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

September 5, 2019

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT

NTSB No: CEN19FA072

A. ACCIDENT

Operator:	Viking Aviation, Inc.
Aircraft:	Bell 407, Registration N191SF
Location:	Zaleski, Ohio
Date:	January 29, 2019
Time:	0650 eastern standard time

B. GROUP

Group Chairman:	Chihoon Shin National Transportation Safety Board Washington, District of Columbia
Member:	Todd Gentry Federal Aviation Administration Washington, District of Columbia
Member:	Doug Wahl Viking Aviation, Inc. Little Rock, Arkansas
Member:	Jack Johnson Rolls-Royce Indianapolis, Indiana
Member:	Gary Howe Bell Fort Worth, Texas
Member:	Beverley Harvey Transportation Safety Board of Canada Quebec, Canada
Member:	Dane Immel Woodward, Inc. Santa Clarita, California

LIST OF ACRONYMS

agl	above ground level
ALF	aft-looking-forward
ATT	aircraft total time
cc	cubic centimeter
CCA	circuit card assembly
CFR	Code of Federal Regulations
DC	District of Columbia
ECU	electronic control unit
FAA	Federal Aviation Administration
FADEC	full authority digital engine control
HMU	hydromechanical unit
ICS	intercommunication system
MCV	main control valve
MGT	Engine measured gas temperature
msl	mean sea level
Ng	Engine gas generator speed
NTSB	National Transportation Safety Board
NVM	non-volatile memory
N1	gas producer turbine-to-compressor
N2	power turbine-to-pinion gear
PCL	pitch change link
P/N	part number
psi	pounds per square inch
SD	Secure Digital
S/N	serial number
STC	Supplemental Type Certificate
TRDS	tail rotor drive shaft

C. SUMMARY

On January 29, 2019, at 0650 eastern standard time, a single-engine, turbine-powered, Bell 407 helicopter, N191SF, collided with forested, rising terrain about 4 miles northeast of Zaleski, Ohio. The helicopter was registered to and operated by Viking Aviation, LLC, doing business as Survival Flight, Inc., as a visual flight rules helicopter air ambulance flight under the provisions of 14 Code of Federal Regulations Part 135 when the accident occurred. The certificated commercial pilot, flight nurse, and flight paramedic were fatally injured, and the helicopter was destroyed. Visual meteorological conditions existed at the departure location, and company flight following procedures were in effect. The flight departed Mt. Carmel Hospital, Grove City, Ohio at 0628, destined for Holzer Meigs Hospital, Pomeroy, Ohio, about 69 miles southeast.

According to the Survival Flight Operations Control Specialist (OCS) on duty at the time of the accident, the night shift pilot had originally accepted the flight. The OCS said that, while he was on the phone with that pilot reviewing flight details at about 0612, he was told that, due to the upcoming shift change, the day pilot would be taking the flight.

The OCS said that, while watching the helicopter on flight tracking software in the Operations Control Center, he observed that, about 15 minutes after departure, the helicopter made a turn to the right, then "a sharp left turn," which was immediately followed by a "no-tracking alarm." The emergency action plan was then initiated. The helicopter wreckage was located on a tree-covered hill and exhibited significant fragmentation.

The wreckage and debris path extended about 600 feet downslope on a heading of about 345° magnetic. A portion of the front-left skid tube was found at the start of the wreckage path, followed by the main rotor hub and blades, tail boom and tail rotor, cockpit and cabin, and the engine and transmission deck. Tree branches broken about 30 ft above ground level (agl) were observed near the front-left skid tube. Additionally, one main rotor blade had separated from the main rotor hub and was embedded in a tree. The elevation of the wreckage area ranged from 850 to 980 ft above mean sea level (msl). There was no evidence of a postcrash fire, but a strong smell of fuel was reported by first responders when the wreckage was first discovered.

The helicopter was equipped with an Outerlink Global Solutions IRIS flight data monitoring system, which provides real-time flight tracking data. The flight tracking information is relayed via satellites to an internet-based storage location in 10-second intervals. According to the IRIS data, the helicopter's last known location was about 4 miles northeast of Zaleski at an altitude of 1,528 ft msl, traveling at 132 knots across the ground, on a course of 072°. In addition to the transmission of data at 10-second intervals, the IRIS stores flight data in 1-second intervals, along with voice and satellite communications. The equipment was removed and sent to the NTSB Vehicle Recorders Laboratory for voice and data extraction.

