NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

September 3, 2019

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT

NTSB No: ERA18MA099

A. ACCIDENT

Operator: Liberty Helicopters, Inc.
Aircraft: Airbus Helicopters AS350 B2, Registration N350LH
Location: New York, New York
Date: March 11, 2018
Time: 1908 eastern daylight time

B. GROUP

Group Chairman:	Chihoon Shin National Transportation Safety Board Washington, District of Columbia
Member:	Scott Tyrrell Federal Aviation Administration Fort Worth, Texas
Member:	Rodrigo Goncalves Liberty Helicopters, Inc. Kearny, New Jersey
Member:	Erell Verleyen Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile Le Bourget, France
Member:	Seth Buttner Airbus Helicopters, Inc. Grand Prairie, Texas

LIST OF ACRONYMS

ALF	aft-looking-forward
ATT	aircraft total time
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile
CFR	*Code of Federal Regulations*
DGAC	Direction Générale de l'Aviation Civile
EASA	European Aviation Safety Agency
EDT	eastern daylight time
FAA	Federal Aviation Administration
FADEC	full authority digital engine control
FFCL	fuel flow control lever
FSOL	fuel shutoff lever
NJ	New Jersey
NTSB	National Transportation Safety Board
NY	New York
NYPD	New York Police Department
PCL	pitch change link
RFM	rotorcraft flight manual
S/N	serial number
TCDS	type certificate data sheet
TRDS	tail rotor drive shaft
65NJ	Helo Kearny Heliport

C. SUMMARY

On March 11, 2018, about 1908 eastern daylight time (EDT), an Airbus Helicopters (formerly Eurocopter) AS350 B2, N350LH, was substantially damaged when it impacted the East River and subsequently rolled inverted after the pilot reported a loss of engine power near New York, New York (NY). The pilot egressed from the helicopter and sustained minor injuries. The five passengers did not egress and were fatally injured. The scheduled 30-minutes, doors-off aerial photography flight was operated by Liberty Helicopters, Inc. on behalf of FlyNYON under the provisions of 14 *Code of Federal Regulations* (CFR) Part 91. Visual meteorological conditions prevailed and no flight plan was filed for the flight which originated from Helo Kearny Heliport (65NJ), Kearny, New Jersey (NJ) about 1850 EDT.

The accident helicopter remained submerged within the East River until it was recovered on March 12, 2018. On March 13-15, 2018 members of the Airworthiness Group documented the recovered helicopter. Examination of the recovered helicopter revealed no evidence of an inflight break up. No major components were missing. Two witness videos captured the accident helicopter descend into the East River.[1] Additionally, a GoPro video recorder was recovered from the accident helicopter.[2]

D. DETAILS OF THE INVESTIGATION

1.0 HELICOPTER INFORMATION

1.1 HELICOPTER DESCRIPTION

The Airbus Helicopters (formerly Eurocopter) AS350 B2 has a three-bladed main rotor system that provides helicopter lift and thrust.[3] A two-bladed tail rotor system provides anti-torque and directional control. The helicopter flight controls are hydraulically assisted by a single hydraulic system. The helicopter was equipped with a high skid-type landing gear and a Safran Helicopter Engines (formerly Turbomeca) Arriel 1D1 turboshaft engine. The AS350 B2 helicopter is type certificated under Federal Aviation Administration (FAA) Type Certificate Data Sheet (TCDS) No. H9EU.

The terms “left”, “right”, “up”, and “down” are used when in the frame of reference of looking forward from the aft end of the helicopter, i.e. aft-looking-forward (ALF). All locations and directions will be viewed from ALF unless otherwise specified. Additionally, clock positions are in the ALF frame of reference unless otherwise specified.

1.2 HELICOPTER HISTORY

The accident helicopter, serial number (S/N) 7654, was manufactured in 2013. According to helicopter records, the airframe had accumulated an aircraft total time (ATT) of about 5,509.7 flight hours at the time of the accident. The engine S/N 19549 was installed on the accident helicopter. For more information on the engine, see the Powerplants Group Chairman’s Factual Report in the docket for this investigation.

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[1] For details on the witness videos, see the Video Study in the docket for this investigation.
[2] For details on the findings of the GoPro video recorder, see the Onboard Recorder Group Chairman’s Factual Report in the docket for this investigation.
[3] The main rotor blades rotate in a clockwise direction when looking down at the main rotor disk from above.

2.0 WRECKAGE DOCUMENTATION AT THE ACCIDENT SITE AND AFTER RECOVERY

On March 12, 2018, members of the Airworthiness Group convened at the East 23rd Street Pier in Manhattan, NY. The wreckage was submerged and inverted in the East River, with only the emergency floatation system visible above the water. The wreckage was tethered to the pier by first responders. A fairing, later determined to originate from the underside of the helicopter, was recovered by first responders, and was on the pier before the Airworthiness Group arrived on scene. The wreckage was recovered (**Figure 1**) and relocated to the New York Police Department (NYPD) Aviation Unit hangar at Floyd Bennett Field in Brooklyn, NY. On March 13-15, 2018, members of the Airworthiness Group convened at the NYPD Aviation Unit hangar to document the recovered wreckage. Unless otherwise noted, all observations were recorded after the helicopter was recovered and relocated to the NYPD Aviation Unit hangar.

