which increases lift and also increases induced drag. The increase in induced drag leads to a decrease in N_R unless there is a proportionate compensatory increase in power. On the S-61N, when the collective is raised, power is automatically increased, up to the point at which the engines reach topping. At that point, any further increase in collective results in an increase in drag that cannot

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[27] *Rotorcraft Flying Handbook* (Washington, DC: U.S. Department of Transportation, Federal Aviation Administration, 2000).

be compensated for, and the main rotor speed begins to decay, or droop. When the speed of the main rotor droops significantly, the main rotor loses lift and the helicopter descends.

In its May 26, 2010, party submission to the National Transportation Safety Board (NTSB), the USFS provided the following additional explanation of engine topping:

> Engine topping refers to maximum physical speed limit of an engine. To illustrate topping, imagine driving in your car from a flat road to an uphill grade and you apply additional gas to the engine by pressing on the accelerator to maintain speed. As the gradient increases, you will find it necessary to press down further on the accelerator to maintain speed. If the gradient becomes steep enough, you will be required to press the accelerator all the way to the floor. At that point, you will reach the maximum allowable gas flow to the engine, which will not be enough to prevent your car from decelerating.

1.6.2.2 Power Assurance Checks

The USFS contract required engine power assurance checks to be performed every 10 flight hours to verify that an engine is producing at least the minimum specification (min spec) power derived from the 2.5-minute power available chart. This check provides assurance that, in the event of an engine failure, the required one engine inoperative (OEI) performance is available. If the min spec power is not achieved, then engine maintenance is required.

The Sikorsky Aircraft S-61N Maintenance Manual (SA 4045-80), which was used by Carson Helicopters, includes two procedures for conducting an engine power assurance check. One procedure is an on-ground test used to verify engine performance without operating the engine at its actual maximum performance level; the maintenance manual provides tables necessary for conducting this test at PAs of up to 2,000 feet. The other procedure, a "topping check," is a test used to verify engine performance by operating the engine at its actual maximum performance level; it can be used at any PA and can be performed on-ground or in-flight. The maintenance manual stated that the engine manufacturer recommends use of the test procedure that does not require operating the engine at its maximum performance level "in lieu of topping checks where possible" because the higher power levels used during a topping check "shorten the life of the hot section."[28]

According to CHSI's chief pilot, CHSI pilots are trained to perform topping checks both on the ground and during a single-engine climb. The helicopter's most recent power check was performed on-ground at Trinity Helibase by the accident flight crew on the day before the accident, about 3.5 flight hours before the accident. The ambient conditions included 3,160 feet PA and 30° C, which meant that a topping check was performed, rather than the other procedure, because the PA exceeded 2,000 feet.

As explained by the CHSI chief pilot, the on-ground topping check procedure is to start both engines and set the engine being checked at full throttle and the other engine at flight idle.

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[28] The hot section is the portion of a gas turbine engine that operates at high temperature and includes the combustor, turbine, and exhaust sections.

The power turbine load is increased by raising the collective, which results in an increase in N_G. The load is increased until N_G levels off, or "tops out," and stops increasing with further load application. The load is then further increased slightly by continuing to raise the collective until N_R decreases, or "droops," to 100 percent. After briefly maintaining this setting, the pilots record the OAT, PA, N_G, T_5, and engine torque readings. After one engine is checked, the other engine is checked in the same manner. The required min spec torque, obtained from a 2.5-minute power available chart, is subtracted from the actual engine torque readings. The difference between the two values is the engine's torque margin. A positive torque margin indicates the engine is producing power above the minimal limit; a negative torque margin indicates the engine is producing less power than the minimal limit and must be repaired or replaced.

The form completed by the pilots to document the results of the helicopter's most recent power check indicated that the actual engine torque readings achieved were 97 and 100 percent for the No. 1 and No. 2 engines, respectively. The form also indicated that the min spec torque for the ambient conditions was 94 percent, resulting in calculated torque margins of +3 and +6 percent for the No. 1 and No. 2 engines, respectively.[29]

1.6.2.3 Engine Fuel System

During engine operation, pressurized fuel from the airframe fuel system is supplied to the engine-driven centrifugal fuel purifier on each engine (see figure 5). This dynamic fuel filter purifies fuel by a centrifugal action rotating filter.[30] After leaving the centrifugal fuel purifier, the fuel enters the engine-driven fuel pump inlet. After the pump boosts its pressure, the fuel is supplied to the FCU and to the stator vane actuator (SVA). Fuel entering the FCU is routed through a screen-type filter assembly referred to as the main filter group. Metered fuel exits the FCU and is passed through the oil cooler, static filter,[31] and flow divider en route to the combustion chamber.

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[29] When National Transportation Safety Board investigators attempted to duplicate the pilots' torque margin calculations, they read, from the 2.5-minute power chart, a min spec torque of 95.5 percent. Using 95.5 percent as the min spec torque resulted in calculated torque margins of +1.5 and +4.5 percent.

[30] The centrifugal fuel purifier was rated by the percentage of contaminants it was designed to remove, not by a specific micron size. It was designed to remove 50 percent of iron oxide contaminants, 90 percent of road dust contaminants, and 99 percent of organic fiber contaminants.

[31] The static filter is a "last chance" filter installed between the oil cooler and the flow divider to prevent contaminants larger than 40 microns from reaching the flow divider and the engine fuel nozzles.

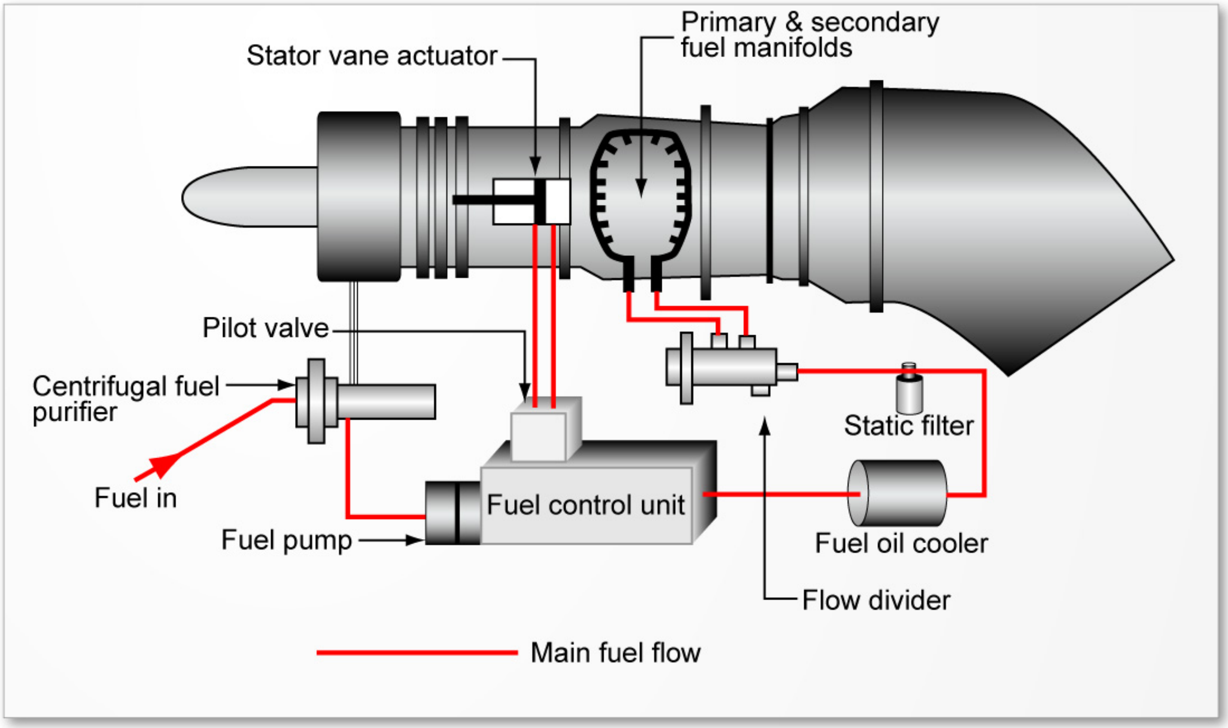

Figure 5. Diagram of the GE CT58-140 engine fuel system.

The centrifugal fuel purifiers installed on the helicopter's engines were both installed at an aircraft total time of 35,161.9 hours, or about 238 hours before the accident. According to the CHSI maintenance program, the centrifugal fuel purifiers were inspected and cleaned every 150 flight hours (Phase 2 inspection). The last Phase 2 inspection was accomplished on June 30, 2008, at an aircraft total time of 35,328.7 hours, or about 71 flight hours before the accident.

Hamilton Sundstrand model JFC26 FCUs were installed on the helicopter's engines. The No. 1 engine FCU was installed on June 7, 2008, at an aircraft total time of 35,278.1 hours, or about 122 flight hours before the accident. The No. 2 engine FCU was installed on May 12, 2008, at an aircraft total time of 35,207 hours, or about 193 flight hours before the accident.

The JFC26 FCU is a device designed to meter the fuel flowing to the engine to maintain a constant power turbine speed and, thus, a constant N_R. The FCU has a fuel metering section and a computing section. The metering section controls the rate of fuel flow to the engine's combustion chamber based on information it receives from the computing section. Fuel entering the FCU is routed into the main filter group (see Figure 6a), which is a two-section filter consisting of a cylindrical cast metal housing, a spring-loaded bypass valve, and two 40-micron (about 0.0016-inch) screens (the main screen and the servo screen). Fuel enters the center of the cylindrical housing and flows out along two parallel paths: through the main screen to the metering section and through the servo screen to the computing section. A spring-loaded bypass valve is provided in case the openings in the main screen become blocked with foreign material. If the bypass valve opens, unfiltered fuel is ported to the metering section. The opening of the bypass valve does not result in activation of a cockpit warning light or other indication to the pilots. If the servo screen becomes blocked, fuel is rerouted to the computing section through the filter relief valve assembly.

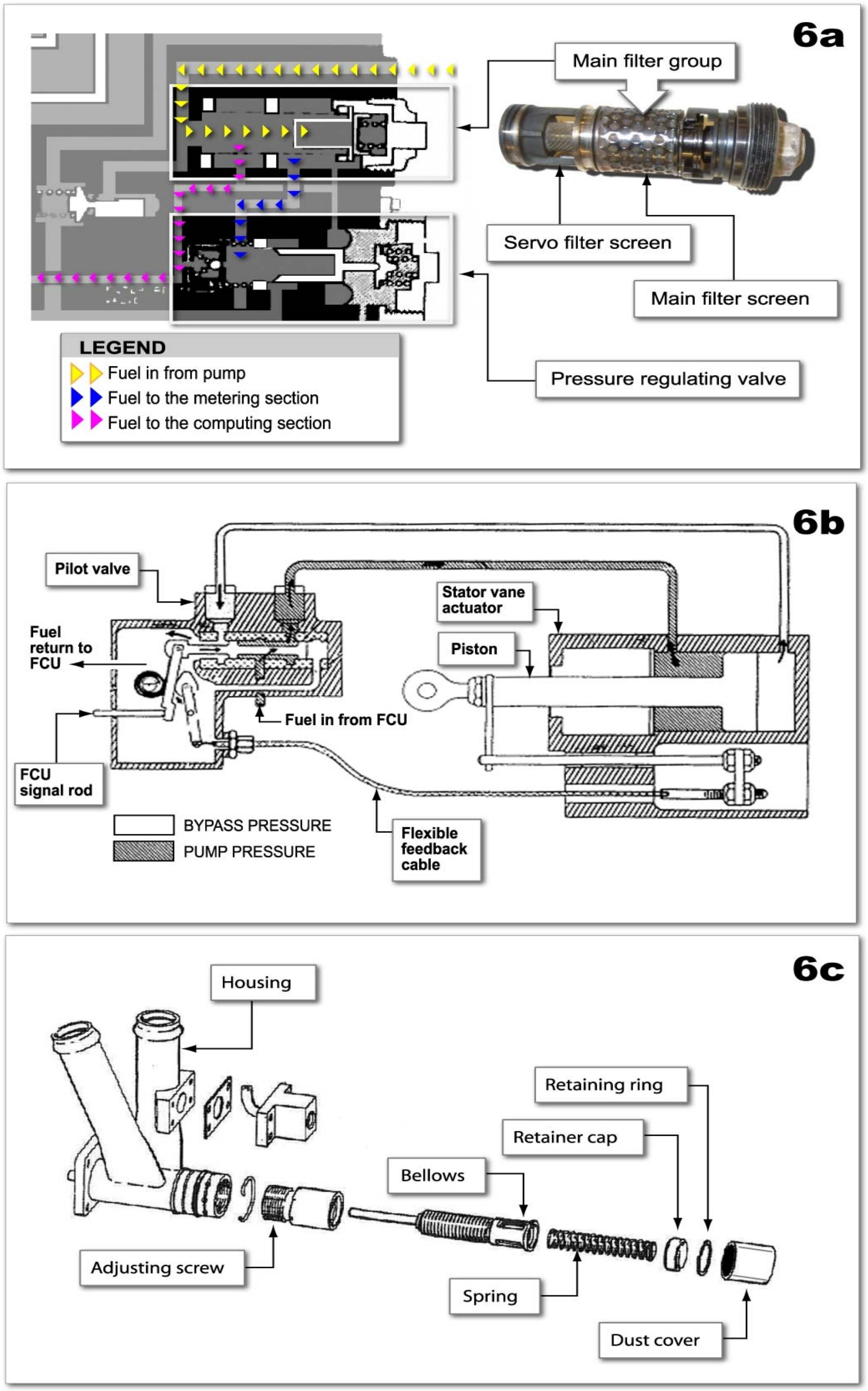

Figure 6. Engine component diagrams: a) FCU main filter group and PRV, b) stator vane actuating system, and c) FCU T_2 bellows group.

Section 73-20-1 in the GE Aircraft Engines CT58 Turboshaft Maintenance Manual provides the following guidance on inspection of the FCU fuel filter elements:

> Position a small light inside the filter element and then visually inspect the element with a 10 power glass. It is necessary that an estimate of the degree of cleanliness be established. Count a representative sample of openings for a given area in the filter screen. Any element which has 70 percent or more of the available open area plugged is operating in partial or full bypass and therefore indicates the need to reduce the filter inspection/cleaning time interval.

Section 73-20-1 of the manual also provides the following guidelines to be used in establishing optimum filter inspection/cleaning intervals:

> 1. Consistent plugging of 40–60 percent of available open area. No change in procedure required.
> 2. Consistent plugging of 61–70 percent of available open area. Recommend 20 percent reduction in inspecting/cleaning interval. (e.g., current cleaning interval = 100 hours, reduce to 80 hours or less.)
> 3. Consistent plugging of more than 71 percent of available area. Reduce inspection/cleaning interval by 40 percent.
> 4. Consistent plugging of less than 40 percent of the available open area. The operator may program an increase in the inspection/cleaning interval. Do not exceed 20 percent of the inspection/cleaning interval on any increase.

At the time of the accident, CHSI's maintenance program required inspection and cleaning of the FCU fuel filters every 150 hours (Phase 2 inspection).[32] Review of the inspection checklist for the last Phase 2 inspection accomplished 71 hours before the accident revealed that the block for the FCU fuel filter inspection was initialed; there was no record of the inspection results, nor was one required.

The pressure-regulating valve (PRV), which is a component of the FCU metering section, maintains a constant pressure differential across the main metering valve by bypassing excess fuel back to the engine fuel pump inlet. The PRV consists of a piston or spool that slides within the bore of a sleeve. When the engine is operating below its maximum N_G, the PRV piston is continually moving within the sleeve to maintain a constant pressure differential across the main metering valve. The PRV spools are manufactured with four circumferential balance grooves and a smaller diameter groove at one end of the spool. The specified clearance between the spool and the PRV sleeve is between 10 and 20 microns, according to the engineering drawings.

1.6.2.4 Stator Vane Operation

The CT58-140 engine's variable stator vane system controls the flow of compressor intake air by regulating the angle of the inlet guide vanes and the stator vanes of the first three compressor stages. The system is designed to produce efficient, stall-free operation throughout

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[32] On February 15, 2009, CHSI revised its maintenance program to inspect the FCU filters more frequently, at 50-hour intervals.

the engine's entire speed range. The variable stator vanes[33] are at their closed position during engine start and open as the engine speed increases. They start to open at about 65 percent N_G and are fully open at about 95 percent N_G on a standard day.[34] As the N_G decreases through 64 percent during a normal engine shutdown, the vanes rotate to their fully closed position.

The stator vane actuating system comprises an SVA, a pilot valve assembly, a feedback cable, a signal actuating mechanism in the FCU, and multiple actuating levers (see figure 6b). The pilot valve receives engine speed commands via movement of the FCU signal actuating mechanism, which results in movement of the pilot valve piston. Depending on the direction of piston motion, the pilot valve ports high-pressure fuel to extend or retract the SVA, which results in corresponding movement of the actuating levers and repositioning of the feedback cable. Movement of the feedback cable results in the pilot valve's piston returning to its null position, shutting off the flow of fuel to the SVA when the desired position is reached.

The stator vane position schedule is provided by a contour on the 3-D cam, which is located within the FCU. The 3-D cam is positioned axially by the N_G governor servo and rotationally by the engine inlet air temperature (T_2) servo. A change in N_G or T_2 input results in a variable stator vane angle change within the region of regulation (65 to 95 percent N_G).

The T_2 sensing system consists of the T_2 servo and the T_2 bellows group. The T_2 bellows group includes the following major components: bellows, bellows housing, override spring, position adjusting screw,[35] spring retainer cap, retaining ring, and dust cover (see figure 6c). The position adjusting screw is manufactured from aluminum tube stock. One end of the screw contains an external thread that attaches to the mating internal threads on the T_2 sensor housing, and the other end contains an internal circumferential groove. The screw is installed in the housing, and the bellows is inserted into the end of the position adjusting screw that contains the groove. The spring and spring retainer cap are then inserted, and the spring is compressed until the retaining ring can be inserted into the groove. In the installed condition, the retaining ring presses against the internal groove in the position adjusting screw and prevents the bellows, spring, and spring retainer cap from sliding out of the housing. The T_2 bellows is protected from the environment by the position adjusting cover, which is a dust cover manufactured from plastic or aluminum.

During normal engine operation, engine inlet air is ported into and through the T_2 bellows housing, causing the bellows to expand or contract with changes in temperature. The bellows is restrained by the spring and retaining ring on one end. A temperature-sensing lever at the other end of the bellows transmits the motion of the bellows to the T_2 servo. The T_2 servo valve requires fuel pressure to function. When fuel pressure is available, movement of the temperature-sensing lever results in translation of the T_2 servo valve and rotation of the 3-D cam. If there is no fuel pressure (for instance, when the engine is not running), movement of the T_2 bellows will not result in movement of the T_2 servo valve or rotation of the 3-D cam.

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[33] The term "variable stator vanes" includes the inlet guide vanes and the stator vanes of the first three compressor stages, all of which are controlled by the variable stator vane system.

[34] On a standard day at sea level, the pressure is 29.92 inches of Mercury and the air temperature is 15° Celsius (C).

[35] The position adjusting screw provides a means of adjusting the initial position of the T_2 bellows during the assembly of an FCU by an overhaul shop. This screw is not adjusted during routine maintenance.

1.6.3 Type Certificate and Supplemental Type Certificates

1.6.3.1 Overview

Type Certificate Number 1H15 for the Sikorsky S-61N was issued on November 2, 1961, and is held by Sikorsky Aircraft, Stratford, Connecticut. The helicopter was certified on the basis of Civil Air Regulations (CAR) 7, dated August 1, 1956, and subsequent amendments to CAR 7, which contained the then-current airworthiness requirements for transport-category rotorcraft.[36]

CHI holds numerous supplemental type certificates (STC)[37] that can be installed on S-61N helicopters, including five STCs that are pertinent to this investigation (see table 2), each of which has a specific associated rotorcraft flight manual supplement (RFMS). Additionally, the table indicates whether or not the accident helicopter's maintenance records included documentation of installation of each STC.[38]

Table 2. List of pertinent STCs.

STC No.	Description	Installation Recorded	RFMS
SR01585NY	Installation of CHI composite main rotor blades	Yes, on 8/10/2007	CH-03
SR02382NY	Increased hover performance applicable to aircraft modified by SR01585NY	No record found[39]	#6
SR02487NY	Increased Category A performance applicable to aircraft modified by SR01585NY	No record found	#7
SR01552SE	Installation of Carson Helicopters "Fire King" aerial liquid dispensing tank	Yes, on 3/25/2008	CHI-FK-FM
SR02507NY	Installation of 600-lb capacity Goodrich Aircraft rescue hoist system	Yes, on 3/25/2008	#8

Review of the helicopter's maintenance records indicated that CHI composite main rotor blades, which replaced the original Sikorsky metal main rotor blades, were installed on August 10, 2007, in accordance with STC SR01585NY. Both a maintenance record entry and FAA Form 337 were completed. The associated RFMS (CH-03) did not include any performance charts, and the performance section of the RFMS stated only "No Change," indicating that the performance section of the original Sikorsky rotorcraft flight manual (RFM) remained applicable.

The maintenance records indicated that, on March 25, 2008, a 900-gallon Fire King aerial liquid dispensing tank was installed in accordance with STC SR01552SE. Both a maintenance record entry and FAA Form 337 were completed. The associated RFMS (CHI-FK-FM) did not

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[36] CAR 7, "Rotorcraft Airworthiness: Transport Categories," has since been replaced by 14 CFR Part 29, "Airworthiness Standards: Transport Category Rotorcraft."

[37] An STC is the FAA's approval of a major change in the type design of a previously type-certificated product.

[38] Typically, when an STC is installed, a maintenance record entry and FAA Form 337 are completed by the person performing the work. A maintenance record entry is required by 14 CFR 43.9(a) for any alteration to an aircraft, and FAA Form 337 is required by 14 CFR 43.9(d) for a major repair or major alteration.

[39] For more information about the positions of Carson Helicopters and the FAA regarding the recording of installation of these STCs, see sections 1.6.3.2 and 1.6.3.3.

include any performance charts. The performance section of the RFMS stated that the helicopter "must incorporate Carson Helicopters, Inc. Composite Main Rotor Blades STC SR01585NY and the performance section for these blades must be used when tank is installed."

Also installed on March 25, 2008, was a Goodrich Aircraft rescue hoist system in accordance with STC SR02507NY. Both a maintenance record entry and FAA Form 337 were completed. The performance section of the associated RFMS (#8) included performance charts, several of which were used by the PIC in performing the load calculations on the day of the accident. A maintenance record entry dated April 22, 2008, stated the following: "Removed Goodrich [Aircraft] Rescue Hoist System as per STC #SR02507NY."

No maintenance record entry or FAA Form 337 was found for either STC SR02382NY or STC SR02487NY, which provide increased performance for helicopters equipped with the CHI composite main rotor blades, greater than that provided in the performance section of the basic Sikorsky RFM. The associated RFMSs for these STCs (#6 and #7) included performance charts, one of which (#7) was used by the PIC in performing the load calculations on the day of the accident. The installation of each of these STCs requires no physical changes to the helicopter; however, as discussed further in section 1.6.3.3, the FAA requires that a maintenance record entry and a Form 337 be completed to document the installation of each one.

1.6.3.2 Carson Helicopters' Position on Use of RFMS #6, #7, and #8

Regarding the use of charts from RFMS #6 and #7 (associated with the performance-enhancing STCs SR02382NY and SR02487NY, respectively), although there was no record of either STC having been installed, the Carson Helicopters party coordinator stated in a January 11, 2010, memorandum that these STCs require no physical alteration of the aircraft because they apply only to aircraft previously modified by STC SR01585NY (the CHI composite main rotor blade STC). The memorandum stated that all required equipment as listed in STC SR01585NY was previously installed on the helicopter when that STC was accomplished on August 10, 2007, and further indicated that "since there was no physical alteration to the aircraft, no maintenance log entry or [Form] 337 is required by FAA regulation to utilize the enhanced performance charts."

Regarding the use of charts from RFMS #8 (associated with the hoist STC SR02507NY), although the hoist was not installed at the time of the accident, the CHSI director of operations (DO) stated in a July 22, 2009, e-mail that "the configuration limitation for applicable aircraft in the front of [RFMS #8] does not require the hoist to be installed." He further indicated that "there is no requirement to have the hoist installed for use of the performance charts in this supplement."

In the January 11, 2010, memorandum, the Carson Helicopters party coordinator provided another response regarding RFMS #8, stating that, on April 22, 2008, "only the hoist motor was removed," while the bracket, wiring, and control head remained installed "as a system in the aircraft." The memorandum stated that "the hoist motor was integrally engineered in the STC to be easily removable for different and changing mission profiles, and a removal procedure for the motor is outlined in the STC." The memorandum further stated that "removal of the hoist motor does not constitute removal of the whole system or STC," and, therefore, RFMS #8 "was applicable" to the helicopter at the time of the accident.

The memorandum also indicated that the performance charts in RFMS #8 "were derived from extensive, FAA-approved flight testing done in December, 2007" and that "the testing was approved for hoist use both with the Fire King tank on and with the tank removed from the aircraft for limitations." Therefore, according to the Carson Helicopters party coordinator, the accident helicopter as configured with the Fire King tank and the hoist "could properly utilize [RFMS] No. 8, which is applicable with the tank on or off the aircraft."

1.6.3.3 FAA Position on Use of RFMS #6, #7, and #8

In an April 7, 2010, letter, the FAA responded to a request from NTSB investigators for its comments on Carson Helicopters' position on the applicability of RFMS #6, #7, and #8 to the accident helicopter. The FAA indicated that it did not agree with Carson Helicopters' statements regarding these supplements and that none of the supplements were applicable to the helicopter as it was configured at the time of the accident.

Regarding RFMS #6 and #7, the FAA stated that the associated STCs are, by definition, major alterations, and, therefore, a maintenance record entry and FAA Form 337 are required to document the installation of each STC. The FAA indicated that the RFMSs cannot be used unless their associated STCs are installed, even if no physical alteration is required for installation.

Regarding RFMS #8, the FAA stated that the supplement does not allow for a partial hoist installation; rather, the RFMS can only be used when the hoist is fully installed. Additionally, the FAA indicated that "the only FAA flight testing which was done [in December 2007] was to enter an out-of-ground-effect (OGE) hover and operate the hoist to ensure that it functioned properly." During the testing, "the Fire King Retardant Tank was never installed nor was any hover performance evaluation accomplished."

The FAA stated that the Fire King tank STC (SR01552SE) requires installation of the CHI composite main rotor blade STC but does not require installation of the hoist STC or the performance-enhancing STCs. Therefore, the performance section of the RFMS for the Fire King tank "informs the operator to use the supplement for the CMRB [composite main rotor blades] (which is RFMS CH-03)."

In an April 26, 2010, memorandum, the FAA responded to a request from NTSB investigators for clarification as to whether the use of performance charts contained in RFMS #8 was appropriate when no external load was being carried. The memorandum noted that, because the helicopter was being operated as a public aircraft, it was not subject to 14 CFR 91.9(a), which states that "no person may operate a civil aircraft without complying with the operating limitations specified in the approved Airplane or Rotorcraft Flight Manual." However, if the helicopter had been operated as a civil aircraft, "use of the performance figures in RFMS [#8] for maximum gross weight calculations when no external-load was being carried would be contrary to the limitations contained in the RFMS, and therefore contrary to 14 C.F.R. § 91.9(a)."

1.6.4 Weight and Balance

A complete weight and balance record for an S-61 helicopter comprises three charts: A, B, and C. When the helicopter is weighed, Chart A and Chart B are prepared. Chart A is a tabulation of all operating equipment that is or may be installed in a definite location in the helicopter and is the primary document that identifies precisely how a helicopter was configured at the time of weighing. Typically, installed items are indicated with a check mark, and items not installed are indicated with a "0" mark. Chart B is a single-page form used for recording the weighing data and computing the empty weight and balance of the helicopter; it provides the individual weights for each scale and shows which type of scale was used to obtain the weight.

Between weighings, Chart C is used to compute changes in the helicopter's weight and balance due to the removal or addition of equipment. Chart C is a varying list that updates the weight obtained from Chart B as equipment is added or removed and shows a continuous history of the helicopter's basic weight, moment arm, and moment resulting from structural and equipment changes in service.

During the investigation, numerous complete and incomplete weight and balance records were found for the accident helicopter. The various documents are summarized in table 3.