From January 30 to February 2, 2019 documentation of the wreckage was performed at the accident site and after recovery. The engine electronic control unit (ECU), selected cockpit instrument gauges, and the main rotor and tail rotor hydraulic actuators were retained for further investigation. On April 16, 2019, the engine ECU was downloaded at Triumph Engine Control Systems facilities in West Hartford, Connecticut. Data was successfully downloaded from the ECU. On May 16, 2019, an attempt was made to download the non-volatile memory (NVM) from select cockpit instrument gauges, but all attempts were unsuccessful in extracting data. From May 20 to 23, 2019, the main rotor and tail rotor hydraulic actuators were examined at Woodward facilities in Santa Clarita, California. At the conclusion of this examination, no further investigative activities for the hydraulic actuators were performed due to a lack of anomalous findings that would have precluded normal operation.

D. DETAILS OF THE INVESTIGATION

1.0 HELICOPTER INFORMATION

1.1 HELICOPTER DESCRIPTION

The Bell 407 is type certificated under Federal Aviation Administration (FAA) type certificate data sheet (TCDS) No. H2SW. The Bell 407 has a four-bladed main rotor system that provides helicopter lift and thrust, and a two-bladed teetering tail rotor system that provides thrust to counteract main rotor torque effect and control helicopter yaw. The helicopter is equipped with one Rolls-Royce (formerly Allison) Model 250-C47B turboshaft engine, mounted behind the main gearbox, which has a maximum continuous power rating of 630 shaft horsepower per TCDS No. H2SW. The helicopter was equipped with a skid-type landing gear.

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.

1.3 HELICOPTER HISTORY

The accident helicopter, serial number (S/N) 53006, was manufactured in 1996. According to helicopter records, engine S/N CAE-847007 was installed. At the end of the day before the accident, the airframe had accumulated an aircraft total time (ATT) of 1,179.7 hours and the engine had accumulated total time of 1,179.7 hours.

2.0 ON-SCENE AND POST-RECOVERY WRECKAGE EXAMINATION

On January 30-31, 2019, members of the Airworthiness Group convened at the accident site to document the wreckage. The wreckage was recovered on January 31, 2019 and was transported to a facility in Springfield, Tennessee on February 1, 2019. On February 2, 2019, members of the Airworthiness Group documented the recovered wreckage.

The wreckage and debris path extended horizontally about 600 feet downslope on a heading of 345° magnetic (**Figure 1**). A portion of the front-left skid tube was found at the start of the wreckage path, followed by the main rotor hub and blades, tail boom and tail rotor, cockpit and cabin (main fuselage), and the engine and transmission deck (**Figure 2**). Broken tree branches, about 30 ft agl, were observed near the front-left skid tube. The elevation of the wreckage area ranged from 850 to 980 feet above msl. There was no evidence of a postcrash fire, but a strong smell of fuel was reported by first responders when the wreckage was first discovered.

Figure 1. Overview of the wreckage debris distribution.

