National Transportation Safety Board
Aviation Accident Final Report

Location:	Seattle, WA	**Accident Number:**	WPR14FA137
Date & Time:	03/18/2014, 0738 PDT	**Registration:**	N250FB
Aircraft:	EUROCOPTER AS 350 B2	**Aircraft Damage:**	Destroyed
Defining Event:	Loss of control in flight	**Injuries:**	2 Fatal, 1 Serious
Flight Conducted Under:	Part 91: General Aviation - Positioning		

Analysis

The pilot was repositioning the helicopter from a rooftop helipad where it had just been refueled to a nearby airport. Video footage revealed that the helicopter lifted off of the helipad and simultaneously started to yaw to the left, consistent with a loss of tail rotor control. The helicopter completed one 360-degree rotation about the yaw (vertical) axis in a near level attitude while climbing. As it continued to rotate (spin) to the left, the helicopter deviated from a level attitude, pitching nose down and banking right, consistent with a loss of main rotor control. The helicopter moved away from the helipad, lost altitude, and impacted the street below. A postcrash fire erupted that consumed most of the fuselage and the forward section of the tailboom.

All major structural components of the helicopter were found at the accident site, and there was no evidence of an inflight failure of the airframe. Examination of the engine revealed that it was producing power at the time of impact. Further, the main rotor and tail rotor systems exhibited damage consistent with powered impact. Flight control continuity could not be confirmed due to fire and impact damage, and most components of the hydraulic system were severely fire damaged or destroyed preventing determination of their preimpact condition.

The NTSB determined that the loss of tail rotor and main rotor control resulted from a loss of hydraulic boost. This determination was made based on a series of deductions. A helicopter can enter a left yaw at takeoff for one of three reasons: 1) a loss of tail rotor effectiveness, 2) a loss of tail rotor drive, or 3) a loss of tail rotor control. In this accident, a loss of tail rotor effectiveness was unlikely because the reported wind speeds at nearby airports at the time of the accident were 4 knots or less. A loss of tail rotor drive was ruled out in this case based on the physical evidence indicating that the tail rotor was powered at ground impact. Thus, the left yaw at takeoff was likely due to a loss of tail rotor control.

A loss of tail rotor control can result from one of three circumstances: 1) a disconnect in the tail rotor pedal control system; 2) a restriction or jam in the pedal controls, or 3) a loss of hydraulic boost to the pedal controls. Although either a disconnect or a restriction/jam in the pedal controls would explain the helicopter's left yaw at takeoff, neither would explain the rapid loss of pitch and bank (main rotor) control that occurred after the first 360-degree yaw rotation that appears consistent with a loss of hydraulic boost to the main rotor controls. Therefore, a loss of hydraulic boost to the pedal controls, followed by a loss of hydraulic boost to the main rotor controls, most likely occurred.

The NTSB then evaluated scenarios that may have led to the complete loss of hydraulic boost to the main and tail rotor controls during takeoff. These scenarios include the following, with the last being the most likely, as described below:

Scenario 1 – <u>Loss of hydraulic pressure due to mechanical failure and simultaneous failure of the yaw load compensator.</u> In this scenario, a loss of pressure to the hydraulic system would result in the loss of hydraulic boost to the main and tail rotor servo controls. The yaw load compensator would provide partial hydraulic boost to the pedal controls unless the compensator failed, which would result in no hydraulic boost to the pedal controls. Because the yaw load compensator would likely have been functionally checked during the preflight hydraulics check, this scenario is considered unlikely because of the low probability of two separate failures occurring simultaneously.

Scenario 2 – <u>A misconfiguration of the hydraulic system at the conclusion of the preflight hydraulic system checks.</u> In this scenario, the pilot would have performed the preflight hydraulic system checks but would have failed to reset the "HYD TEST" button, the hydraulic cut-off switch, or both, at the end of the preflight hydraulic system checks. The accumulator check, which requires the pilot to activate and then reset the "HYD TEST" button, is the first of the two preflight hydraulic system checks. Activating the "HYD TEST" button depressurizes the main and tail rotor servo controls, depletes the yaw load compensator, but does not deplete the main rotor accumulators. The hydraulic cut-off test, which activates and then resets the hydraulic cut-off switch, is the second of the two preflight hydraulic system checks. Activating the hydraulic cut-off switch depressurizes the main and tail rotor servo controls, depletes the main rotor accumulators, but does not depressurize the yaw load compensator. The preflight hydraulic system checks require the pilot to visually confirm that the "HYD" warning light yaw load compensator. The preflight hydraulic system checks require the pilot to visually confirm that the "HYD" warning light turns off after completion of each check, and this light would have remained illuminated had either or both the "HYD TEST" button and hydraulic cut-off switch not been reset by the pilot. Unless the pilot was performing the preflight hydraulic checks via tactile feel of the controls alone, without visual confirmation of the "HYD" warning light on the caution-warning panel, and did not verify all caution and warning lights were extinguished before takeoff, as required by the flight manual, the scenario of a misconfigured hydraulic system at the conclusion of the preflight hydraulic checks is unlikely.

Scenario 3 – <u>Loss of pressure during the preflight hydraulic system accumulator check due to activation of the "HYD TEST" button combined with an unlocked collective stick.</u> In this scenario, the pilot would have engaged the "HYD TEST" button and then moved the cyclic control stick to verify that the main rotor accumulators were functioning properly. If the collective stick was not locked during this check and one or more of the main rotor accumulators were depleted by the cyclic movements, the collective would have moved up rapidly. This uncommanded collective movement is caused by a design characteristic of the main rotor system in the AS350 helicopter. The uncommanded movement is prevented by engaging the collective lock as specified in the preflight checklist. Although accidents have occurred in which an unsecured collective stick moved up enough to cause an inadvertent liftoff (see NTSB accident investigations LAX01LA083 and LAX02TA299), postaccident ground testing with an exemplar helicopter showed that, at its estimated takeoff weight, the accident helicopter would not have become airborne or light on its skids due to uncommanded collective movement as a result of main rotor accumulator depletion alone.

Revision 3 of the AS350-B2 rotorcraft flight manual indicated that the preflight hydraulic system checks were to be conducted with the fuel flow control lever (FFCL) set between the "OFF" and "FLIGHT" detents. The pilot was trained in this procedure. During the ground tests, no heave (upward movement) was felt during the tests conducted with the FFCL set properly between the "OFF" and "FLIGHT" detents. However, the operator's checklist, which was likely used by the pilot, specified that the FFCL be set to the "FLIGHT" detent (a higher power setting) during the preflight hydraulic system checks. During the ground tests with the FFCL in the "FLIGHT" detent, when the collective moved up, a heave was felt by the occupants of the exemplar helicopter.

If the pilot did not lock the collective and performed the accumulator check with the FFCL in the "FLIGHT" detent per the operator's checklist, he may have been startled by an uncommanded increase in collective and the accompanying heave. The pilot may have reacted by manually increasing collective pitch, resulting in an unplanned takeoff. Once airborne, the lack of hydraulic boost to the pedals would have resulted in an uncontrolled left yaw, and, as all three main rotor accumulators became depleted, the main rotor controls would have lost hydraulic boost, resulting in a rapid loss of control. This scenario best matches the video evidence.