A search of the helicopter's Canadian maintenance records stored at the CHI facility in Perkasie revealed a complete weight and balance record (Charts A, B, and C) covering the period from April 22, 2003, when the helicopter was weighed by CHC, to June 21, 2007, when it was sold to CHI. The last weight recorded on the CHC Chart C was 13,279 lbs. Documents were obtained indicating CHI had weighed the helicopter six times after purchasing it from CHC.[40] One of these weighings was performed on August 11, 2007, and indicated an empty weight of 11,476 lbs, which was 1,803 lbs lighter than the last CHC Chart C empty weight from June 21, 2007. Review of the helicopter's maintenance records did not indicate the removal of any equipment during this time period that would account for the weight difference. An attempt was made to compare the items shown as installed in the CHC records with those shown as installed on the CHI Chart A for August 11, 2007, but the Chart A templates were different, and an exact comparison could not be performed.

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[40] Six Chart Bs were obtained. Two were provided by CHSI, one was obtained from the FAA, two were obtained from FAA designees, and one was discovered in subpoenaed documentation.

Table 3. Weight and balance documents found for N612AZ.

Date of Document	Documentation	Empty Weight	Chart A	Chart B	Chart C	Source of Information
4/22/2003	Weighing by CHC	13,506 lbs	Yes	Yes	N/A	CHI
6/21/2007	Equipment Changes Made After 4/22/03 Weighing	13,279 lbs	N/A	N/A	Yes	CHI
8/6/2007	Weighing by CHI	12,491 lbs	No	Yes	N/A	Designated airworthiness representative[41]
8/11/2007	Weighing by CHI	11,476 lbs	Yes	Yes	N/A	CHSI
8/15/2007	Weighing by CHI	13,073 lbs	No	Yes	N/A	Designated engineering representative[42]
12/26/2007	Weighing by CHI	12,369 lbs	No	Yes	N/A	FAA
1/4/2008(a)	Weighing by CHI	12,013 lbs	Yes	Yes	N/A	CHSI
1/4/2008(b)	Weighing by CHI	12,328 lbs	Yes	Yes	N/A	Carson Helicopters subpoena
3/25/2008	Equipment Changes Made After 1/4/08(b) Weighing	13,553 lbs	N/A	N/A	Yes	Carson Helicopters subpoena
6/27/2008	Equipment Changes Made After 1/4/08(a) Weighing	12,408 lbs	N/A	N/A	Yes	CHSI

The last recorded physical weighing of the helicopter was on January 4, 2008, in Perkasie, Pennsylvania, and two different Chart As and Chart Bs were found for that weighing: one set prepared by CHSI personnel in Grants Pass, Oregon (labeled as 1/4/2008[a] in table 3), and one set prepared by CHI personnel in Perkasie, Pennsylvania (labeled as 1/4/2008[b] in table 3). The CHSI vice president stated that the helicopter was never at the Grants Pass facilities and that the set of charts prepared in Grants Pass were completed by obtaining the weighing data from CHI personnel in Perkasie and transferring it to a CHSI form. Both the Grants Pass-prepared and the Perkasie-prepared Chart Bs for the January 4, 2008, weighing indicated the same center of gravity position,[43] but each gave a different value for the helicopter's empty weight.

1.6.4.1 Grants Pass January 4, 2008, Weight and Balance Charts

CHSI provided the Grants Pass-prepared records for the January 4, 2008, weighing in Perkasie to NTSB investigators early in the investigation. The PIC used these charts when he

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[41] This Chart B was obtained from the designated airworthiness representative who completed an airworthiness conformity inspection of the helicopter on August 10, 2007.

[42] This Chart B was obtained from the designated engineering representative who oversaw flight tests that were conducted using the helicopter.

[43] The calculated center of gravity was 263.1 inches aft of datum.

conducted the load calculations on the day of the accident, and CHI submitted them to the USFS in the bid proposal for the contract. However, as the investigation progressed, CHSI acknowledged that these records were erroneous.

The Grants Pass-prepared Chart A for the January 4, 2008, weighing indicated that the aerial liquid tank (Fire King tank) weighing 1,090 lbs was installed at the time of weighing. The Chart A box for the liquid tank for this weighing had what appeared to be a check mark written over a “0” mark.

The Grants Pass-prepared Chart B for the January 4, 2008, weighing, which was prepared by the CHSI director of maintenance (DOM), indicated that roll-on type scales were used and that the helicopter’s empty weight was 12,013 lbs. The left main, right main, and tail landing gear scale readings were recorded on Chart B to the nearest tenth of a lb. The NTSB’s examination of the roll-on scales revealed that the scale system provided a digital readout of the scale weights to the nearest whole lb; the scales were not capable of measuring tenths of a lb. During a June 10, 2009, interview, the CHSI DOM stated that he prepared the Grants Pass Chart B using numbers that he transferred directly from the Perkasie-prepared Chart B.[44] He further stated that the numbers were “altered afterwards” by someone who “established the [empty] weight they wanted” and modified the numbers to obtain that weight.

The Chart C that accompanied the January 4, 2008, Grants Pass-prepared weighing documents listed the addition of seven single and eight double passenger seats to the helicopter. The chart indicated the seats were installed on June 27, 2008, adding a total of 395 lbs to the empty weight of the helicopter, resulting in an empty weight of 12,408 lbs.

1.6.4.2 Perkasie January 4, 2008, Weight and Balance Charts

The Perkasie-prepared records for the January 4, 2008, weighing in Perkasie were found in material provided by Carson Helicopters in response to a subpoena the NTSB issued on December 4, 2008.

The Perkasie-prepared Chart A for the January 4, 2008, weighing indicated that the aerial liquid tank was not installed at the time of weighing. All other equipment marks for this weighing were the same as those on the Grants Pass-prepared Chart A. The Perkasie-prepared Chart A also had an additional column dated March 25, 2008, that recorded installation of the liquid tank (1,090 lbs) and the Goodrich rescue hoist (135 lbs).

The Perkasie-prepared Chart B for the January 4, 2008, weighing, which was prepared by the CHI DOM, indicated that jack-point type scales were used and that the helicopter’s empty weight was 12,328 lbs, or 315 lbs heavier than that recorded on the Grants Pass-prepared Chart B.

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[44] A review of material Carson Helicopters provided in response to an NTSB subpoena determined that the Perkasie-prepared Chart A and Chart B for the January 4, 2008, weighing were e-mailed from Perkasie personnel to Grants Pass personnel on March 28, 2008.

In a May 13, 2009, memorandum, the Carson Helicopters party coordinator stated that the Perkasie-prepared Chart A was incorrect because it “did not include equipment that we know was on the aircraft from photos and personal recollection taken after the weighing.” According to the memorandum, the items that were installed at the time of weighing but not listed on Chart A were five single and four double passenger seats (273 lbs), the hoist (135 lbs), and a bubble window (18 lbs). The memorandum stated that no maintenance log entries were available to substantiate this claim. In lieu of maintenance log entries, Carson Helicopters submitted a digital photograph of the helicopter taken on March 25, 2008, stating that “a careful zoom examination” of the photos “shows the dark seatbacks in the windows of the aircraft.” Additionally, the memorandum stated that the company president “personally recalls seeing that the seats, hoist and bubble windows were on the aircraft” for the hoist testing that took place in late December 2007 and the subsequent weighing on January 4, 2008. Further, Carson Helicopters acknowledged some of the weighing errors, stating the following:

> N612AZ was utilized for multiple missions and configurations in the 13 months that Carson owned the aircraft. It was used for hurricane rescue relief work in Texas, FAA hoist supplement verification testing, water dropping/firefighting in Florida, firefighting and helitack missions in the western U.S., and configured for demonstration/static display in the eastern U.S. As such, the configuration changed several times and the aircraft was weighed at least 4 times in less than 12 months, which is very unusual for a large helicopter (for example, the previous owner, CHC, weighed the aircraft once in 4 years). This generated multiple Chart B weighing sheets, and Chart A and Chart C entries. Carson has been made aware of and has acknowledged that there were errors and/or conflicts in some of the entries, and we have extensively modified our weighing procedures and our General Maintenance Manual procedures to reflect increased strict control to avoid mistakes in weighing or in annotation in the future.

During an October 8, 2009, interview, the CHI DOM verified that he completed the Perkasie-prepared Charts A and B. He stated that the weighing documents would have been completed in his office, but “his normal routine was to look at the aircraft before or after the weighing and to ask the weighing mechanic if there were any changes to what we consider an empty aircraft, i.e. installation of ice shield, air inlet screens, cargo hook, etc. that would have to be entered in the chart A.” He further stated that the Chart A and B that he completed were both correct.

A Chart C was also found in the documents provided in response to the NTSB’s subpoena that referenced the empty weight from the Perkasie-prepared Chart B. The Chart C listed two items (the liquid tank and the rescue hoist) that were installed on March 25, 2008, adding a total of 1,225 lbs to the empty weight of the helicopter, resulting in an empty weight of 13,553 lbs. The date of installation listed on Chart C for these items corresponded to that shown in the helicopter’s maintenance records.

1.6.4.3 Estimated Empty Weight at Accident

The helicopter’s weight at the time of the accident was estimated using the March 25, 2008, Chart C weight of 13,553 lbs as the starting point. The equipment added to or removed from the helicopter after this date was determined from the helicopter's maintenance records and information provided by USFS and Carson Helicopters personnel (see table 4).

Table 4. Estimated empty weight of N612AZ at the time of the accident.

Add/Remove +/-	Item	Weight in Lbs	Arm in Inches	Moment in Lbs × Inches	Date Installed
	Empty Weight (3/25/08)	13,553	261.87	3,549,100	3/25/08
+	Seats (6 singles and 6 doubles)[45]	354	256	90,624	8/4/08
+	Cargo Box	95	405	38,475	7/4/08
+	Siren	20	221	4,420	6/1/08
+	Rappel Bracket	17	156	2,652	Unknown
-	Foam Tank	-29	328	-9,512	7/4/08
+	Bird Screens	33	154	5,082	Unknown
+	Survival Kit	35	371	12,985	7/1/08
-	Hoist	-135	211	-28,485	3/25/08
-	Cargo Hook	-75	267	-20,025	Unknown
-	Transmission Panels	-5	280	-1,400	7/5/08
-	Bubble Window (Copilot)	-18	99	-1,782	8/5/08
	Total Empty Weight	13,845	263.19	3,643,916	8/5/08

Based on these equipment changes, the helicopter's empty weight at the time of the accident was calculated to be 13,845 lbs, which is 1,437 lbs heavier than the empty weight of 12,408 lbs the PIC used to complete load calculations on the day of the accident.

Using the NTSB-calculated empty weight of 13,845 lbs and adding the flight crew weight of 440 lbs, the inspector pilot's weight of 210 lbs, the load manifest weight of 2,355 lbs, and the helicopter's estimated fuel load at the time of the accident of 2,158 lbs,[46] the total weight of the helicopter at the time of the accident was calculated to be 19,008 lbs. By calculation, no center of gravity limitations were exceeded.[47]

Carson Helicopters' May 13, 2009, memorandum (discussed in section 1.6.4.2) stated that, by taking into account the additional items that it believed were installed at the time of the January 4, 2008, weighing, Carson Helicopters calculated an empty weight for the helicopter at the time of the accident of 13,440 lbs. Later, Carson Helicopters provided several different

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[45] This was the actual number of passenger seats installed in the helicopter when it crashed, as verified by witness statements. For further details on the helicopter's seating configuration, see section 1.15.

[46] This estimate was determined by starting with the 2,500 lbs of fuel on board following the refueling at Trinity Helibase and subtracting a calculated 349 lbs of fuel consumed from that point to the accident. The fuel consumed was calculated using rates of 20 and 10 lbs per minute for flight and ground time, respectively, and times of 12.75 and 9.4 minutes of flight and ground time, respectively.

[47] The calculated center of gravity was 258.71 inches, which falls within the limits of 258 to 267 inches stated in the helicopter's flight manual.

estimated empty weights, of which the most recent, as stated in its May 28, 2010, party submission, was 13,432 lbs, which is 1,024 lbs heavier than the 12,408 lbs empty weight CHSI provided to the pilots. Using the Carson Helicopters-estimated empty weight of 13,432 lbs, the total weight of the helicopter at the time of the accident was calculated to be 18,595 lbs.

1.6.4.4 Weight and Balance Charts for Other Carson Helicopters' Aircraft

NTSB investigators examined the weighing documentation that Carson Helicopters submitted to the USFS for 2008 contract bids. Chart Bs were submitted for 11 helicopters (including the accident helicopter). Nine of the 11 Chart Bs were recorded as being prepared at Grants Pass, and 8 of those 9 (including the accident helicopter's Chart B) were prepared by the same individual. Each of the eight Chart Bs recorded the weight under each tire to the nearest tenth of a lb, even though the scales used did not display this precision. In addition, the differences between the left and right main gear scale readings were exactly 80 lbs for all eight helicopters.[48]

In an October 29, 2009, e-mail, Carson Helicopters provided an explanation concerning the recording of weights to the nearest tenth of a lb and the consistent 80-lb weight differences, stating, in part, the following: "Based on our investigation, we are of the opinion that the contract bid weight information was calculated using a formula that would yield the information based on an overall aircraft weight and CG [center of gravity], so the bid weights were not all obtained from actual weighings of the aircraft involved." The e-mail further stated that Carson Helicopters believed an employee "used a formula to calculate the estimated weights at the individual jack/weighing points rather than actual scale reading data for each aircraft."

Between September 25 and October 2, 2008, the USFS weighed the 10 Carson Helicopters' aircraft operating under contract to the USFS and compared those weights to the helicopters' current Chart C weights. For 9 of the 10 helicopters, discrepancies were found between the Chart C weight and the actual helicopter weight (see table 5).

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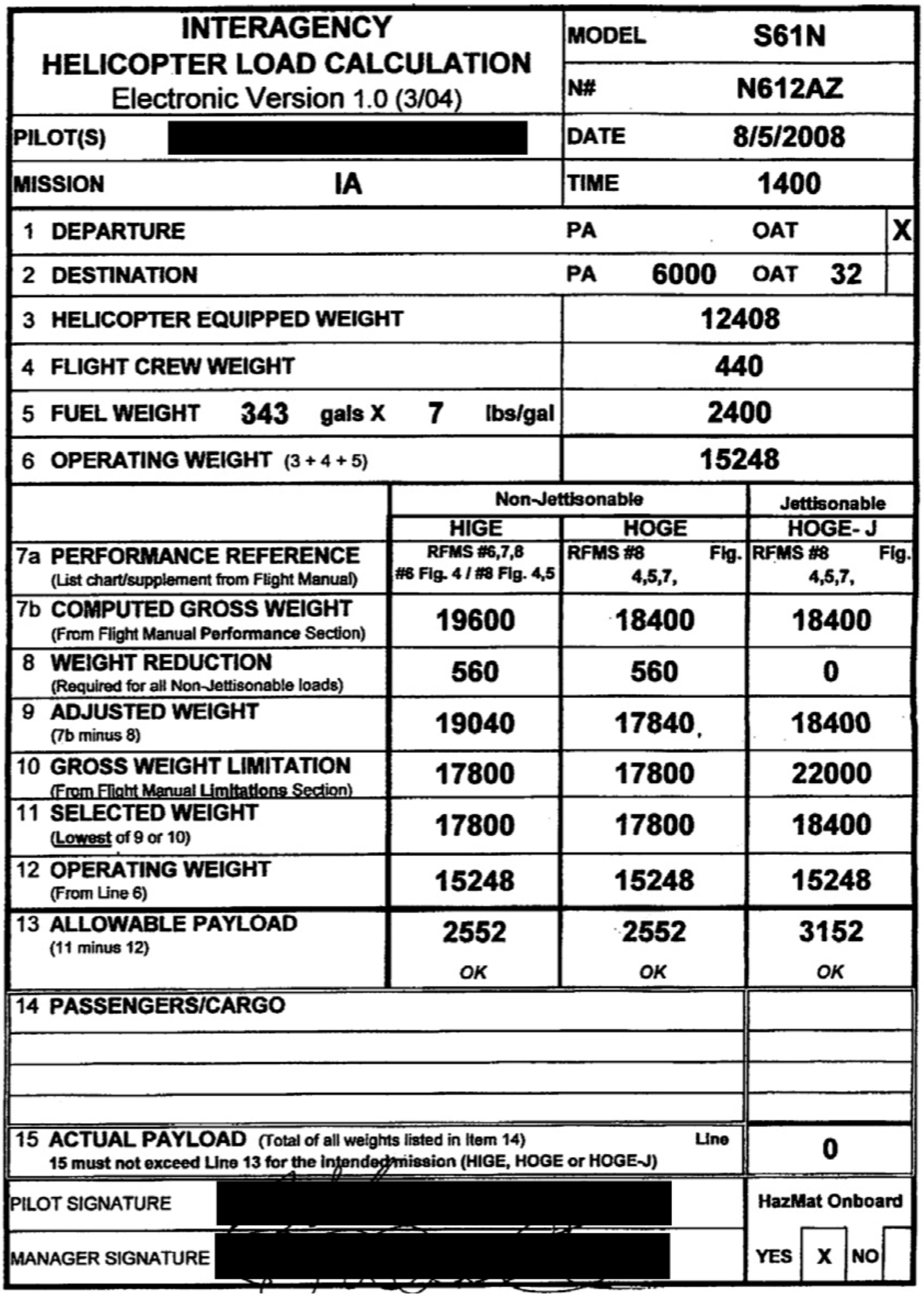
[48] The differences between the left and right main gear scale readings for actual weighings of eight different helicopters would be expected to vary considerably rather than be equivalent.

Table 5. Bid weights and postaccident weights for 11 Carson Helicopters' aircraft.

	Chart B Tail Weight	Chart B Left Main	Chart B Right Main	Right − Left	Chart B Weight	Chart C Weight	USFS Actual Weight	Difference Actual − Chart C
612AZ	1,758.5	5,087.2	5,167.2	80	12,013	N/A	N/A	N/A
4503E	2,343.3	4,794.9	4,874.9	80	12,013	11,273	11,946	673
7011M	2,366.2	4,852.9	4,932.9	80	12,152	11,258	11,843	585
612RM	2,242.8	4,351.6	4,431.6	80	11,026	11,083	11,084	1
116AZ	2,359.2	4,784.9	4,864.9	80	12,009	11,064	11,198	134
905AL	1,830.1	5,179.4	5,259.4	80	12,269	10,934	11,938	1,004
410GH	1,879.4	5,276.3	5,356.3	80	12,512	11,760	12,181	421
61NH	1,843.7	5,043.2	5,123.2	80	12,010	11,380	11,787	407
103WF	N/A	N/A	N/A	N/A	N/A	11,325	11,980	655
725JH	N/A	N/A	N/A	N/A	N/A	12,129	12,667	538
3173U	N/A	N/A	N/A	N/A	N/A	10,763	10,797	34

1.6.5 Performance Charts

NTSB investigators obtained the original copies of the performance load calculation forms the PIC signed as being completed on the day of the accident. Review of the forms revealed that calculations were performed for the following conditions: 500 feet PA at 38° C, 3,500 feet PA at 32° C, 6,000 feet PA at 32° C, and 7,000 feet PA at 25° C. The completed load calculation form for 6,000 feet PA and 32° C is shown in figure 7.



INTERAGENCY
HELICOPTER LOAD CALCULATION
Electronic Version 1.0 (3/04)

MODEL	S61N		
N#	N612AZ		
PILOT(S)	[redacted]	**DATE**	8/5/2008
MISSION	IA	**TIME**	1400

1 **DEPARTURE**	PA		OAT		X
2 **DESTINATION**	PA	6000	OAT	32	

3 **HELICOPTER EQUIPPED WEIGHT**	12408
4 **FLIGHT CREW WEIGHT**	440
5 **FUEL WEIGHT** 343 gals X 7 lbs/gal	2400
6 **OPERATING WEIGHT** (3 + 4 + 5)	15248

	Non-Jettisonable		Jettisonable
	HIGE	HOGE	HOGE- J
7a **PERFORMANCE REFERENCE** (List chart/supplement from Flight Manual)	RFMS #6,7,8 #6 Fig. 4 / #8 Fig. 4,5	RFMS #8 Fig. 4,5,7,	RFMS #8 Fig. 4,5,7,
7b **COMPUTED GROSS WEIGHT** (From Flight Manual Performance Section)	19600	18400	18400
8 **WEIGHT REDUCTION** (Required for all Non-Jettisonable loads)	560	560	0
9 **ADJUSTED WEIGHT** (7b minus 8)	19040	17840	18400
10 **GROSS WEIGHT LIMITATION** (From Flight Manual Limitations Section)	17800	17800	22000
11 **SELECTED WEIGHT** (Lowest of 9 or 10)	17800	17800	18400
12 **OPERATING WEIGHT** (From Line 6)	15248	15248	15248
13 **ALLOWABLE PAYLOAD** (11 minus 12)	2552 OK	2552 OK	3152 OK

14 **PASSENGERS/CARGO**	
15 **ACTUAL PAYLOAD** (Total of all weights listed in Item 14) Line 15 must not exceed Line 13 for the intended mission (HIGE, HOGE or HOGE-J)	0

PILOT SIGNATURE	[redacted]	**HazMat Onboard**	
MANAGER SIGNATURE	[redacted]	YES X	NO ☐

Figure 7. Load calculation form completed by PIC for 6,000 feet PA and 32° C.

Line 7a of the load calculation form specified which performance charts were to be used to complete the load calculations. The following charts were listed on line 7a:

- RFMS #6 Figure 4, Power Required to Hover In Ground Effect (HIGE), 103 percent N_R was used to determine the maximum gross weight at which the helicopter was capable of a HIGE.[49]
- RFMS #8 Figure 4, Power Available, Takeoff Power, 103 percent N_R was used to determine the min spec torque available per engine with the engine operated at its rated takeoff power.
- RFMS #8 Figure 5, Indicated Torque versus Engine Shaft Horsepower was used to convert the torque value derived from Figure 4 to engine SHP.
- RFMS #8 Figure 7, Power Required to Hover Out of Ground Effect (HOGE), 103 percent N_R was used to determine the maximum gross weight at which the helicopter was capable of a HOGE.[50]

In addition to these four performance charts, one additional chart from the operating limitations section of RFMS #7 Figure 7-1-2, Category "B" Maximum Takeoff and Landing Gross Weight 103 percent N_R, was used to determine the helicopter's maximum gross weight limitation (line 10 on the load calculation form). According to USFS and CHSI personnel, the charts that the PIC used were contained in the Trinity Helibase binder[51] for the helicopter and came from CHSI.

1.6.5.1 RFMS #8 Figure 4, Takeoff Power Available

Takeoff power available charts, such as RFMS #8 Figure 4, show the maximum specification torque available for either a period of not more than 5 minutes during takeoff operations with both engines operating or a period of not more than 30 minutes with OEI.

During its review of the CHSI-provided copy of RFMS #8 contained in the Trinity helibase binder for the helicopter, NTSB investigators noted that figure 4 was slightly askew on the page and had less crisp, distinct lines than the other charts in the RFMS (see figure 8a). Investigators also noted that the figure's graphical section had only a single reference line for the main gearbox limit, whereas this type of chart would typically include two reference lines: one each for the twin engine and OEI gearbox limits. NTSB investigators compared the graphical section of RFMS #8 Figure 4 with that of other figures in RFMS #8 and found that it appeared to be identical to the graphical section of RFMS #8 Figure 1, Power Available, 2.5 Minute Power, 100 percent N_R. No difference existed in the torque values given by the two graphical sections.

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[49] A helicopter hovering in ground effect is in flight but is not moving over the ground and is flying at a height equal to or less than the span of its rotor above the surface. The proximity of the ground plane to the rotor increases the performance of the helicopter such that, at a given engine power, the helicopter can HIGE at a higher gross weight than it can hover out of ground effect (HOGE). Similarly, at a given weight, the helicopter requires less power to HIGE than HOGE.

[50] A helicopter hovering out of ground effect is in flight but is not moving over the ground and is flying at a height above the ground greater than the span of its rotor. Out of ground effect, the ground plane is too far away from the rotor to provide any performance benefit.

[51] This binder, referred to as the "football," contained weight and balance charts, performance charts, duty time records, phone lists, copies of contracts, and other documents pertaining to the accident helicopter.

For example, at 6,000 feet PA and 32° C, the torque value from both figures was 82.5 percent. Typically, for a given PA and temperature, the torque value from a takeoff power available chart, commonly referred to as 5-minute power, would be less than the torque value from a 2.5-minute power available chart.

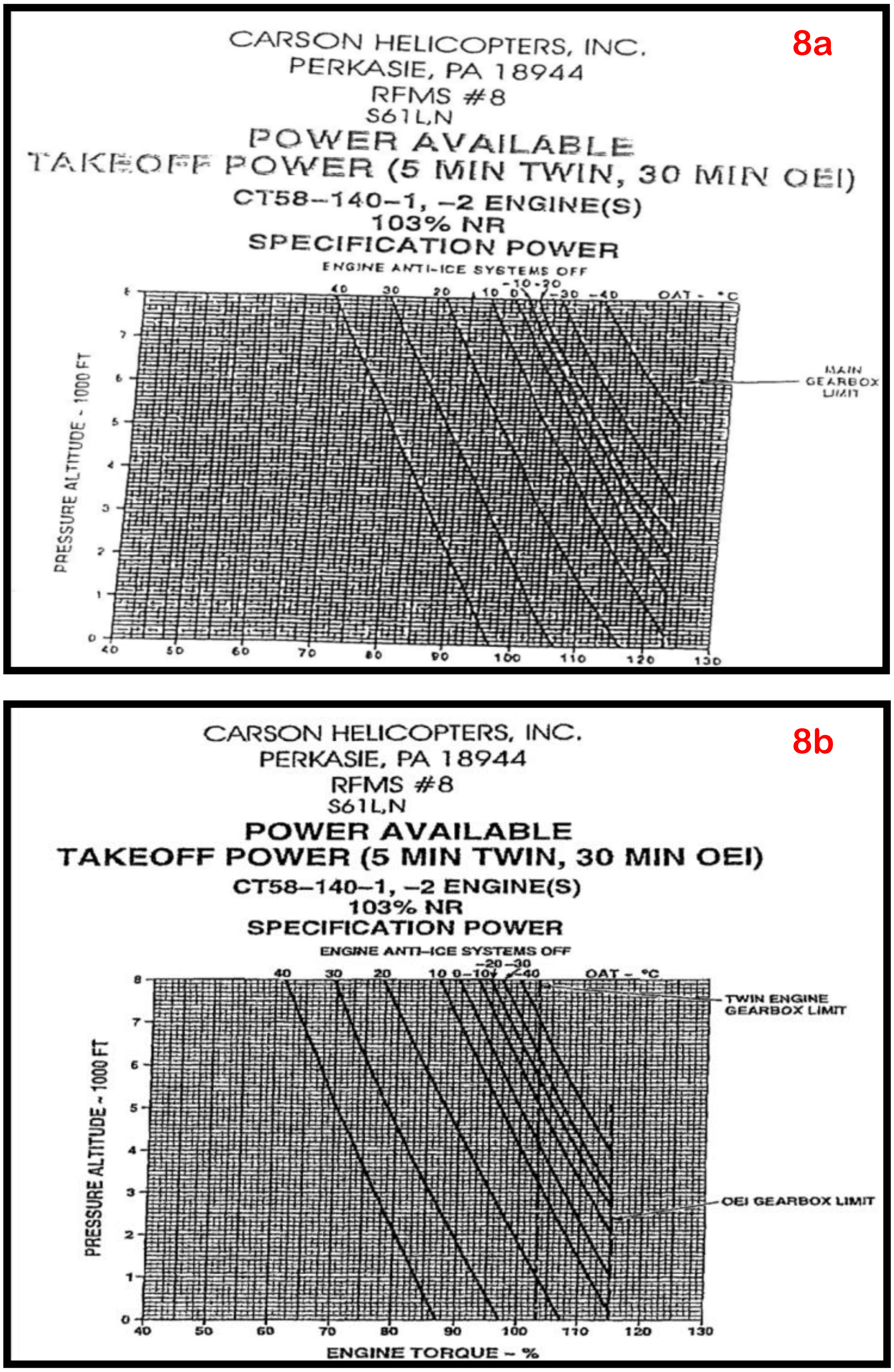

Figure 8. Figures from RFMS #8: a) CHSI-provided Figure 4 and b) FAA-provided Figure 4.

A copy of RFMS #8 was obtained from the FAA's New York Aircraft Certification Office (ACO) that had approved RFMS #8. The FAA-provided RFMS #8 Figure 4 looked identical in format to the CHSI-provided RFMS #8 Figure 4, with the same text at the top and bottom of the figures, and both figures were date-stamped as FAA-approved on February 7, 2008. The notable difference was that the graphical sections were not the same. The graphical section of the FAA-provided chart had crisp, distinct lines and two reference lines: one each for the twin engine and OEI gearbox limits (see figure 8b). The torque value from the FAA-provided figure at 6,000 feet PA and 32° C was 73 percent.