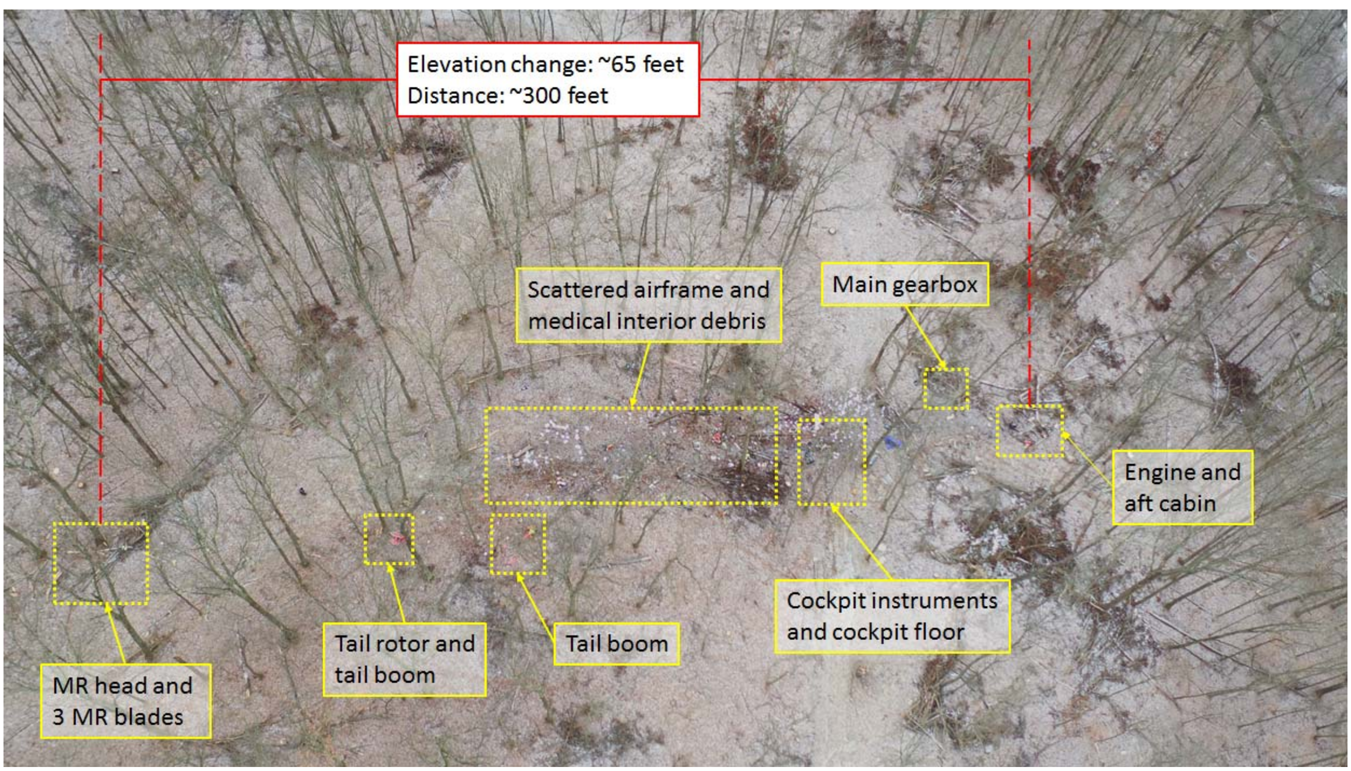

Figure 2. Detailed wreckage debris distribution from the main rotor head and main rotor blades to the engine and aft cabin. **(photo courtesy of Ohio State Highway Patrol, edited by NTSB)**

2.1 STRUCTURES

2.1.1 OVERVIEW

The helicopter structure comprises the main fuselage, the tail boom and empennage, and a skid-type landing gear. The main fuselage contains the cockpit, cabin, bladder-type fuel tanks, and baggage compartment. The main fuselage supports the engine, main rotor gearbox, and the main rotor and its controls. The intermediate fuselage connects the tail boom to the main fuselage. The tail boom and empennage contain the tail rotor drive system and the tail rotor and its controls. The left and right horizontal stabilizers are mounted about mid-length of the tail boom. Vertical end plates are mounted to the outboard edge of each horizontal stabilizer. The upper and lower vertical fins are mounted near the aft-end of the tail boom and are co-located with the tail rotor gearbox.

2.1.2 OBSERVATIONS

The airframe exhibited significant fragmentation. The remnant skid pieces were separated from the main fuselage and found in the debris trail. The left-front skid tube was found at the start of the wreckage path (**Figure 3**). Both forward and aft skid cross tubes were found separate from each other.

Figure 3. The left-front skid tube.

A portion of the aft fuselage, composed of the baggage compartment and structure about 3 feet aft of the baggage compartment, had impacted and embedded itself into the trunk of a tree. Pieces of tail boom and empennage, containing the tail rotor, were found to the right of this tree, while pieces of the cabin were found to the left of this tree.