Because scenarios 1 and 2 are considered unlikely, scenario 3 is left as the most likely scenario for this accident. However, because of the damage to the hydraulic system components and because the helicopter was not equipped with any type of flight recording device, no determination could be made regarding the pilot's actions during performance of the preflight hydraulic checks or regarding the hydraulic system configuration when the helicopter became airborne. If a recorder system that captured cockpit audio, images, and parametric data had been installed, it would likely have enabled reconstruction of the sequence of events leading to the loss of control.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

The loss of helicopter control due to a loss of hydraulic boost to the tail rotor pedal controls at takeoff, followed by a loss of hydraulic boost to the main rotor controls after takeoff. The reason for the loss of hydraulic boost to the main and tail rotor controls could not be determined because of fire damage to hydraulic system components and the lack of a flight recording device.

Findings

Aircraft	Rotorcraft servo system - Not specified
	Hydraulic, main system - Not specified
	Accumulator, main - Not specified
	Yaw control - Attain/maintain not possible
	Pitch control - Attain/maintain not possible
	Lateral/bank control - Attain/maintain not possible
Not determined	Not determined - Unknown/Not determined (Cause)

Factual Information

This report was modified on November 24, 2015, and September 6, 2016. Please the docket for this accident to view the original report.

HISTORY OF FLIGHT

On March 18, 2014, about 0738 Pacific daylight time (PDT), an Airbus Helicopters (formerly Eurocopter) AS 350 B2, N250FB, was destroyed when it impacted terrain following takeoff from the KOMO TV Heliport (WN16), Seattle, Washington. The helicopter was registered to, and operated by, Helicopters Incorporated, Cahokia, Illinois, under the provisions of Title 14 Code of Federal Regulations Part 91. The commercial pilot and one passenger were fatally injured, and one person, located in a stationary vehicle, was seriously injured. Visual meteorological conditions prevailed, and no flight plan was filed for the local repositioning flight, which was originating at the time of the accident. The pilot's intended destination was the Renton Municipal Airport (RNT), Renton, Washington.

The Electronic News Gathering (ENG) equipped helicopter had landed on the KOMO News helipad about 30 minutes prior to the accident. The purpose was to refuel for its repositioning flight to RNT. A witness who was located on the south side of the helipad reported that he observed the helicopter initially lift off of the helipad to about 15 ft, followed by a muffled sound like a car backfiring. The witness opined that after lifting off it immediately pointed nose up, and began rotating counter-clockwise, after which it rotated out of sight. A second witness, who was stationed in a crane a few hundred feet to the northeast of the helipad, reported that he observed the helicopter lift up off of the helipad, turn toward the west, and then shot straight back with its nose up, and out of control. It then nosed down into the street below. The helicopter descended into an occupied automobile near a main street intersection, after which a postimpact fire ensured.

During the investigation, a review of three security camera recordings, which were provided to the National Transportation Safety Board (NTSB) investigator-in-charge (IIC) by the Seattle Police Department, revealed that the helicopter initially landed on the helipad, and remained stationary for about 15 minutes. The helicopter lifted off and simultaneously began to rotate counter-clockwise in a near level attitude. The helicopter continued to rotate counter-clockwise for about 180 degrees while it ascended slightly above the elevated helipad, after which it began to ascend further while moving slightly away from the elevated helipad. After the helicopter completed about a 360-degree rotation, the helicopter transitioned to a nose-low (tail-high) attitude while it continued to rotate counter-clockwise. The helicopter rotated counter-clockwise another 180 degrees, and then began to lose altitude while moving rapidly away from the elevated helipad. The helicopter then descended until ground impact.

Examination of the accident site revealed that the helicopter came to rest on its right side, oriented on a magnetic heading of about 050 degrees. A vehicle located east of the main wreckage was fire damaged. Another vehicle, which was located immediately west of the main wreckage and oriented on a southerly heading, exhibited impact damage. All major structural components of the helicopter were located in the immediate area of the main wreckage. Wreckage debris was located within an approximate 340 foot radius to the main wreckage.

The helicopter was recovered to a secured location for further examination.

PERSONNEL INFORMATION

Pilot in Command

General

The pilot, age 59, possessed a commercial pilot certificate with a helicopter instrument rating. He also held a helicopter flight instructor certificate with an instrument helicopter rating. His most recent second-class medical certificate was issued on February 6, 2014, with the limitation, "Must wear corrective lenses and possess glasses for near and intermediate vision." The pilot successfully completed his most recent flight review in the accident helicopter on February 8, 2014.

A review of the pilot's personal pilot logbooks revealed that as of February 7, 2014, he had accumulated a total flight time of 6,538.8 hours, all in rotorcraft-helicopters. Additionally, the pilot had accumulated 6,295.5 hours as pilot-in-command, 2,841 hours of instruction given, 1,047 hours in the Airbus AS350-D, and about 5.5 hours in the Airbus AS350-B2 helicopter. Additionally, the pilot had logged 1,122 hours in the Bell 206 helicopter, and a total of 1,092 hours flight time in the Bell 407.

A family member revealed during an interview with NTSB investigators that the pilot worked part time as an ENG pilot on the early morning shift. He would normally awaken between 0300 and 0400, and report for work at 0500, normally Monday thru Friday, but sometimes on weekends if there was a need. He would normally return home from his full time job as an engineer for a local airplane manufacturing company, and predictably go to bed at 2000. The family member said that the pilot was in excellent health, had no sleep disorders, and had performed this schedule for many years. Additionally, the family member opined that the pilot was looking forward to flying full time after retiring from his full time job.

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Pilot's ENG Operational Experience

A further review of the pilot's recorded personal logbook entries revealed that he had started ENG flight operations in a Bell 206 on May 30, 2002, accumulating a total of 1,090 hours in this make and model helicopter, prior to transitioning to the Airbus AS350-D model on August 16, 2004. The pilot then operated this make and model helicopter in ENG operations until July 9, 2008, having accumulated a total time of 1,047 hours in the AS350-D.

Prior to concluding ENG flight operations in the AS350-D during July 2008, the pilot received Bell 407 transition training with Bell Helicopters on April 26, 2006. The pilot then flew the Bell 407 on a limited basis from August, 2006 to January 2008, accumulating a total of about 24 hours of flight time during this period. On January 21, 2008, the pilot attended Bell 407 recurrent training, having received 2.5 hours of flight training. The pilot subsequently began flying the Bell 407 helicopter in ENG flight operations on March 24, 2008, with his last flight logged in this make and model helicopter on February 7, 2014. At this time, the pilot had accumulated a total flight time of 1,092 hours in the Bell 407.

Pilot's Airbus AS350 B2 Training

According to Helicopters Incorporated personnel, the accident helicopter arrived at the company's Renton base of operations on January 30, 2014. The helicopter had been ferried from St. Louis, Missouri, to Renton by a part time company Check Airman, and the Renton based pilot who shared flying duties with the accident pilot; this pilot normally flew the afternoon shift, relieving the accident pilot about 1000.

According to training records supplied to the NTSB IIC at the request of Helicopters Incorporated, the pilot began Airbus AS350-B2 training January 31, the day after the helicopter arrived at the Renton base. At this time the Check Airman gave the pilot 0.5 hours of recurrent training. Subsequently, on February 8, the accident pilot received an additional 3.0 hours of flight instruction, which was inclusive of a check ride. The pilot satisfactorily passed the check ride, as well as the Airbus AS350 limitations written test. The pilot next flew the accident helicopter on the day of the accident, March 18, which would have been 39 days after his most recent flight in the helicopter.