Figure 1. The accident helicopter recovered from the East River.

2.1 STRUCTURES

2.1.1 OVERVIEW

The helicopter structure consists of the main fuselage, tail boom and empennage, and skid-type landing gear. The main fuselage comprises: the [central] body structure, primarily supporting the fuel tank, main transmission, and landing gear; the rear structure, primarily supporting the engine and baggage compartment; the bottom structure, primarily supporting the main cabin; and the canopy, primarily supporting the doors and windows. The tail boom is attached to the rear structure and supports the tail gearbox, horizontal stabilizer, tail rotor drive shafts, and the vertical fin.

2.1.2 OBSERVATIONS

The helicopter airframe remained generally intact. The main fuselage did not exhibit evidence of major breakup or fractures. The center fairing, adjacent to the landing lights, was deformed upward. The left front door and the two right doors were removed prior to the accident flight; according to the operator, the removed doors were still at the operator's facility in Kearny, NJ. The left sliding door, normally locked in the open position during doors-off flights, was missing and not recovered (**Figure 2**). A remnant piece of plastic block, part of the left sliding door installation, was found within the lower track for the left sliding door. The fuel tank remained installed in the main fuselage and did not exhibit evidence of fractures or leaks. After recovery, a hole was drilled into the left side of the fuel tank to empty its liquid contents; a plug was installed over the drilled hole.

Figure 2. Front quarter view of the accident helicopter.

Both left and right skids remained attached to the forward and aft skid cross tubes, which in turn remained attached to the airframe. The skids and cross tubes did not exhibit evidence of major deformation. The emergency flotation system remained installed on the skids. For more information on the emergency floatation system, see the Emergency Flotation Group Factual Report in the docket for this investigation.

The tail boom remained attached to the main fuselage. Wrinkled metal skin on the tail boom was observed immediately forward of the horizontal stabilizer, but the remainder of the tail boom structure was generally intact. The right horizontal stabilizer was folded downward and exhibited a partial fracture about 18 inches outboard of, but remained attached to, the tail boom. The left horizontal stabilizer was fractured and the majority of it was missing. The remnant portion of the left horizontal stabilizer that remained attached to the tail boom exhibited impact deformation with an aft and inboard directionality. The upper vertical fin was partially fractured from the tail boom and leaning over to the left side of the tail boom during recovery at the East 23rd Street Pier. The upper vertical fin was separated after recovery. The upper vertical fin was generally intact. The lower vertical fin remained attached to the tail boom and was generally intact.

An impact mark was observed on the tail rotor drive shaft (TRDS) cowling at the frame station coincident with the trailing edge of the horizontal stabilizer. The remaining TRDS cowlings remained installed and intact along the tail boom. The engine cowling remained installed and intact.

2.2 MAIN ROTOR SYSTEM

2.2.1 SYSTEM OVERVIEW

Power from the engine reduction gearbox is transferred to a power transmission shaft, the forward end of which is connected to a freewheel shaft. The freewheel shaft is connected to the engine-to-transmission drive shaft (also known as the "main transmission input driveshaft") via a splined adapter. Flexible couplings on both ends of the engine-to-transmission shaft allow for minor misalignment. The engine-to-transmission shaft is connected to the main transmission input pinion pulley flange, which drives the main transmission input pinion, the aft hydraulic pump, and air conditioning unit, the latter two of which are belt driven via the pulley flange. The main transmission contains a single-stage sun and planetary gear system that turns the main rotor shaft. The main rotor shaft is attached to the Starflex via 12 bolts. The main transmission is attached to the airframe via four rigid suspension bars and an anti-torque bi-directional crossbeam with laminated pads installed between the lower transmission housing and the airframe.

The three main rotor blades attach to the Starflex via blade sleeves (two sleeves per blade). An elastomeric bearing connects the inboard end of the sleeves to the Starflex, while an elastomer block (also known as the "frequency adapter") is located near the outboard end of the sleeves and is attached to the outboard end of each Starflex arm with a ball joint. The blade is secured to the outboard end of the sleeve via blade pins. The elastomeric bearing allows for the blade to move in the flapping, lead-lag, and pitch change directions. The Starflex arms are flexible in flapping, but rigid in lead-lag and pitch change directions. The frequency adapter is flexible in lead-lag, but rigid in the flapping and pitch change directions. Each set of main rotor blades, sleeves, and pitch change links are assigned a color for identification purposes; the assigned colors are 'blue', 'red', and 'yellow'.

2.2.2 MAIN ROTOR OBSERVATIONS

The Starflex did not exhibit evidence of fractures (**Figure 3**). All three main rotor blades remained attached to their respective sleeve assemblies, which in turn remained attached to the Starflex via their respective elastomeric spherical thrust bearings and frequency adapters.[4] The sleeve assemblies did not exhibit evidence of fractures. All three pitch horns remained installed on their respective sleeve assemblies and all three main rotor blade pitch change links (PCL) remained installed between the pitch horn and the rotating swashplate. The vibration absorber remained installed above the Starflex.

Figure 3. Main rotor Starflex and the 'yellow' and 'blue' sleeve assemblies.