Before 2006, S-61 operators had bid on USFS contracts using performance numbers derived from the 2.5-minute power available charts. In a March 20, 2006, letter addressed to all S-61 operators, the USFS stated the following:

> After review of the S-61 flight manual and consultations with GE technical representatives, Sikorsky Aircraft Corporation and the FAA, we have determined that the 2.5 minute power available charts are intended for OEI…operations only,…[and] USFS does not permit the use of performance charts for other than their approved and intended application. Allowing operators of S-61 helicopters to use enhanced performance data (2.5 Minute OEI Power Available Charts) to better the aircraft's performance for bidding or dispatch purposes not only compromises safety, but gives S-61 operators an unfair advantage over other comparable [heavy] helicopters that are contracting to the USFS.

The letter also stated, "Upon receipt of this letter, the 2.5 Minute OEI Power Available Charts shall not be used for contract bidding, or for load calculations in the field."

On April 28, 2006, CHI formally protested the USFS's decision regarding the termination of the use of the 2.5-minute power available chart because, according to CHI, the chart did not specifically state that it was intended for OEI operations only. According to the USFS, no change was made as a result of CHI's protest because, before issuing the March 20, 2006, letter, it had already received confirmation from GE, Sikorsky, and the FAA that the 2.5-minute power available chart was intended only for OEI use and was not intended for dual-engine operation to permit the helicopter to operate at higher powers.

When asked to explain the discrepancy between the CHSI-provided and FAA-approved figures, CHSI personnel acknowledged that the CHSI-provided RFMS #8 Figure 4 was altered and that the FAA-provided RFMS #8 Figure 4 was correct. They reported that the origin of the mislabeled chart was unknown.

The altered RFMS #8 Figure 4 chart was distributed as an attachment to a July 7, 2008, email from the CHSI chief pilot to all of the company's pilots, including the accident pilots. The email's subject line read "New load Calc info" and stated, in part, to "take out the 5 min power 103%, page 15 of 19 in your aircraft's RFM hoist supplement and replace it with the new 5 min power chart in this email, both are dated 7 Feb 2008."

As shown in table 6, when used to calculate a HOGE gross weight at 6,000 feet PA and 32° C, the FAA-provided RFMS #8 Figure 4 gave a result of 16,400 lbs, which was 1,200 lbs less than the 17,600 lbs obtained using the CHSI-provided RFMS #8 Figure 4.

Table 6. HOGE weight calculations at 6,000 feet PA and 32° C.

	Torque from RFMS #8 Figure 4	Adjusted Torque	SHP from RFMS #8 Figure 5	SHP x 2	HOGE Weight from RFMS #8 Figure 7 (lbs)
FAA-provided Figure 4	73%	+0 = 73%	920	1,840	16,400
CHSI-provided Figure 4	82.5%	+0 = 82.5%	1,030	2,060	17,600
PIC Load Calculation	82.5%	+5.5% = 88%	1,100	2,200	18,400

1.6.5.2 Use of Above-Minimum Specification Torque

On line 7b of the load calculation form that the PIC prepared for the condition of 6,000 feet PA and 32° C (figure 7), the PIC listed a HOGE gross weight of 18,400 lbs, which was 2,000 lbs more than the 16,400 lbs obtained by NTSB investigators. As shown in table 6, to reproduce the PIC's HOGE gross weight, the min spec torque obtained from the CHSI-provided RFMS #8 Figure 4 had to be adjusted upwards 5.5 percent to 88 percent. The average of the two engines' positive torque margins from the topping check performed the day before the accident (3 and 6 percent) was 4.5 percent.

In a July 16, 2009, e-mail, the CHSI DO stated that, "as long as an operator does not exceed the maximum horsepower rating for each engine, then actual available torque for each engine can be utilized to convert to available horsepower for HOGE performance." He further stated that this was "specifically authorized by the approved flight manual and the USFS." The DO provided a copy of a procedure contained in RFMS #8 for using higher topping torque as determined from the helicopter's most recent power check to calculate HOGE performance. This procedure was located in the performance section of RFMS #8 under the heading "Recommended Procedure For Over Specification Engines." The first step in the procedure called for the pilot to "top each engine and determine available torque…use the average of the torques." The second step stated, "using ambient pressure altitude and temperature, determine available engine torque for a minimum spec. engine from…Figure 4….If topping torque is higher, it can be used."

When NTSB investigators inquired whether it was acceptable to use positive torque margins from power checks to gain additional power for performance planning, the USFS indicated in a September 17, 2009, memorandum that, when an 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 calculation. The memorandum indicated that the contract specifically included the wording, "performance enhancing data (Power Assurance Checks, wind charts, etc.) shall not be used and will not be considered for the evaluation of proposals," and although the same wording was not included in the section of the contract governing operations, the omission of this wording did not constitute permission for their use in actual performance planning. Further, the memorandum indicated that "this is clearly understood in the field by pilots and helicopter managers. Any performance enhancing data shall not be used."

During a postaccident interview, the copilot commented that positive torque margins were not used in the load calculations. When asked whether he recalled any malfunctions resulting in a loss of or reduction in power, the copilot stated the following:

> No, the aircraft was running great. I mean we had two strong motors. One of the motors was a plus four and the other motor I think was a plus five, which is pretty significant. All our numbers, based on our load calcs are all based off min spec, meaning zero engines. And when we did our load calc we did not take that plus four and plus five into account. We went back to min spec so that we knew there again, is an additional safety margin built in.

1.6.5.3 Load Calculations

After determining the HOGE gross weight, the PIC's next step in completing the load calculation for the condition of 6,000 feet PA and 32° C was to subtract a weight reduction required by the USFS when carrying nonjettisonable loads.[52] As defined in the Interagency Helicopter Operations Guide (IHOG),[53] a weight reduction is a fixed weight, differing for each make and model of helicopter that provides a margin of safety. The required weight reduction for the S-61 was 550 lbs, although in the load calculations performed by the PIC, a weight of 560 lbs was used.[54] After applying the weight reduction, the PIC then completed the remainder of the form and determined that the allowable payload was 2,552 lbs.[55]

The PIC's allowable load calculation was performed using the altered CHSI-provided RFMS #8 Figure 4, with the min spec torque derived from that figure increased by 5.5 percent and the helicopter empty weight of 12,408 lbs (the weight initially provided by CHSI to NTSB investigators). Table 7 lists the PIC's allowable load calculation and the following four allowable load calculations performed by NTSB investigators:

1. Using the altered CHSI-provided RFMS #8 Figure 4, with no increase to the min spec torque derived from the figure, and the empty weight of 12,408 lbs;
2. Using the correct FAA-provided RFMS #8 Figure 4, min spec torque, and the empty weight of 12,408 lbs;

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[52] A nonjettisonable load is one that cannot be jettisoned by the pilot from his or her normal flight position.

[53] The IHOG is published under the auspices of the USFS, certain bureaus and offices within the U.S. Department of the Interior (DOI), and various state and local agencies for the purpose of promoting interagency standardization of helicopter operations. The guide defines national, interagency helicopter management, and operational procedures for helicopter users from participating agencies.

[54] This 10-lb discrepancy apparently resulted from an error in a USFS publication, where 560 lbs was erroneously printed as the weight reduction for the S-61.

[55] The PIC subtracted 560 lbs from 18,400 lbs, resulting in an adjusted HOGE gross weight of 17,840 lbs. Using RFMS #7 Figure 7-1-2, the PIC determined that the helicopter's maximum gross weight limitation was 17,800 lbs. Since 17,800 lbs was less than 17,840 lbs, the PIC subtracted his estimate of the helicopter's operating weight from it (17,800 – 15,248) to derive an allowable payload of 2,552 lbs.

3. Using the correct figure, min spec torque, and the Carson Helicopters-calculated empty weight of 13,450 lbs; and
4. Using the correct figure, min spec torque, and the NTSB-calculated empty weight of 13,845 lbs.

Table 7. Allowable payload calculations at 6,000 feet PA and 32° C.

	HOGE Weight	Adjusted Weight	Operating Weight	Allowable Payload	Difference from PIC Payload
PIC Load Calculation	18,400	17,800	15,248	2,552	0
Using Min Spec Torque	17,600	17,040	15,248	1,792	-760
Using Correct Figure 4	16,400	15,840	15,248	592	-1,960
Using 13,450 lb Empty Wt	16,400	15,840	16,290	-450	-3,002
Using 13,845 lb Empty Wt	16,400	15,840	16,685	-845	-3,397

1.7 Meteorological Information

1.7.1 Automated Weather Observations

No weather observations were available at the H-44 LZ other than a rudimentary wind indicator consisting of ribbons tied to several trees about 5 to 6 feet above the ground near the LZ. Investigators therefore determined the meteorological conditions in the area surrounding the accident site using official National Weather Service (NWS) meteorological aerodrome reports and USFS Remote Automatic Weather Station (RAWS)[56] observations. Table 8 lists the weather conditions recorded near the time of the accident at the official NWS weather reporting facility closest to H-44 (Redding Municipal Airport, Redding, California) and at the RAWS sites within 25 nautical miles (nm) of H-44.

Table 8. Weather observations recorded near the time of the accident.

Station Name	Station Type	Station Location mi/dir to H-44	Station Elevation (ft)	Observation Time	Temp °C	Wind (mph)
Redding	NWS	50 nm ESE	505	1953	33	SSE 8
Backbone	RAWS	6 nm ESE	4,700	1949	25	SSE 5
Big Bar	RAWS	10 nm S	1,500	1941	30	W 3
Underwood	RAWS	16 nm SW	2,600	1941	27	Calm[a]
SRF53	RAWS	16 nm W	615	1941	29.5	Calm
Trinity Base	RAWS	22 nm ESE	3,207	1950	27	ESE 2

[a] In RAWS reports the wind is reported as calm when the average 10-minute wind is less than 1 mph.

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[56] About 2,200 RAWS, which are strategically located throughout the United States, automatically monitor the weather and provide weather data that assists land management agencies with a variety of projects, such as monitoring air quality, rating fire danger, and providing information for research applications. The RAWS network typically provides hourly values of air temperature, dew point, relative humidity, wind speed, wind direction, precipitation, fuel temperature, and fuel moisture. Fuel temperature and fuel moisture refer to the temperature and water content of the vegetation at a RAWS location.

Table 9 provides weather conditions for the various locations and times of the helicopter's takeoffs from about 1707 to 1941. The wind directions and speeds were estimated by plotting the RAWS station data on a topographical chart and applying a streamline analysis of the winds.[57] The plot of the observations depicted a cyclonic (counterclockwise) circulation in the immediate vicinity of the accident site with sustained wind speeds of 5 kts or less over the area. The circulation pattern was consistent with a thermal low,[58] or a warm core low pressure system associated with the forest fire.

The temperatures in table 9 were estimated by reviewing the RAWS data in conjunction with other available meteorological information—including the synoptic conditions, sounding data, model data, and satellite data—and adjusting for elevation differences, time of day, closeness to the actively burning area of the Buckhorn fire, and other local effects. The PAs were estimated by taking known station pressure and altimeter settings from Redding and correcting for nonstandard temperature. Density altitudes (DAs) were then calculated for each takeoff using the estimated temperature and PA.[59]

Table 9. Estimated weather conditions for various takeoffs.

No.	Location	Takeoff Time	Minutes Before Accident	Temp °C	Wind (kts)	PA (ft)	DA (ft)
1	Trinity	1707	154	30	ESE 8	3,168	5,657
2	H36	1751	110	34	WNW 5-10	1,500	4,000
3	H44	1814	87	29	Calm	6,105	9,072
4	H36	1829	72	33	WNW 5-10	1,500	3,950
5	H44	1843	58	27	Calm	6,106	8,840
6	H36	1854	47	31	W 3-10	1,500	3,800
7	Trinity	1923	18	27	SE 2-8	3,168	5,354
8	H44	1941	0	23	Calm	6,106	8,476

The temperature, PA, and wind speed at H-44 for the accident takeoff were estimated at 23° C, 6,106 feet, and calm,[60] respectively. The calculated DA was 8,476 feet.

1.7.2 Weather Observations from Other Sources

Seven ground witnesses commented on the wind conditions about the time of the accident. Three witnesses reported the wind was calm, while the other four witnesses reported the following wind conditions: light wind out of the southeast, wind 3 to 7 mph out of the south-southeast, light headwind at less than 3 kts, and a possible headwind of 0 to 5 mph. In an

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[57] A streamline analysis is a series of arrows oriented parallel to wind, showing wind motion within a certain geographic area.

[58] A thermal low, also known as a heat low, is an area of low pressure due to the high temperatures caused by intensive heating at the surface. It tends to remain stationary over the source area, with weak cyclonic circulation.

[59] Density altitude is the pressure altitude adjusted for non-standard temperature.

[60] All references to calm in this report refer to wind speeds of 2 kts or less unless otherwise noted. In automated surface observation system reports, the wind is reported as calm when the average 2-minute wind speed is 2 kts or less.

interview, the copilot reported that the wind was 3 to 5 kts from the south-southwest during the third landing at H-44.

The CVR transcript indicates that, about 1931, the helicopter was about 8 miles from H-44 inbound for the third landing, and the H-44 radio operator provided a report of "wind out of the south about three to five." About 1935 and about 1 minute before touchdown, the copilot stated that the OAT gauge read 20° C. About 1939, while the helicopter was on the ground at H-44, the copilot stated that the temperature was 12 to 13 degrees cooler than the temperature of 32° C used for the load calculation that the pilots were referencing.

A passenger in a helicopter that arrived over the accident site about 5 minutes after the accident reported that the smoke from the postcrash fire rose vertically for about 400 to 500 feet before it began drifting to the northwest. Photographs taken by the passenger show a nearly vertical smoke plume at low levels that gradually began to dissipate downwind to the north (see figure 9).

Carson Helicopters does not agree with the NTSB's estimate of the temperature and winds (23° C and calm) at the time of the accident takeoff and takes the position that the temperature and wind observations recorded by the CVR (20° C and southerly winds at 3 to 5 kts) accurately represent the conditions at the time of the accident takeoff.

Figure 9. Photograph of smoke plume at the accident site taken about 1946.

1.8 Aids to Navigation

None.

1.9 Communications

There were no known difficulties with communications.

1.10 Airport Information

The H-44 LZ was located in a natural opening along a ridge in a wide saddle aligned west-southwest to east-northeast, located about 20 miles west-northwest of Weaverville (see figure 2). The elevation at the accident helicopter's landing spot at H-44 was 5,945 feet above mean sea level.[61] The overall open area on the ridge at the time of the accident was approximately 400 feet wide and 250 feet long with numerous isolated trees dotting portions of the ridge. Because of the trees, the usable landing and hover area was limited to an area approximately 200 feet wide by 250 feet long. The surface was generally rocky and uneven, thus allowing for limited landing options within the clear area. The natural opening sloped off gradually and steepened to the south-southeast. Due to the lack of natural vegetation and exposed soil, dusty conditions prevailed, especially at the landing area adjacent to the foot trail.

For helispots to be used by heavy helicopters, such as the accident helicopter, the IHOG required a 30-foot-by-30-foot touchdown pad surrounded by an obstruction-free area, referred to as a safety circle, with a diameter of 110 feet or more. The IHOG required a minimum approach-departure path length equal to the diameter of the safety circle for ridge top locations and stated that "the ideal approach-departure path should be 300 feet long minimum and slightly downhill." The approach-departure path was to be cleared of brush and trees higher than the touchdown pad.

According to interviews with USFS personnel, H-44 was used on a recurring basis by different types of helicopters, including another CHI S-61N (N7011M), between July 31 and August 5, 2008.

1.11 Flight Recorders

The helicopter was equipped with a Penny & Giles Multi-Purpose Flight Recorder that combined a CVR and a flight data recorder (FDR) in one self-contained unit. The solid-state unit was capable of recording 2 hours of digital cockpit audio and at least 25 hours of flight data. Specifically, the CVR portion contained a two-channel recording of the last 2 hours of operation and separately contained a four-channel recording of the last 30 minutes of operation.

The exterior of the recorder sustained significant heat and fire damage, but the interior case did not appear to have any heat or structural damage. Digital FDR data and CVR audio files were successfully downloaded from the memory board.

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[61] This elevation and those given in section 1.12 were determined by a survey of the accident site conducted on August 8, 2008, by a state-licensed surveyor.

For the 2-hour portion of the CVR recording, both channels contained good quality[62] audio information. The 30-minute portion of the recording consisted of three channels of good quality audio information and one channel that did not contain any audio information.[63]

The recording began at 1737:44 as the helicopter was airborne en route to land at H-36 for the first time and ended at 1941:38.7. A summary transcript was prepared of key events heard during the first 1 hour and 30 minutes of the recording. A verbatim transcript was prepared of the time from the engine start following the refueling at Trinity Helibase to the end of the recording (see appendix B).

The FDR recording contained about 77 hours of data. The FDR-recorded data were compared with flight times and takeoff and landing profiles that were obtained from the SkyConnect aircraft tracking system in an attempt to identify the accident flight. No match could be made between the SkyConnect data and the recorded FDR data. The data recovered from the accident helicopter's FDR were recorded at some unknown time before the accident flight. The investigation could not determine exactly when the recording was made or why the FDR had ceased recording contemporaneous data.

1.11.1 FDR Carriage Requirements

In general, large turbine-powered helicopters must be equipped with an FDR that records a minimum of 17 to 26 parameters depending on the aircraft size and manufacture date. The FAA has exempted most older turbine helicopters from the FDR requirements such that very few helicopters registered in the United States have an FDR installed.[64] Specifically, the accident helicopter was exempted from the FDR carriage requirements and was not required to be equipped with an FDR.

1.12 Wreckage and Impact Information

Examination of the area identified by witnesses as the helicopter's point of departure revealed marks in the rock soil consistent in size to the helicopter's tail wheel. The main wreckage was located about 150 yards south-southeast of the departure point at an elevation of 5,880 feet (see figure 10).

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[62] The NTSB rates the audio quality of CVR recordings according to a five-category scale: excellent, good, fair, poor, and unusable. The NTSB considers a good-quality audio recording to be one in which most of the crew conversations could be accurately and easily understood. The transcript that was developed might indicate several words or phrases that were not intelligible. Any loss in the transcript could be attributed to minor technical deficiencies or momentary dropouts in the recording system or to a large number of simultaneous cockpit/radio transmissions that obscured each other.

[63] The three usable channels were the pilot's station, the copilot's station, and the cockpit area microphone.

[64] The requirements for FDRs for aircraft operating under 14 CFR Part 91 are specified in section 91.609 and exempt aircraft manufactured before October 11, 1991. The requirements for FDRs for aircraft operating under 14 CFR Part 135 are specified in section 135.152 and exempt several specific types of aircraft, including the S-61N.

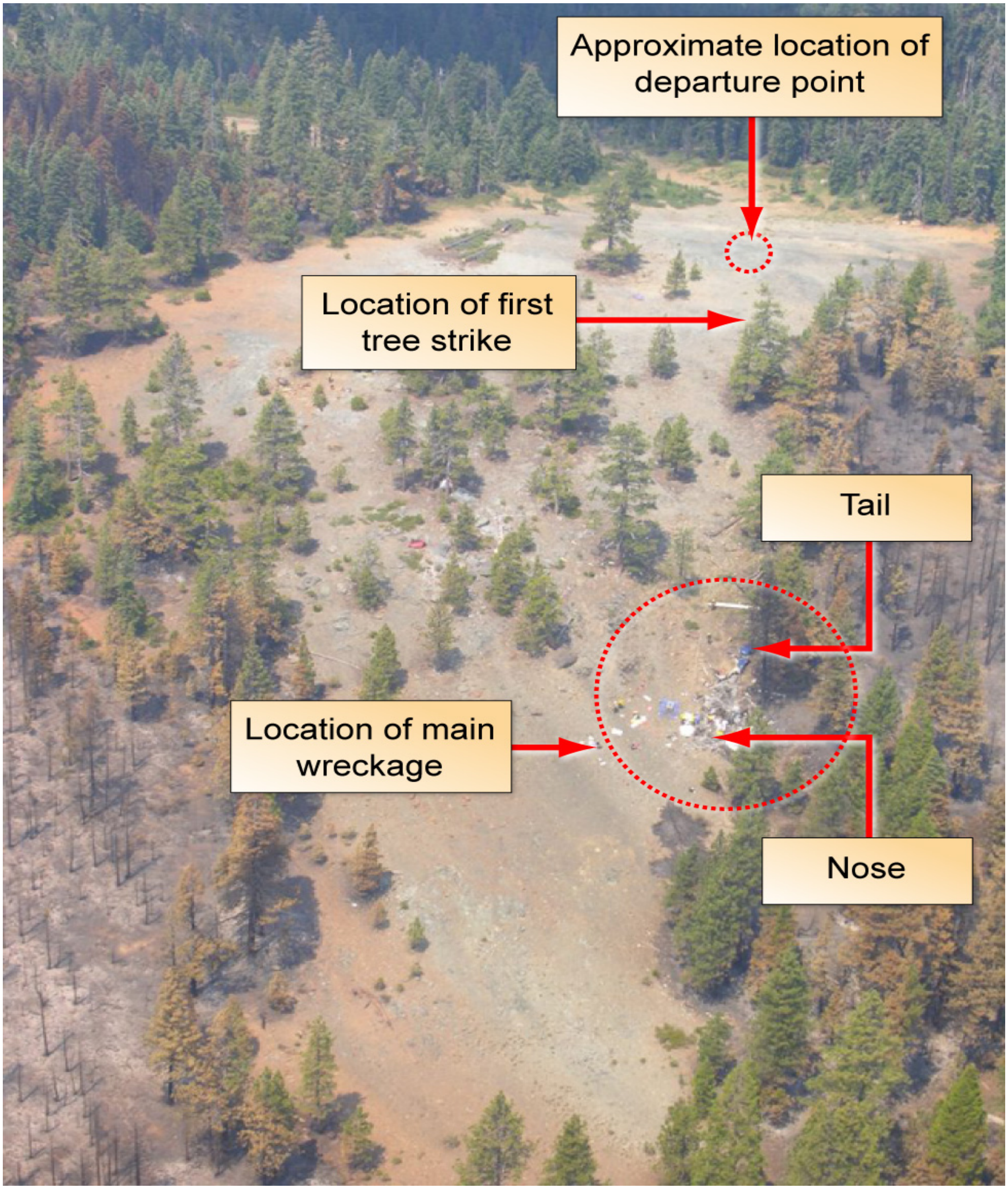

Figure 10. Aerial photograph of accident site.

An assessment of the surrounding trees revealed evidence of main rotor blades contacting several trees between the departure point and the main wreckage. Of these trees, the one closest to the departure point was a pine tree located about 65 yards south-southeast of the departure point. The ground elevation of the tree was 5,931.6 feet, and the height from the base of the tree to the blade contact point was about 49.5 feet. To inspect the blade contact point, the tree was cut down. Examination showed that the tip of a retreating[65] main rotor blade contacted the tree, consistent with the fuselage being to the right of the tree at the time of contact.

The helicopter was found on a downward slope of about 15° to 20°; it was resting on its left side with its nose down slope from its tail boom. The magnetic heading of the wreckage was about 155°. A postcrash fire had consumed most of the helicopter's airframe and structure forward of the tail boom. Solidified molten metal was noted in several areas of the wreckage and in the impact area. Sections of the helicopter's lower fuselage structure, including all fuel tank cells and the cabin flooring, were consumed by the postcrash fire. Most of the forward fuselage, including the cockpit and the electronics compartment, was inverted and consumed by fire (see figure 11).

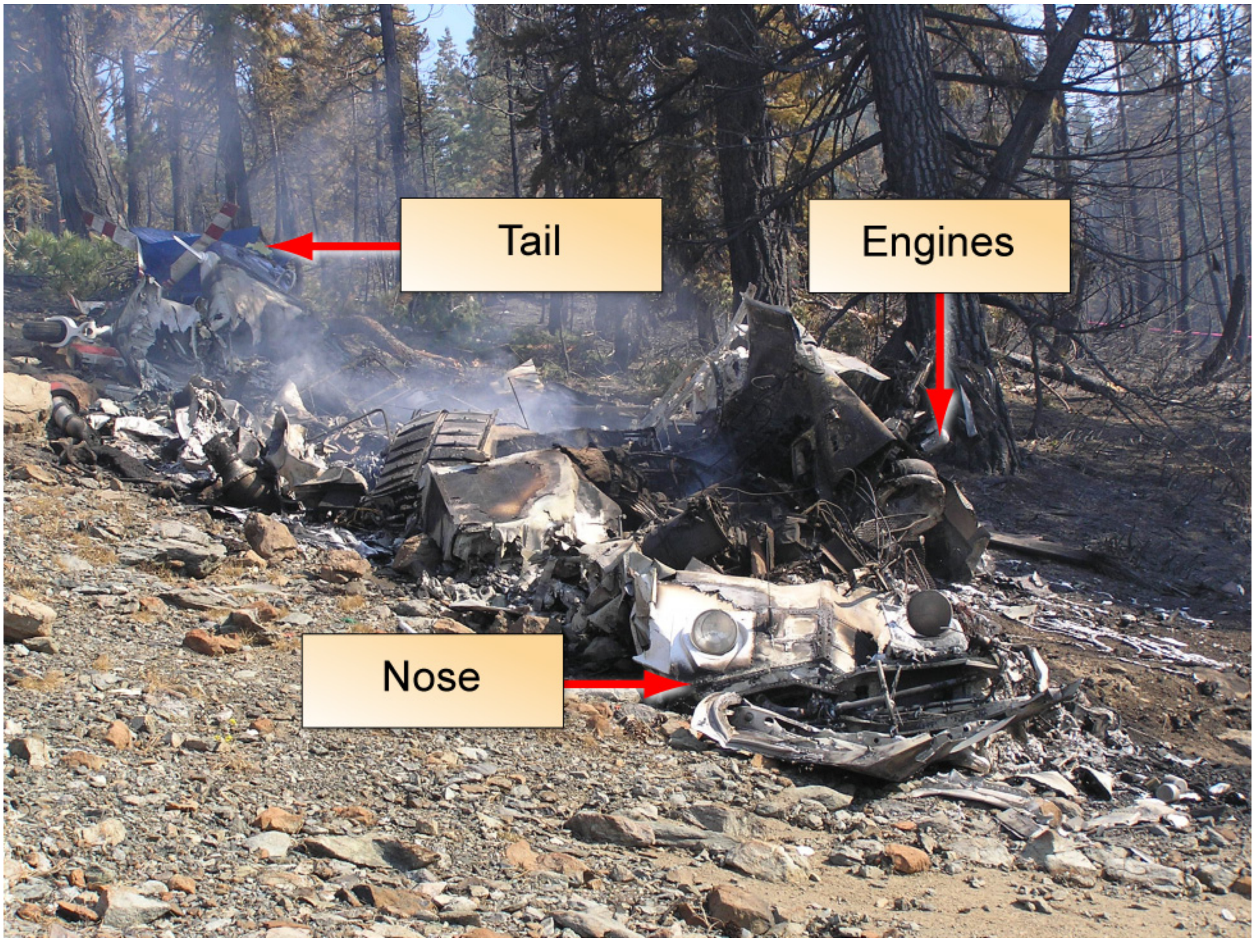

Figure 11. Photograph of main wreckage.

Fragmented sections of all five main rotor blades were located in the immediate area around the main wreckage of the helicopter. A visual assessment of the main rotor blades revealed that all damage was consistent with multiple leading edge impacts with trees.

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[65] The main rotor blades of an S-61 rotate counterclockwise as seen from above looking down at the rotor system. The retreating blades are on the left side of the helicopter, and the advancing blades are on the right side.

The main rotor head was found in the central wreckage area still attached to the main gearbox by the mast. All main rotor hub components displayed evidence of exposure to heat and fire. Examination revealed that the hub assembly was intact and remained connected to the rotor shaft. According to Sikorsky, the damage to the main rotor blades and main rotor hub was consistent with tree and ground impacts occurring at an N_R below normal operating N_R.

Examination of the main gearbox at the accident site revealed that the postcrash fire consumed the magnesium section of the main gearbox; only the steel components, such as gears, shafts, and bearings, remained. No damage was evident to gear teeth on any of the visible gears. The left and right input freewheel units remained attached to the main gearbox; both units were coated with a white material and showed surface oxidation consistent with exposure to fire and heat.

Both engines remained attached to the engine deck and cabin roof by their mounting structures. The engine deck was resting on its left side, pointing downhill at an angle of about 25° to 30°. The inlet of the No. 1 engine was resting on the ground. Both engines exhibited widespread heat and fire damage on their external components. Drive shaft continuity existed from both engines to their respective input freewheel units. The inlet guide vanes of both engines were at or near their closed positions.