Airbus AS350 B2 Checklists Used During Training

During the postaccident examination of the helicopter, inclusive of the onsite and follow-up layout examinations, the helicopter's checklist was not observed. In several discussions with the Helicopters Incorporated Assistant Director of Operations and the company's Director of Safety, it was frequently stated that the Abbreviated Checklist for the AS350 BA/B2, Revision 1 (an internal document), dated June 30, 2009, which was a two-sided laminated checklist with a Federal Aviation Administration (FAA) Approved Date of August 20, 2009, and signed by an FAA inspector assigned to the St. Louis (STL) Missouri Flight Standards District Office, had been delivered with the helicopter when it arrived at the Renton base. Additionally, the Renton-based pilot (who had ferried the helicopter from St. Louis to Renton with the part-time company Check Airman, when interviewed by the NTSB IIC and asked which checklist would have been in the helicopter at the time of the accident), revealed that it was a two-sided, laminated checklist, and that it had an FAA approved stamp on it.

At the time of the accident, the most current revision to the AS350-B2 Rotorcraft Flight Manual (RFM) was Revision 4, dated the 11th week of year 2010. Revision 3, dated the 21st week of year 2006, contained changes to Paragraph 3 ("Starting") of Section 4.1 ("Operating Procedures") to set the fuel flow control lever (FFCL) to a position between the "OFF" and "FLIGHT" detents in order to achieve a gas generator speed (Ng) of between 67-70% before performing the hydraulic system checks. According to the airframe manufacturer, an Ng of 67-70% will result in a corresponding main rotor speed (Nr) of about 270 rotations per minute (RPM). According to the RFM, 100% Nr on the ground at low pitch is between 375-385 RPM. The previous procedure (Revision 2 and prior) was to set the FFCL to the "FLIGHT" detent, about 82% Ng, resulting in 100% Nr, prior to performing the hydraulic system checks. According to the airframe manufacturer, the change to the starting procedures in the RFM was a result of several events where the helicopter became unintentionally airborne due to the collective stick becoming unlocked during the hydraulic system checks. By performing the hydraulic system checks at 67-70% Ng, the helicopter should not become airborne if the collective stick was not locked, or becomes unlocked during the hydraulic system checks.

According to the airframe manufacturer, six copies of Revision 3 to the RFM were mailed to the operator on May 12, 2010. However, there was no evidence that the previous edition of the checklist, the Abbreviated Checklist dated June 30, 2009, had been revised to reflect the lower Ng setting prior to conducting the hydraulic system checks.

When the part-time Check Airman, who provided the recurrent flight training for the accident pilot was asked during a meeting of parties to the investigation on May 22, 2014, which checklist he used during training, the Check Airman stated that he used the procedures that were outlined in Revision 3 of the RFM. Additionally, the Check Airman stated that he had instructed both the accident pilot and the second pilot who shared the local ENG duties with the accident pilot, to use the procedures outlined in Revision 3 of the RFM (Ng of 67-70%). In addition, an FAA inspector recalled that during the conference meeting, the Check Airman mentioned that the checklist used had the hydraulic checks being conducted with the engine throttle in the Flight Gate (Ng about 82%). Further, the Check Airman stated that after Revision 3 became active, he notified the operator's Chief Pilot of the change to the Ng setting prior to performing the hydraulic system checks; however, the checklist in use at the time was not revised. The operator opined that the Abbreviated Checklist was neither revised nor removed from their AS350 B2 fleet as a result of an oversight.

When the part time Check Airman, who provided the recurrent flight training for the accident pilot was asked several weeks after his initial statement to the investigative team on May 22, 2014, if he remembered if the Abbreviated Checklist was in the accident helicopter, either during the ferry flight to Renton from St. Louis, or during the training he conducted after he had arrived back to the Renton base following the ferry flight, he said that he could not recall.

AIRCRAFT INFORMATION

General

The helicopter, an Airbus Helicopters AS350-B2, serial number (S/N) 3669, was equipped with a Turbomeca Arriel 1D1 engine. A review of the maintenance records revealed that the helicopter had accumulated a total time of 7,706.5 hours at the time of the accident. Additionally, the engine, S/N 9849, had accumulated 7,122.9 hours since new, and 538 hours since it last overhaul.

Maintenance

According to the operator, the helicopter was maintained in accordance with the Manufacturer's Inspection Program. On March 13, 2014, at an aircraft total time (ATT) of 7,698.5 hours, the most recent inspection was performed and documented per a Maintenance Log Entry. The inspection revealed the following:

• a 30-hour check of the tail rotor blades in accordance with (IAW) Chapter 64-10 of the Eurocopter Airworthiness Limitations Section, Rev. 004, dated June 6, 2013, with no defects noted.
• Complied with Eurocopter Alert Service Bulletin 05.00.60, Rev. 0, tail rotor pitch change links check, with no defects noted.
• Complied with Airworthiness Directive (AD) 2011-22-05, inspection of tail rotor pitch change links, with no defects noted.
• Performed 30-hour engine inspection IAW Turbomeca Arriel 1D1 Maintenance Manual, update #17, dated October 30, 2013, with no defects noted.
• Complied with AD 2003-02-05, Sliding Door Rail Inspection, with no defects noted.
• Complied with Eurocopter Alert Service Bulletin 05.00.74 Rev. 1, Tail Rotor Pitch Horn Inspection, with no defects noted.
• Complied with 100-hour inspection items that have no margin in the Eurocopter Airworthiness Limitations Section 04-20-00, Rev. 4 dated June 6, 2013, with no defects noted. This was accomplished in order to extend the 100-hour inspection by using the 10-hour tolerance.

On March 5, 2014, at an ATT of 7,676.1 hours, the operator complied with FAA Airworthiness Directive (AD) No. 2014-02-05, a recurrent inspection of the clearance between the main rotor collective control lever and the collective locking stud. The AD specifically defined an unsafe condition as the main rotor collective pitch lever (collective) locking stud inadvertently locking in the low pitch position, which could result in a subsequent loss of control of the helicopter. (Refer to the AD, which is appended to the docket for this report.)

On March 29, 2012, at an ATT of 6,548.0 flight hours and a component total time (CTT) of 6,007.0 hours, a tail rotor servo control, S/N 1298, was installed on the accident helicopter. The tail rotor servo control was overhauled on February 21, 2012 by UTAS in Vernon, France.

COMPANY OVERVIEW

The operator of the helicopter, Helicopters Incorporated, was founded in 1978 by a private individual. As of August 14, 2014, it was reported that the company operated more than 70 ENG helicopters in 36 markets nationwide. In calendar year 2013, the company flew over 35,000 hours in support of ENG operations.

The company's organization consists of the following:
• Director of Operations
• Assistance Director of Operations
• Chief Pilot
• Director of Maintenance
• Director of Safety
• ADPM & Security Coordinator

The company's employment base consisted of the following:
• Pilots – 149
• Maintenance support personnel – 49
• Total employees – 285

The company's complement of aircraft/helicopters includes the following:

• Bell 206B – 24
• Bell 206L3 – 2
• Bell 206L4 – 26
• Bell 407 – 11
• Airbus AS350BA – 3
• Airbus AS350B2 – 6
• Airbus AS350B3 – 1

Total number of aircraft – 73

AERODROME INFORMATION

WN16 was activated on May 1982. The address of the heliport was 100 4th Avenue North, Seattle, Washington, and was located at coordinates 47 degrees, 37.30 minutes north latitude and 122 degrees, 20.68 minutes west longitude. The estimated elevation above mean sea level (msl) was reported as 363 feet. The height above the street level where the helicopter came to rest was about 85 ft. The operational surface area of the heliport, constructed of concrete, was about 65 feet in diameter. The heliport incorporated edge lighting around its perimeter. It also incorporated sunrise to sunset (SS-SR) lighting, which was pilot controlled. The operator reported that the company has no outlined departure or arrival procedures for the heliport.