The 'red' main rotor blade exhibited a chordwise fracture about 4 feet outboard of the blade attachment bolt holes but was generally whole. The 'blue' and 'yellow' main rotor blades were removed from the rotor head after recovery and were generally whole. The 'blue' and 'yellow' main rotor blades exhibited a slight opening of the trailing edge at the inboard end of the airfoil; the trailing edge openings were collocated with chordwise cracks observed on the blade skin. The tip end trailing edge of the 'yellow' main rotor blade exhibited a gouge on its upper surface. The 'yellow' main rotor blade lower surface exhibited maroon-colored paint transfer marks near the blade midpoint and at its outboard end. The barge utilized to transport the recovered helicopter from the East River to a pier in Brooklyn had maroon-colored paint at its waterline.

2.2.3 MAIN ROTOR DRIVE SYSTEM OBSERVATIONS

The main transmission remained installed on the airframe via four suspension bars and the antitorque crossmember (underneath the main transmission). The main transmission housing, the four suspension bars and crossmember did not exhibit anomalous damage. The engine-to-transmission drive shaft remained attached at its forward end to the transmission input pinion pulley flange and to the freewheel unit at its aft end. The flexible couplings for the engine-to-transmission drive shaft did not exhibit anomalous damage. The rotor brake remained installed on the support tube (also known

[4] The 'yellow' and 'blue' main rotor blades were removed from their respective sleeve assemblies prior to transportation to Floyd Bennett Field.

as the liaison tube) between the engine and main transmission. The air conditioning unit and hydraulic pump remained installed and their respective belts remained attached to the pulley flange. Both drive belts did not exhibit anomalous damage.

Manual rotation of the free turbine[5], through the engine exhaust, resulted in a corresponding rotation of the main rotor head. Freewheel unit functionality was confirmed when rotation of the power turbine in the opposite direction did not result in rotation of the main rotor.

2.3 TAIL ROTOR SYSTEM

2.3.1 SYSTEM OVERVIEW

Engine power is transferred to the tail rotor via two TRDS and a tail gearbox. The forward TRDS, made of steel, is connected to a flange connected to the aft end of the freewheel shaft. The aft TRDS, made of aluminum, connects to the forward TRDS via a splined steel flange and adapter. Flexible couplings are located between each drive shaft attachment point to allow for minor misalignment. Five hanger bearings, mounted within support brackets along the tail boom, support the TRDS. The tail gearbox provides gear reduction and changes the direction of drive. The tail rotor hub, connected to the tail gearbox output shaft, provides final drive to the tail rotor.

The two tail rotor blades share a common composite spar that is flexible in both the flapping and pitch change (torsional) directions. Two metal half-shells are clamped to the center of the spar. The inboard half-shell connects to the tail rotor hub and allows for the tail rotor to teeter. Blade pitch is changed via pitch change links mounted between a pitch horn and a pitch change assembly (also known as the “spider”). The pitch horns rotate about a set of elastomeric bearings at the root end of each blade. The spider slides along the tail gearbox output shaft and is controlled by a pitch change bell crank. Each set of tail rotor blades and pitch change links are assigned a color for identification purposes; the assigned colors are ‘red’ and ‘yellow’.

2.3.2 TAIL ROTOR OBSERVATIONS

The two tail rotor blades remained attached to the tail rotor hub, which remained installed on the tail gearbox output shaft. One tail rotor blade exhibited a chordwise fracture about 6 inches from its rod end; the PCL this tail rotor blade was bent near its outboard spherical bearing. The second tail rotor blade was generally intact and its PCL did not exhibit anomalous damage. Both PCLs were attached to their respective blades and the pitch change spider.

[5] The free turbine is also known as the power turbine.

Figure 4. Rear quarter view of the accident helicopter.

2.3.3 TAIL ROTOR DRIVE SYSTEM OBSERVATIONS

The forward end of the steel TRDS remained installed to the aft end of the freewheel (power transmission) shaft. The splined flange remained connected to the aft end of the steel TRDS. The splined adapter, normally bonded and riveted to the forward end of the aluminum TRDS, remained installed within the splined flange. The aluminum TRDS remained installed on the tail boom via five hanger bearings. The aluminum TRDS exhibited bending deformation in two locations: one about 8-inches forward of the aft-most hanger bearing and another about 21 inches aft of the aft-most hanger bearing. The bearing housing for the aft-most hanger bearing was rotated forward. The remaining four hanger bearings were intact.

Manual rotation of the power turbine (through the engine exhaust) resulted in a corresponding rotation of the steel TRDS, splined flange, and splined adapter, but no rotation of the tail rotor drivetrain aft of, and inclusive of, the aluminum TRDS. Manual rotation of the tail rotor resulted in a corresponding rotation of the aluminum TRDS up to its splined adapter; the tail rotor drivetrain forward of, and inclusive of, the splined adapter did not rotate when the tail rotor was manually rotated. Peeled paint was visible at the interface between the aluminum TRDS and its forward splined adapter. There was no evidence of binding when the tail rotor was manually rotated.