The tail gearbox remained mounted to the vertical pylon and displayed no evidence of external damage. Four of the five tail rotor blades remained attached to the tail rotor hub and displayed tears, punctures, and bends, but were intact. One blade was severed with a portion remaining attached to the tail rotor hub; the remainder of the blade was found about 25 feet behind the main wreckage. The lack of damage to the leading edges and minor rotational scarring on the tail rotor blades indicated minimal rotational energy at the time of impact.

1.13 Medical and Pathological Information

At the request of the Trinity County Coroner's Office, the remains of the nine persons fatally injured in the accident were examined by Forensic Medical Group, Inc., Fairfield, California. Their cause of death was determined to be "combined blunt force trauma and thermal injury."

Toxicology tests were performed for the Trinity County Coroner's Office by Central Valley Toxicology, Inc., Clovis, California, on a tissue specimen obtained from the PIC; no drugs or alcohol were detected.

The NTSB obtained a blood sample from the copilot that was drawn at 2112 when he arrived at the hospital and had it tested by the FAA's Civil Aerospace Medical Institute for ethanol and the following major drugs of abuse: benzodiazepines, barbiturates, marijuana, cocaine, phencyclidine, amphetamines, and opiates. All tests were negative.

1.14 Fire

No evidence or witness statements indicated an in-flight fire. The evidence indicated that all fire damage occurred after the helicopter impacted the ground.

1.15 Survival Aspects

The helicopter was equipped with 2 pilot seats in the cockpit and 18 passenger seats in the cabin. As shown in figure 12, five rows of forward-facing double seats with non-locking folding seatbacks were on the right side of the cabin, and six rows of forward-facing single seats with non-locking folding seatbacks were on the left side of the cabin. A double seat faced aft on the forward left side of the cabin. The aft-facing double seat and the first forward-facing single seat on the left side of the cabin were designated for helicopter crewmembers. An aisle separated the passenger seats on either side of the cabin. For reference, NTSB investigators numbered the cabin seats from front to back by row (1 to 8) and from left to right by letter (A to D).

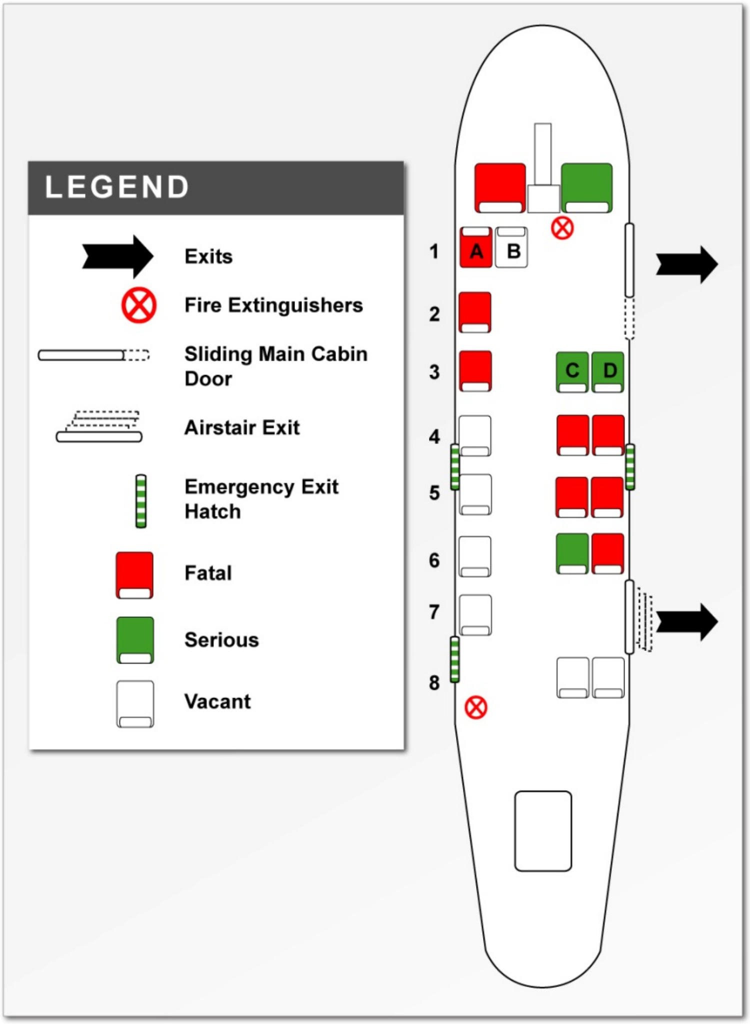

Figure 12. Cabin diagram for N612AZ.

Two main entry doors were located on the right side of the cabin, and two emergency exit hatches were located near the center of the cabin on each side of the fuselage. A third emergency exit hatch was located on the left side of the aft fuselage. The helicopter was configured with 20 pop-out windows (9 on the right side and 11 on the left side of the fuselage) equipped with removable rubber seals that allowed the window frames to be used as emergency exit hatches.

The two cockpit seats were mounted on seat tracks that attached to the cockpit floor and were equipped with four-point restraints manufactured by Pacific Scientific.

All of the forward-facing seats in the cabin were secured on their inboard sides to the cabin floor and on their outboard sides to the cabin wall. Each of the forward facing seats had two inboard legs that were attached to floor-mounted pan fittings by spring-loaded, single-stud hold-down fittings at the base of the seat legs. The outboard seat mounts consisted of seat tracks mounted to the sides of the cabin about 15 inches above the floor. Single-pin fittings at the outboard ends of the seat cross tubes attached each seat to its seat track; the aft pin was spring-loaded and locked the seat into the cabin sidewall seat track. The seatbacks folded forward and were not equipped with mechanical stops to lock them in the upright position.

The forward-facing seats in the cabin were equipped with four-point restraints consisting of a Schroth rotary buckle, a lap belt, and a Y-type shoulder harness. Snap-on hooks at each end of the lap belt connected to the seat, and a single bolt-on fitting attached the shoulder harness to the seatback’s lower cross tube. One section of the lap belt was permanently attached to the rotary buckle. The other section of the lap belt and the two shoulder straps had latches for the occupant to insert into receptacles in the rotary buckle. The buckle unlatched by twisting the buckle cover 90° in either direction. The buckle incorporated a “lost motion” feature, in which the first 30° of rotation in either direction did not activate the unlatching mechanism. This feature was designed to prevent items such as tool belts worn by passengers from inadvertently unlatching the buckle.

The aft-facing double seat in the cabin was mounted on a raised platform and attached to the platform by four short standoffs instead of seat legs. Additionally, the seat’s outboard side was attached to the cabin sidewall. The restraints for this seat consisted of Schroth rotary buckles with lap belts only.

The fatally injured occupants included 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. Those killed included the pilot, who was seated in the left cockpit seat; the safety crewmember (inspector pilot), who was seated in cabin seat 1A; and seven firefighters, who were seated in cabin seats 2A , 3A, 4C, 4D, 5C, 5D, and 6D. The four survivors included the copilot, who was seated in the right cockpit seat, and three firefighters, who were seated in cabin seats 3C, 3D, and 6C.

Interviews of the surviving firefighters revealed that they had been briefly knocked unconscious, and, when they regained consciousness after the crash, the cabin was on fire. One survivor reported that, when he woke up, “there was fire and smoke throughout the cabin,” and he was “soaked in fuel.” Another survivor reported that, when he woke up, the cabin was on fire from its midpoint all the way to the front. Two of the three surviving firefighters reported that objects were lying on top of them. One stated that “something was on top of him pinning him down." The other stated that "there was something on top of him that felt like a seat or an engine" and that "he thought that all the other seats behind him had broken."

All three surviving firefighters reported that they were not familiar with the operation of the rotary buckle on their restraints and that they experienced difficulty releasing their restraints. One survivor stated that he was accustomed to flip latch buckles and did not understand how the rotary buckle released. After the crash, he could not release his restraint buckle, so he pulled the shoulder restraints off and wiggled out of the lap belt. Another survivor stated that he thought that he needed to push a button on the center of the buckle and turn the buckle to release it. When he could not release the buckle, he also pulled the shoulder restraints off and wiggled out of the lap belt. The third survivor stated that he had problems fastening his restraint and described it as "pretty tricky." After the impact, he attempted to release his restraint by turning the buckle, but it would not unbuckle. He pulled the shoulder restraints off and started to crawl out of the lap belt, but his seat separated from the floor and went with him. He freed himself from the seat by pushing the lap belt off of his hips.

Each surviving firefighter evacuated the cabin through a right-side pop-out window. The copilot was unable to recall how he evacuated the helicopter; his first memory of events after the accident was of standing outside the wreckage and then rolling on the ground to extinguish his burning clothing. All of the survivors sustained multiple serious injuries and burns and were transported to hospitals.

1.15.1 Emergency Response

Immediately after the accident, the other firefighters awaiting transport and the helitack crewmembers at H-44 ran toward the helicopter to assist the victims. About 1941, as he was running toward the helicopter, one of the helitack crewmembers radioed Willow Creek Helibase[66] and Trinity Helibase to notify them of the accident. According to a USFS radio log, about 1946, a helicopter[67] was ordered to proceed to the site, "orbit and report back;" this helicopter facilitated communication between ground personnel at H-44 and Trinity Helibase.

The radio log indicated that, about 1952, medics were requested and were en route about 1953. About 1955, the log indicated that four survivors with serious injuries were found. About 2007, the first of three helicopters that were used to deliver medics and supplies and transport the survivors landed at H-44. The second helicopter landed about 2009, and the third about 2025. One survivor was airlifted out about 2035, one about 2056, and two about 2057.

1.15.2 Restraint Installation on Passenger Seats

Examination of the helicopter's maintenance records revealed only one instance in which the installation or removal of seats was documented: the Chart C provided to the accident pilots,

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[66] Willow Creek Helibase, which is located about 21 miles west-northwest of H-44, was the base of operations for a portion of the helicopters assigned to the Iron Complex fire. The helicopters based there included a helicopter on standby for emergency response.

[67] This helicopter was already airborne and proceeding to H-44 on a mission to pick up two helitack crewmembers when the accident occurred.

which listed the installation of 23 passenger seats "with harnesses" on June 27, 2008. No logbook entry corresponded to this installation, nor were there any other logbook entries indicating the installation or removal of seats. Also, no logbook entries or documentation of approval existed for the installation of the four-point harnesses on the forward-facing cabin seats, except for one logbook entry dated July 25, 2008, that stated a two-point lap belt on "crew seat position C-1" was replaced with a four-point harness.[68]

In response to a request from NTSB investigators for documentation of the installation of the four-point harnesses on the cabin seats, CHI provided FAA Form 8110-3, Statement of Compliance with the Federal Aviation Regulations, dated July 12, 2006, which was prepared and signed by a designated engineering representative (DER). The form stated that it was applicable to eight S-61N helicopters that were specified by serial number. The accident helicopter was not owned by CHI when the form was issued and was not listed on the form. No documentation was provided by CHI showing that the form was ever revised to include the accident helicopter's serial number. The form referenced Report No. SR2006-1, titled "Installation of Seat Harnesses," a handwritten document dated July 12, 2006, also prepared by the DER that contained structural design data and analysis that demonstrated the installation of the shoulder harness restraints on the cabin seats met the requirements of CAR 7. The stated purpose of the data was "in support of a major alteration to install shoulder harnesses. The approval is design data approval only and is not installation approval." CHI maintained that the installation of the four-point shoulder harness was not a major alteration because the installation did not affect the structural strength of the seat.

The NTSB requested further clarification from the FAA regarding the installation of the four-point harnesses. In a letter dated June 18, 2009, the FAA asserted that the installation of the four-point harness to existing helicopter seats was a major alteration and that, therefore, CHI needed to complete both a maintenance record entry and FAA Form 337 for the installation. Additionally, for CHI to use or reference Form 8110-3, dated July 12, 2006, on the accident helicopter, the form would have needed to be revised to include the accident helicopter serial number. Furthermore, the FAA affirmed that logbook entries were needed for the installation and removal of seats from the helicopter.

In addition to Report No. SR2006-1, CHI provided a copy of another report by the DER, Report No. CH-8233, which was a formalized document dated September 18, 2008, that contained similar calculations. Report No. SR2006-1 stated that the shoulder harness attached to the "lower seatback horizontal tube" and was routed over the "top seatback horizontal tube;" it did not state that the seatback folded. Report No. CH-8233 stated that the shoulder harness attached to the "seat bottom cross tube" and was routed over the "(folding) seatback." The structural substantiation of the shoulder harness installation contained in both reports calculated that the application of a 4 G[69] load with a 170-lb person occupying the seat would result in a load on the shoulder harness of 452 lbs. Since the rated tensile strength of the shoulder harness to be

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[68] The mechanic who made this entry was apparently referring to seat 2A, as this was the only one of the three seats designated for crewmembers that had a shoulder harness attachment fitting.

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

installed in the helicopter was 1,500 lbs,[70] the shoulder harness was deemed sufficiently strong for installation on the seat. The reports also determined that the harness attachment points on the seats were sufficiently strong for the installation of the shoulder harness. The reports did not address the fact that the seats had non-locking folding seatbacks, nor did they consider the integrity of the seat attachment to the floor, the relationship of the shoulder harness to the seat, or the interaction between the occupant and the seat and restraint.

During an interview, the DER who prepared Report No. SR2006-1 NC and Report No. CH-8233 stated that his knowledge of the design and operation of the seats was limited to drawings and photographs of the seats. No operating manual or instructions on seat operation were available. The drawings showed the material of the seats, and the DER determined the loads that a restrained occupant would impose on the seat structure based on the dimensions and material of the crossbar where the shoulder restraints attached to the seat.

1.16 Tests and Research

1.16.1 Engine Examinations

The No. 1 and No. 2 engines were examined and disassembled at the Columbia Helicopters' facility.[71] No evidence of casing penetrations existed on either engine. No debris or contamination was found during visual examinations of both static filters and the filter elements from both centrifugal fuel purifiers.

Both SVAs were found with their pistons in the fully retracted (vanes closed) position. The feedback cables between each SVA and its associated pilot valve remained connected, and both cables were in positions consistent with a closed position of the SVA. The mechanical linkages between the pilot valves and the FCUs remained connected.

Examination of the No. 1 engine revealed that all of the compressor blades were present and remained connected to the compressor disk. There was evidence of foreign object damage throughout the compressor. Loose fine light brown dirt was observed on all the compressor blades. All of the first-stage compressor blades exhibited leading edge damage. The trailing edges of all of the second-stage compressor blades were found dented near the blade tips. Examination of the third- through the tenth-stage compressor blades revealed that about 5 percent of the blades exhibited tearing on the leading and trailing edges, and about 60 percent of the blades were dented and deformed on their leading and trailing edges. All blades of the first-stage gas generator turbine wheel were found fractured with about 1/3 of the blades' tips separated. All of the second-stage gas generator turbine wheel blade tips showed rub. The power turbine wheel was intact, all blades were present, and the leading edges appeared to be undamaged.

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[70] The restraints installed in the helicopter met the requirements of Society of Automotive Engineering Aerospace Standard 8043B, "Restraint Systems for Civil Aircraft."

[71] This facility was used because the engine manufacturer no longer services or overhauls CT58-140 engines, and it was the only facility in the United States certificated by the engine manufacturer to service and overhaul CT58-140 engines.

Examination of the No. 2 engine revealed that all of the compressor blades were present and remained connected to the compressor disk. The compressor section was noted to have a coating of black material consistent with soot on its blades. Most of the first-stage compressor blades appeared to be undamaged. Very light rotational scoring existed on the tips of the second-stage compressor blades. Examination of the third- through the tenth-stage compressor blades revealed that about 5 percent of the blades were nicked or torn predominantly on the trailing edge tips. The first-stage gas generator turbine wheel was intact, and all blades were present and exhibited a light tip rub. Several of the second-stage gas generator turbine wheel blades had dents on the leading edge tips. The hub and blade assembly of the power turbine wheel appeared to be undamaged.

The first-stage gas generator turbine wheels from both engines were further examined at the NTSB's materials laboratory. Examination of the fractured blades on the No. 1 engine's first-stage turbine wheel revealed similar features on all blades. The fracture surfaces appeared typical of high-temperature stress rupture separations with no indications of progressive cracking, such as that caused by fatigue. The microstructure of a typical blade also showed features and changes consistent with high-temperature exposure in the airfoil region. The original blade coating was intact on most of the blade surfaces but was partially spalled[72] from the blade adjacent to the fractures. Soil deposits were present on the areas of intact blade coating and absent on the areas of spalled blade coating. The blades were intact on the No. 2 engine's first-stage turbine wheel along with the blade coating. No blade cracking or peeling of the blade coating or other indications of thermal distress were visible. The blade microstructure appeared consistent with a typical in-service blade.

The pilot valves from both engines were further examined at the NTSB's materials laboratory and were disassembled by removing the piston and its sleeve from the housing.[73] When the sleeves were removed, investigators noted that their o-rings were brittle and crumbled; some were partially burned. No metallic or fibrous debris existed in either valve. Areas of dark discoloration consistent with heat exposure were noted on the pistons from both pilot valves. These areas were consistent with the dimensions of the SVA ports on the sleeves, indicating both pilot valves were in the closed position during the postcrash fire.

1.16.2 FCU Examinations

The No. 1 and No. 2 FCUs were examined and disassembled at the Columbia Helicopters' facility. The FCUs were further examined at the Hamilton Sundstrand facility, Windsor Locks, Connecticut.

The exterior surfaces of both FCUs displayed discoloration, soot, and ash deposits consistent with exposure to high external temperatures. Both FCUs remained intact. Upon disassembly of the units, the inside of each FCU was found dry and coated with a thin layer of black material consistent with residue from coked fuel. Each FCU's fuel filter was disassembled.

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[72] Spall means to break or split off in small chips.

[73] The piston from the No. 2 engine's pilot valve was removed during the examination at Columbia Helicopters. The piston from the No. 1 engine's pilot valve and both sleeves were removed during examination at the NTSB's materials laboratory.

When each filter screen was held up to a light for visual examination, the light was visible when looking through both main screens and both servo screens. Further visual examination using a microscope revealed fiber strands on the inner surfaces of both main screens and both servo screens.

Examination of the No. 1 FCU revealed that its PRV assembly remained intact. An arbor press was used to separate the PRV's spool from its sleeve with very little force. No evidence of contamination was observed during visual examination of the PRV spool's balance grooves, and, other than soot, the sleeve appeared to be clean. The 3-D cam was found rotated to its full hot (maximum T_2) position and was not axially centered in its housing. The T_2 bellows aluminum dust cover remained intact and lock-wired in place. When the lock wire was cut and the cover removed, the components of the bellows assembly were loose within the housing. When the FCU was turned onto its side, the components (snap retainer ring, spring retainer cap, spring, and bellows) fell out of the housing.[74] One end of the position adjusting screw was fractured around its circumference.

Examination of the No. 2 FCU revealed that its PRV assembly remained intact. An arbor press was used to separate the PRV's spool from its sleeve with very little force. Examination of the PRV assembly using a microscope revealed unidentified fiber strands resting in the second balance groove from the metering end of the spool. No other evidence of contamination was observed. The 3-D cam was found rotated to its nominal temperature position[75] and axially centered in its housing. The T_2 bellows dust cover was not present, but its lock wire remained in place and intact. The components of the T_2 bellows assembly were not present. One end of the position adjusting screw was found fractured around its circumference.

1.16.3 Laboratory Examinations of FCU Components

Components from both FCUs, including the T_2 bellows housings and position adjusting screws, the PRV spools and sleeves, and the fuel filter screens, were further examined at the NTSB's materials laboratory.

Examination of the No. 2 FCU's T_2 bellows housing revealed fragments adhering to the housing in an area corresponding to the size and position of the bellows dust cover. Bench binocular examination of these fragments revealed glass fibers with a cross-weave pattern consistent with those found in an exemplar dust cover.

Examination of the position adjusting screws from both FCUs revealed similar features. Inspection of each screw revealed a fracture that extended around the entire circumference of the

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[74] All parties to the investigation were present during the examination at the Columbia Helicopters' facility. Following the examination, both FCUs were stored at Columbia Helicopters and then shipped to the NTSB headquarters in Washington, DC. Upon opening the shipping containers, the NTSB conducted an inventory of the hardware, which revealed that the following components of the No. 1 FCU's T_2 bellows assembly were not present: aluminum dust cover, snap retainer ring, spring retainer cap, spring, and bellows. A review of a video recording taken by Columbia Helicopters personnel of the packaging of the FCU parts determined that the missing parts were not present at the time of packaging and therefore were not packaged and shipped to the NTSB. For further information about these missing parts, see the document in the public docket for this accident investigation titled "Memorandum of NTSB Administrative Investigation (Previously Released under FOIA)."

[75] The T_2 bellows is sensitive to temperatures from -65° F to +160° F. Its nominal setting is about 59° F.

screw in the area of the internal groove for the retaining ring. The remnant portion of the screw that extended between the circumferential fracture and the open end of the screw was not recovered. Scanning electron microscope examination found that each circumferential fracture contained intergranular globular features and showed no evidence of fatigue cracking. Examination of a prepared and etched section from each fracture revealed a microstructure that contained solid solution melting at the grain boundaries consistent with an overheated aluminum alloy.

The filter screens from both FCUs were examined by inserting a fiber optic light into each screen, viewing the outside of the screen with a 12.5-power glass, and observing the areas on the inner surface of the screen that did not permit the passage of light. Table 10 indicates the estimated plugging[76] of available open area on the inner surface portion of each screen. Estimated plugging is expressed in percent, with 100 percent indicating the available open area on the inner screen surface is completely blocked with foreign material and 0 percent indicating the inner screen surface has no foreign material blockage.

Table 10. Results of FCU filter screen inspection.

Filter	Estimated Plugging of Available Open Area (%)
No. 1 FCU Servo Screen	10
No. 1 FCU Main Screen	25
No. 2 FCU Servo Screen	20
No. 2 FCU Main Screen	50

According to the guidelines in the GE Aircraft Engines CT58 Turboshaft Maintenance Manual, the plugging such as that found on the accident helicopter filters does not require a change in CHSI's filter inspection/cleaning intervals.

Particles were removed from the inner face of each filter screen for scanning electron microscope examinations.[77] The examinations found straight and curled fibers and irregular block-like particles of similar dimensions on each screen with a greater quantity of particles noted on the screens from the No. 2 FCU relative to the screens from the No. 1 FCU. The length and width of the irregular block-like particles measured as large as 120 microns and as small as 20 microns. The diameter of the straight fibers varied in size with typical diameter sizes of 5, 10, 20, and 40 microns measured. The length of the straight fibers measured as long as 400 microns, and the length of the curled fibers measured as long as 600 microns.

Energy-dispersive spectroscopy analysis of a typical irregular block-like particle revealed that it contained elements such as silicon, aluminum, and potassium that are typically found in soil particles. The spectrum of a curled particle contained carbon and oxygen, consistent with organic fibers, such as those in cotton cloth. The spectrum of a straight particle contained silicon

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[76] Plugging is defined as interstices in the filter occluded by particles or assemblages of particles such that high-intensity light will not pass through.

[77] The particles were removed using a piece of 0.3-inch-wide carbon double-sided adhesive tape inserted into the bore of the filter and pressed against the inner face of the screen. The tape was then peeled from the screen.

and minor amounts of aluminum, calcium, iron, magnesium, carbon, and oxygen, consistent with silicate glass such as E-glass, a fiber used in materials such as fiberglass.

Visual examination of the balance grooves in the No. 1 PRV's spool revealed no evidence of particle contamination. Bench binocular microscope and scanning electron microscope examination of the spool revealed each of the four balance grooves contained between two and three fragments of straight rod-like fibers. The typical length and diameter of the straight rod-like fibers measured about 60 and 10 microns, respectively. Energy-dispersive spectroscopy analysis of a fiber produced a spectrum consistent with silicate glass fiber, similar to the spectrum of the straight fibers found in the fuel filter screens.

Visual examination of the balance grooves in the No. 2 PRV's spool with the naked eye revealed no evidence of particle contamination. Scanning electron microscope examination of the spool revealed that an area in one of the four balance grooves contained fragments of curled fibers, the typical thickness of which measured about 20 microns. Energy-dispersive spectroscopy analysis of a fiber produced a spectrum that contained major elemental peaks of carbon and oxygen, similar to the spectrum of the curled fibers found in the fuel filter screens.

To determine whether the fiberglass collector cans located in the helicopter's forward and aft fuel tanks were a potential source of fuel contamination, CHSI submitted a piece of the wall from a collector can to the NTSB's materials laboratory. Scanning electron microscope examination revealed the wall contained a cross-weave pattern of straight rod fibers with a measured diameter of 8 to 10 microns, similar to the diameter of the fibers found in the balance grooves of the No. 1 PRV's spool. Energy-dispersive spectroscopy of a fiber from the collector can produced a spectrum consistent with silicon glass fiber, similar to the spectra of the fibers found in the balance grooves of the No. 1 PRV and of the straight fibers found in the fuel filter screens.

1.16.4 Airframe Fuel Filter Examination

On June 8, 2010, the wreckage was reexamined at Plain Parts, Inc., Sacramento, California, in order to locate the two airframe fuel filters, which had not previously been examined. Both airframe fuel filter assemblies were located within storage bags containing a combination of helicopter wreckage and soil from the accident site. Visual examination of the filter assemblies revealed that both filter housings sustained thermal and structural damage, exposing their respective internal filter elements to the environment. Visual inspection revealed that each filter element had a metal mesh screen indicating that it was a 52-0505-2 element rated at 40 microns.[78]

1.16.5 Cabin Seat and Restraint Examinations

The cabin interior components were examined on October 28, 2008, after the wreckage was relocated from the accident site to Plain Parts, Inc., Sacramento, California. The cabin interior was destroyed by impact and fire damage except for portions of the steel seat frames and

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[78] For further information regarding the airframe fuel filter elements available for installation in the helicopter, see section 1.18.3.3.

some metal components of the seats and restraints. All seat frame remnants were charred, and no fabric or seat cushions remained attached to the frames. Portions of 7 of the 11 forward-facing cabin seat assemblies[79] and the sole aft-facing cabin seat assembly were identified. Regarding the 7 forward-facing seat assemblies, 12 of the 14 seat legs and 13 of the 14 seat bottom cross tubes were identified; 6 of the 12 single-stud hold-down fittings that attached these seat legs to the floor separated from the seat legs,[80] and 11 of the 13 single-pin hold-down fittings that attached these cross tubes to the cabin sidewall separated from the cross tubes. Regarding the sole aft-facing seat assembly, the four fittings that attached the seat to the floor and the two fittings that attached the seat to the cabin sidewall were intact.

The restraint webbing was consumed by fire. The buckles from 15 of the 18 passenger restraints were identified. Ten of the 15 buckles were fully latched with the lap belt latch and both shoulder harness latches engaged.[81] Four of the 15 buckles were partially latched: one had the lap belt latch and one shoulder harness latch engaged, and three had only the lap belt latch engaged. One of the 15 buckles had no latches engaged.

1.16.6 CVR Sound Spectrum Study

The NTSB conducted a sound spectrum study using the 2-hour CVR recording to document significant rotor system and engine sounds heard during the helicopter's various takeoffs and landings. Specifically, the study examined the two previous successful takeoffs and one wave-off from H-44; the accident takeoff attempt from H-44; the three successful takeoffs from H-36; and the landing, shutdown, and successful takeoff from Trinity Helibase. In addition, the study examined the power check performed at H-36.

The audio sounds recorded on the cockpit area microphone channel of the CVR were digitized and examined using a software frequency analysis program to document the sounds. Sound signatures were identified on the audio recording that corresponded to the rotational frequencies of the engines' N_G turbines. In addition to the N_G turbine sound signatures, several tones were identified that could be associated with the rotation of the helicopter's main rotor system. Using conversion documentation supplied by Sikorsky, the recorded sounds were converted from the recorded frequencies to rotational speeds in percent. The data were then depicted by plotting traces of N_R and of the N_G for both engines versus time for each of the takeoffs and the landing. The two N_G traces on each plot are labeled as engine A and engine B, as it was not possible to determine which of the helicopter's engines produced what sound trace on the various takeoffs and landings. Figure 13 shows the plot generated for the accident takeoff.

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[79] Four of the five forward-facing double seats from the right side of the cabin and three of the six forward-facing single seats from the left side of the cabin were identified.

[80] Because the helicopter's floor, including the floor pan fittings for the seat legs attachment to the floor, was consumed by fire, it was not possible to determine whether any of the single-stud hold down fittings separated from the floor pan fittings during the crash.

[81] One of the fully latched buckles had the lap belt latch engaged in the buckle position for a crotch strap.