GLOBAL POSITIONING SYSTEM (GPS) DATA

The helicopter was equipped with a Garmin GPSMAP 496 battery-powered portable 12-channel GPS receiver. The device included a built-in Jeppesen database, and was capable of receiving XM satellite radio for flight information. The device stored date, route-of-flight, and flight-time information for up to 50 flights. A flight record was triggered when groundspeed exceeded 30 knots and GPS altitude exceeded 250 feet. The log ended when groundspeed dropped below 30 knots for 10 minutes or more. A detailed tracklog, including latitude, longitude, date, time, and GPS altitude information, was stored within the device.

A NTSB Vehicle Recorder Specialist reported the device had sustained impact damage to the screen, housing, and soft-key controls. A surrogate screen was used, and power was applied to the accident device. Recorded waypoint, route, and tracklog data was successfully downloaded from the device via the universal serial bus (USB) port. The data extracted included 44 sessions from March 1, 2014, through March 18, 2014, and consisted of 10,001 total data points. The accident event was identified from the recorded date and time starting at 14:35:46 coordinated universal time (UTC) and ending at 14:39:49 UTC on March 18, 2014, consisting of 6 data points.

Recovered data revealed that the helicopter was at rest on the helipad at 14:39:10 UTC. At 14:39:43 UTC, the helicopter began to move and depart to the right. The final groundspeed and altitude were 12 knots, and 203 ft, respectively. Additionally, data revealed that the flight prior to the accident flight departed from the RNT at 12:35:33 UTC; however, the recording ended just after departing the airport at 12:41:33 UTC. For more information about the GPS receiver, see the NTSB Specialist's Factual Report in the public docket for this accident.

WEIGHT AND BALANCE

The operator reported that the helicopter's maximum gross weight was 4,960 pounds. The operator further reported that at the time of takeoff the helicopter's weight would have been 4,752 pounds. The computed data also revealed that the helicopter was within the center-of-gravity limits.

FUELING

According to the operator, the helicopter would have departed the WN16 with full fuel (about 143 gallons) at the time of departure. Reportedly, the pilot had just landed, and added 75 gallons. The operator reported that normal procedures were for the pilot to have "topped off" the helicopter prior to departure back to their facility at RNT.

METEOROLOGICAL INFORMATION

At 0751 PDT, the automated weather reporting facility at Boeing Field (BFI), which was located about 5 nautical miles (nm) south-southeast of the accident site, reported wind 120 degrees at 4 knots (kts), 6 miles visibility, haze, broken clouds at 1,500 feet, broken clouds at 2,100 feet, overcast clouds at 3,100 feet, temperature 6 degrees C, dew point 3 degrees C, and an altimeter setting of 30.00 inches of mercury.

At 0753 PDT, the automated weather reporting facility at RNT, located about 9 nm southeast of the accident site, reported wind calm, visibility 10 miles, overcast clouds at 4,100 ft, temperature 4 degrees C, dew point 2 degrees C, and an altimeter setting of 30.33 inches of mercury.

At 0737 PDT, the automated weather reporting facility at the Seattle-Tacoma International Airport (SEA), located 9 nm south of the accident site, reported wind 130 degrees at 4 kts, visibility 10 miles, broken clouds at 2,800 feet, overcast clouds at 3,700 feet, temperature 4 degrees C, dew point 1 degrees C, and an altimeter setting of 30.32 inches of mercury.

At 0730 PDT, the automated weather reporting facility at the Snohomish County Airport, also known as Paine Field (PAE), located about 17 nm north of the accident site, reported wind variable at 3 kts, visibility 10 miles, overcast clouds at 1,500 feet, temperature 4 degrees C, dew point 1 degree C, and an altimeter setting of 30.31 inches of mercury.

WRECKAGE AND IMPACT INFORMATION

On the morning of the accident, the NTSB IIC, assisted by the Deputy Regional Chief of the NTSB's Western Pacific Regional Office, and two NTSB Aviation Accident Investigators, as well as two Aviation Safety Inspectors from the FAA, performed an onsite investigation of the helicopter wreckage.

The main wreckage and associated debris was located on a street curb and sidewalk, and in a grassy area just north of the street, about 200 feet distant. The majority of the helicopter's structure was burned or totally consumed by a post-impact fire. The helicopter was observed to have passed through the outer branches of two trees prior to making impact with a parked car. The energy path was generally oriented on a northerly heading, with the tail boom and aft section, half lying out of the fire burn area, on a magnetic heading of about 050 degrees. The angular flight path, when measured from the center of the main wreckage to the first tree strike and the top of the helipad was measured at 30 degrees. The components observed at this location included the helicopter's skids, cabin area, engine, transmission, and rotor blades. All of the dynamic and static components of the helicopter were accounted for at the accident site. The two trees in the immediate area of the accident site exhibited branch strikes from the fuselage, and/or main rotor blades (MRB). Vegetation and the street pavement in the area about 50 feet surrounding the helicopter's at rest location sustained post-impact thermal consumption.

Both landing gear skid tubes were observed to have been broken in multiple locations. The forward and aft cross tubes full lengths were separated from the skids and step. The tail stinger skid exhibited forward skid scratches more pronounced on the right side than the left side.

All three main rotor blades exhibited signatures of powered impact strikes throughout the length of the blades, primarily exhibiting fraying to the outboard 4 to 5 feet, with thermal decomposition to the rest of the blades up to the roots of the rotor hub. The red MRB was observed cut at the sleeve by the salvage recovery team. One of the blade tip balance weights was found 300 feet north of the main wreckage, and one MRB metal tip was found lodged in the driver's side door of a gray pickup truck, which was second in line at the stop light.

The forward section of the tailboom was consumed by postimpact fire damage. The right horizontal stabilizers exhibited impact bending damage and scratches from the outboard to inboard, and down and aft. The vertical stabilizer, ventral, and dorsal fin were impact damaged, with signatures similar to that of pavement scraping on the right side.

The engine output tail rotor drive shaft flange remained bolted to the engine. However, all three flange tangs that attach to the flex couplings were bent and pulled aft and separated at the flex coupling, with torsional splaying observed.

The engine side of the short shaft exhibited the remainder of the flex coupling. Torsional splaying was also observed, with flange tangs bent forward in the direction of the engine.

The tangs were observed to have broken off at the aft side of the short shaft. The splined coupling remained attached to the flex coupling.

The forward splined end of the main tail rotor drive shaft was thermally separated from the remainder of the main tail rotor drive shaft at the forward most hangar support bearing. Two diagonal impact indentations were observed on the shaft between the 3rd and 4th hangar support bearings.

The tail rotor drive shaft fairing also exhibited various impact signatures from the right side through the fairing, in the same location as the indentations on the drive shaft. The coupling at the aft end of the drive shaft to the tail rotor gear box (TRGB) was partially connected, but separated at the tangs on both sides of the flex coupling under tension. The TRGB exhibited impact damage, and was partially attached to the monocoque structure.