2.4 FLIGHT CONTROL SYSTEM

2.4.1 OVERVIEW

The cyclic and collective control inputs are transmitted from the pilot controls to the stationary swashplate through a series of push-pull tubes and bell cranks. The main rotor cyclic and collective controls are hydraulically assisted via three single-cylinder main rotor servo controls: fore/aft, right-roll, and left-roll. The main rotor servo controls contain accumulators which provide backup hydraulic assistance in the event of a loss of hydraulic pressure in the system. The main rotor servo controls are mounted to the transmission upper housing and the stationary swashplate. The pedal control inputs are transmitted to the single-cylinder tail rotor servo control through a series of control linkages, bell cranks, and a flexible ball control cable. A yaw load compensator, with an accumulator, is connected to the tail rotor servo control output piston via the compensator connecting link, which actuates a push-pull tube connected to the pitch change bell crank mounted to the tail gearbox. The pilot seat is normally located on the right side of the helicopter. Adjacent to the collective control, located between the pilot seat and the front-left passenger seat(s), are three floor-mounted controls: the rotor brake lever, the fuel flow control lever (FFCL)[6], and the fuel shutoff lever[7] (FSOL). The AS350 B2 helicopter can be equipped with either single (pilot-only) or dual (pilot and co-pilot) flight controls. The accident helicopter was equipped only with the pilot flight controls installed at the forward-right seat position.

2.4.2 OBSERVATIONS

The three main rotor servos remained installed between the main transmission housing and the stationary swashplate. The stationary and rotating scissor links remained attached. The tail rotor servo and yaw load compensator remained in its normally installed position. The tail rotor control tube remained continuous from the aft end of the tail rotor servo to the tail gearbox bell crank. As previously mentioned, the hydraulic pump belt remained installed and did not exhibit anomalous damage. The hydraulic fluid reservoir was found in its normally installed location; evidence of hydraulic fluid was observed in the reservoir sight glass.

The cyclic and collective controls remained in their normally installed positions. The collective control was found nearly fully down. The collective friction lock was able to be rotated by hand. The collective lever lock was in its stowed position on the center console. The cyclic control was found to be aft-right of center. The cyclic friction lock was able to be rotated by hand. Manual movement of the cyclic and collective controls resulted in a corresponding movement of the swashplate, main rotor blade PCLs, and main rotor blades. The pedals remained in their normally installed location. Manual movement of the pedals was attempted but they could not be moved. Manual movement of the tail rotor blades was attempted but they too could not be moved.

The engine controls and rotor brake lever were found in their normally installed, floor-mounted location adjacent to the collective control (**Figures 5 and 6**). The FFCL was found in the shutoff position.[8] The FSOL was found in the forward and down position, consistent with the fuel shutoff valve being in the open position.[9] A snap wire[10] is normally installed around the FSOL and routed through a hole in the fuel control plate. The snap wire was found around the FSOL but was broken at its bottom end where it normally routes through the plate hole. The snap wire was retained for further examination.[11] Movement of the FSOL from the forward-down position to the aft-up

[6] The FFCL is an engine control lever.
[7] The FSOL, also known as the fuel shutoff valve control lever, provides a means to open and close a valve on the fuel line between the fuel tank and the engine.
[8] The accident helicopter was equipped with modifications Nos. 07-3283 and 07-4685, via service bulletin AS350-76.90.21, that incorporated locking detents for the FFCL.
[9] When the FSOL position is forward and down, the valve is open, permitting fuel to flow to the engine. When the FSOL position is aft and up, the valve is closed, cutting off fuel flow to the engine.
[10] The "snap wire" is also known as a "breakable wire", is intended to keep the FSOL in the open position.
[11] Additional findings for the FSOL snap wire can be found in the NTSB Materials Lab Factual Report No. 18-059.

position resulted in a corresponding movement of the fuel shutoff valve at the engine firewall, consistent with closing of the fuel shutoff valve. The FSOL could not be moved fully into the detent for fuel shutoff. The rotor brake lever[12] was found in the forward and down position, consistent with being stowed.[13]