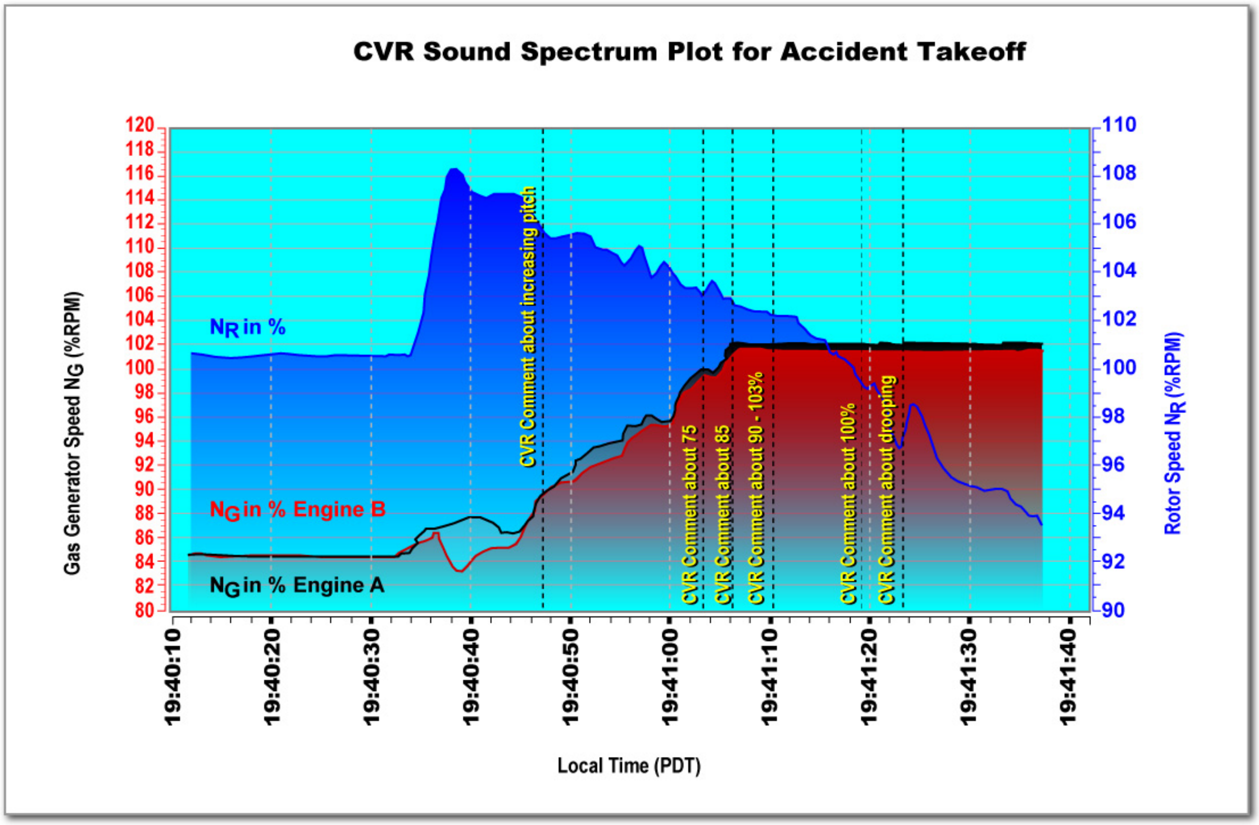

Figure 13. Plot of N_Gs and N_R versus time for accident takeoff.

1.16.7 Hover Study

The NTSB's hover study reviewed the results of relevant HOGE flight tests conducted by CHI in 2006, by Sikorsky for the U.S. Navy in 2008, and jointly by CHI and Sikorsky in 2010. In addition, results of a separate flight test sponsored by CHI in 2009 were reviewed, and the effect of the Fire King tank on HOGE performance was considered.

Flight testing was conducted by CHI in 2006 using an S-61N helicopter equipped with CHI CMRB. Report No. CHI-1000-1 documenting this testing contains a plot of power coefficient (C_P) versus thrust coefficient (C_T) points[82] developed from the flight test data that form the basis for the performance charts presented in RFMS #8. According to CHI, data was collected at wind speeds of 3 kts or less following the industry standard procedure of pointing the helicopter's nose into the wind. A spot check of a curve fit through the C_P versus C_T data showed that, at the accident conditions, the curve agreed with the HOGE weight predicted by RFMS #8 Figure 8.

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[82] The power coefficient (C_P) and the thrust coefficient (C_T) are dimensionless quantities that together define the HOGE performance of the helicopter and allow the power required to HOGE at any combination of weight and density altitude to be determined. C_P is the power required to HOGE, divided by the product of the air density, the rotor disk area, and the cube of the rotor tip speed. C_T is the net thrust required to HOGE, divided by the product of the air density, the rotor disk area, and the square of the rotor tip speed.

Flight testing was conducted by Sikorsky for the U.S. Navy in 2008 using a VH-3A[83] helicopter equipped with CHI CMRB. According to Sikorsky, data was collected with wind speeds of 3 kts or less at four different azimuth angles relative to the wind. On the basis of the data collected during the VH-3A test program, Sikorsky predicted the hover performance of both S-61A (short body) and S-61N (long body) helicopters equipped with CHI CMRBs by applying performance increments and decrements, as appropriate, to account for the configuration differences between the helicopters.[84] At the accident conditions, the Sikorsky prediction for the S-61N shows about 575 lbs less HOGE capability than predicted by RFMS #8.

In August 2010, Sikorsky and CHI jointly conducted flight testing with an S-61A helicopter equipped with CHI CMRBs. Plots of C_P versus C_T points from this flight testing showed considerable scatter, amounting to differences of up to 700 lbs of HOGE lift capability at the accident conditions.

CHI's report on the 2010 joint flight testing attributed the scatter to "an unconventional test technique" selected by Sikorsky "where each loading condition [was] evaluated at four different azimuth angles relative to the wind" rather than the standard test technique of gathering data only with the helicopter's nose pointed into the wind. The report stated that "the use of all azimuth data tends to produce an apparent significant increase in power, even though the wind is less than 3 knots." It further stated that "restricting consideration to a comparison of nose into the wind data from this test program" to data from the CHI 2006 flight tests showed "excellent agreement" and noted that the CHI 2006 flight tests were "taken by the standard method of hover testing with the aircraft nose into the wind."

Sikorsky's report on the 2010 joint flight testing stated that the C_P versus C_T data points from all azimuths "correlated well" to its predicted hover performance for the S-61A based on the VH-3A testing. Sikorsky's use of their predicted hover performance data, in contrast to CHI's selection of only the nose-into-the-wind flight-test data points, resulted in a more conservative prediction of the helicopter's HOGE performance. When questioned by NTSB investigators about the differences between the results from the two companies, FAA engineers stated that the only HOGE performance testing requirement related to wind is that winds must be 3 knots or less. They further stated that there is no requirement for testing at different azimuth angles relative to the wind and that typically all HOGE performance tests are done with the nose into the wind.[85] However, the FAA engineers also stated that testing at different azimuth angles would also be acceptable, since it would result in more conservative performance charts.

A separate flight test was conducted by Whipple Aviation Services on behalf of CHI in November 2009 using an S-61N equipped with CHI CMRBs. The test helicopter was also

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[83] The VH-3A is a military version of the S-61 configured for use as a VIP transport helicopter.

[84] The configuration differences corrected for included fuselage length, tail rotor diameter, and type of landing gear. The VH-3A and S-61A fuselages are about 50 inches shorter than the S-61N fuselage. The S-61A and S-61N have a larger diameter tail rotor than does the VH-3A, and they are also equipped with fixed landing gear instead of the sponsons and retractable landing gear of the VH-3A.

[85] Guidance provided by the FAA in Advisory Circular (AC) 29C, "Certification of Transport Category Rotorcraft," states that "to obtain consistent data, the wind velocity should be 3 knots or less. Large rotorcraft with high downwash velocities may tolerate higher wind velocities." The AC does not mention hover testing at different azimuth angles.

equipped with an adjustable-load, 700-gallon water bucket with a 200-foot long-line for loading water to adjust the weight carried by the helicopter. The helicopter was not equipped with a Fire King tank and neither were any of the helicopters used in the previously discussed flight testing. The Whipple test was intended as a simple check of hover capability at weights and conditions similar to those of the accident takeoff. Consequently, there was no on-board instrumentation with which to record data, so values of torque, N_R, and airspeed were read from the aircraft flight instruments and manually recorded. Also, there was no weather balloon or anemometer package with which to monitor winds at the test altitude, so winds at altitude were assumed to be close to zero based on observed light winds at the surface. While several flight conditions are documented in the report on this test, only two steady-state hover points were identified. The C_P and C_T values obtained from these points were plotted and observed to fall between the performance predicted by RFMS #8 Figure 7 and the more conservative performance predicted by Sikorsky. The report also documented that when the collective was pulled to its upper limit, the rotor drooped to and stabilized at about 94 percent N_R, similar to the N_R behavior for the accident takeoff where N_R stabilized at about 95 percent between 1941:31 and 1941:34 before starting to droop again.

The Carson Helicopters party coordinator stated that the S-61N has the same hover performance with the Fire King tank installed as it does with a long-line weight on the helicopter. He further stated that a flight test conducted by CHI in October 2008 using a Fire King tank-equipped S-61N showed similar performance to that documented in the Whipple test report. A 2-page memorandum describing the October 2008 “informal” flight test included gross weight, atmospheric conditions, N_R, and torque values for certain maneuvers performed. Two maneuvers were described under the heading “hover out of ground effect,” but there is no indication in the description of these maneuvers that the helicopter was in a stabilized hover in near zero-wind conditions at the time that the torque and N_R values were recorded, as would be required to obtain useful data from which to draw any conclusions regarding the effect of the Fire King tank on HOGE performance.

At the NTSB’s request, Sikorsky estimated the effect of the Fire King tank on the hover performance of an S-61N using tank dimensions obtained from the Carson Helicopters party coordinator.[86] Sikorsky calculated a predicted download factor for the tank of 0.54 percent. By Sikorsky’s calculation, at a gross weight of 19,000 lbs, the tank reduced the helicopter’s lifting capability by 103 lbs (0.54 percent of 19,000 lbs).

The maximum weight at which the helicopter could HOGE for all three H-44 takeoffs was calculated using both the performance charts in RFMS #8 and the more conservative performance predicted by Sikorsky. For each scenario, the HOGE weight was reduced by 100 lbs to account for the negative effect of the Fire King tank on hover performance and then compared to the helicopter’s gross takeoff weight to determine the weight margin. For example, for the first takeoff from H-44, subtracting the helicopter’s gross weight of 18,368 lbs from the RFMS #8 maximum HOGE weight of 18,481 lbs yields a weight margin of 113 lbs. The results of these calculations are presented in table 11.

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[86] According to the Carson Helicopters party coordinator, the tank protruded about 22.5 inches beyond each side of the fuselage and was about 107 inches long, extending from fuselage station 213 to 320. The surface area exposed to the rotorwash was calculated to be 33.44 square feet.

Table 11. Results of HOGE calculations.

Takeoff	OAT (° C)	Wind	PA (ft)	Gross Weight (lbs)	RFMS #8 Weight (lbs)	RFMS #8 Margin (lbs)	Sikorsky Weight (lbs)	Sikorsky Margin (lbs)
H-44 1st	29	Calm	6,106	18,368	18,481	113	17,915	-453
H-44 2nd	27	Calm	6,106	18,001	18,634	633	18,066	65
H-44 3rd	23	Calm	6,106	19,008	19,020	12	18,445	-563

The study determined the sensitivity of the HOGE weight to small variations in temperature, headwind, and engine power available to be -80 lbs/°C, +30 lbs/kt, and +108 lbs/percent, respectively. For example, a 1° C increase in temperature, a 1-kt increase in headwind, and a 1-percent increase in power available will change the maximum HOGE weight by -80 lbs, +30 lbs, and +108 lbs, respectively. Conversely, a 1° C decrease in temperature and a 1 percent decrease in power available will change the maximum HOGE weight by +80 lbs and -108 lbs, respectively.[87]

Additionally, the torque developed by the engines during the accident takeoff was calculated from the N_R and N_G speeds obtained from the CVR sound spectrum study. Plots of the calculated torque versus time indicate that the torque callouts by the copilot during the accident takeoff are consistent with the torque calculations. Thus, the power developed by the engines during the accident takeoff matched the power expected based on the N_G values determined from the sound spectrum analysis and the mathematical models of the engines' performance provided by GE.

Finally, the study included the results of simulations of the accident takeoff performed by Sikorsky using the GenHel helicopter simulation computer program. The program used the N_R obtained from the sound spectrum study, as well as the approximate time from liftoff to impact with the trees as determined from the CVR transcript, to compute the flightpath of the helicopter during the accident takeoff, for each of the following conditions:

- HOGE performance from RFMS #8, at an OAT of 23° C.
- HOGE performance from RFMS #8, at an OAT of 20° C.
- HOGE performance predicted by Sikorsky, at an OAT of 23° C.
- HOGE performance predicted by Sikorsky, at an OAT of 20° C.

All simulations were performed using a helicopter gross weight of 19,008 lbs and no headwind. The results of the simulations are shown in figure 14.

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[87] The sensitivity of the maximum HOGE weight to tailwind and crosswind conditions was not determined as data to calculate the effect of these conditions on the power required to HOGE was not available from RFMS #8 Figure 7.

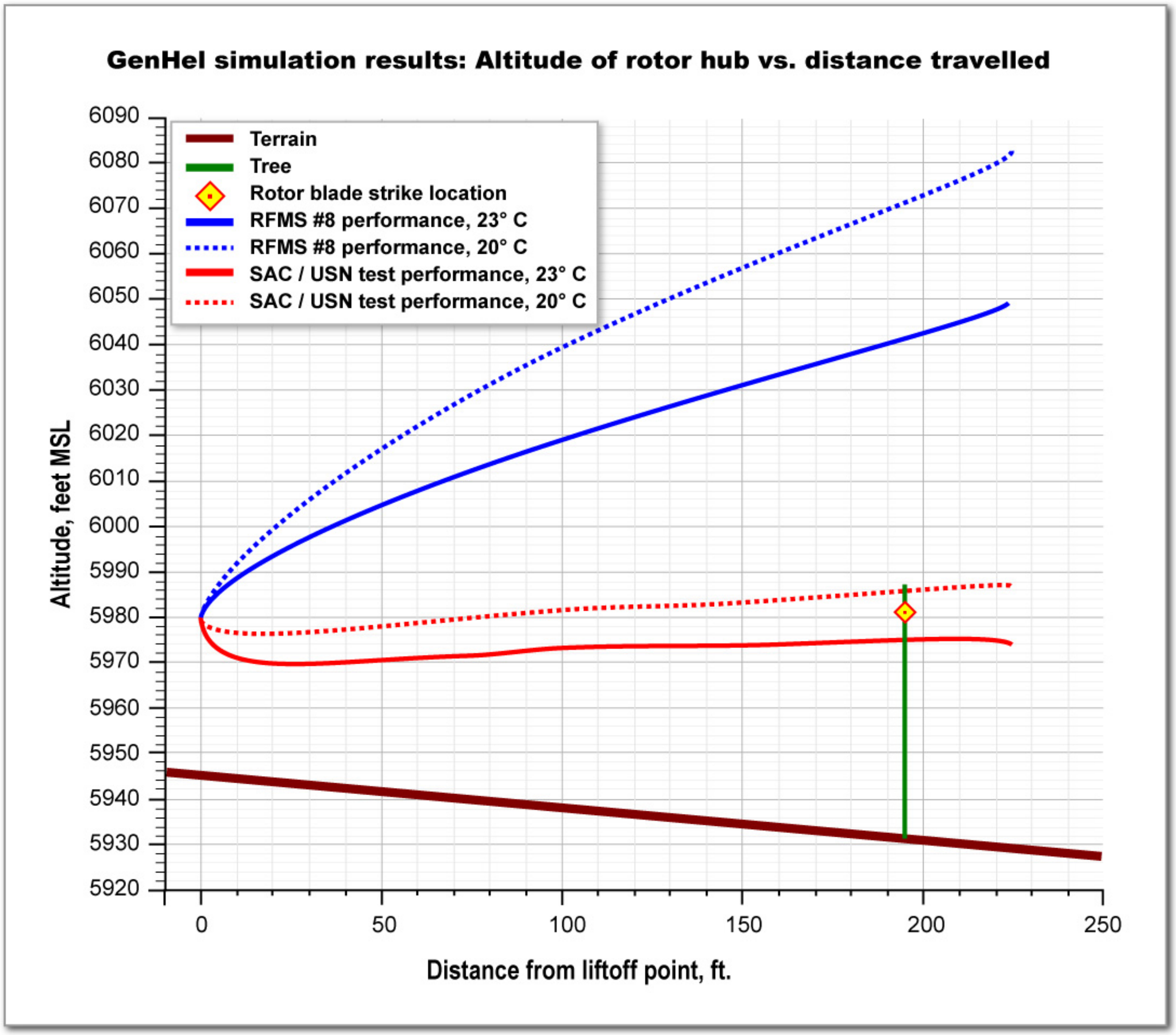

Figure 14. GenHel simulation plots. In all the simulations, the helicopter is assumed to lift off and HIGE at a wheel height of about 20 ft before accelerating forward toward the tree.

1.16.8 Approach and Landing Study

The NTSB conducted a study of the helicopter's last approach and landing at H-44 before the accident takeoff to accurately estimate the helicopter's altitude when the CVR recorded the copilot stating that the OAT was 20° C. Using SkyConnect data, the CVR transcript, the CVR sound spectrum study, and witness statements, the study reconstructed the helicopter's flightpath. The study determined that the helicopter climbed from 6,000 feet to cross the ridge that extended to the northeast from H-44 and was about 6,600 feet or higher when the 20° C callout was made. Applying the dry adiabatic lapse rate of 3° C per 1,000 feet, the temperature at 6,000 feet (the approximate elevation of H-44) was calculated to be about 22° C, which was within 1° C of the 23° C temperature determined by evaluation of the available meteorological information as discussed in section 1.7.1.

1.17 Organizational and Management Information

1.17.1 Carson Helicopter Services and Carson Helicopters

CHSI is headquartered in Grants Pass and is a separate legal entity from CHI, which is headquartered in Perkasie. Both companies are privately owned by the same individuals and both have the same president. CHI maintains a West Coast office in Grants Pass, and the two companies share facilities in that location. CHSI and CHI held individual operating certificates, which were issued by the FAA Portland, Oregon, and Allentown, Pennsylvania, flight standards district offices (FSDOs), respectively.

CHSI held certificates for 14 CFR Part 133 operations and 14 CFR Part 137 operations.[88] Additionally, CHSI held an air carrier certificate issued on March 30, 2006, for Part 135 operations, which permitted conduct of on-demand air carrier operations in the contiguous United States and the District of Columbia. Pursuant to the FAA-approved operations specifications[89] for the Part 135 certificate, CHSI was authorized to carry passengers and cargo in S-61N series helicopters under VFR. Operations under instrument flight rules were prohibited. The accident helicopter was added to CHSI's Part 135 operations specifications on June 3, 2008.

CHI held operating certificates for Part 133 rotorcraft external-load operations and Part 137 commercial agriculture aircraft operations; CHI did not have a certificate to conduct operations under Part 135.

At the time of the accident, CHSI was leasing 10 Sikorsky S-61N helicopters (including the accident helicopter) from CHI. The lease agreement, dated June 8, 2008, stated that, "It is understood by CHSI and Carson [CHI] that CHSI will be operating as a Part 133 Rotorcraft External Lift Carrier AND/OR Part 135 On-Demand Air Carrier" and that "CHSI will exercise full operational control of the Helicopters." It further stated that "All operations shall be conducted in accordance with CHSI's operation specifications."

CHSI started in 2003 as a western operation that almost exclusively performed logging operations. The facilities, located at the Grants Pass Airport, consisted of a welcome counter, several offices, and a maintenance hangar. From 2005 to 2008, CHSI's primary operations during the summer comprised performing contracts for the USFS, mainly water-dropping missions. In the winter, their operations included relocating helicopters to Australia for firefighting and performing a variety of logging and construction missions. The cycle for summer operations started in March with bid preparation for upcoming USFS contracts. CHSI's helicopters each accumulated about 1,400 hours annually.

At the time of the accident, CHSI employed just over 200 people, including 50 pilots (32 of which were qualified to operate under Part 135) and 51 maintenance personnel. CHSI's pilots

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[88] Title 14 CFR Part 133 prescribes operating and certification rules governing the conduct of rotorcraft external-load operations in the United States, while Part 137 prescribes rules governing agricultural aircraft operations within the United States.

[89] Operations specifications contain the authorizations, limitations, and certain procedures under which each kind of operation, if applicable, is to be conducted by the certificate holder.

had an average experience level of more than 12,000 flight hours. The pilots had a normal duty schedule of 12 days on and 12 days off. They were paid a predetermined salary for the year; however, if they flew in excess of 130 days, they would receive a daily rate for each day thereafter. According to several CHSI pilots who were interviewed after the accident, the duty schedule and pay were above average compared to industry standards.

CHSI had a full-time DO and a chief pilot based in Grants Pass who were both hired in the 6 months before the accident. Previously, the vice president had additionally worked in the capacity of chief pilot.

The previous DO left the company in October 2007 after about 3 years of full-time employment. The new DO had previously been the vice president of commercial operations and the chief pilot for Silver State Helicopters, Inc. He had about 4,000 hours total flying experience, of which about 30 hours were accumulated in the S-61. While at Silver State, he accumulated about 6 years of experience as PIC in Part 135 operations.

The new chief pilot had been a pilot with CHI for about 2 years before being hired by CHSI. He had about 10,500 total hours flying experience, most of which involved logging and firefighting operations; he had accumulated about 605 hours in the S-61. Before his employment with CHI, he worked as a pilot for Columbia Helicopters, Inc.

1.17.1.1 Postaccident Actions

In its May 28, 2010, party submission to the NTSB, Carson Helicopters stated that it was unaware “that there were anomalies and irregularities in the weight documents maintained for N612AZ, and in the performance charts in Carson’s, and presumably the accident aircraft’s, flight manuals” until after the accident. The submission also stated that “the reason for this incorrect information could not be determined by Carson” and that “many of the anomalies and irregularities appear to have originated from documents created or assembled by…Carson’s Vice President of Operations,” who was subsequently fired. Further, the submission stated that “in response to these anomalies and irregularities, Carson has modified its operations and procedures, including, but not limited to, improving internal controls over the weighing process, to minimize chances of such anomalies and irregularities occurring in the future.”

1.17.2 U.S. Forest Service

The USFS uses both “call when needed” (CWN) and “exclusive use” (EU) contracts to obtain helicopter resources for firefighting. Separate contracts are written for helicopters used primarily for water delivery, referred to as large fire support (LFS), and helicopters used for passenger transport[90] as well as water delivery, referred to as initial attack (IA). Both Type I and Type II[91] helicopters are used for LFS and IA.

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[90] In USFS contracts, a passenger is defined as any person on board an aircraft who does not perform the function of a flight crewmember or crewmember.

[91] A Type I (heavy) helicopter has 15 or more passenger seats, or 5,000 lbs minimum payload, and 700 gallons minimum retardant capacity. A Type II (medium) helicopter has between 9 to 14 passenger seats, or 2,500 to 4,999 lbs payload, and 300 to 699 gallons retardant capacity. The accident helicopter was a Type I helicopter.

For each contract, a solicitation is posted for public bidding, typically staying open for 30 to 60 days. After the date for receipt of proposals has closed, the USFS contracting officer convenes a technical evaluation team to evaluate each bidder's proposal. The items evaluated are mandatory documentation, aircraft technical assessment, safety/risk management, past performance, organizational experience, and price. The price evaluation considers overall price reasonableness and cost per lb delivered for each specific helicopter being offered. The cost per lb is computed using the best value formula given in the solicitation, which factors the helicopter's payload capability with the bidder's proposed price. If the proposed price for two helicopters is the same, the helicopter with the larger payload capability will have a lower cost per lb and will therefore be considered a better value.

In 2007, the USFS completed a study of its helicopter usage for firefighting. The study revealed that, between 1999 and 2006, helicopters were being activated for a fire season beginning around May 1 with a gradual buildup to the peak of the season, occurring between July 1 and September 1; thereafter, the demand would decrease. At the peak of a fire season, as many as 55 Type I helicopters were in the field. Between 2004 and 2006, as many as 60 Type II helicopters were in the field. Based on the study results, the USFS determined that the addition of EU contracts would increase preparedness costs but would result in a substantial reduction in suppression costs due to decreased use of CWN contracts. The USFS decided that, for 2008, 35 EU water-delivery helicopters for LFS and 33 EU passenger-transport helicopters for IA would be adequate.

The USFS awarded contracts for 40 Type I and 17 Type II EU helicopters in 2008. Including 9 Type II helicopters that were awarded in 2007 on a 2-year contract, the USFS had 66 EU helicopters available for use during the 2008 fire season, of which 34 were on LFS contracts and 32 were on IA contracts.

1.17.2.1 2008 Contract Details

The USFS issued two EU solicitations in 2008 for 25 Type I and Type II helicopters to be used for IA. The first solicitation was issued in March 2008 for 25 Type II helicopters; however, vendors bid only 10 helicopters, of which 9 helicopters were awarded contracts. To obtain more helicopters, a second solicitation was issued in May 2008 for Type I as well as Type II helicopters. The required minimum performance for Type I helicopters was a HOGE capability at 7,000 feet PA and 20° C with a load of 3,000 lbs jettisonable weight, which bidders demonstrated by submitting current weight and balance documents and applicable performance charts. CHSI submitted a proposal and, on June 20, 2008, received five awards for Type I helicopters to be used for IA and based in John Day, Oregon; Missoula, Montana; Dillon, Montana; Ogden, Utah; and Santa Ynez, California (Contract AG-024B-C-08-9354, item numbers 1, 3, 4, 5, and 9, respectively). This was the first time CHSI had been awarded a contract to perform firefighter-transport operations in the United States.

The USFS issued one EU solicitation in 2008 for 34 Type I and Type II helicopters to be used for LFS. The solicitation specified the required performance in three tiers. Tier 2, which required HOGE capability at 7,000 feet PA and 20° C with a load of 3,000 lbs jettisonable weight, was expected to attract S-61 proposals. CHI submitted a bid in response to the solicitation on April 10, 2008. In the bid verbiage, CHI stated that it was offering

10 standard-category helicopters (including the accident helicopter) and 2 restricted-category helicopters. The bid stated that “the offered aircraft are maintained on Carson Helicopters, Inc. Federal Aviation Administration (FAA) 14 CFR Part 133, 135, & 137 operating certificates.” Submitted with the bid documentation were Part 133 and Part 137 certificates under the name of CHI and a Part 135 certificate under the name of CHSI. The USFS did not notice that the Part 135 certificate submitted by CHI was actually CHSI’s certificate and was not aware until after the accident that CHI did not have a Part 135 certificate.

The bid listed CHI’s additional capabilities for the 2008 fire season as follows:

- Improved Category A and B performance for the S-61 (STC #SR02487NY Dated Dec. 5, 2007 [RFMS #7]), which gives a tremendous enhancement in performance for Internal Payload/Passengers at Hot Temperatures and/or High Altitudes.
- FAA-approved Goodrich Rescue Hoist with the capacity of 600 lbs.
- Improved Take Off Power Performance for the CT58-140-1 engine (STC #SR02507NY Dated Feb. 07, 2008 [RFMS #8]).

Additionally, the bid stated that “CHI’s aircraft are the only S-61’s that can legally fly with External Loads at Altitudes up to 14,000’ Density Altitude & Take Off and Land at 12,000’ Density Altitude (See STC #SR02382NY [RFMS #6]).”

On June 6, 2008, CHI received five awards for Type I helicopters to be used for LFS and based in Hemet, Casitas, Van Nuys, San Bernardino, and Mariposa, California (Contract AG-024B-C-08-9340, item numbers 11, 12, 13, 16, and 23, respectively). The accident helicopter was assigned to item number 16 with a host base of San Bernardino, California, for a 150-day period beginning on July 1, 2008. Modification No. 02 to the LFS contract, with an effective date of June 29, 2008, changed the helicopter’s host base from San Bernardino to Trinity Helibase. The USFS requested the modification because of the need for a helicopter at Trinity Helibase that could be used for passenger transport as well as water delivery. According to the USFS, the contracting officer and the national helicopter program manager initiated the modification by calling the CHI vice president and asking if CHI would agree to such a contract modification. The vice president replied that the helicopter was Part 135 compliant (a USFS contract requirement for passenger transport) and that he did not see a problem with the contract modification. The modification required additional equipment to be furnished by CHI, including rappel capability and seating for 16 passengers.