The oil cap was not observed. The filler neck exhibited impact scratches; some straw yellow/brown colored oil was observed leaking from the unit. Continuity was confirmed through the tail rotor gear box. The tail rotor blades rotated freely when the drive shaft input was rotated by hand; the rotor shaft was bent slightly. No particles were observed on the chip detector, which was found loose and out of its socket. One of the pitch change links was bent and damaged, with scratches and yellow paint observed (similar to that found on the street curb). The hub was not removed from the rotor shaft; the "woodruff key" was not examined at this time. The yaw load compensator was found broken, thermally damaged, and separated from the helicopter. It was subsequently located in the main wreckage.

One of the tail rotor blade (paddles) exhibited leading edge impact, which destroyed the blade from the blade tip to about 18 inches from the root. The leading edge exhibited a yellow paint transfer on the surface, and had a rough concrete type dimpling similar to that of the street pavement. The accompanying blade was observed more intact, and exhibited a shape closer to its original design; however, it was significantly damaged from impact forces. Both blades were observed broken at the hub, but original design, however, it was significantly damaged from impact forces. Both blades were observed broken at the hub, but remained attached to the tail rotor system at the root through the hub. The tail rotor blades were retained for further examination.

Flight control continuity could not be confirmed due to fire and impact damage. Only the right side pilot's controls were installed. The anti-torque pedals, cyclic, and collective controls were observed lying loose in the area of the cockpit wreckage debris; they were thermally damaged and separated from the remainder of the push/pull, or hydraulic control system. The right anti-torque pedal 'foot arm' was bent up slightly. The hydraulic switch on the collective control was thermally destroyed. Flight control continuity was only observed aft of the tail rotor push pull shaft to the TRGB. The flex-ball cable system exhibited heavy thermal and impact damage.

The instruments, the caution-warning annunciator panel, and the 30 Alpha switch button panel were heavily damaged from the impact forces and post-impact fire. Switch positions and instrument readings or condition of the instruments were not available or reliable for readout. The rotor brake, fuel flow control lever, and fuel shutoff quadrant were completely separated from the helicopter, and heavily damaged from the postimpact fire.

The helicopter's fuel system was consumed by fire. The fuel boost pumps were observed loose in the wreckage, with impact and thermal damage.

The transmission was separated from the airframe, and found lying on its right side. It was observed relatively intact and remained attached to the rotor head (mast and hub), which included the Starflex, and the red, blue, and yellow main rotor blades, with their sleeves and spherical thrust bearings attached. Also observed were the three main rotor servos, three pitch change links, and the top half of the control rods. The bottom half of the control rods were consumed by the fire. Two of the Starflex arms were broken with a 45-degree break across their arms; one was observed broken at approximately 90 degrees across the arm. The hydraulic system's tank, pump, and associated lines were consumed by the post-impact fire. The remaining hydraulic system components, including all three MR servos, yaw load compensator/servo, and manifold were removed from the rotor system, and retained by the NTSB for further examination.

The main rotor hub vibration absorber and weight was separated from the top of the rotor head mast in sheer at its attachment bolts.

The engine was partially separated from the airframe, and found lying within the area of the main wreckage. The main rotor drive shaft to the transmission was torsionally broken, and separated approximately three-fourths of the way from the engine.

All of the observed damage, failures, and deformations during the wreckage examination were determined to be a result of the impact forces and post-impact fire. No pre-impact anomalies were noted with the helicopter during the investigation that would have precluded normal operation.

MEDICAL AND PATHOLOGICAL INFORMATION

On March 19, 2014, an autopsy on the pilot was performed at the facility of the King County Medical Examiner's Office, Seattle, Washington. The examination revealed that the cause of death was the result of blunt force injury and thermal charring.

The FAA's Civil Aeromedical Institute in Oklahoma City, Oklahoma, performed toxicology testing on the pilot. The test was negative for carbon monoxide, ethanol, and tested drugs. Testing for cyanide was not performed.

TESTS AND RESEARCH

Engine Examination

On March 19th and 20th, 2014, under the supervision of the NTSB IIC, a TurbomecaUSA Accident and Investigation Safety technician performed a field examination of the Turbomeca Arriel 1D1 engine, serial number 9849. The technician reported the following:

The engine as found was still partially connected to the transmission via the liaison tube and gimble. The rear engine mount had been broken away from the engine deck. The engine exhibited external thermal damage from the postcrash fire, as well as impact damage mainly in the area of the exhaust pipe and linking tube.

All fuel, oil, and air pipes were found properly connected and safetied.

The gas generator (module 3) could be rotated by hand. The axial compressor blades showed signs of FOD damage on the leading edges, and one blade was curled forward at the leading edge tip.

The reduction gearbox (module 5) was removed to examine the input pinion slippage mark. The mark was found slipped ≈ 2mm in the tightening direction consistent with the engine providing power at time of a main rotor strike.

Continuity was confirmed through the reduction gear box and could be turned by hand. After removal of the reduction gearbox, the free turbine could be turned freely by hand, however the power shaft still could not be turned.

The engine front support exhibited impact damage. It was removed, revealing the freewheel shaft / power shaft mating flanges. After the front support was removed, the power shaft / freewheel shaft could be turned freely by hand, and proper freewheel operation was confirmed. Continuity was confirmed through the accessory gearbox (module 1).

The engine was subsequently shipped to the Turbomeca-USA facility in Grand Prairie, Texas, for a detailed examination.

On May 21, 2014, under the supervision of the NTSB IIC, a detailed examination of the engine was performed by the Turbomeca-USA Accident and Investigation Safety technician, at the Turbomeca-USA facility in Grand Prairie, Texas. The technician reported the following:

Due to the condition of the engine upon arrival, a test cell run could not be performed.

The initial external examination of the engine revealed extensive impact and thermal damage. Subsequent to the removal of all external accessories, the free turbine (Module 4) was removed and examined. The turbine could be freely rotated by hand. Aluminum splatter could be observed on the leading edge of the turbine blades near the root.

The accessory gearbox (Module 1) was removed from the gas generator. The FCU (fuel control unit) was removed, and continuity through both the N1 and N2 gear train was confirmed. No further disassembly of the module was performed.

The axial compressor (Module 2) was removed from the gas generator (Module 3). The compressor wheel could be turned freely by hand. The axial compressor blades showed numerous signs of FOD damage consistent with the engine continuing to run during and after the accident sequence. No further disassembly of the module was deemed necessary.

The gas generator (Module 3) was completely disassembled and examined. Aluminum splatter was observed on the nozzle guide vanes and turbine blades of both the 1st and 2nd stages. This aluminum splatter was most likely the result of displacement of the air intake bell mouth during the accident sequence into the axial compressor, which was then partially ingested, subsequently melted by the combustion section, and deposited on the stationary and rotating parts in the gas path aft of the combustor. No other noteworthy observations were made in the gas generator.

All indications from both the on-site investigation and the engine teardown examination are that the engine was producing torque prior to and during impact, which was evident by the displacement of the input pinion alignment marks.

No evidence could be found of mechanical anomalies with the engine that would have precluded normal operation.

Computed Tomography (CT) Examination

The retained hydraulic system components were examined using CT scans. The scans revealed the piston liner for the left roll servo control was deformed inward immediately below the piston head, and the yaw load compensator accumulator exhibited signatures of pitting on its internal wall. The scans also revealed evidence consistent with pitting on the inner wall of the yaw load compensator accumulator. Furthermore, the scans revealed the hydraulic pump bearing and pump gears did not exhibit evidence of smearing. The pump's splined shaft was engaged with no evidence of spline tooth shearing.