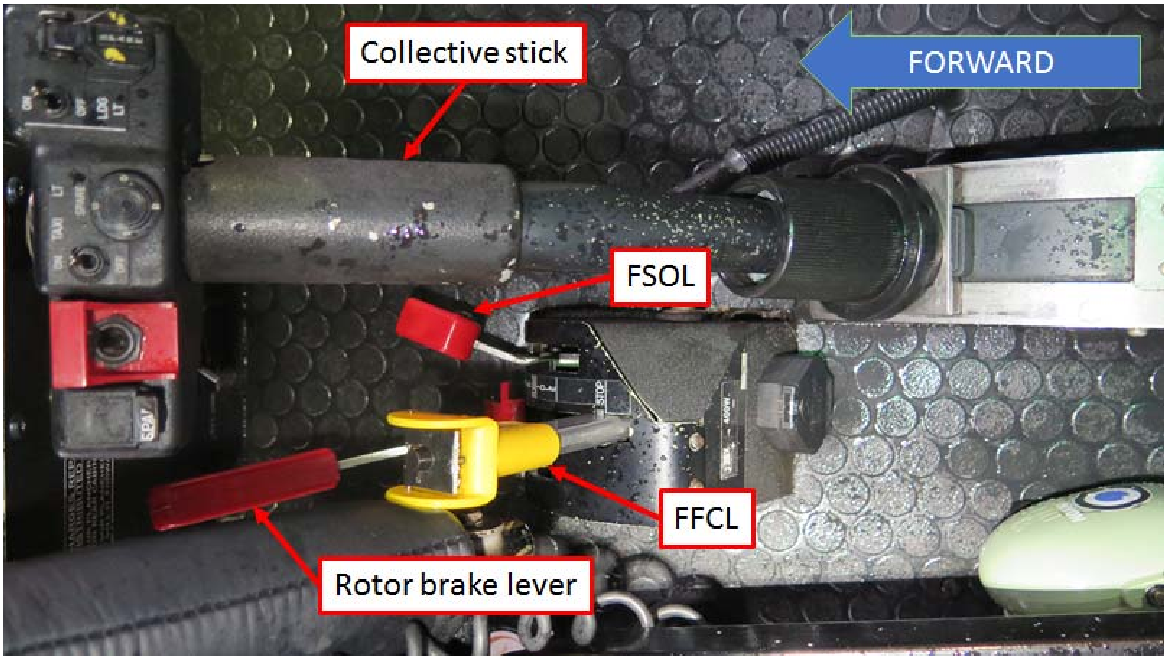

Figure 5. The engine controls and rotor brake lever.

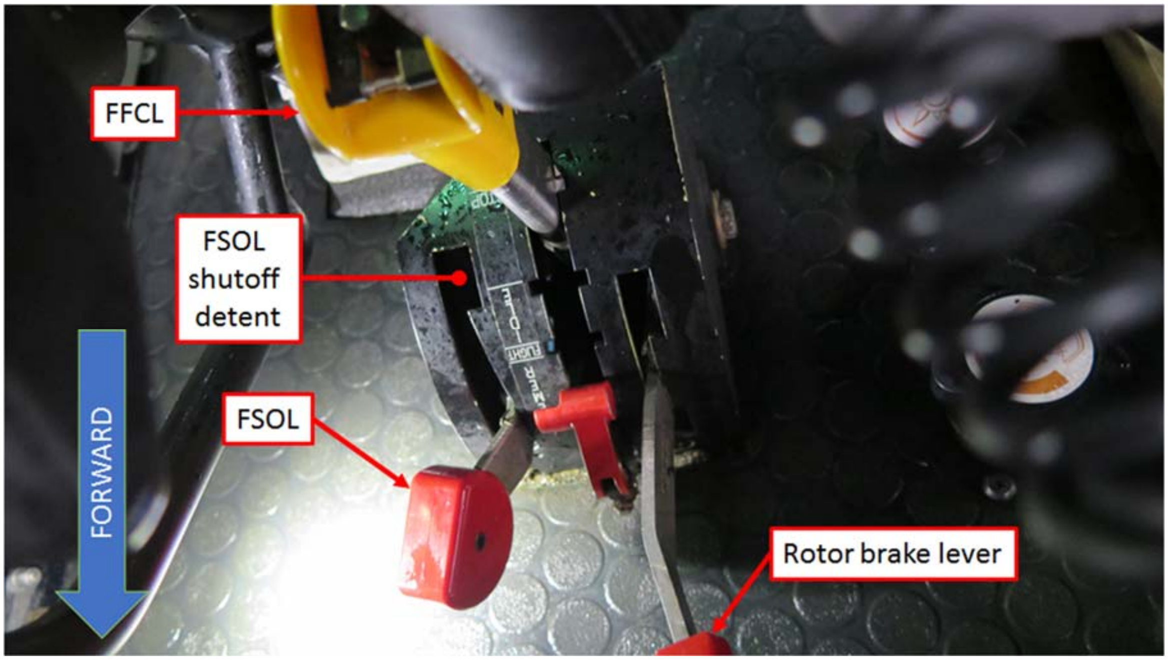

Figure 6. A view of the engine controls and rotor brake lever showing their travel paths and detents.

[12] The accident helicopter was equipped with modification No. 07-4337 which modified the shape of the rotor brake lever to avoid interference with the collective control.

[13] When the rotor brake lever position is forward and down, the rotor brake is stowed. When the rotor brake lever position is aft and up, the rotor brake is engaged.

2.5 ENGINE

2.5.1 ENGINE DESCRIPTION

The Arriel 1D1 turboshaft engine features a single-stage axial flow compressor and a single-stage centrifugal flow compressor, an annular combustor, a two-stage turbine rotor that drives the compressor, and a free turbine rotor. A reduction gearbox is driven via a splined coupling (also known as a "muff coupling") connected to the free turbine rotor. The reduction gearbox provides final drive to the power transmission shaft. The freewheeling unit is mounted to the forward end of the power transmission shaft.

2.5.2 ENGINE FINDINGS

The engine air inlet barrier filter did not exhibit evidence of anomalous damage. The bypass, behind the barrier filter on the top of the engine cowling, remained closed. The airframe-mounted engine oil reservoir remained installed on the transmission deck.

For detailed findings regarding the accident helicopter engine, see the Powerplant Group Chairman's Factual Report in the docket for this investigation.