1.17.2.2 Excerpts from 2008 Contract

Regarding aircraft performance specifications to be used for proposal evaluation purposes, clause B-3 of the 2008 contract under the heading “Aircraft Performance Specifications (Minimum)” stated the following:

> Aircraft performance shall be based on minimum engine specification… . Performance enhancing data (Power Assurance Checks, wind charts, etc.) shall not be used and will not be considered for the evaluation of proposals. Only FAA approved charts based on minimum specification performance shall be used.

> The helicopter-equipped weight shall be based on the actual weighing of the aircraft and shall meet the following requirements:
>
> The weighing shall be accomplished prior to submission of the bid. The weighing must take place within 24 months prior to the beginning of the first mandatory availability period (MAP).
>
> Helicopter(s) under initially awarded contract(s) under this solicitation shall remain at or below contracted helicopter equipped weight as bid. Helicopters will be allowed 1 percent above the awarded contracted helicopter equipped weight during the contract option period(s). The aircraft's equipped weight is determined using weight and balance data which was determined by actual weighing of the aircraft within 24 months preceding the starting date of the MAP and 36 months thereafter or following any major repair or major alteration or change to the equipment list which significantly affects the center of gravity of the aircraft. If the government requires additional equipment after contract award no penalty will be assessed. [92]

Regarding FAA certificate requirements, clause C-2 of the contract under the heading "General" stated, in part, that "Contractors shall be currently certificated to meet 14 Code of Federal Regulations (CFR), 133 (External Load Operations), 135 (Air Taxi Operators and Commercial Operations), and 137 (Agricultural Operations), as applicable."

Regarding passenger-carrying flights, clause C-2 of the contract under the heading "Standard Category Helicopters" stated, in part, that "All passenger-carrying flights, regardless of the number of passengers carried, shall be conducted in accordance with the Contractor's 14 CFR Part 135 operations specifications."

Regarding the requirements for seat belts and shoulder harnesses, clause C-4 of the contract under the heading "General Equipment" stated, in part, "Seat belts for all seats. One set of individual lap belts for each occupant… . For aircraft equipped with airline type seats, a single or double FAA approved shoulder harness integrated with a seat belt with one single point metal-to-metal quick release mechanism for each passenger position."

Regarding compliance with operations specifications and 14 CFR Part 91, clause C-10 of the contract under the heading "Operations" stated, in part, the following:

> Regardless of any status as a public aircraft operation, the Contractor shall operate in accordance with their FAA Operations Specifications and all portions of 14 CFR 91 (including those portions applicable to civil aircraft) and each certification required under this Contract unless otherwise authorized by the CO [Contracting Officer].

Regarding computation of weight and balance, clause C-10 of the contract under the heading "Pilot Authority and Responsibilities" stated, in part, the following:

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[92] This paragraph regarding the contracted helicopter equipped weight was also repeated verbatim in clause C-5 of the contract under the heading "Aircraft Maintenance."

> The pilot is responsible for computing weight and balance for all flights and for assuring that the gross weight and center of gravity do not exceed the aircraft's limitations. Pilots shall be responsible for the proper loading and securing of all cargo. Load calculation (Exhibit 13, Form 5700-17/OAS-67) shall be computed and completed by the pilot using appropriate flight manual hover performance charts.

1.17.2.3 Oversight

After a contract is awarded, the USFS performs an inspection to determine whether the contractor has met all contractual requirements. Typically, the inspection occurs at the contractor's main facility; however, many times, because of ongoing fire activity, inspections occur away from the contractor's main base of operation. Inspections consist of reviewing aircraft maintenance records; physically inspecting the aircraft; ensuring that aircraft maintenance technicians meet USFS contractual requirements; inspecting fuel trucks and fuel truck drivers; reviewing pilot records to determine that flight times are accurate and meet USFS requirements; and, when necessary, conducting pilot flight evaluations. When all contractual requirements are judged to have been met, the aircraft, maintenance personnel, and pilots are each issued a USFS card specifying their qualifications.

Regional helicopter inspector pilots, maintenance personnel, and contracting officers visited and inspected the CHSI facilities in Grants Pass on July 3 and 4, 2008. During this inspection, the contract was used as a checklist with which to evaluate CHSI. No problems or concerns were identified.

The USFS inspection for issuance of the accident helicopter's card, referred to as a carding inspection, was performed at the CHI facilities in Perkasie on June 26, 2008. At that time, a USFS Helicopter Data Record, Form FS-5700- 21(a), also referred to as a helicopter card, was completed. An entry on the form indicated that the last weighing was completed on January 4, 2008. The boxes for entries titled "equipped weight" and "bid weight" were empty. The USFS representative who performed the inspection stated that he did not include an equipped weight or bid weight on the form because the USFS was in the midst of modifying its contract with CHI, which would change both weights. The form indicated that authorized uses for the helicopter included the following: passenger and cargo, low-level reconnaissance, external load (sling), rappelling, fire suppression, water/retardant bucket, helitanker, and long-line/remote hook.

1.17.2.4 Inspector Pilots

USFS policy and contract language require that all contractor pilots performing flight services on USFS contracts be approved by an inspector pilot. The USFS inspector pilot process for performing a pilot evaluation flight starts with a review of the contractor pilot's logbook. Following confirmation of adequate flight time and a current medical certificate, the inspector pilot gives a briefing on how the evaluation will be conducted and safety procedures to be followed. Once the briefing and paperwork are complete, the contractor pilot is required to perform a load calculation based on either the contract specifications or, if on an active fire, the conditions of the day. Once the load calculation is verified, the practical portion of the flight evaluation is completed. The inspector pilot uses the Interagency Helicopter Practical Test Standards to evaluate the contractor pilot's performance. In addition to tasks covering areas common to civil helicopter operations, such as hovering and maneuvering by ground references, these standards include tasks that require the pilot to demonstrate the ability to perform various special use activities, such as long-line vertical reference, water/retardant delivery, mountain flying, fire suppression and helitack, rappelling, and other fire-related flight maneuvers.

Typically, an inspector pilot does not reevaluate the tasks performed during an FAA practical test; the USFS evaluations do not determine competency to act as a pilot. As stated in the Interagency Helicopter Practical Test Standards, the practical test is not intended to "duplicate the FAA Part 135 evaluation, but it is recognized that some duplication is inevitable. The Inspector Pilot is not expected to accept that a pilot is proficient simply based on a paperwork presentation…. The Inspector Pilot may select tasks to be demonstrated so as to assure that the pilot meets the appropriate interagency requirement." The inspector pilot should determine whether a pilot is proficient in skills typically not evaluated by the FAA that are necessary to conduct operations in the wildland fire environment.

In 2008, USFS inspector pilots were performing helitack evaluations on all CHSI pilots assigned to helicopters on IA contracts. The USFS assumed that most of the pilots had never performed passenger-transport missions in a fire environment, which have different procedures than the water-dropping missions they routinely performed. CHSI pilots were additionally given a mountain flying evaluation in conjunction with the helitack evaluation. The ground portion of the helitack evaluations focused on performance planning and power checks, load calculations and downloads, judgment and decision-making, responsibilities and authorities, and crew resource management (CRM). The flight portion of the helitack evaluations focused on safety-related skills, such as adherence to fire traffic area requirements, LZ selection, high-density altitude operations, wind recognition skills, mountainous terrain operations, and confined area/slope operations.

According to the USFS, the inspector pilot was on board the accident helicopter to conduct the evaluations detailed above, as well as to evaluate the PIC's CRM abilities as demonstrated by his interactions with the copilot and the USFS helitack crewmembers. The USFS did not require inspector pilots to be carded or type rated in the helicopter in which they were performing an evaluation because USFS inspector pilots did not act as PIC during evaluations. Typically, in the case of aircraft requiring two pilots, such as the accident helicopter, the inspector pilot conducted the flight evaluation from a jumpseat or other approved location in the aircraft that does not have access to the flight controls.

1.17.2.5 Operational Procedures

According to the USFS, while an aircraft is operating under the mandatory availability period of an EU contract, the USFS maintains operational control. However, the PIC remains the final authority for the safe operation of the aircraft. The operational control functions conducted by the USFS, with the concurrence of the PIC, include dispatch, flight-following, load manifests, and safety briefings.

The USFS requires pilots to follow the IHOG procedures for completing performance calculations. The IHOG requires that helicopter load calculations be completed for all flights using HOGE performance data, the purpose of which is to ensure that the helicopter will perform within the limitations established in the RFM and applicable RFMSs without exceeding the gross weight for the environmental conditions in which the helicopter is to be operated. Every day, the pilot should calculate the HOGE performance for the highest altitude and hottest temperature to be encountered. Once the pilot has determined the HOGE computed gross weight, that weight is reduced by an established amount to provide a safety margin for unknown conditions and for maneuvering the helicopter. This reduction in weight is referred to as the download, or weight reduction. Operating within HOGE limitations should allow a helicopter to takeoff, climb, hover, and transition to forward flight while remaining clear of all obstacles.

According to the IHOG, a government representative (for instance, a helicopter manager, project flight manager, or loadmaster) is responsible for providing an accurate passenger/cargo manifest weight. As part of the manifest makeup, a listing of all passengers and cargo being transported is required and may be accomplished on the Interagency Helicopter Passenger/Cargo Manifest or the load calculation form. Hand crews may provide a precompleted crew manifest using their own format as long as the information on the form is accurate and verified. The listing of passengers must include the full name of each passenger, clothed weight of each passenger with personal gear, weight of additional cargo, and the destination. While the helicopter manager or another authorized individual is responsible for completing the manifest before each flight leg, the pilot is responsible for ensuring that the actual payload on a manifest does not exceed the allowable payload on the load calculation.

Regarding safety briefings, the IHOG indicates that, before each takeoff, the PIC shall ensure that all passengers have received a safety briefing. This briefing, which can be delegated to a helitack crewmember, must include the following: required personal protective equipment, entry and exit procedures, operation of helicopter doors, location of emergency equipment, and emergency procedures.

1.17.2.6 Postaccident Carson Helicopters Contract Actions

From August 13 to 18, 2008, a USFS contract compliance inspection team examined six helicopters operating on Carson Helicopters contracts, three of which were on CHI’s LFS contract and three of which were on CHSI’s IA contract. On August 21, 2008, the USFS contracting officer sent a letter notifying CHI of items found during the examinations that were not in compliance with the contracts. A list of “items of concern” was provided for each of the six helicopters inspected. Five of the six helicopters had the following concern listed: “Chart ‘C’ and the equipment list did not reflect the current equipment installed and configuration of the aircraft.”

Between September 26 and October 2, 2008, the USFS issued four cure notices[93] suspending all work on both Carson Helicopters contracts. These notices resulted from the

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[93] A cure notice is issued by the government to inform the contractor that the government considers the contractor’s failure a condition that is endangering performance of the contract. The cure notice specifies a period (typically 10 days) for the contractor to remedy the condition. If the condition is not corrected within this period, the cure notice states that the contractor may face the termination of its contract for default.

reweighing of helicopters on the contracts, which revealed significant discrepancies from the weights Carson Helicopters submitted in its bid proposals (see table 5). The USFS issued the cure notices to provide CHI with "an opportunity to provide an explanation of why the helicopters are not meeting the contract equipped weights."

On November 7, 2008, the USFS issued a cure notice for additional concerns and responded to information submitted by CHI in their reply to the initial cure notices. Regarding the information submitted by CHI, the USFS stated, in part, that "the information we received and reviewed is still unclear… . We continue to have the same questions on the weights of the helicopters as in the initial cure notice." The USFS requested "accurate information in respect to the weights of the helicopters." Regarding additional concerns, the USFS stated, in part, that "the performance charts that were submitted with your response to the cure notice are different than what was provided with your initial [bid] proposal." Specifically, the USFS pointed out that the Takeoff Power Available chart submitted with the response to the cure notice gave torque values that were "significantly less" than those derived from the Takeoff Power Available chart submitted with the bid proposal, and asked, "which Power Available chart is correct and why are they different?"

On February 18, 2009, the USFS terminated both Carson Helicopters contracts for cause because of "Carson's responses to [the] cure notices" and "Carson's failure to comply with the contract terms and conditions." The USFS identified three specific contract violations. The first violation was that 7 of the 10 helicopters under the contracts weighed "more than their equipped weight as bid," putting them in default of clause B-3 of the contracts, which stated that helicopters "initially awarded contract(s) under this solicitation shall remain at or below contracted helicopter equipped weight as bid." The second violation was that 5 of the 10 helicopters under the contracts did not comply with the minimum performance specifications in clause B-3, which required a minimum payload capability of 3,000 lbs for helicopters operating at 7,000 feet PA and 20° C. The third violation was that Carson Helicopters had breached clause C-10 of the contracts with respect to all 10 helicopters "by using in its operations an improperly modified performance chart that was propagated into Carson's internal flight manuals." Clause C-10 required compliance with "all portions of 14 CFR 91 (including those applicable to civil aircraft)," and the USFS identified the relevant regulation as 14 CFR 91.9(b), which states, in part, that "no person may operate a U.S.-registered civil aircraft…unless there is available in the aircraft a current, approved Airplane or Rotorcraft Flight Manual, approved manual material…or any combination thereof."

1.17.2.7 Postaccident Contract Changes

In its May 26, 2010, party submission to the NTSB, the USFS described the changes the agency has incorporated into the 2010 Heavy and Medium Exclusive Helicopters—National Standard Category Fire Support Contract as a result of the accident. These changes included the following:

- Added a requirement for single-lift lever, latch-type seat belts for heavy-transport helicopters.

- Added a requirement that all seats, seatbelts, and shoulder harnesses for all helicopters must either be an original equipment manufacturer installation, approved by STC, approved for installation by FAA Form 8110-3 with all DER supporting engineering substantiation documentation attached, or field approved for installation with supporting FAA Form 8110-3 and all DER supporting engineering substantiation documentation attached.
- Added performance of "HOGE Power Check" and "Special Use Passenger Transport" tasks during evaluation flights for all pilots to determine whether the pilot exhibits the knowledge and skills to properly perform a HOGE power check before landing at or departing from helispots located in confined areas, pinnacles, or ridgelines.
- Instituted contract compliance team assurance checks during the contract mandatory availability period.
- Instituted spot checks witnessed by a USFS maintenance inspector that may include inspections/weighing/tests as deemed necessary to determine the contractor's equipment and/or personnel currently meet specifications.
- Added a requirement that after proposal evaluations and before or post award, all aircraft will be physically weighed with the weighing witnessed by agency aircraft inspectors. The objective of this second and separate weighing is to validate that the contractor's proposed weight as configured complies with the solicitation requirements.
- Clarified in the contract's operations section that performance shall be based upon minimum engine specification. Performance-enhancing data (such as power assurance checks and wind charts) shall not be used. Only FAA-approved charts based upon min spec engine performance shall be used.

On November 29, 2010, the USFS provided an update on its postaccident changes, which stated that in addition to the changes detailed in its party submission, the agency was "currently writing directives to implement a Safety Management System/Quality Assurance program for [US]FS Aviation Operations."

1.17.3 Federal Aviation Administration

The three FAA operating certificates held by CHSI were overseen by the Portland FSDO. The Portland FSDO's area of geographic responsibility included approximately the western two-thirds of the state of Oregon. The POI for CHSI was assigned to all three certificates in 2006. FAA records indicated that the POI oversaw a total of 58 certificates[94] as well as 24 designated examiners. The POI stated that an assistant POI aided him with the oversight of all his assigned operators. He reported that he and the assistant POI visited CHSI about every 1 to 1 1/2 months and that many of their visits comprised the entire day. During a visit, his typical activities

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[94] Of the 58 certificates assigned to the POI, 21 were Part 133 operators, 12 were Part 135 operators, 23 were Part 137 operators, and 2 were Part 141 operators.

included reviewing records, auditing the flight locating system, and giving checkrides for S-61 type ratings.

According to the FAA work program for the CHSI Part 135 certificate, in fiscal year 2008,[95] the POI and principal maintenance inspector (PMI) were required to visit the CHSI facilities a minimum of once that year. A search of FAA records revealed that, during the 12 calendar months before the accident, a total of 43 work activities were entered in the FAA's program tracking and reporting subsystem (PTRS) for the CHSI Part 135 certificate. Of those activities, 13 were operations related, 16 were maintenance related, and 14 were avionics related. Thirty-two of the 43 activities had a location entry, and, with one exception,[96] the location recorded was Grants Pass. Additionally, the FAA records showed that 20 and 3 work activities were entered in the PTRS for the CHSI Part 133 and 137 certificates, respectively. The comment sections of a majority of the PTRS records were blank, precluding determination of what each activity entailed.

FAA PTRS records for the CHI Part 133 and 137 certificates overseen by the Allentown FSDO were also reviewed. During a December 2007 examination of pilot records, an Allentown FSDO inspector discovered a "potential problem" when he noted that, in addition to the 4 pilots listed on the CHI certificates, there were 23 other pilots listed on the CHSI certificates issued by the Portland FSDO. Further investigation by the inspector revealed discrepancies with the number of pilots and aircraft listed in the FAA safety performance analysis system.[97] This finding raised concerns that determining which helicopters, pilots, or certificates were being used for Part 133 and 137 operations would not be possible and that compliance with certain Part 133 regulations could not be ascertained.[98]

After discussions involving personnel from CHI, CHSI, the Allentown FSDO, and the Portland FSDO, Carson Helicopters decided that all helicopters would be moved to the CHSI certificates, one helicopter would remain on the CHI certificates, and CHI would request a deviation to the regulation (14 CFR 133.19) requiring exclusive use of one helicopter. According to FAA records, these actions were completed and the issue was resolved by July 2, 2008.

On June 3, 2008, the accident helicopter and three other S-61N helicopters (N103WF, N61NH, and N725JH) were added to CHSI's Part 135 operations specifications, which increased the total number of aircraft on the certificate from two to six S-61N helicopters. 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. The only PTRS entry indicating that any of these three helicopters had ever been seen by a Portland FSDO inspector was an entry for a ramp check of N103WF conducted on March 25, 2008, by the POI.

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[95] The 2008 fiscal year ran from October 1, 2007, to September 30, 2008.

[96] The exception was an operations inspection conducted on December 7, 2007, in Van Nuys, California.

[97] The safety performance analysis system is the primary tool for data access and analysis used by FAA aviation safety inspectors to assess information about aviation certificate holders (such as air operators, repair stations, aviation schools, and airmen).

[98] Specifically, the Allentown inspector mentioned 14 CFR 133.19, which requires a certificate holder to have exclusive use of at least one helicopter, and 14 CFR 133.37, which requires the certificate holder's chief pilot to give knowledge and skill tests to each pilot it intends to use.

When the accident occurred, all six helicopters listed on CHSI's Part 135 operations specifications were operating on USFS contracts. The accident helicopter was operating on the LFS contract, and the other five helicopters (N4503E, N7011M, N103WF, N61NH, and N725JH) were operating on the IA contract.

1.17.3.1 Postaccident Actions

FAA PTRS records indicated that, on September 19, 2008, while conducting a records inspection at CHSI, the PMI requested to examine maintenance records for the accident helicopter covering the "installation/alteration" of the passenger seats and four-point restraints. The CHSI DOM informed the PMI that "he could not provide the requested records for the entire installation of seats and seat belt/harness because the maintenance was not documented." The PMI conducted an investigation and determined that the passenger seats installed in the helicopter were approved; however, no approval or maintenance record existed for the installation of the four-point restraints. Additionally, the PMI found that four of the other S-61 helicopters listed on CHSI's Part 135 certificate (N103WF, N61NH, N4503E and N7011M) were also altered by the installation of four-point restraints that were mounted to the folding seatbacks of the passenger seats. The PTRS record indicated that the PMI requested that the Seattle ACO conduct an evaluation of the "adequacy of this alteration." A November 30, 2010, memorandum prepared by the rotorcraft program manager of the Seattle ACO stated that the ACO's "review found that the structural substantiation was correct in its determination that the shoulder harness installation met the regulatory requirements."

On October 16, 2008, the Portland FSDO received two letters written by two different S-61 pilots questioning the actions of CHSI before the accident and requesting an FAA investigation. The authors of both letters expressed concerns about the weight information and performance charts that CHSI provided to the flight crew of the accident helicopter. The assistant POI for CHSI completed a complaint investigation into the items mentioned in the two letters and recorded his findings on November 19, 2008.

The record of the investigation listed eight issues raised in the letters[99] and provided a response to each issue. One of the issues listed was that both letters alleged the weights of CHSI's helicopters were "consistently under reported and this data was on the [Chart] C's with the aircraft." The response stated that the findings of the investigation were "unable to support a violation, as it appears that the weight and balance errors were inadvertent," and "all flights with miscalculated weights were as public operations and not under Part 135."

Another issue listed was that "both letters also referred to aircraft charts and whether the correct ones were used." The response stated, in part, the following:

> With respect to the bidding on the contracts, there is no violation. It is not the FAA's concern about what another agency allows within its contract bidding. No violation could be found on actually using the inappropriate chart. The use of the

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[99] The listed issues were: weights of helicopters, bidding on USFS solicitations, performance charts, USFS load calculations, crew training, maintenance, cause of accident, and a CHSI press release.

> correct charts would be a proper Part 135 question, but the accident aircraft has been declared “public use” by FAA headquarters.

A December 2, 2008, PTRS record indicated that, on that date, the PMI finished following up on a potential problem with CHSI’s weight and balance records. The record stated that the previous weights of CHSI’s S-61N helicopters were “brought into question after it was discovered that the scales that were previously used were incorrect/damaged,” and “as a result of this discovery, all fleet aircraft were reweighed.” The reweighing revealed that the previous weights of the helicopters were an average of 500 lbs lower than their actual weights. The record stated that “no evidence of CFR violation [was] noted. However, this is a safety issue that will be closely monitored.”

On January 30, 2009, the manager of the Portland FSDO wrote a letter to the CHSI vice president, notifying him that the FAA planned to conduct “a compliance audit of your company’s operations under parts: 133, 135 and 137.” The letter stated that the purpose of the audit was “to verify that [CHSI] is able to operate safely and in compliance with applicable requirements.” On March 10 through 12, 2009, a team of FAA inspectors (the POI, assistant POI, PMI, and the principal avionics inspector) performed the initial phase of the inspection at the CHSI facilities “to ensure that CHSI has processes and procedures in place necessary to continue operations as required by 14 CFR, Part 119 and 135.”

An April 10, 2009, report detailed the results of the initial phase of the compliance audit, listing 12 maintenance findings and 5 operations findings, the majority of which were recommendations for improvements to CHSI’s manuals and procedures. The report stated that the initial phase would be complete as follows:

> When all proposed revisions to CHSI manuals and programs are accepted/approved. Following the completion of the initial phase, the inspection team will conduct field and shop surveillance to determine if [CHSI’s] processes and procedures are effective in actual operations and are appropriately complied with.

On September 2, 2009, the follow-up surveillance called for after completion of the initial phase of the compliance audit was transferred to the FAA principal inspectors’ fiscal year 2010 work program “as enhanced analysis, surveillance, risk identification and mitigation.”

1.18 Additional Information

1.18.1 Previous Accident Involving HOGE Margin

In its May 28, 2010, party submission to the NTSB, Sikorsky provided information about a May 30, 2002, accident in which a U.S. Air Force Reserve HH-60G helicopter crashed during an attempt to rescue an injured mountain climber at an altitude above 10,000 feet on Mount Hood, Oregon. The U.S. Air Force Safety Investigation Board investigated the accident with the technical assistance of Sikorsky.

The investigators obtained and analyzed raw high-quality news video footage of the accident to produce a record of N_R throughout the sequence of events. The analysis showed that the helicopter successfully hovered out of ground effect with no rotor droop during the first hover on scene. During that hover, the helicopter lowered a 200-lb crewman and a litter and equipment weighing about 50 lbs to the surface. The helicopter then departed the hover and orbited for about 15 minutes, consuming approximately 250 lbs of fuel. Then, at a gross weight about 500 lbs lighter than the previous hover, the helicopter returned to the exact same location and altitude to retrieve the litter. As the pilot was making very small control inputs to position the helicopter for hoist recovery, N_R began to droop at a rate of approximately 1.18 percent per second, indicating that the power required had exceeded the power available. When N_R drooped below 90.7 percent, yaw control (tail rotor control) was lost, and the helicopter spun out of control, impacting and rolling down the mountain. The investigation determined that the helicopter's engines were producing full power throughout the accident sequence.

Sikorsky analyzed the helicopter's predicted performance based on actual ambient conditions and aircraft gross weight versus N_R. This analysis predicted a loss of tail rotor control would occur if N_R dropped to less than 91 percent. Postaccident calculations of the power required and power available indicated that, at the ambient PA and temperature, in calm winds, the helicopter would have had a positive HOGE margin of about +3.4 percent. However, with a slight tail wind of 3 to 5 kts, the HOGE margin became negative. The performance analysis supported a conclusion that the first hover was successful because it was conducted in calm winds; however, the second attempted hover was not because the wind had shifted sufficiently to create a negative HOGE margin and subsequent rotor droop. This accident demonstrated that small changes in atmospheric conditions can affect performance when a helicopter is operating close to the power available/power required margin.

1.18.2 Pilot Interviews

NTSB investigators interviewed five former CHSI pilots following the accident. Four of the pilots reported that, while it was not normal to reach engine topping during passenger-carrying operations, it was a more common occurrence during water-hauling or logging operations. One pilot stated that, "when you reach topping, you jettison. This is a daily experience that pilots deal with when carrying water rather than passengers." Another pilot stated the following:

> Logging and passenger operations provide an entirely different environment. In logging, the aircraft has no interior or seats, bare metal and wiring, and carries only what is necessary for the operation. Time is money, and logging is a timed event paid by board foot. By contrast, passenger operations are [paid] by the hour. You cannot jettison loads. Topping is normal in logging, but only as an emergency measure. It is not normal with passengers, where calculations are based on takeoff power rather than topping.
>
> In earlier times, pilots would try to carry more than the helicopter was capable of carrying. Therefore, load calculations are now made as a guide and are rigorously held to in Part 135 operations. With firefighting operations, when carrying water, these calculations are not etched in stone. You trim for comfort, check power

> available before loading water, then take on water. For example, you pull in 81% torque as the best power before drooping, therefore at 71% torque you stop loading water.

The pilots reported that, typically, on water-dropping missions, an in-flight power check was performed to verify the helicopter's available power before filling the Fire King tank. To perform this power check, the pilot increased power by pulling up on the collective until the N_R began to droop. The pilot then noted the engine torque attained for use as a reference. While hovering over the water reservoir and pumping water into the tank through the snorkel, the pilot monitored the torque gauge, and when the torque reached about 10 percent below the reference engine torque determined by the power check, the pilot shut off the pump and departed. The pilots indicated that this practice is common in the industry and is considered a safety check to ensure that enough power exists to safely accomplish a mission.

1.18.3 Additional Information Regarding FCU Contamination

During the course of its investigation, NTSB investigators learned of a condition in which contaminants in fuel can cause N_G fluctuations, erratic operation, or slow acceleration of CT58-140 engines. The condition occurs when foreign solid contaminants smaller than 40 microns enter the FCU, pass through the fuel filter, and lodge within the PRV, causing the PRV's spool to stick within its mating sleeve.

Investigators reviewed a November 10, 2004, Hamilton Sundstrand report regarding the engineering evaluation of two PRVs that were found stuck. One PRV came from the FCU of an S-61 involved in a December 16, 2002, accident in Canada.[100] According to the Transportation Safety Board of Canada's report on the accident, the helicopter's No. 1 engine lost power due to a mechanical failure, and the No. 2 engine did not respond quickly enough to the increased load demand from the main rotor, resulting in a hard landing on a road. According to the report, the combination of a misadjusted SVA, incorrect FCU topping settings, and a sticking PRV prevented the No. 2 engine from assuming the total load.

The second PRV came from an FCU that was removed from a CHI S-61 in 2003 due to N_G fluctuations, and the Hamilton Sundstrand report stated that examination of this PRV "under an optical microscope revealed a notable amount of silt-like particulate on the mating diameters" of the spool and sleeve. Chemical analysis of a sampling of the debris showed "a significant quantity of silica (glass) fibers," as well as the presence of oxides of aluminum and silicon.

Regarding the PRV from the 2002 Canadian accident, the report stated that, during examination under an optical microscope, "a considerable amount of debris" was noted in the four balance grooves of the spool. Chemical analysis of a sampling of the debris revealed "mainly abrasive mineral oxides of silicon, aluminum, calcium and magnesium as well as silica (glass) fibers roughly 0.0001 inch [about 2.5 microns] in diameter." The size of the angular

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

oxides was roughly 25 microns. The report concluded that “the ingestion of materials, mainly hard angular oxides and silica (glass) fibers, into the tight clearance between the spool and sleeve is cited as the likely cause of the stick-slide operation and/or temporary seizure of the two PRVs.”