For additional information on the findings from the CT scans, see the Computed Tomography and Aircraft Systems Specialist's Factual Report in the public docket for this accident.

Hydraulic System Component Examinations

The retained hydraulic system components were shipped to the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) for disassembly and further examination. On June 23-24, 2014, members of the Airworthiness Group convened at the United Technologies Corporation Aerospace Systems (UTAS), formerly Goodrich Actuation Systems, facilities in Vernon, France, for disassembly and examination of the hydraulic distribution block and the left roll, right roll, fore-aft, and tail rotor servo controls. On June 25-26, 2014, members of the Airworthiness Group convened at Airbus Helicopters facilities in Marignane, France, for disassembly and examination of the yaw load compensator, hydraulic pump, and the accumulator assemblies from the servo controls.

Left Roll Servo Control (S/N 913)

The piston rod extension of the left roll servo control was measured to be about 3.85 inches, and visually did not exhibit bending deformation. The rod end threads exhibited no evidence of thread wear, but did exhibit small nicks consistent with impact damage. The piston rod was removed from the servo control and the piston liner was removed and confirmed to have deformation damage. A tan-colored liquid remnant was observed within the piston housing; the piston housing contained a brown-colored residue on its interior surface. A green- locking pin was visually confirmed to be in the locked position. The locking pin contained small, reddish-tan colored globules. The servo control filter screen contained a wet, black colored residue on its surface. The sliding valve was removed, and colored residue was observed on the central area of the piston surface. The control input exhibited no evidence of gouges, but the surfaces exposed to the hydraulic ports exhibited a residue similar to that control input exhibited no evidence of gouges, but the surfaces exposed to the hydraulic ports exhibited a residue similar to that found on the filter. The sliding valve sleeve had a clean appearance with no evidence of damage.

The solenoid piston assembly did not exhibit evidence of heat distress, but was sooted on its outer surfaces. Its outer and inner springs were present. The outer spring was measured to be about 0.73 inches in length. An oily, tan-colored residue was observed within the solenoid piston housing. No evidence of blockages was found in the solenoid piston hydraulic port. The valve for the accumulator did not move when pressed. The accumulator was sectioned and the inside contained charred bladder remnants and soot against the accumulator walls. The inner walls of the yaw load compensator accumulator exhibited evidence of surface oxidation.

Right Roll Servo Control (S/N 1381)

The piston rod extension of the right roll servo control was measured to be about 4.21 inches, and visually did not exhibit bending deformation. The piston upper housing rotated about 0.08 inches. Examination of the contact surfaces between the conical lower attachment (the tri-lobe piece) and the piston upper housing exhibited no evidence of fretting or galling. On the piston head, the plastic scraper seal exhibited evidence of melting due to heat exposure. The piston liner remained intact. The filter screen contained a black, soot-like residue but was otherwise clean. The control input locking pin was visually confirmed to be in the locked position. The locking pin contained small, reddish-tan colored globules. The sliding valve was removed and exhibited no evidence of gouges, but the surfaces exposed to the hydraulic ports exhibited a soot-like residue. The sliding valve sleeve was removed and exhibited damage to the outer diameter of the sleeve, but there was no evidence of damage on the sliding valve contact surfaces.

The solenoid assembly exhibited evidence of heat exposure. Residue was observed on the return port of the solenoid valve. The solenoid piston assembly exhibited discoloration of its lower end consistent with heat exposure. Both its outer and inner springs were present. The outer spring was measured to be about 0.59 inches in length. No evidence of blockages was found in the solenoid piston hydraulic port.

The valve for the accumulator did not move when pressed. The accumulator was sectioned and the inside contained charred bladder remnants and soot against the accumulator walls.

Fore-Aft Servo Control (S/N 172)

The valve for the accumulator did not move when pressed. The accumulator was sectioned and the inside contained charred bladder remnants and soot against the accumulator walls. The piston rod extension of the fore-aft servo control was not measured. The piston rod was bent about 4.05 inches from the lower end of the rod. The piston rod surfaces within the servo had a clean appearance. The piston liner had a slight bulge about 2.56 inches from its lower end. The control input locking pin was visually confirmed to be in the locked position. No debris was observed on the locking pin and spring. The filter screen contained a black, soot-like residue but was otherwise clean. The sliding valve was removed, and its surfaces exposed to the hydraulic ports exhibited a soot-like residue, but exhibited no evidence of gouges. The inner diameter of the sliding valve sleeve exhibited no evidence of damage.

The solenoid assembly exhibited evidence of heat exposure. The solenoid piston housing exhibited a tan-color stained appearance. Both its outer and inner springs were present. The outer spring was measured to be about 0.67 inches in length. No evidence of blockages was found in the solenoid piston hydraulic port.

Tail Rotor Servo Control (S/N 1298)

The piston rod extension of the tail rotor servo control was measured to be 7.28 inches. The piston rod and piston liner exhibited evidence of heat distress. A dark-colored band was observed on the piston liner about 3.70 inches from the aft end of the piston liner; the dark-colored band was relatively the same width as the piston head. The locking pin was visually confirmed to be in the locked position. The locking pin, spring, and filter screen exhibited evidence of heat distress. The sliding valve exhibited no evidence of gouges, but exhibited sooting and oxidation products on the surfaces exposed to the hydraulic ports. The sliding valve sleeve was damaged during removal from the servo control.

Yaw Load Compensator

The yaw load compensator exhibited signatures of heat distress. The inner surfaces of the output piston and piston bore, both of which contacts hydraulic fluid, exhibited surface oxidation. The output piston scraper seals were present, but only partially continuous on their circumference. The solenoid was disassembled, and its electrical connections appeared secured. The solenoid piston exhibited no evidence of cracks, but did exhibit signatures of heat distress primarily on its lower surface contacting the hydraulic port. The solenoid piston's outer and inner springs were present, with the outer spring exhibiting heat distress. The outer spring was measured to be about 0.55 inches in length. No evidence of blockages were found in the solenoid piston hydraulic port.

The valve for the accumulator did not move when pressed. The accumulator was sectioned, and the inside contained charred bladder remnants and soot against the accumulator walls. The inner walls of the yaw load compensator accumulator exhibited evidence of surface oxidation.

evidence of surface oxidation.

Hydraulic Distribution Block

The clogging indicator in the hydraulic distribution block was observed popped out, with the button exhibiting heat distress. The pressure regulator cap was observed to be hand tight, with the regulator cap and spring exhibiting heat distress. The filter cap was jammed; a hand saw was used to cut off the filter cap to access the filter. The filter was removed, and appeared to have a soot-like residue, but was otherwise clean of debris.

Hydraulic Pump

The hydraulic pump exhibited signatures of heat distress. The hydraulic pump strainer was sooted, and metallic particles were observed on the side of the strainer that was exposed to a fractured hydraulic port. The chip detector was sooted, and the chip detector remained magnetized. Debris found within the chip detector was not magnetic. The pump gear teeth exhibited no evidence of abnormal wear or fractured gear teeth. The male and female splines for the pulley exhibited signatures of heat distress, but did not exhibit evidence of abnormal spline wear or fractured splines. The pulley, shaft, and gears could not be manually rotated. (Refer to the Airworthiness Group Chairman's Factual Report, which is included in the docket for this report.)

Servo Control Residue

The reddish-tan color globules found on the locking pin spring of the left roll and right roll servo controls were analyzed by an NTSB Materials Laboratory chemist in Washington, D.C. A sample of globules taken from the left servo control was sent to an independent, third-party laboratory for analysis, which found the presence of four aluminum hydroxides and magnesium hydroxide, consistent with corrosion products. (For additional details, see the NTSB Materials Laboratory Factual Report No. 15-012, which is located in the docket for this investigation.)