Pieces of the cabin interior, acrylic glass, seats, and medical equipment were found in the debris path. A portion of the cabin roof structure was separated from the main fuselage and remained attached to the main gearbox. A portion of the aft-right side of the cabin, including the fuel fill port, was found adjacent to the engine inlet barrier filter downhill from the cabin and tail boom pieces. A portion of the right aft-facing seat was found near the aft piece of the cabin. A portion of the forward fuselage was found in the debris path and contained push-pull tubes and bell cranks for the cockpit flight controls as well as cockpit instruments and wiring.

The forward fuel bladder tank was found near the engine. The forward fuel cell exhibited a tear on its upper-left corner. The aft bladder was found uphill and exhibited a tear on its upper surface. The fuel quantity probe in the aft fuel cell was fractured near its upper end.

The tail boom and empennage were fractured into four large pieces. The outboard sections of the left and right horizontal stabilizer were fractured but their root sections remained attached to the tail boom. The vertical stabilizer was found separated from the empennage and exhibited impact damage.

2.2 MAIN ROTOR SYSTEM

2.2.1 SYSTEM OVERVIEW

Power from the engine reduction gearbox is transferred through a sprag clutch[1] to the main rotor gearbox via the input drive shaft. Kaflex couplings on both the forward and aft ends of the input drive shaft allow for minor misalignment. The accident helicopter was equipped with a rotor brake which was installed between the engine reduction gearbox output flange and the aft Kaflex coupling of the input drive shaft. The main rotor gearbox contains a single-stage sun and planetary gear system that turns the main rotor shaft (also known as the main rotor mast). The main rotor hub is splined onto the main rotor shaft. The main rotor gearbox is attached to the airframe via pylon assemblies containing elastomeric mounts for vibration dampening.

The main rotor hub is composed of a yoke which is mounted between an upper and lower [hub] plate. Each main rotor blade is connected to the yoke via a grip assembly. An elastomeric thrust bearing, which accommodates blade pitch changes, a pitch horn, and an elastomeric shear (pivot) bearing attach to the blade grip. An elastomeric lead-lag damper bearing, installed inboard of the pitch horn, is connected to the pivot bearing as well as both the upper and lower hub plates. The four main rotor blades are identified by color and the shape[2] of identification stickers adhered to each rotor blade, presented in the order of advancing rotation: 'blue' (diamond), 'orange' (square), 'red' (triangle), and 'green' (circle). The main rotor blades are composite in construction, with a fiberglass spar, fiberglass skin, and Nomex honeycomb core. Blade pitch control is achieved via pitch change links (PCL) connected between each blade's pitch horn and the rotating swashplate. The accident helicopter was previously equipped with a Frahm-type damper, normally mounted to the top of the main rotor hub for vibration attenuation, which was removed prior to the accident.

2.2.2 MAIN ROTOR OBSERVATIONS

The main rotor hub was found downhill of the left-front skid piece. The main rotor hub contained the yoke, the upper and lower plates, and a portion of the main rotor shaft (**Figure 4**). The 'orange', 'green' and 'blue' main rotor blades, found adjacent to the main rotor hub, contained multiple fractures that exhibited a broomstrawed appearance. Major

[1] A sprag clutch is a type of freewheeling unit.
[2] Stickers of a certain shape and color are normally placed on the Bell 407 main rotor blades to identify them. The stickers are typically found on the blade grip and the inboard end of the blade.

portions of the blade afterbody was separated on the 'orange', 'green' and 'blue' main rotor blades. Pieces of main rotor blade skin and core material were found distributed in the debris field near the main rotor hub. The 'orange' and 'green' blades and pitch horns remained attached to their respective grips, which remained attached to the yoke via their elastomeric thrust bearing. The upper portion of the 'orange' PCL remained attached to its pitch horn. The 'green' PCL remained attached to its pitch horn. The 'green' PCL rod was present down to the threaded connection for the lower spherical bearing. The 'blue' blade and pitch horn remained attached to its grip, but the pitch horn was fractured at the horn arm. The 'blue' grip was separated from the yoke at the main rotor hub, but a remnant piece of the yoke was still attached to the grip via its elastomeric thrust bearing. The 'red' main rotor blade assembly was found within a tree near the main rotor hub. The 'red' blade and pitch horn remained attached to its grip. The 'red' grip was separated from the yoke at the main rotor hub, but a remnant piece of the yoke was still attached to the grip via its elastomeric thrust bearing. The upper portion of the 'red' PCL remained attached to its pitch horn. The 'red' main rotor blade contained multiple fractures that exhibited a broomstrawed appearance. Major portions of the blade afterbody was separated on the 'red' main rotor blade.