2.6 MISCELLANEOUS OBSERVATIONS

The helicopter battery was in its normally installed location on the right-side baggage compartment. The battery was disconnected after recovery.

A portable fire extinguisher was found loose on the front-right chin bubble, immediately below its mount which remained attached to the airframe.

The aft-left baggage compartment was found in the opened position during recovery of the helicopter. According to the operator, the rotorcraft flight manual (RFM) and flight logbook were moved from the cockpit to the aft-left baggage compartment during doors-off flights. No items were observed in the aft-left baggage compartment.

The helicopter was equipped with a skid-mounted emergency floatation system. For more information on the emergency floatation system, see the Emergency Floatation System Group Factual Report in the docket for this investigation.

3.0 MAINTENANCE

The helicopter was maintained under the aircraft manufacturer's recommended inspection program. According to the helicopter logbook, the last airframe 100-hour inspection was performed on March 6, 2018, when the airframe had accumulated about 5,496.3 hours ATT, and the last airframe 1-month inspection was performed on February 28, 2018, when the airframe had accumulated about 5,481.1 hours ATT. No defects were noted in either inspection. Daily inspection sign-offs were found in the aircraft daily maintenance report logs.

In 2017, from August to September, the airframe 600-hour/24-month inspection was performed and completed on N350LH. This inspection included a test of the FSOL and its ball valve to check for excessive friction and force to operate. No defects were noted in the FSOL inspection.

The Appareo Vision 1000 cockpit image recorder was installed on N350LH at the time of its manufacture. The AS350 B2 maintenance manual contained a requirement for a 12-month inspection of the Vision 1000 camera which included functional test of the camera. According to the maintenance records for N350LH, the Vision 1000 camera maintenance was labeled as "N/A" (not applicable) during the last airframe 12-month inspection on October 27, 2017. The operator's director of maintenance stated they did not know the function of the camera installed on the helicopter until the accident when investigators identified it. For more information on the Appareo Vision 1000 camera recovered from N350LH, see the Recorder Group Factual Report in the docket for this investigation.

Section 7.14 of the AS350 B2 RFM contains a system description of the Vision 1000 along with a figure that depicts its location within the cockpit. Additionally, Airbus Helicopters Information Notice No. 3022-I-25, dated November 8, 2017, contains information on the Vision 1000 system, its intended use, and the potential benefits of the data it collects. Attachment 1 of this report contains a copy of Airbus Helicopters Information Notice No. 3022-I-25.

4.0 AS350 B2 CERTIFICATION

4.1 CERTIFICATION BASIS FOR AS350 B2

The AS350 B2 helicopter was approved by the FAA on June 8, 1990 and added to TCDS No. H9EU. The certification basis for the AS350 B2 was 14 CFR 21.29; Part 27, effective February 1, 1965, including Amendments 27-1 through 27-10; and FAA Special Conditions No. 27-79-EU-23, dated August 13, 1977. Additionally, an equivalent safety, in lieu of direct compliance, was found with respect to 14 CFR 27.1189 ("shutoff means").

4.2 SHUTOFF MEANS (14 CFR 27.1189)

The subject group within Part 27 concerning powerplant fire protection, §27.1183 through §27.1195, contains a regulation concerning [powerplant] shutoff means. Amendment 27-2, effective February 25, 1968 and applicable to the certification basis of the accident helicopter, modified §27.1189 to the following:

> (a) There must be means to shut off each line carrying flammable fluids into the engine compartment, except--
>
> (1) Lines forming an integral part of an engine; and
>
> (2) For reciprocating engine installations only, engine oil system lines in installations using engines of less than 500 cu. in. displacement.
>
> (b) There must be means to guard against inadvertent operation of each shutoff, and to make it possible for the crew to reopen it in flight after it has been closed.
>
> (c) Each shutoff valve and its controls must be on the remote side of the firewall from the engine if they cannot function under any fire condition likely to result from an engine fire.

The current version of §27.1189, modified through Amendment 27-23 and effective October 3, 1988, states the following:

(a) There must be means to shut off each line carrying flammable fluids into the engine compartment, except--

(1) Lines, fittings, and components forming an integral part of an engine;

(2) For oil systems for which all components of the system, including oil tanks, are fireproof or located in areas not subject to engine fire conditions; and

(3) For reciprocating engine installations only, engine oil system lines in installations using engines of less that 500 cu. in. displacement.

(b) There must be means to guard against inadvertent operation of each shutoff, and to make it possible for the crew to reopen it in flight after it has been closed.

(c) Each shutoff valve and its control must be designed, located, and protected to function properly under any condition likely to result from an engine fire.

4.2.1 EQUIVALENT SAFETY DETERMINATION FOR §27.1189

The Airworthiness group chairman requested the FAA provide information on the equivalent safety determination for shutoff means (§27.1189) for the AS350-series helicopter. Working with the European Aviation Safety Agency (EASA) and Airbus to answer this query, the FAA provided an excerpt of notes taken from a meeting on October 21-22, 1976 between the FAA, Aérospatiale[14], and the Direction Générale de l'Aviation Civile (DGAC) of France[15]. The excerpt stated there was no shutoff valve on the engine oil circuit, and despite what was required by §27.1189, an equivalent level of safety was determined because the [oil] hoses were fireproof in the engine compartment. A note from a meeting between FAA and Aérospatiale on September 20, 1977 stated the FAA agreed to an equivalent level of safety for the engine oil circuit shutoff valve requirement. There was no mention of the FSOL in the equivalent safety determination.