Additionally, on May 12, 2008, an FCU was removed from the accident helicopter due to “the engine hanging at 50 percent torque.” A replacement FCU was installed, and the helicopter was returned to service. The FCU that was removed was sent to Columbia Helicopters for repair. Upon disassembly, this FCU was found contaminated with metal particles. According to Columbia Helicopters, in accordance with normal shop procedures, the parts were cleaned, and no samples of the contaminants were retained.

1.18.3.1 Research on History of FCU Contamination

NTSB investigators queried the Aviation Safety Communiqué (SAFECOM)[101] database for GE CT58 engine events involving FCUs. A search of the database from January 1, 2003, to the day of the accident revealed six SAFECOM reports that indicated an FCU was replaced, but none provided any information on findings from FCU examinations.

NTSB investigators also queried the FAA service difficulty report (SDR)[102] database for events involving JFC-26 FCUs. From January 1, 1996, through December 31, 2009, there were six SDRs for the JFC-26 FCU. Four of the six SDRs indicated the FCU was identified as the cause of low engine power or failure of the engine to respond to power demand; none of these four SDRs provided any information on findings from examination of the FCUs that were replaced. Two of the six SDRs reported FCU contamination; one SDR stated that contamination was found within the FCU and the fuel purifier, while the other SDR stated that contamination was due to “material breakdown from filter.”

NTSB investigators reviewed data from 583 Columbia Helicopters’ work orders on JFC-26 FCUs from January 1, 2005, through December 31, 2008. During this period, Columbia had removed 159 FCUs from its own helicopters for routine overhaul or for unscheduled repairs. During this same period, customers (government and commercial) had sent Columbia a total of 424 FCUs for routine overhaul or for unscheduled repairs. The records were reviewed for repetitive items, maintenance trends, and discrepancies relating to contamination.

Of the 159 FCUs removed from Columbia’s helicopters, 63 units (40 percent) were removed for unscheduled work. Contamination (typically metal) was found in 17 of the 63 FCUs in the areas of the filter and the PRV. The specific amount or size of any contamination found was not documented in the work orders, and none of the work orders described the contamination as fiberglass.

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[101] This database fulfills the Aviation Mishap Information System requirements for aviation mishap reporting for the DOI agencies and the USFS. Categories of reports include incidents, hazards, maintenance, and airspace. The system uses the SAFECOM Form AMD-34/FS-5700-14 to report any condition, observation, act, maintenance problem, or circumstance with personnel or the aircraft that has the potential to cause an aviation-related mishap.

[102] A service difficulty report (SDR) is a report of an occurrence or detection of each failure, malfunction, or defect as required by 14 CFR 121.703 and 121.704.

Of the 424 FCUs removed from customer helicopters, 152 units (36 percent) were removed for unscheduled work. Contamination (typically metal) was found in 38 of the 152 FCUs in the areas of the filter and the PRV. Of the 38 units, 8 were noted as having contamination throughout the unit. The specific amount or size of any contamination found was not documented in the work orders, and none of the work orders described the contamination as fiberglass.

1.18.3.2 Examination of FCUs from Other Helicopters

On July 17, 2009, a Croman SH-3H helicopter,[103] N613CK, sustained substantial damage when it collided with a water tank during takeoff near Willow Creek, California.[104] The helicopter was operating as a public aircraft under contract to the USFS, and the purpose of the flight was water dropping. Although the flight crew did not report a loss of engine power during the event, the FCUs were removed from the helicopter's engines for examination. Functional testing of both FCUs conducted at Columbia Helicopters' facility under the direct supervision of NTSB investigators determined that each unit was capable of supplying sufficient fuel to its respective engine. During testing, both PRVs functioned as designed and moved freely when commanded. A fuel sample was obtained from one of the FCUs,[105] and visual observation of the sample revealed that it was contaminated with particles. Examination of several particles by the NTSB's materials laboratory determined that they ranged in size from 18 to 380 microns and had material characteristics consistent with nonmetallic organic material and lead.

On August 19, 2009, a Sikorsky S-61N helicopter experienced a partial loss of engine power on approach to land and landed uneventfully at a military airfield in Afghanistan. The operator reported that, on normal approach, the pilot lowered the collective to about 20 percent torque and then reduced N_R to about 103 percent. The No. 1 engine's torque immediately dropped to 10 percent, its N_G dropped to 52 percent, and its T_5 increased to about 750° C. The operator removed the FCU from the left engine and sent it to Columbia Helicopters' facility, where it was examined under the direct supervision of NTSB investigators. Inspection revealed that the fuel filter assembly was not present,[106] particle contamination existed throughout the FCU, and the PRV's spool was stuck within its sleeve. Examination of several particles by the NTSB's materials laboratory determined that many particles were larger than 40 microns and had varying material characteristics, including characteristics consistent with aluminum alloy, stainless steel, nickel, cadmium, plastic, and nonmetallic organic material.

1.18.3.3 Development of 10-Micron Airframe Fuel Filter Element

A June 19, 2006, letter from GE Aviation to Sikorsky stated that "GE has recently been informed that S-61 aircraft can be equipped with either a 40-micron or an alternative 10-micron

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[103] The Croman SH-3H is equipped with the same FCUs as the Sikorsky S-61N.

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

[105] The other FCU did not contain any residual fuel.

[106] According to the operator, maintenance personnel removed the filter assembly before sending the FCU to Columbia Helicopters.

aircraft fuel filter element." The letter cited Hamilton Sundstrand's 2004 report with its finding of contaminants (fiberglass and hard angular oxides) "ranging in size from 2.5 to 25 microns" in PRVs as support for its suggestion that Sikorsky "issue a service document to S-61 aircraft operators…recommending that they use 10-micron aircraft filter elements and discontinue use of the 40-micron elements."

According to Sikorsky, until 2010, the civil parts catalog for the S-61 did not contain a 10-micron fuel filter element; however, there were two types of paper, disposable 10-micron elements (part number [P/N] 52-01064-1 and -2)[107] designed for military use that were also used by a number of civilian operators. The civil parts catalog listed a metal, cleanable 40-micron element (P/N 52-0505-2), which was the type installed in the accident helicopter.

In September 2006, representatives of Camar Aircraft Parts Company, a parts distributor specializing in supplying parts for out-of-production aircraft such as the S-61, visited CHI's Perkasie facility. According to an e-mail from one of the representatives, during this visit, CHI personnel reported that the company was having difficulty obtaining the P/N 52-01064-1 and -2 (10-micron) elements and was not satisfied with the metal, cleanable P/N 52-0505-2 (40-micron) element because it was expensive and difficult to clean. Additionally, CHI wanted to install a 10-micron filter instead of a 40-micron filter because it "had several cases of fuel contamination, which had led to an extra cost of at least $50,000 due to unscheduled removals of various fuel related components." At the end of the visit, CHI gave the Camar representatives a P/N 52-01064-1 (10-micron) fuel filter element so that Camar could forward it to Falls Filtration Technologies, a company that manufactured filters, to investigate the possibility of producing an FAA-approved replacement part.

Falls Filtration Technologies developed a 10-micron paper, disposable filter element (AM52-01064-1) to be installed in place of the 52-01064-1 and 52-0505-2 fuel filter elements and received an FAA parts manufacturer approval (PMA)[108] on August 31, 2007, for installation of the element on Sikorsky models S-61L, S-61N, S-61R, and S-61NM with GE CT58-110-1, -110-2, -140-1, and -140-2 series engines installed. According to documentation obtained from Camar, CHI purchased 100 of the 10-micron filter elements in November 2007. In an e-mail, the CHI chief inspector stated that the 40-micron metal, cleanable filter elements were being replaced with the 10-micron paper, disposable filter elements on an attrition basis. He explained that the company felt no urgency to replace the filter elements because, until January 2010, CHI was "under the assumption" that the AM52-01064-1 filter elements were 40-micron filter elements, not 10-micron filter elements.

On January 15, 2010, Sikorsky issued Alert Service Bulletin No. 61B28-1, applicable to all S-61 series helicopters, which provided instructions to replace the forward and aft fuel system P/N 52-0505-2 (40-micron) fuel filter elements with P/N AM52-01064-1 (10-micron) fuel filter elements. On February 2, 2010, the bulletin was superseded by Alert Service Bulletin

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[107] Sikorsky reported that both these 10-micron elements were made of paper, and the major difference between them was that the -1 had more pleats than the -2.

[108] A PMA is a combined design and production approval for modification and replacement parts that allows a manufacturer to produce and sell these parts for installation on type-certificated products.

No. 61B30-16, which revised the recommended compliance time to within 150 flight hours from release of the bulletin. The background information provided in the bulletin stated the following:

> Due to instances of contaminants being found in the fuel control pressure regulating valves, the potential existed for possible seizures of the fuel control pressure regulating valves. The fuel system currently operates with a 40 micron fuel filter installed. 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.

1.18.4 Comparison of Pertinent 1961 Helicopter Certification Standards with Current Standards

When the accident helicopter was certificated in 1961, it was required to meet the certification standards in CAR 7. Regarding emergency landing conditions, CAR 7.260 stated, in part, the following:

> (a) The structure shall be designed to give every reasonable probability that all of the occupants, if they make proper use of the seats, belts, and other provisions made in the design…will escape serious injury in the event of a minor crash landing[109]…in which the occupants experience the following ultimate inertia forces relative to the surrounding structure:
>
> 1. Upward 1.5 G (downward 4.0 G)
>
> 2. Forward 4.0 G.
>
> 3. Sideward 2.0 G.

Regarding seats and safety belts, CAR 7.355(a) stated the following:

> At all stations designated as occupiable during take-off and landing, the seats, belts, harnesses (if used) and adjacent parts of the rotorcraft shall be such that a person making proper use of these facilities will not suffer serious injury in the emergency landing conditions as a result of the forces specified in CAR 7.260.

Regarding fuel tank construction and installation, CAR 7.420(b) stated that “fuel tanks and their installation shall be designed or protected so as to retain the fuel supply without leakage when the rotorcraft is subjected to the emergency landing conditions specified under CAR 7.260.”

Transport-category helicopters manufactured today are required to meet the certification standards in 14 CFR Part 29. Regarding emergency landing conditions, section 29.561 states, in part, the following:

> (b) The structure must be designed to give each occupant every reasonable chance of escaping serious injury in a crash landing when—

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[109] CAR 7 does not contain a definition of the term “minor crash landing.”

> > (1) Proper use is made of seats, belts, and other safety design provisions;
> >
> > (2) The wheels are retracted (where applicable); and
> >
> > (3) Each occupant and each item of mass inside the cabin that could injure an occupant is restrained when subjected to the following ultimate inertial load factors relative to the surrounding structure:
> >
> > > (i) Upward—4 G.
> > >
> > > (ii) Forward—16 G.
> > >
> > > (iii) Sideward—8 G.
> > >
> > > (iv) Downward—20 G, after the intended displacement of the seat device.
> > >
> > > (v) Rearward—1.5 G.

Regarding emergency landing dynamic conditions, 14 CFR 29.562 states, in part, the following:

> (b) Each seat type design or other seating device approved for crew or passenger occupancy during takeoff and landing must successfully complete dynamic tests or be demonstrated by rational analysis based on dynamic tests of a similar type seat in accordance with the following criteria. The tests must be conducted with an occupant simulated by a 170-pound anthropomorphic test dummy…sitting in the normal upright position.
>
> > (1) A change in downward velocity of not less than 30 feet per second…. Peak floor deceleration must occur in not more than 0.031 seconds after impact and must reach a minimum of 30 G's.
> >
> > (2) A change in forward velocity of not less than 42 feet per second…. Peak floor deceleration must occur in not more than 0.071 seconds after impact and must reach a minimum of 18.4 G's.

Regarding fuel system crash resistance, 14 CFR 29.952 states, in part, the following:

> Unless other means acceptable to the Administrator are employed to minimize the hazard of fuel fires to occupants following an otherwise survivable impact (crash landing), the fuel systems must incorporate the design features of this section. These systems must be shown to be capable of sustaining the static and dynamic deceleration loads of this section, considered as ultimate loads acting alone, measured at the system component's center of gravity without structural damage to the system components, fuel tanks, or their attachments that would leak fuel to an ignition source.

> (b) Fuel tank load factors. Except for fuel tanks located so that tank rupture with fuel release to either significant ignition sources, such as engines, heaters, and auxiliary power units, or occupants is extremely remote, each fuel tank must be designed and installed to retain its contents under the following ultimate inertial load factors, acting alone.
>
> (1) For fuel tanks in the cabin:
>
> (i) Upward—4 G.
>
> (ii) Forward—16 G.
>
> (iii) Sideward—8 G.
>
> (iv) Downward—20 G.

Regarding safety belts and shoulder harnesses, 14 CFR 29.785(c) states, in part, that “each occupant’s seat must have a combined safety belt and shoulder harness with a single-point release.”

1.18.5 CHI STC for Seat Installation

On December 5, 2008, the FAA issued STC SR02327AK to CHI for the installation on S-61 helicopters of sidewall-mounted crash-attenuating seats manufactured by Martin Baker. According to documentation provided by Martin Baker, the seat was designed to withstand 10 G lateral loads in the inboard and outboard directions and was tested dynamically up to 30 G in various crash orientations. NTSB investigators reviewed the data submitted by CHI to the FAA supporting the STC and found that it included drawings showing that the Martin Baker seat would be mounted on aluminum-channel seat rails and fittings attached to the S-61 fuselage-frame structure. The data included two documents prepared by a DER, document DM0733-1, dated November 5, 2007, titled “Certification Plan for a Seat Installation in an S61N Helicopter for Carson Helicopters, Inc.,” and document DM0733-2, dated May 19, 2008, titled “Structural Substantiation for a Side Facing Seat Installation on Sikorsky S61 Helicopters.”

Review of DM0733-1 revealed that the DER established that the seat installation was not required to meet the current certification standards of 14 CFR 29.561 and 29.562 using the guidance in Advisory Circular (AC) 21.101, “Establishing the Certification Basis of Changed Aeronautical Products.” In relation to 14 CFR 29.561, the DER stated:

> The new requirements are not practical. The latest amendment level of [Federal Aviation Regulation] FAR 2[9].561[110] requires significant load increases to the seat installation. It is an economic burden to substantiate these loads. The crew seats are not changed by this project and do not meet the higher amendment

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[110] The original report refers to FAR 27.561 and 27.562. According to the DER, these were typographical errors, and he intended to refer to FAR 29.561 and 29.562.

> levels. Therefore, the higher amendment levels would not substantially increase safety and is an economic burden.
>
> In relation to 14 CFR 29.562 the DER stated:
>
> The new requirements are not practical. FAR 2[9].562 requires dynamic testing for seat installation. It is an economic burden to substantiate these requirements. The crew seats are not change[d] by this project and do not meet the dynamic testing requirements. Therefore, this regulation would not substantially increase safety and is an economic burden.

Review of DM0733-2 revealed that it contained the calculation of the interface loads for the attachment of the Martin Baker seat to the helicopter structure by means of CHI's rails and fittings. These calculations determined that CHI's attachment of the seat to the fuselage met the load requirements of CAR 7.260: 4 G forward, 4 G downward, 1.5 G upward, and 2 G sideward.

1.18.6 Public Aircraft Operations

Both the USFS and the DOI conduct firefighting flights on behalf of the U.S. Government. Aircraft conducting these flights are considered to be public aircraft, which are exempt from many FAA regulations applicable to civil aircraft. During the NTSB's February 2009 public hearing on the safety of helicopter emergency medical service operations,[111] FAA representatives testified that, with the exception of operations within the National Airspace System, the FAA has no statutory authority to regulate public aircraft operations. Title 49 *United States Code* (U.S.C.) Section 44701 is the primary authority for Federal aviation regulations. This section instructs the FAA administrator to "promote the safe flight of civil aircraft in air commerce" through regulations and standards prescribed in the interest of safety.

According to AC 00-1.1, "Government Aircraft Operations," dated April 19, 1995, the status of an aircraft as a "public aircraft" or "civil aircraft" depends on its use in government service and the type of operation that the aircraft is conducting at the time. The AC states, "rather than speaking of particular aircraft as public aircraft or civil aircraft, it is more precise to speak of particular operations as public or civil."

As defined in 49 U.S.C. section 40102(a)(41), a "public aircraft" includes "(A) …an aircraft used only for the United States Government, except as provided in section 40125 (b)." Title 49 U.S.C. section 40125(b) states that an aircraft described in subparagraph (A) of section 40102(a)(41) does not qualify as a public aircraft "when the aircraft is used for commercial purposes or to carry an individual other than a crewmember or a qualified non-crewmember."

Title 49 U.S.C. section 40125(a) defines "commercial purposes" as "the transportation of persons or property for compensation or hire" and defines a "qualified non-crewmember" as "an

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[111] In response to the increase in fatal accidents involving helicopter emergency medical service (HEMS) operations in 2008, the NTSB conducted a public hearing from February 3 through 6, 2009, to critically examine safety issues concerning this industry. HEMS operations are conducted by both civil and public operators. For details, see the NTSB website at <http://www.ntsb.gov/events/Hearing-HEMS/default.htm>.

individual, other than a member of the crew, aboard an aircraft…whose presence is required to perform, or is associated with the performance of, a governmental function." It defines "governmental function" as "an activity undertaken by a government, such as national defense, intelligence missions, firefighting, search and rescue, law enforcement (including transport of prisoners, detainees, and illegal aliens), aeronautical research, or geological resource management."

According to AC 00-1.1, the term "firefighting" includes "the transport of firefighters and equipment to a fire or to a base camp from which they would be dispersed to conduct the firefighting activities."

FAA Order 8900.1,[112] Volume 3, Chapter 14, Section 2, "Public Aircraft Operations and Surveillance Government Aircraft Operations Versus Civil Aircraft Operations," dated September 13, 2007, states the following regarding FAA surveillance of government aircraft operators:

> Government-owned aircraft operators holding any type of FAA certification will be included in the normal surveillance activities such as spot inspections of the aircraft and aircraft records. This includes any aircraft exclusively leased to the Federal Government. Any aircraft or operation certificated by the FAA is subject to this surveillance regardless of whether they are operating as public or civil. For example, if an operation is considered public and the operator holds an airworthiness certificate, its maintenance records are eligible for review.

1.18.7 Previous Related Safety Recommendations

1.18.7.1 Safety of Public Firefighting Aircraft

On April 23, 2004, as a result of the investigative findings of three in-flight breakups of firefighting aircraft, the NTSB issued Safety Recommendations A-04-29 through -31 to the DOI and the USFS and Safety Recommendation A-04-32 to the FAA. In its safety recommendation letter, the NTSB noted that, since public firefighting flights are not statutorily required to comply with most FAA regulations or subject to FAA oversight, the DOI and the USFS, as the operators of these flights, are primarily responsible for ensuring the safety of these operations. The NTSB's investigations revealed that, although the DOI and the USFS attempted to compel safe operations through the use of contract language that required compliance with FAA regulations, their oversight and infrastructure were not adequate to ensure safe operations. The NTSB concluded that these agencies must ensure the continuing airworthiness of their firefighting aircraft, which includes monitoring the adequacy of their maintenance programs. To address this issue, the NTSB issued Safety Recommendations A-04-29 through -31, asking the DOI and the USFS to do the following:

> Develop maintenance and inspection programs for aircraft that are used in firefighting operations that take into account and are based on: 1) the airplane's

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[112] FAA Order 8900.1 contains aviation safety policy used by aviation safety inspectors in performance of their official duties.

> original design requirements and its intended mission and operational life; 2) the amount of operational life that has been used before entering firefighting service; 3) the magnitude of maneuver loading and the level of turbulence in the firefighting environment and the effect of these factors on remaining operational life; 4) the impact of all previous flight hours (both public and civil) on the airplane's remaining operational life; and 5) a detailed engineering evaluation and analysis to predict and prevent fatigue separations. (A-04-29)
>
> Require that aircraft used in firefighting operations be maintained in accordance with the maintenance and inspection programs developed in response to Safety Recommendation A-04-29. (A-04-30)
>
> Hire personnel with aviation engineering and maintenance expertise to conduct appropriate oversight to ensure the maintenance requirements specified in Safety Recommendation A-04-29 are met. (A-04-31)

Based on the DOI's responses, on July 6, 2005, the NTSB classified Safety Recommendations A-04-29 through -31 "Open—Acceptable Response." Based on the USFS's responses, on July 6, 2005, the NTSB classified Safety Recommendations A-04-29 and -30 "Open—Acceptable Response," and, on February 13, 2007, A-04-31 was classified "Closed—Acceptable Action." In a September 18, 2009, letter to the USFS, the NTSB stated that Safety Recommendations A-04-29 and -30 remain classified "Open—Acceptable Response" pending implementation of a program that will ensure that all aircraft used by the USFS in firefighting service are covered by instructions for a continuing airworthiness program that reflects the unique and severe flight environment associated with this service.

In addition, in its April 23, 2004, safety recommendation letter, the NTSB noted that aircraft used for public firefighting flights may also be used for civil flights during the portion of the year that they are not under contract to the USFS or the DOI. When operated as civil aircraft, they are governed by FAA regulations and subject to FAA oversight. The NTSB concluded that the FAA's oversight of these aircraft will be of limited value if it does not take into account factors associated with the public firefighting operations that can have a direct bearing on airworthiness, such as flight hours and structural stresses. Therefore, the NTSB issued Safety Recommendation A-04-32, asking the FAA to do the following:

> Require that restricted-category aircraft used for any part of the year in firefighting operations be maintained in accordance with appropriate maintenance and inspection programs that take into account and are based on: 1) the airplane's original design requirements and its intended mission and operational life; 2) the amount of operational life that has been used before entering firefighting service; 3) the magnitude of maneuver loading and the level of turbulence in the firefighting environment and the effect of these factors on remaining operational life; 4) the impact of all previous flight hours (both public and civil) on the airplane's remaining operational life; and 5) a detailed engineering evaluation and analysis to predict and prevent fatigue separations. (A-04-32)

On July 22, 2004, the FAA indicated that it was providing technical information and guidance to the USFS and the DOI on developing an effective maintenance and inspection program for the firefighting environment. On October 21, 2004, the NTSB stated that, to implement this recommendation, the FAA needed to take more action than providing technical advice. Pending development and issuance of a requirement that maintenance and inspection programs for aircraft that spend portions of the year in public operations take into account, and are based on, the five items described in the recommendation, the NTSB classified Safety Recommendation A-04-32 "Open—Acceptable Response."

1.18.7.2 Coordination of Federal Aviation Administration and Department of Defense Oversight

On November 27, 2004, a CASA 212 airplane, operated by Presidential Airways, Inc., under a Department of Defense (DoD) contract operating under 14 CFR Part 135, collided with mountainous terrain near Bamiyan, Afghanistan, killing all six persons on board.[113] The NTSB's investigation found numerous deficiencies in Presidential Airways' Part 135 operations in Afghanistan, as well as a lack of in-country FAA and DoD oversight of Presidential Airways. The NTSB concluded that, had the FAA and the DoD coordinated their oversight responsibilities to ensure effective oversight of civilian operations in Afghanistan, many of the deficiencies noted during the investigation could have been eliminated. To address this issue, on December 4, 2006, the NTSB issued Safety Recommendations A-06-77 and -78 to the FAA and the DoD, respectively. The recommendations and the addressees' responses are discussed below.

> Coordinate with the Department of Defense to ensure oversight, including periodic en route inspections, is provided at all contractor bases of operation for civilian contractors that provide aviation transportation to the U.S. military overseas under 14 *Code of Federal Regulations* Part 121 or Part 135. (A-06-77)

On February 22, 2007, the FAA indicated that it was initiating a broad review with the DoD of issues related to the safety oversight of aircraft operations under DoD contract and that this review would include the issues addressed in this recommendation. Pending the results of the review and appropriate action, the NTSB classified Safety Recommendation A-06-77 "Open—Acceptable Response." After receiving the response of the DoD to a companion recommendation (described below), the NTSB determined that the FAA had completed the action recommended and, on January 11, 2008, reclassified Safety Recommendation A-06-77 "Closed—Acceptable Action."

> Coordinate with the Federal Aviation Administration to ensure oversight, including periodic en route inspections, is provided at all contractor bases of operation for civilian contractors that provide aviation transportation to the U.S. military overseas under 14 *Code of Federal Regulations* Part 121 or Part 135. (A-06-78)

On April 19, 2007, the DoD informed the NTSB that it instituted periodic cockpit observations of contracted aviation operations, primarily with local military personnel. In

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

addition, the DoD reviewed the memorandum of understanding with the FAA and determined that it appropriately addressed sharing of information. Both agencies agreed to enhance their mutual communications and brief each other on a continuous basis regarding oversight efforts of DoD operations in austere locations. After obtaining additional information from a teleconference with DoD personnel, on December 12, 2007, the NTSB classified Safety Recommendation A-06-78 "Closed—Acceptable Action."

1.18.7.3 Flight Recorder Systems

The NTSB's first participation in a helicopter accident investigation in which the helicopter was equipped with an FDR involved the August 10, 2005, accident of a Sikorsky S-76C+ helicopter that experienced an in-flight upset and crashed into the Baltic Sea, killing all 12 passengers and 2 pilots.[114] Without the FDR data, investigators would not have been able to identify the airworthiness issue that resulted in the NTSB's November 17, 2005, issuance of three urgent safety recommendations (A-05-33 through -35) to the FAA.[115] On March 7, 2006, the NTSB also issued Safety Recommendations A-06-17 and -18 concerning flight recorder systems to the FAA. The recommendations and the FAA's responses are discussed below.

> Require all rotorcraft operating under 14 *Code of Federal Regulations* Parts 91 and 135 with a transport-category certification to be equipped with a cockpit voice recorder (CVR) and a flight data recorder (FDR). For those transport-category rotorcraft manufactured before October 11, 1991,[116] require a CVR and an FDR or an onboard cockpit image recorder with the capability of recording cockpit audio, crew communications, and aircraft parametric data. (A-06-17)

On May 22, 2006, the FAA indicated that it would review and identify changes in FDR technology since 1988 to ensure that current technology used in airplanes is appropriate for helicopter operations. The FAA further stated that it would consider changes to its regulations based on this review. On November 29, 2006, the NTSB indicated that it did not believe the

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[114] The Aircraft Accident Investigation Commission of Estonia investigated the accident with the assistance of accredited representatives from the NTSB and the Finland Accident Investigation Board under the provisions of Annex 13 to the International Convention on Civil Aviation.

[115] Safety Recommendation A-05-33 asks the FAA to "require Sikorsky S-76 helicopter operators to 1) conduct an immediate internal leakage test of all main rotor actuators with more than 500 hours since new and/or overhaul; 2) conduct subsequent recurrent tests at a period not to exceed 500 hours; 3) report the test results to the FAA and/or Sikorsky; and 4) correct any problems as necessary." This recommendation is classified "Open—Acceptable Response.

Safety Recommendation A-05-34 asks the FAA to "require Sikorsky S-76 helicopter operators to 1) conduct immediate visual and laboratory examination of hydraulic fluid and filter elements in hydraulic systems with actuators with more than 500 hours since new and/or overhaul for plasma flakes or other contamination that exceeds the manufacturers' allowable limits of concentration and size; 2) conduct subsequent recurring tests at a period not to exceed 500 hours; 3) report findings of contamination and flakes to the FAA and/or Sikorsky; and 4) correct any problems as necessary." This recommendation is classified "Open—Acceptable Response."

Safety Recommendation A-05-35 asks the FAA to 'direct POIs of all Sikorsky S-76 helicopter operators to reemphasize the importance of and requirement for a preflight check of control movement smoothness and flight control "stick-jump" at every engine start.' This recommendation is classified "Closed—Acceptable Action."

[116] Several sections of the regulations were changed on October 11, 1991, to upgrade the flight recorder requirements to require that multiengine, turbine-engine powered airplanes or rotorcraft having a passenger seating configuration, excluding any required crewmember seat, of 10 to 19 seats be equipped with a digital flight recorder.

FAA's study was necessary and that it should begin the process to mandate that all rotorcraft operating under Parts 91 and 135 with a transport-category certification be equipped with a CVR and an FDR. Pending such a requirement, Safety Recommendation A-06-17 was classified "Open—Unacceptable Response." Following its investigation of a September 27, 2008, accident involving an Aerospatiale SA365N1 transport-category helicopter that crashed in District Heights, Maryland,[117] which was not equipped with a CVR or an FDR, the NTSB reiterated Safety Recommendation A-06-17.