Figure 4. The recovered main rotor head and main rotor blades.

Impact damage was observed on the droop and flap stops on all four blade assemblies. The lead-lag damper remained installed on the hub for the 'orange', 'red', and 'green' blades. The lead-lag damper remained attached to the grip assembly for the 'blue' blade. The pivot bearing was torn and separated from the 'red' blade grip. The pivot bearing for the 'orange', 'green', and 'blue' blades remained installed between their respective lead-lag damper and pitch horn.

The lower hub plate exhibited a downward deformation at the 'blue' blade position and exhibited impact marks on its surfaces. The lower cone seat remained attached to the lower hub plate, and the lower cone remained attached to the lower cone seat. The mast nut remained installed and the upper portion of the fractured main rotor shaft remained connected to the main rotor hub. The main rotor shaft had fractured several inches below the splines mating to the rotating scissors (drive link) and its fracture surface exhibited signatures consistent with overload. For observations on the remaining portion of the main rotor shaft, see Section 2.2.3 of this report. The upper hub plate remained installed and exhibited impact marks on its surfaces.

2.2.3 MAIN ROTOR DRIVE SYSTEM OBSERVATIONS

The main transmission pylons remained attached to the airframe and the main transmission remained attached to its pylons (**Figure 5**). The forward Kaflex coupling for the engine-to-transmission drive shaft remained attached to the input flange. The forward flange of the engine-to-transmission drive shaft remained attached to the forward Kaflex coupling but the remainder of the shaft was not found. The forward flange fracture surfaces exhibited signatures consistent with overload. The main rotor shaft remained installed within the main transmission but exhibited a fracture corresponding to the fracture observed on the main rotor head wreckage. The fracture surfaces exhibited signatures consistent with overload. Cracking of the main transmission housing was observed near the lower-right mount. The forward lower-left main transmission chip detector was slightly loose; removal of the chip detector showed no evidence of metallic chips. The main rotor shaft chip detector was not present. Manual rotation of the main transmission input flange resulted in a corresponding rotation of the main rotor shaft.

Figure 5. The recovered main transmission with pylons and airframe attached.

The rotor brake remained installed at the forward end of the freewheeling unit. A remnant portion of the aft Kaflex coupling for the engine-to-transmission drive shaft remained attached to the rotor brake. The fracture surfaces exhibited signatures consistent with overload. A seat belt (restraint) was wrapped around the aft Kaflex coupling. The freewheeling unit chip detector was removed and exhibited no evidence of metallic chips.

2.3 TAIL ROTOR SYSTEM

2.3.1 SYSTEM OVERVIEW

Power from the engine reduction gearbox sprag clutch is transferred to the tail rotor via the tail rotor drive system. The tail rotor drive system contains a total of 6 tail rotor drive shafts (TRDS): 1 steel TRDS[3] is mounted between the sprag clutch and the oil cooler blower followed by 5 aluminum TRDS[4] between the oil cooler blower and the tail rotor gearbox. The steel TRDS is connected to the sprag clutch flange and oil cooler blower flange via flexible coupling disc packs. The 5 aluminum TRDS are supported along the tail boom structure by 4 hanger bearings. In this report, the aluminum TRDS are numbered 1 through 5 from the forward to aft position, respectively. Each aluminum TRDS is connected to each other via flexible coupling disc packs. A flexible coupling disc pack is also found between the No. 5 TRDS and the tail rotor gearbox input flange. The tail rotor gearbox, mounted near the aft end of the tail boom, changes the direction of drive and also reduces the output speed of rotation at the tail rotor. The tail rotor gearbox output shaft connects to the tail rotor yoke.

The two-bladed tail rotor is a semi-rigid (teetering) rotor system. Each tail rotor blade, composite in construction, is attached to the tail rotor yoke via two spherical bearings. The two spherical bearings accommodate blade pitch changes.