Collective Locking Device

The collective locking plate is mounted to the central console in the cockpit. The pilot can lower the collective stick, and insert the locking stud on the forward end of the collective stick into the circular cut-out in the locking plate to lock the collective stick. This action is intended to prevent inadvertent collective stick manipulation during the starting checks (for additional information, see the Hydraulic System Checks section of this report). The locking plate is spring-loaded forward, which requires the pilot to physically move the plate aft in order to lock the collective. To disengage, the pilot would have to add a downward force on the collective stick in order to release it from the locking plate. The spring-loaded feature, in addition to a recurrent inspection to ensure proper clearance between the locking stud and the locking plate, is intended to prevent an inadvertent locking of the collective when the collective is bottomed out (moved to the full down position) during flight.

Hydraulic System Checks

The RFM requires hydraulic system checks during the starting procedures (pretakeoff). The hydraulic system checks consists of two separate checks performed in the following order: 1) the hydraulic accumulator check (HYD TEST) and 2) the hydraulic isolation check. The HYD TEST verifies the proper operation of the main rotor accumulators. According to the airframe manufacturer, main rotor control forces will increase above a certain airspeed. In the event of a hydraulic system failure that results in a drop in hydraulic system pressure, the main rotor accumulators provide limited hydraulic assistance to allow for the pilot to reduce airspeed to a point where the main rotor control forces are reduced to an acceptable level for manual control with no hydraulic assistance. The hydraulic isolation check is to verify the proper operation of the main and tail rotor servo control solenoids which serves to depressurize the servo controls in the event of a seizure of a servo control distributor. According to the airframe manufacturer, the collective lever must be locked during both hydraulics checks, as the depressurization of the main rotor servo controls and the depletion of the main rotor accumulator's results in an uncommanded increase in collective pitch, and could result in the helicopter becoming inadvertently airborne.

The hydraulic accumulator check consists of depressing the "HYD TEST" button on the center console, which depressurizes the main and tail rotor servo controls as well as the yaw load compensator. This action results in no hydraulic assistance to the pedals. However, the main rotor accumulators provide backup hydraulic assistance to the cyclic and collective until they become depleted through movement of the cyclic (and/or collective) stick. To avoid reaching the complete depletion of the accumulators, the checklist requires only 2 to 3 movements in the 10 percent range of each axis. Once the check is complete, "HYD TEST" button is depressed again to return the button to its original position.

The hydraulic isolation check consists of setting the hydraulic cut-off switch, mounted on the collective stick, to the "off" position. This action results in the depressurization of the main and tail rotor servo controls as well as the main rotor accumulators, resulting in no hydraulic assistance to the cyclic and collective controls. However, the yaw load compensator remained pressurized and will continue to provide limited hydraulic assistance to the pedals. Once the check is complete, the hydraulic cut-off switch is returned to its original ("on") position.

Activation of one or both switches during the above referenced checks would result in the illumination of the HYD light on the caution warning panel. Additionally, should Nr be below 360 rpm or the hydraulic pressure less than 30 bars, an aural warning horn will sound continuously; the aural warning can be silenced by activating the HORN button on the center console annunciator panel.

Accidents and Incidents Related to the Hydraulic System Checks

The airframe manufacturer stated that between 2000 and 2006, there were five known events which involved the inadvertent unlocking or the pilot's failure to ensure that the collective stick control was properly locked prior to performing the pretakeoff hydraulic checks, which resulted in an inadvertent lift off during the hydraulic system checks. These known events included two that resulted in NTSB investigations (NTSB LAX01LA083 and LAX02TA299). Investigations into these previous events revealed that when the main rotor accumulators were depleted during the hydraulic HYD TEST, the unsecured collective stick raised enough to cause the helicopter to inadvertently lift off. Three events described the helicopter as spinning counterclockwise simultaneous to the lift off. Because the pilots of these events did not have hydraulic assistance to the main and tail rotor controls, the pilots could not regain control of the helicopter, and subsequently the helicopter impacted terrain. All of the known events occurred on the ground and the helicopter did not reach a high altitude prior to descent and ground impact. There were no fatal injuries associated with the five known events.

Due to the accidents and incidents related to the hydraulic system checks, the airframe manufacturer took several actions in an effort to mitigate the risk of becoming unintentionally airborne during the hydraulic system checks. The RFM was modified via Revision 3 to reduce Ng from 82% (FFCL in the flight detent) to 67-70% prior to performing the hydraulic systems checks, which resulted in a lower Nr at the time the hydraulic system checks are performed; reduced Nr would lower the lift that would be produced by the main rotor in the event the collective locking device became unlocked, mitigating the risk of an inadvertent take off. Additionally, an improved collective locking stud was introduced via Service Bulletin No. 67.00.37 (originally released on September 27, 2007) in an effort to mitigate the risk of the locking stud disengaging from the locking plate. The improved collective locking stud incorporated a steel stud with a different shape that also resulted in a higher wear resistance, as excessive wear of the original design collective locking stud was found to be a factor in at least one prior event.

A review of the operator's maintenance records revealed that on July 16, 2008, the following entry was made: "Complied with S.B. 67.00.37 R1, pilot's collective lever lock replacement (Mod 073237). Installed Lock (P/N 350A27-3155-22)."

Simulator Scenarios

On May 22, 2014, several AS350-B2 Hydraulic/Tail Rotor related scenarios were conducted at the Airbus Helicopter's simulator facility in Grand Prairie, Texas. In attendance were members of the FAA, NTSB, BEA, Turbomeca, Helicopters, Inc., and Airbus Helicopters. The purpose of the seven operational scenarios was to attempt to understand what might have precipitated the lift off and counter-clockwise spin that was observed from the security videos.

The simulator used for the demonstrations was a full-motion, Indra AS350 Simulator, certified to FAA Level B standards. Prior to the demonstrations, the investigative team discussed the limitations of the simulator for the purpose of the demonstrations. In summary, the simulator is modeled to a specific level of fidelity based on a specific helicopter within a given flight regime. While the simulator generally reacts the way one would expect when a specific condition or situation is induced, the simulator will not necessarily represent the actual helicopter reaction and performance with that specified level of fidelity when the situation falls outside the flight regime, or conditions to which the simulator is modeled.

A review of the results of the simulator scenarios revealed the following:

With the collective stick not locked down or if it had become unlocked during the pretakeoff Hydraulic Isolation test or Hydraulic Accumulator (HYD) test with the FFCL in either the Ground Idle or Flight Idle positions, the collective pitch control rose rapidly to a point above the full down and locked position. In both instances the helicopter was not observed to have lifted off of the ground. Additionally, relative torque value could not be accurately determined based on the limitations of the simulator.

With respect to a mechanical failure of the tail rotor servo prior to departure due to a slide valve failure, it was the consensus of the group that yaw control can be achieved in this scenario when the emergency procedure is properly applied. Additionally, if a loss of tail rotor control was due to control linkage failure/jammed tail rotor control device (stuck anti-torque pedal), the results of the loss of tail rotor control were varied, and were dependent upon when the failure was initiated, and the reaction time of the pilot. Therefore, no definitive information was available relative to this scenario.