4.2.2 FSOL CERTIFICATION AND HISTORY

The FAA Rotorcraft Standards office stated that §27.1189 was applicable to the design of the FSOL. According to an excerpt from the AS350 B type certification, provided by the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA), the FSOL was to be "maintained in 'open' position with a breakable wire." The FAA could not find additional documents or notes specifically addressing the FSOL during initial certification of the AS350-series helicopter. The FAA Rotorcraft Standards engineers posited that, at the time of certification, the FSOL design met §27.1189(b), the requirement to guard against inadvertent operation, because the FSOL head was a different color and shape than the other two adjacent levers on the central floor-mounted controls. Specifically, the FSOL was a shorter lever (in length) and had a circular, red-colored head. In contrast, the FFCL was longer in length and has a yellow-colored head that is trapezoidal in shape, and the rotor brake lever was also longer in length and has a red-colored head that is rectangular in shape. The different colors and shapes of these three levers would allow the pilot to determine, via visual and tactile means, which control they have grasped, guarding against inadvertent operation of the incorrect lever. The FAA Rotorcraft Standards engineers further explained that during the certification process, certain assumptions must be made in evaluating a design. Examples of

[14] Aérospatiale initially developed the AS350-series helicopter. In 1992, the merger of Aérospatiale and Deutsche Aerospace led to the creation of Eurocopter, which was later rebranded in 2014 as Airbus Helicopters.

[15] DGAC translates to general directorate for civil aviation. Prior to the creation of the EASA in 2002, the French DGAC was responsible for approving type certificates and airworthiness approvals for the country of France.

assumptions included the securement of loose equipment or items in the cockpit area or having only qualified crewmembers in the cockpit.[16] Additionally, a violation of those assumptions could reduce the effectiveness of the risk-mitigating features of a control design. According to the FAA and Airbus, a search of their reportable events database revealed no reported events of inadvertent activation of the FSOL in flight.

The majority of the AS350 B3[17] equipped with the Arriel 2B engine and subsequent variants and models added to TCDS No. H9EU have the FSOL and rotor brake lever mounted on the cockpit ceiling. The ceiling-mounted FSOL incorporated a breakaway plate that is intended to prevent inadvertent activation. The ceiling-mounted rotor brake lever incorporated a button to release the locking mechanism for the rotor brake lever. Additionally, these models replaced the floor-mounted FFCL with a collective-mounted twist grip engine control.

4.3 ENGINE CONTROLS

The subject group within Part 27 concerning powerplant controls and accessories, §27.1141 through §27.1163, contain regulations for the design of engine controls. The original version of §27.1141, dated February 1, 1965 and titled "powerplant controls: general," was applicable to the certification basis of the accident helicopter and stated the following:

> (a) Powerplant controls must be located and arranged under Sec. 27.777 and marked under Sec. 27.1555.
> (b) Each flexible powerplant control must be approved.

Amendment 27-12, effective May 2, 1977, modified §27.1141 to the following:

> (a) Powerplant controls must be located and arranged under Sec. 27.777 and marked under Sec. 27.1555.
> (b) Each flexible powerplant control must be approved.
> (c) Powerplant valve controls located in the cockpit must have—
>> (1) For manual valves, positive stops or in the case of fuel valves suitable index provisions, in the open and closed position; and
>> (2) For power-assisted valves, a means to indicate to the flight crew when the valve—
>>> (i) Is in the fully open or fully closed position; or
>>> (ii) Is moving between the fully open and fully closed position.
>
> (d) For turbine engine powered rotorcraft, no single failure or malfunction, or probable combination thereof, in any powerplant control system may cause the failure of any powerplant function necessary for safety.

The current version of §27.1141, modified through Amendment 27-33 and effective August 8, 1996, states the following:

[16] According to TCDS No. H9EU, the AS350-series helicopter has a minimum crew of 1 pilot and maximum passenger load of 5 (1 in front and 4 in the rear of the cabin) with an option for 6 passengers (2 in front and 4 in the rear of the cabin).

[17] The AS350 B3 was originally approved to be equipped with the Arriel 2B engine which incorporated a full authority digital engine control (FADEC). Subsequent revisions to TCDS No. H9EU allowed the AS350 B3 to be equipped with the Arriel 2B1 and Arriel 2D engines.

(a) Powerplant controls must be located and arranged under Sec. 27.777 and marked under Sec. 27.1555.
(b) Each flexible powerplant control must be approved.
(c) Each control must be able to maintain any set position without—
 (1) Constant attention; or
 (2) Tendency to creep due to control loads or vibration.
(d) Controls of powerplant valves required for safety must have—
 (1) For manual valves, positive stops or in the case of fuel valves suitable index provisions, in the open and closed position; and
 (2) For power-assisted valves, a means to indicate to the flight crew when the valve—
  (i) Is in the fully open or fully closed position; or
  (ii) Is moving between the fully open and fully closed position.
(d) For turbine engine powered rotorcraft, no single failure or malfunction, or probable combination thereof, in any powerplant control system may cause the failure of any powerplant function necessary for safety.