> 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)

This recommendation was issued, in part, to address 14 CFR 135.152(k), which allows an exception to the FDR requirement for certain models of rotorcraft produced before August 18, 1987. In its May 22, 2006, letter, the FAA informed the NTSB that, due to technical and economic considerations, it could not justify the installation of an FDR in the rotorcraft listed in section 135.152(k). In its November 29, 2006, response, the NTSB indicated that this exception was unwarranted and contrary to the interests of aviation safety and that Safety Recommendation A-06-18 was issued to prompt the FAA to correct this situation. Pending FAA removal of the exceptions in section 135.152(k), Safety Recommendation A-06-18 was classified "Open—Unacceptable Response."

Following its investigation of a July 27, 2007, accident involving two electronic news-gathering helicopters that collided in midair while maneuvering in Phoenix, Arizona,[118] neither of which was equipped with an FDR, the NTSB issued Safety Recommendation A-09-11 on February 9, 2009, which asked the FAA to do the following:

> Require all existing turbine-powered, nonexperimental, nonrestricted-category aircraft that are not equipped with a flight data recorder and are operating under 14 *Code of Federal Regulations* Parts 91, 121, or 135 to be retrofitted with a crash-resistant flight recorder system. The crash-resistant flight recorder system should record cockpit audio (if a cockpit voice recorder is not installed), a view of the cockpit environment to include as much of the outside view as possible, and parametric data per aircraft and system installation, all to be specified in European Organization for Civil Aviation Equipment [EUROCAE] document ED-155, "Minimum Operational Performance Specification for Lightweight Flight Recorder Systems," when the document is finalized and issued.

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

[118] See *Midair Collision of Electronic News Gathering Helicopters KTVK-TV, Eurocopter AS350B2, N613TV, and U.S. Helicopters, Inc., Eurocopter AS350B2, N215TV, Phoenix, Arizona, July 27, 2007,* Aircraft Accident Report NTSB/AAR-09/02 (Washington, DC: National Transportation Safety Board, 2009). <http://www.ntsb.gov/publictn/2009/AAR0902.html>.

In August 2009, EUROCAE document ED-155 was approved and published. On August 27, 2009, pending the FAA's issuance of a technical standard order that includes the specifications of ED-155, Safety Recommendation A-09-11 was classified "Open—Acceptable Response."

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

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[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,

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[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

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[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

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[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

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[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.

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[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

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[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

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[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)

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[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

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[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

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[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

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[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:

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[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.

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[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

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[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.

Appendix B: Cockpit Voice Recorder Transcript

Transcript of a Penny & Giles MPFR combination CVR/FDR solid-state cockpit voice recorder, serial number unk, installed on an Carson Helicopters Sikorsky S-61N (N612AZ), which crashed on takeoff from forward operating site H-44 near Weaverville California.

LEGEND

CAM	Cockpit area microphone voice or sound source
INT	Flight crew intercom audio panel voice or sound source
RDO	Radio transmissions from N612AZ
Helispot 44	Radio transmission from landing site H-44 coordinator
Helco	Radio transmission from the Helco coordinator
TRI	Radio transmission from the Trinity controller
-1	Voice identified as the pilot
-2	Voice identified as the co-pilot
-3	Voice identified as the load master
-?	Voice unidentified
*****	Unintelligible word
#	Expletive
@	Non-pertinent word
( )	Questionable insertion
[ ]	Editorial insertion

Note 1: Times are expressed in pacific daylight time (PDT).

Note 2: Generally, only radio transmissions to and from the accident aircraft were transcribed.

Note 3: Words shown with excess vowels, letters, or drawn out syllables are a phonetic representation of the words as spoken.

Note 4: A non-pertinent word, where noted, refers to a word not directly related to the operation, control or condition of the aircraft.

INTRA-COCKPIT COMMUNICATION		**AIRCRAFT-TO-GROUND COMMUNICATION**	
Time (PDT) **SOURCE**	**CONTENT**	Time (PDT) **SOURCE**	**CONTENT**
19:18:37 **START OF VERBATUM PORTION OF TRANSCRIPT**			
19:18:37.9 **INT-1**	we can use these electric hats now		
19:18:40.3 **INT-2**	okay rotor brake		
19:18:46.0 **INT-2**	rotor brake is on it is overhead circuit breakers - center fuel closed it is		
19:18:49.2 **INT-1**	transfer's closed		
19:18:49.8 **INT-2**	center fuel transfer switches		
19:18:50.7 **INT-1**	good		
19:18:51.5 **INT-1**	okay check your fuel quantity		
19:18:53.2 **INT-1**	good		
19:18:54.3 **INT-2**	okay compass slaves - engine transmission gauges		
19:18:58.0 **INT-1**	all good		
19:19:00.5 **INT-1**	good		

Time (PDT) **SOURCE**	INTRA-COCKPIT COMMUNICATION **CONTENT**	Time (PDT) **SOURCE**	AIRCRAFT-TO-GROUND COMMUNICATION **CONTENT**
19:19:01.2 **INT-2**	radio avionics and caution panel		
19:19:02.8 **INT-1**	good		
19:19:03.2 **INT-2**	fire king is off anti collision light on		
19:19:05.2 **INT-1**	good		
19:19:05.8 **INT-1**	anti-collision’s on		
19:19:06.6 **INT-2**	rotor brake is on master start is on		
19:19:08.8 **INT-1**	master start's on		
19:19:10.3 **INT-2**	igniters on fuel valve		
19:19:11.0 **INT-1**	open		
19:19:12.0 **INT-1**	fuel valve's open		
19:19:13.7 **INT-2**	clear engine start clear on the left oh no we got a truck comin' down		
19:19:17.6 **INT-1**	got the truck		

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (PDT) **SOURCE**	**CONTENT**	Time (PDT) **SOURCE**	**CONTENT**
19:19:23.1 **INT-1**	clear left		
19:19:24.1 **INT-1**	we are not clear on the right		
19:19:26.6 **INT-1**	there he goes okay now we are clear		
19:19:29.5 **INT-2**	okay engine start I'm gunna put this down and ah back you up on it		
19:19:34.0 **INT**	((sound of increasing engine noise))		
19:19:34.6 **INT-1**	okay oil pressure's comin’ up N-G's comin' up comin’ down below one hundred there we go here we go around the horn		
19:19:54.0 **INT-1**	forty five trigger release		
19:19:58.5 **INT-1**	Tee five stabilized good start oil pressure's up		
19:20:02.0 **INT-2**	okay		
19:20:02.9 **INT-1**	number two		
19:20:05.9 **INT-1**	starter's engaged		

INTRA-COCKPIT COMMUNICATION Time (PDT) **SOURCE**	**CONTENT**	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) **SOURCE**	**CONTENT**
19:20:07.9 **INT**	((sound of increasing engine noise))		
19:20:08.4 **INT-1**	fuel pressure's comin' up - oil pressure's comin' up		
19:20:11.4 **INT-1**	nineteen percent - twenty percent below one hundred - there we go fuel		
19:20:23.1 **INT-1**	forty five trigger release		
19:20:25.8 **INT-1**	Tee five stabilizing NG good		
19:20:30.7 **INT-1**	oil pressure's good - good light off		
19:20:32.4 **INT-2**	okay		
19:20:33.4 **INT-2**	good start on two- mo-gen		
19:20:35.1 **INT-1**	mo-gen here we go		
19:20:36.8 **INT-2**	transmission oil pressures hydraulic pressures		
19:20:39.6 **INT-1**	okay hydraulic pressure's are all good light's out		
19:20:46.2 **INT-2**	okay adjust flight controls		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:20:48.2 **INT-1**	flight controls are centered good and free go ahead and lock the collective		
19:20:53.6 **INT-2**	okay rotor engagement - strobe on		
19:20:56.5 **INT-1**	strobe light's on pulse		
19:21:00.5 **INT-1**	there it is - the strobe is on okay there it is all lights are on		
19:21:05.3 **INT-2**	okay controls centered check that you have two torques, three pressures and three lights out		
19:21:09.1 **INT-1**	two torques three pressures no lights tail wheel is locked brakes are set		
19:21:13.6 **INT-2**	collective lock is on clear the aircraft and ready to engage		
19:21:17.1 **INT-1**	clear on the left		
19:21:18.0 **INT-2**	and we are clear on the right		
19:21:36.1 **INT-2**	okay we are makin' power		
19:21:37.7 **INT-1**	good chargin' - battery		
19:21:38.9			

INTRA-COCKPIT COMMUNICATION

AIRCRAFT-TO-GROUND COMMUNICATION

Time (PDT) SOURCE	CONTENT	Time (PDT) SOURCE	CONTENT
INT-2	main battery off		
19:21:39.7 **INT-2**	okay DC gen light is out		
19:21:43.1 **INT-2**	there went the droops		
19:21:48.7 **INT-2**	master battery is on		
19:21:56.6 **INT-1**	generators on		
19:21:58.6 **INT-1**	ground inverter's off transformer rectifier's on		
19:22:04.5 **INT-1**	boost pump's on		
19:22:07.0 **INT-2**	okay GPS set		
19:22:09.8 **INT-2**	okay rotor DC gen caution light's out AC generator's are on		
19:22:12.9 **INT-1**	yes		
19:22:13.4 **INT-2**	tail takeoff light is out		
19:22:14.4 **INT-2**	ground inverter's off		
19:22:14.5 **INT-1**	yes		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:22:15.6 **INT-2**	transformer rectifier's on		
19:22:16.8 **INT-1**	good		
19:22:16.8 **INT-2**	external power off		
19:22:16.9 **INT-1**	good		
19:22:17.4 **INT-1**	boost pump's on		
19:22:18.6 **INT-2**	good		
19:22:19.8 **INT-2**	radio and avionics on tail takeoff light checked		
19:22:22.0 **INT-1**	good		
19:22:23.2 **INT-2**	okay matched torque		
19:22:24.5 **INT-1**	okay		
19:22:25.2 **INT-2**	takeoff - before taxi		
19:22:27.8 **INT-2**	speed selector tail wheel lock collective lock is off		

INTRA-COCKPIT COMMUNICATION Time (PDT) **SOURCE**	**CONTENT**	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) **SOURCE**	**CONTENT**
		19:22:31.9 **RDO-1**	Helibase, helitanker seven six six ready for departure
19:22:35.9 **INT-2**	okay before takeoff		
		19:22:37.1 **TRI**	Trinity base copies the winds are calm no other aircraft in the area depart at your discretion
19:22:41.5 **INT-2**	okay pressures and temperatures are all good		
		19:22:42.1 **RDO-1**	*
19:22:44.6 **INT-2**	we got plenty of fuel for the mission collective lock is off - AFCS is on beeper trim is off		
19:22:52.3 **INT-1**	landing light on		
19:22:55.0 **INT-2**	and on on the right		
19:22:57.1 **INT-2**	throttles coming up		
19:23:03.5 **INT-1**	comin' up		
19:23:04.6 **INT-2**	okay power is set you are clear on the right		
19:23:16.5			

INTRA-COCKPIT COMMUNICATION

AIRCRAFT-TO-GROUND COMMUNICATION

Time (PDT) **SOURCE**	**CONTENT**	Time (PDT) **SOURCE**	**CONTENT**
INT-2	power's good		
19:23:18.5 **INT-1**	comin' up		
19:23:22.9 **INT-2**	you're clear all the way around		
19:23:25.8 **INT-2**	clear right		
19:24:02.6 **INT-2**	yup right over the top of those		
19:24:04.1 **INT-1**	yup		
19:24:05.1 **INT-1**	go direct		
19:24:53.7 **INT-2**	once we get on top of the hill I'll call helco		
19:24:55.8 **INT-1**	roger		
19:25:02.5 **INT-3**	hay Bill the next guy will probably have to do the full twelve day shift		
19:25:06.7 **INT-2**	say that again		
19:25:07.9 **INT-3**	on the next check I'll probably have to do full twelve day shift with em		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:25:10.5 **INT-2**	yeah you'll have to		
19:25:13.6 **INT-2**	I'm sure they'll make it worth your while		
19:25:15.4 **INT-3**	yeah		
19:25:16.9 **INT-3**	all the diet coke I can drink right		
19:25:18.5 **INT-2**	yeah		
19:25:18.9 **INT-1**	all the diet coke you can drink absolutely you see how well that has worked for me		
19:25:23.6 **INT-3**	yeah I I see		
19:25:25.8 **INT-3**	for every diet coke you can have a malt right		
19:25:28.2 **INT-1**	heck yes or a bag of M&M's		
19:25:31.9 **INT-1**	as long as you wash it down with a diet coke you're okay		
19:25:38.0 **INT-2**	ah if you want to come about another almost ten degrees to the right when you can that's more direct		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:25:44.3 **INT-1**	okay		
19:25:45.8 **INT-3**	yeah I think they said that they were goin' to have a helco up when you come back instead of air attack		
19:25:48.6 **INT-2**	yeah that's what he said, I was gunna try and get him when we crested this ridge here		
19:26:45.4 **INT-1**	yeah we'll probably have two more loads of people then we got to come back for a third load and get our guys		
19:26:52.1 **INT-2**	okay		
19:26:53.2 **INT-1**	I bet you that's what it's all about		
19:26:55.2 **INT-2**	okay		
19:26:56.4 **INT-2**	so what we can do - is a when we drop the last of the second load of their people we can pick up our five go up to the top -		
19:27:05.7 **INT-1**	and pick up the other five and then head home absolutely		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:27:09.3 **INT-2**	copy		
19:27:15.0 **INT-2**	god, it's beautiful country		
19:27:16.9 **INT-3**	it was before they burned it down		
19:27:20.0 **INT-3**	that's the sad thing they can't go back in and log or replant it		
19:27:23.8 **INT-2**	why is that?		
19:27:24.6 **INT-3**	the environmentalists won't let them go in there and let them log it then with all the snags and stuff nobody can afford to manually go in there and replant it		
19:27:31.8 **INT-2**	yeah		
19:27:32.3 **INT-3**	they won't let you spray any more		
19:27:33.9 **INT-1**	it's crazy		
19:27:35.4 **INT-3**	what is it- it's really		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:27:36.9 **INT-1**	it's sad		
19:27:38.2 **INT-3**	it's a huge resource we're just wastin'		
19:27:40.6 **INT-1**	just wastin' away absolutely		
19:27:42.4 **INT-3**	and on that fire there that they had up by the glacier area up there the jumpers wanted to jump it and it was just a single snag there when they first saw it and they said naw it's a let burn now they put probably hundreds of thousand of dollars in air tanker drops and helicopter time		
19:27:59.1 **INT-2**	that's too bad		
19:28:00.7 **INT-1**	doesn't make much sense		
		19:28:07.7 **RDO-2**	helco seven six six
		19:28:11.3 **RDO-1**	Trinity Helibase seven six six is in contact with helco at this time frequency change
		19:28:13.8 **HELCO**	seven six six this is helco
		19:28:15.8 **RDO-2**	seven six six is off of trinity enroute

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
			to Helispot forty four showing six minutes enroute
		19:28:24.7 **HELCO**	and four your information seven six six is ah I was asked could you advise willow Helibase after your last load to H forty four please over
19:28:35.2 **INT-2**	do what		
19:28:36.2 **INT-1**	yes advise willow Helibase of our last load to H forty four		
		19:28:40.4 **RDO-2**	seven six six wilco
		19:28:43.4 **HELCO**	thank you clear
19:28:46.1 **INT-1**	did you tell him to speak English		
19:28:48.3 **INT-2**	I'm sure glad that you speak something else other than English		
19:28:52.5 **INT-2**	I didn't understand what he was tryin' to tell us		
19:28:55.0 **INT-3**	that was those Australian people they brought over for the fires		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:28:59.7 **INT-3**	they only have a couple of days left		
19:29:01.5 **INT-2**	you dump trinity?		
19:29:03.3 **INT-1**	I dump I dump trinity yes		
19:29:07.4 **INT-1**	thank you		
19:29:36.7 **INT-3**	that guy that is a helco he's from Perth oh and I said what do you do there he said my family are farmers, and I said what do they farm, and he said wait and shape. and I said what the hell are wait and shape and he said you know wheat and sheep - you know wait and shape		
19:29:50.9 **INT-1**	ah that's funny		
19:29:52.6 **INT-3**	you know wait and shape are kind of a weird way to describe a product but that's the way people talk		
19:29:58.9 **INT-1**	that's funny		
		19:30:04.5 **RDO-1**	Helispot forty four helitanker seven six six
19:30:15.7 **INT-1**	still eight miles out		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:30:17.1 **INT-2**	yup		
		19:30:18.7 **Helispot 44**	and seven six six forty four on air to ground
		19:30:22.9 **RDO-1**	Hello Mat seven six six we're inbound right now eight miles out be at your location maybe in three minutes
		19:30:33.7 **Helispot 44**	seven six six forty four copies about eight - wind are the same out of the south about three to five and we're ready for you seven six six
		19:30:46.3 **RDO-1**	alright
19:30:47.2 **INT-2**	same approach		
		19:30:48.6 **RDO-1**	same approach same landing spot everything will be exactly the same we'll be there in about three minutes
		19:30:58.0 **Helispot 44**	forty four copies

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (PDT) **SOURCE**	**CONTENT**	Time (PDT) **SOURCE**	**CONTENT**
19:31:01.4 **INT-2**	okay I'm going to do the before landing now?		
19:31:03.6 **INT-1**	please		
19:31:04.2 **INT-2**	before landing throttles are set		
19:31:06.6 **INT-2**	fuel panel is secure		
19:31:08.9 **INT-2**	got plenty of fuel for this mission makin' the three turns pressures and temperatures		
19:31:18.0 **INT-?**	sound of double mike click		
19:31:19.1 **INT-2**	are all reading normally		
19:31:21.0 **INT-2**	avionics - we are up air to ground we got helco		
19:31:24.7 **INT-2**	GPS is set tail wheel switch is locked parking brake is set before landing complete		
19:31:30.8 **INT-3**	that sun is a miserable #		
19:31:32.1 **INT-1**	yes		
19:31:33.6 **INT-1**	look right into the sun that helps doesn't it		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:31:36.6 **INT-1**	that bites		
19:31:38.6 **INT-1**	why am I down to four thousand		
19:31:40.4 **INT-1**	yeah I know		
19:31:41.5 **INT-2**	we're going for that saddle right there		
19:31:42.3 **INT-1**	roger		
19:32:11.5 **INT-1**	boy I'm glad Pastor cleaned the windows		
19:32:14.9 **INT-2**	yeah I know we're a little warm here but we're on the bottom edge of the green		
19:32:19.1 **INT-1**	roger		
19:32:20.5 **INT-1**	pretty normal with our transmissions they're always at the bottom edge which is kind of hot		
19:32:26.6 **INT-2**	yeah the oil is pretty thin right now		
19:32:28.2 **INT-1**	yeah		
19:32:29.6 **INT-2**	if we turn that up that should turn that down right		

INTRA-COCKPIT COMMUNICATION | **AIRCRAFT-TO-GROUND COMMUNICATION**

Time (PDT) **SOURCE**	**CONTENT**	Time (PDT) **SOURCE**	**CONTENT**
19:32:35.4 **INT-2**	is that right?		
19:32:36.2 **INT-1**	yes		
19:32:37.1 **INT-2**	I'm almost thinkin' that we need to up that a little bit		
19:32:41.8 **INT-1**	yup		
19:33:02.1 **INT-2**	okay - we got an hour		
19:33:05.2 **INT-1**	okay I think we can do three trips in an hour and be home		
19:33:08.4 **INT-2**	I'm thinkin’ we can		
19:33:09.3 **INT-1**	yup		
19:33:28.7 **INT-1**	the world wants to disappear on us		
19:33:31.4 **INT-2**	yup we're at six thousand feet now		
19:33:33.4 **INT-1**	yup		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:33:34.0 **INT-1**	we're just gunna come to the right so we can get better visibility		
19:33:36.6 **INT-2**	yup and that's where it's showin' it is it's right off -		
19:33:39.2 **INT-1**	okay yah got it		
19:33:40.6 **INT-2**	okay stop turn it should be right off your nose		
19:33:43.0 **INT-1**	okay I want to come here a little bit more to the right here for the visibility sake		
19:33:47.0 **INT-2**	yup		
19:33:47.6 **INT-1**	we'll just cut right to the edge of the smoke here until I can pick up the ridge		
19:33:51.6 **INT-2**	and you can fly past it and come back around		
19:33:54.0 **INT-1**	yup		
19:33:54.6 **INT-1**	and do a left hand left hand traffic		
19:33:57.4 **INT-2**	copy		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:34:02.4 **INT-1**	okay I can see it now		
19:34:010.0 **INT-2**	should be right out at our ten o'clock		
		19:34:15.6 **RDO-1**	okay forty four seven six six we're starting our approach to your location
19:34:21.3 **INT-2**	should be right over in here		
19:34:23.8 **INT-1**	yup		
19:34:29.6 **INT-1**	smoke here we'll be able to see em right away		
19:34:32.2 **INT-2**	yeah should be right down in there		
19:34:33.7 **INT-1**	yup		
19:34:36.3 **INT-1**	okay we're slowin' down there they are		
19:34:39.8 **INT-1**	okay down wind left down wind slowin' down		
19:34:42.1 **INT-2**	okay yup		
19:34:43.0 **INT-2**	and just be advise we at twenty -		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:34:45.8 **INT-1**	we're gunna be heavier		
19:34:46.0 **INT-2**	three hundred pounds of fuel so we're right at the edge		
19:34:49.1 **INT-1**	okay		
19:34:51.2 **INT-1**	what's the OAT again?		
19:34:52.6 **INT-2**	we are at twenty degrees		
19:34:54.5 **INT-1**	so it's gotten cooler		
19:34:55.9 **INT-2**	we've got ah we're good on the approach comin in		
19:35:00.9 **INT-2**	we've got ah quite a bit of performance with the drop in temperature		
19:35:06.0 **INT-1**	okay		
19:35:08.9 **INT-1**	low recon still looks good, they've got those bags set out for sling loads - but keep an eye on those		
19:35:15.3 **INT-2**	okay yup got them they shouldn't be a factor		

INTRA-COCKPIT COMMUNICATION Time (PDT) **SOURCE**	**CONTENT**	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) **SOURCE**	**CONTENT**
19:35:22.2 **INT-1**	okay got my spot picked out		
19:35:24.0 **INT-2**	okay		
19:35:24.5 **INT-1**	everything looks good they've watered it more		
19:35:27.4 **INT-2**	you're clear on the right		
19:35:35.6 **INT-2**	you're clear right below		
19:35:36.9 **INT-1**	and here we come straight down here		
19:35:41.1 **INT-3**	you're at eight feet		
19:35:44.2 **INT-3**	five		
19:35:47.1 **INT-3**	three		
19:35:48.9 **INT-3**	one		
19:35:52.0 **INT-3**	left's down		
19:35:54.7 **INT-1**	good solid aircraft's is not rolling it felt solid		

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (PDT) **SOURCE**	**CONTENT**	Time (PDT) **SOURCE**	**CONTENT**
19:36:01.6 **INT-1**	okay		
19:36:02.2 **INT**	((throttle reduction))		
19:36:11.3 **INT-2**	okay throttles beeper trim collective lock AFCS is off		
19:36:26.2 **INT-2**	we've got plenty of tank clearance		
19:36:30.8 **INT-1**	is that Erin over there or Matt		
19:36:33.2 **INT-2**	it has to be Matt cause Erin wears a red hat		
19:36:35.4 **INT-1**	Oh I got yaw		
19:36:46.0 **INT-1**	yeah that's Matt		
19:36:47.0 **INT-2**	I don't see another group of guys?		
19:36:49.0 **INT-1**	yeah there in the trees on my side		
19:36:50.5 **INT-2**	oh okay got it		
		19:36:53.0 **RDO-1**	Hay Matt we've got two more loads after this total?

INTRA-COCKPIT COMMUNICATION Time (PDT) **SOURCE**	**CONTENT**	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) **SOURCE**	**CONTENT**
		19:36:59.9 **Helispot 44**	Ah seven six six that's affirmative two more after this
		19:37:04.6 **RDO-1**	okay it does not appear to be a problem the last load that's just you guys we got one more load of ah personnel and then one load of you guys and that's it correct
		19:37:21.1 **Helispot 44**	that's affirmative seven six six one more load of hand crew and one more load of hand crew leadership and the rest of the fly crew
		19:37:30.4 **RDO-1**	okay - okay I got ya I understand now
19:37:30.5 **INT-2**	so it will be a full load		
		19:37:35.9 **Helispot 44**	also seven six six ah there possibly might be a medium available do you think we need to get them in the mix or can we get ah everybody off the hill
19:37:46.1 **INT-2**	should be able to get them off		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
		19:37:46.5 **RDO-1**	I think with the time remaining we have enough time to get everybody the next two trips will be no problem
		19:37:54.7 **HELCO**	I copy
		19:37:57.9 **RDO-1**	you brought all your overnight gear didn't ya
		19:38:01.0 **Helispot 44**	oh you bet ya we're always prepared
		19:38:04.8 **RDO-1**	I know
19:38:13.7 **INT-2**	okay they are expediting back here everything is lookin' good so far they just about got all the gear inside everybody's seated they're just checking the last couple of seatbelts		
		19:38:31.2 **RDO-1**	ah Matt what is the weight on this load?
		19:38:36.5 **Helispot 44**	the weight on this load is twenty three fifty five - two three five five and there is some saws onboard

Time (PDT) **SOURCE**	**INTRA-COCKPIT COMMUNICATION** **CONTENT**	Time (PDT) **SOURCE**	**AIRCRAFT-TO-GROUND COMMUNICATION** **CONTENT**
			so there is haz-mat onboard
19:38:47.2 **INT-2**	got it		
		19:38:47.8 **RDO-1**	okay thank you
19:38:50.3 **INT-2**	okay so		
19:39:18.5 **INT-2**	okay at thirty two degrees we were good for twenty five fifty two so we're two hundred pounds under we are twelve degrees		
19:39:22.9 **INT-1**	okay		
19:39:26.1 **INT-1**	colder		
19:39:26.6 **INT-2**	we're ah almost thirteen degrees colder		
19:39:29.4 **INT-1**	and two hundred pounds lighter		
19:39:31.0 **INT-2**	and two hundred pounds lighter we're good to go		
19:39:32.3 **INT-1**	excellent		
19:39:43.3 **INT-3**	just a little bit longer they all want the tender touch of the female		

INTRA-COCKPIT COMMUNICATION Time (PDT) SOURCE	CONTENT	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) SOURCE	CONTENT
19:39:47.1 **INT-2**	copy - can't blame them for that		
19:39:49.1 **INT-3**	nope		
19:39:49.5 **INT-2**	they're boys aren't they		
19:39:50.4 **INT-3**	yup		
19:39:54.5 **INT-2**	kind of like gettin' their mothers touch		
19:40:13.5 **INT-2**	okay collective lock is off, Ramage is closing the door		
19:40:17.0 **INT-1**	okay		
19:40:17.4 **INT-2**	he's headin' back to his seat okay ah got the thumbs up from the ground crew door's closed-confirm door's closed Ramage is gettin' seated		
19:40:26.9 **INT-2**	okay beeper trim is off AFCS is on collective lock is off throttles coming up		
19:40:31.4 **INT-1**	throttles comin up		

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (PDT) **SOURCE**	**CONTENT**	Time (PDT) **SOURCE**	**CONTENT**
19:40:32.1 **INT-2**	waitin' for Ramage		
		19:40:38.1 **RDO-1**	seven six six we're on the go
19:40:40.4 **INT-3**	okay I'm gunna be all set by the time you pull pitch		
19:40:42.9 **INT-1**	okay we're pulling pitch Jim		
19:40:44.3 **INT-2**	here we go		
19:40:45.9 **INT-2**	you're clear on the right		
19:40:46.9 **INT-1**	pullin' pitch		
19:40:47.7 **INT-2**	okay just nice and smooth here		
19:40:50.1 **INT-1**	yup		
19:41:02.9 **INT-2**	okay there’s seventy five - there's eighty		
19:41:06.4 **INT-2**	there's eighty five		
19:41:10.5 **INT-2**	there's ninety showin’ ah hundred and three percent		

INTRA-COCKPIT COMMUNICATION Time (PDT) **SOURCE**	**CONTENT**	AIRCRAFT-TO-GROUND COMMUNICATION Time (PDT) **SOURCE**	**CONTENT**
19:41:18.8 **INT-2**	nope hundred percent Roark		
19:41:22.9 **INT-2**	no ah droopin' Roark		
19:41:24.8 **INT-1**	oh God		
19:41:25.8 **INT-2**	oh #		
19:41:29.1 **INT-2**	fly darlin’		
19:41:30.3 **INT-2**	fly darlin’		
19:41:31.3 **INT-2**	fly darlin’		
19:41:32.9 **INT-2**	fly darlin’		
19:41:34.5 **INT-2**	#		
19:41:35.3 **INT-1**	#		
19:41:35.9 **INT-1**	#		
19:41:38.7 **INT**	End of Recording End of Transcript		