Other hydraulic or flight control related failures, which might prevent the pilot from correcting for the uncommanded left turn/spin were examined in the simulator. As a result, the consensus of the group was that control forces required to maintain control of the AS350 B2 helicopter are manageable in the absence of hydraulic pressure.

For a detailed review of the of the simulator scenarios that were considered during the investigation, refer to the Airbus Helicopters Simulator Summary report in the docket for this accident.

Fuel Examination/Testing

Fuel samples were obtained on the day of the accident from the heliport's fuel facility. The samples were subsequently fuel tested by an independent, third-party laboratory, with a copy of the test report submitted to the NTSB Materials Laboratory in Washington, D.C., for review by an NTSB chemist. Upon review, the chemist reported that all results were within acceptable specification ranges.

Ground Testing Using Exemplar Helicopter

On March 15, 2016, ground tests were conducted using an exemplar AS350-B2 helicopter configured to the estimated weight and balance of the accident helicopter. The purpose of the ground testing was twofold: 1) to demonstrate the helicopter's reaction to an unlocked collective stick when performing the preflight hydraulics checks at varying rotor speeds and 2) to determine how those helicopter responses translated to effects felt by the pilot. During all tests performed, when the collective stick moved up upon depletion of the main rotor servo control accumulators, the helicopter did not become airborne or get light on its skids. During the tests performed with the FFCL set at 67-70% Ng, no anomalous vibrations, heaves, or bumps were noted by those within the helicopter when the collective stick moved up upon depletion of the main rotor servo control accumulators. During the tests performed with the FFCL in the "FLIGHT" detent, a noticeable heave (upward movement) was felt by those within the helicopter when the collective stick moved up upon depletion of the main rotor servo control accumulators. For a detailed description of the ground testing, refer to Addendum 1 to the Airworthiness Group Chairman's Factual Report, which is included in the docket for this accident.

ADDITIONAL INFORMATION

According to Eurocopter Service Letter No. 1673-67-04, dated April 2, 2005, "Main rotor rotating clockwise: Reminder concerning the YAW axis control for all helicopters in some flight conditions," various events were documented during flight near the ground and at very low speed in light wind conditions on aircraft fitted either with conventional tail rotors or with Fenestrons. (Refer to the above referenced Service Letter, which is appended to the docket for this report.)

History of Flight

Takeoff	Loss of control in flight (Defining event)
Uncontrolled descent	Collision with terr/obj (non-CFIT)

Pilot Information

Certificate:	Commercial	**Age:**	59
Airplane Rating(s):	None	**Seat Occupied:**	Right
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	4-point
Instrument Rating(s):	Helicopter	**Second Pilot Present:**	No
Instructor Rating(s):	Helicopter; Instrument Helicopter	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 With Waivers/Limitations	**Last FAA Medical Exam:**	02/06/2014
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	02/08/2014
Flight Time:	(Estimated) 6600 hours (Total, all aircraft), 1055 hours (Total, this make and model), 6600 hours (Pilot In Command, all aircraft), 17 hours (Last 90 days, all aircraft), 2 hours (Last 30 days, all aircraft), 2 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	EUROCOPTER	**Registration:**	N250FB
Model/Series:	AS 350 B2 B2	**Aircraft Category:**	Helicopter
Year of Manufacture:		**Amateur Built:**	No
Airworthiness Certificate:	Normal	**Serial Number:**	3669
Landing Gear Type:	Skid	**Seats:**	4
Date/Type of Last Inspection:	03/13/2014, AAIP	**Certified Max Gross Wt.:**	4960 lbs
Time Since Last Inspection:	8 Hours	**Engines:**	1 Turbo Shaft
Airframe Total Time:	7704 Hours at time of accident	**Engine Manufacturer:**	Turbomeca
ELT:	Not installed	**Engine Model/Series:**	Arriel 1D1
Registered Owner:	HELICOPTERS INC	**Rated Power:**	732 hp
Operator:	HELICOPTERS INC	**Operating Certificate(s) Held:**	Agricultural Aircraft (137); Rotorcraft External Load (133); On-demand Air Taxi (135)

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual Conditions	**Condition of Light:**	Day
Observation Facility, Elevation:	KBFI, 30 ft msl	**Distance from Accident Site:**	5 Nautical Miles
Observation Time:	0751 PDT	**Direction from Accident Site:**	160°
Lowest Cloud Condition:	Thin Broken / 1500 ft agl	**Visibility**	6 Miles
Lowest Ceiling:	Overcast / 3100 ft agl	**Visibility (RVR):**	
Wind Speed/Gusts:	4 knots /	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	120°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30 inches Hg	**Temperature/Dew Point:**	6°C / 3°C
Precipitation and Obscuration:	Light - Partial - Haze; No Precipitation		
Departure Point:	Seattle, WA (WN16)	**Type of Flight Plan Filed:**	None
Destination:	Renton, WA (RNT)	**Type of Clearance:**	None
Departure Time:	0738 PDT	**Type of Airspace:**	

Airport Information

Airport:	KOMO TV Heliport (WN16)	**Runway Surface Type:**	Asphalt
Airport Elevation:	202 ft	**Runway Surface Condition:**	Dry
Runway Used:	N/A	**IFR Approach:**	None
Runway Length/Width:		**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	1 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:	1 Fatal	**Aircraft Fire:**	On-Ground
Ground Injuries:	1 Serious	**Aircraft Explosion:**	None
Total Injuries:	2 Fatal, 1 Serious	**Latitude, Longitude:**	47.620278, -122.348611

Administrative Information

Investigator In Charge (IIC):	Thomas Little	**Report Date:**	10/04/2016
Additional Participating Persons:	Roy Hardie; Federal Aviation Administration; Renton, WA Joseph P DiMarco; Federal Aviation Administrationi; Renton, WA Scott Tyrrell; Federal Aviation Administration; Fort Worth, TX Jon Jordan; Federal Aviation Administration; Fort Worth, TX Matt Rigsby; Federal Aviation Administration; Fort Worth, TX Thierry LOO; Bureau d'Enquetes et e'Analyses; Touloouse-Blagnac, Gilles Romeuf; Bureau d'Enquetes et e'Analyses; Toulouse-Blagnac, Marc Lever; Bureau d'Enquetes et e'Analyses; Le Bourget, Seth Buttner; Airbus Helicopters; Grand Prairie, TX Lindsay Cunningham; Airbus Helicopters; Grand Prairie, TX Michel Martin; Airbus Helicopters; Marignane, Yves Aranjo; Airbus Helicopters; Marignane, Jean-Luc Simonazzi; UTC Aerospace Systems; Cergy-Pontoise, William E DeReamer; Helicopters Inc.; Cahokia, IL Jeff Lieber; Helicopters Inc.; Cahokia, IL William Houska; Helicopters Inc.; Cahokia, IL Jule Boyer; Helicopters Inc.; Cahokia, IL Robert Boehm; Helicopters Inc.; Cahokia, IL Jack Brandt; Helicopters Inc.; Cahokia, IL Bryan Larimore; Turbomeca USA; Grand Prairie, TX		
Publish Date:	10/04/2016		
Note:	The NTSB traveled to the scene of this accident.		
Investigation Docket:	http://dms.ntsb.gov/pubdms/search/dockList.cfm?mKey=88928		

probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

The Independent Safety Board Act, as codified at 49 U.S.C. Section 1154(b), precludes the admission into evidence or use of any part of an NTSB report related to an incident or accident in a civil action for damages resulting from a matter mentioned in the report. A factual report that may be admissible under 49 U.S.C. § 1154(b) is available here.