§27.777, titled "cockpit controls", had not been modified since its introduction on February 1, 1965 and was applicable to the certification basis of the accident helicopter. §27.777 currently states the following:

Cockpit controls must be—
(a) Located to provide convenient operation and to prevent confusion and inadvertent operation; and
(b) Located and arranged with respect to the pilots' seat so that there is full and unrestrictive movement of each control without interference from cockpit structure or the pilot's clothing when pilots from 5'2" to 6'0" in height are seated.

The requirements for the design of the engine controls are discussed in §27.1143. The original version of §27.1143, dated February 1, 1965 and titled "throttle controls," was applicable to the certification basis of the accident helicopter and stated the following:

(a) There must be a separate throttle control for each engine.
(b) Throttle controls must be grouped and arranged to allow—
 (1) Separate control of each engine; and
 (2) Simultaneous control of all engines.
(c) Each throttle control must provide a positive and immediately responsive means of controlling its engine.

Amendment 27-11, effective February 1, 1977, modified the title of §27.1143 to "engine controls" and stated the following:

(a) There must be a separate throttle control for each engine.
(b) Throttle controls must be grouped and arranged to allow—
 (1) Separate control of each engine; and
 (2) Simultaneous control of all engines.
(c) Each throttle control must provide a positive and immediately responsive means of controlling its engine.
(d) If a power or thrust control incorporates a fuel shutoff feature, the control must have a means to prevent the inadvertent movement of the control into the shutoff position. The means must—

(1) Have a positive lock or stop at the idle position; and
(2) Require a separate and distinct operation to place the control in the shutoff position.

The current version of §27.1143, modified through Amendment 27-29 and effective October 17, 1994, states the following:

(a) There must be a separate power control for each engine.
(b) Power controls must be grouped and arranged to allow—
(1) Separate control of each engine; and
(2) Simultaneous control of all engines.
(c) Each power control must provide a positive and immediately responsive means of controlling its engine.
(d) If a power control incorporates a fuel shutoff feature, the control must have a means to prevent the inadvertent movement of the control into the shutoff position. The means must—
(1) Have a positive lock or stop at the idle position; and
(2) Require a separate and distinct operation to place the control in the shutoff position.
(e) For rotorcraft to be certificated for a 30-second OEI power rating, a means must be provided to automatically activate and control the 30-second OEI power and prevent any engine from exceeding the installed engine limits associated with the 30-second OEI power rating approved for the rotorcraft.

The original FFCL design is found on AS350 variants preceding the AS350 B3 equipped with the Arriel 2B engine. The FFCL moves in a track that has three positions, two of which incorporate detents. The first position is the stop detent; the second position is the flight detent; and the third position opens the emergency fuel valve.[18] The FFCL travels in about a 90-degree arc with the first position resulting in the FFCL in a mostly aft/up position and the third position resulting in the FFCL in a mostly forward/down position. Travel between the detents requires movement of the FFCL to the right to remove it from a detent, followed by movement of the lever to the desired position. The FFCL is spring-loaded to inherently move the FFCL to the left, which is intended to retain the FFCL in the detent it is currently in. On October 20, 2010, the NTSB recommended to the FAA and the EASA to require Eurocopter to review the design of the FFCL and/or its detent track on AS350-series helicopter and require modification to ensure that the FFCL is protected to prevent unintentional movement out of its detents and that it does not move easily to an unintended position.[19] In April 2015, Airbus Helicopters released service bulletin No. AS350-76.00.21 which replaces the original FFCL design with a new design. The newly developed FFCL incorporated locking detents with a push-plate on top of the FFCL knob to unlock the lever to move it to a different position. Additionally, the new FFCL design incorporated a gate to restrict access to the emergency fuel valve position unless the gate is flipped open. In May 2015, Airbus Helicopters began installing the new FFCL design onto its newly manufactured AS350-series helicopters that were equipped with an FFCL. At the time of this report, neither the FAA nor the EASA has mandated incorporation of the new FFCL design for existing AS350-series helicopters.

4.4 ROTOR BRAKE CONTROLS

Within the original Part 27 regulation, effective February 1, 1965, §27.921 contained design criteria applicable to the rotor brake system. The regulation, which had not been modified

[18] The position to open the emergency fuel valve does not have a detent.
[19] For additional information, see NTSB Safety Recommendation Nos. A-10-129 through A-10-131.

since its introduction, was applicable to the certification basis of the accident helicopter and states:

> If there is a means to control the rotation of the rotor drive system independently of the engine, any limitations on the use of that means must be specified, and the control for that means must be guarded to prevent inadvertent operation.

Amendment 27-33, effective August 8, 1996, introduced §27.1151, titled "rotor brake controls." §27.1151 states the following:

> (a) It must be impossible to apply the rotor brake inadvertently in flight.
> (b) There must be a means to warn the crew if the rotor brake has not been completely released before takeoff.

According to Airbus, the design of the FFCL contains a mechanical interlock which prevents activation of the rotor brake lever when the FFCL is in the flight detent. This mechanical interlock is found on the designs of both the original and modified FFCL.

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