2.3.2 TAIL ROTOR OBSERVATIONS

Both tail rotor blade roots remained attached to the tail rotor hub (**Figure 6**). One of the two tail rotor blades, identified in this report as the “unmarked” tail rotor blade, exhibited impact damage on its leading edge. About two-thirds of the outboard section of the unmarked tail rotor blade was separated. A fractured section of the unmarked tail rotor blade leading edge was found next to the tail rotor and exhibited a broomstrawed appearance; the afterbody was not present on the fractured section. The second tail rotor blade, which had a green-colored sticker at the blade root and on its PCL, was whole and exhibited opening of its trailing edge near its outboard end. The flap stop for the unmarked tail rotor blade was fractured and separated. The flap stop for the ‘green’ tail rotor blade was deformed but still attached.

[3] The steel TRDS is also known as the forward short shaft.
[4] The forward-most aluminum TRDS is also known as the aft short shaft.

Figure 6. The tail rotor and tail rotor gearbox at the accident site. **(photo courtesy of Ohio State Highway Patrol)**

2.3.3 TAIL ROTOR DRIVE SYSTEM OBSERVATIONS

The tail rotor drive output flange, located on the aft side of the engine reduction gearbox and normally connected to the forward end of the steel TRDS, was present. The steel TRDS was fractured at its forward end and its forward flange remained attached to the tail rotor drive output flange. The splines from the steel TRDS, which mated to the oil cooler blower, did not exhibit anomalous damage. The blower exhibited crushing damage and was not able to be manually rotated.

All five aluminum TRDS were recovered. The No. 1 TRDS was continuous. The No. 2 TRDS was fractured about mid-length but its forward segment was connected to the No. 1 TRDS and its aft segment was connected to the No. 3 TRDS. The No. 3 TRDS was continuous but deformed near its aft end. A piece of helicopter fairing, which had a red paint color similar to that of the exterior of the helicopter, was embedded between the shaft tube and riveted flange on the aft end of the No. 3 TRDS. The No. 4 TRDS tube was fractured at its forward riveted flange. The forward riveted flange remained attached to the aft flange of the No. 3 TRDS, but one of its two flanges was fractured. The remainder of the No. 4 TRDS was continuous up to the flange attachment to the No 5 TRDS. The No. 5 TRDS was continuous up to its aft flange, and one of its two aft flanges was fractured. The fractured portion of the aft flange for the No. 5 TRDS remained attached to the tail rotor gearbox laminated coupling, which remained attached to the tail rotor gearbox input flange. Neither the internal splines at the forward end of the No. 1 TRDS nor its mating external splines at the aft end of the blower exhibited anomalous wear. All four TRDS hanger bearings were present and remained installed on the TRDS. The aft-most bearing was separated from its hanger support but the remaining three hanger bearings remained within their hanger supports, but the hanger supports were separated from the tail boom.

The tail rotor gearbox was separated from the airframe, but a portion of the structural mount remained attached to the tail rotor gearbox. Rotation of the input flange resulted in a corresponding movement of the tail rotor.

2.4 FLIGHT CONTROL SYSTEM

2.4.1 OVERVIEW

The cockpit flight control system is composed of cyclic, collective, and directional (pedal) controls. The left and right main rotor hydraulic actuators provide hydraulic assistance for the cyclic control while the collective main rotor hydraulic actuator provides hydraulic assistance for the collective control. The left, right, and collective main rotor hydraulic actuators are located on the roof of the cockpit, in front of the main transmission. The tail rotor hydraulic actuator provides hydraulic assistance for the directional controls and is located in the intermediate fuselage (between the main fuselage and tail boom). The mechanical linkages for the pilot (right seat) flight controls are routed below the pilot and passenger seats, aft to the center of the helicopter, and vertically to the cabin roof. The Bell 407 is equipped with an airspeed-actuated pedal restrictor control system (PRCS).[5]

2.4.2 ROTOR FLIGHT CONTROL OBSERVATIONS

Continuity of the push-pull tubes was established from the hydraulic actuator inputs through the broom closet[6] but were fractured at their lower rod ends normally connected to the mixing unit (**Figure 7**). The three main rotor hydraulic actuators remained installed in a separated section of airframe. All input linkages remained installed to all three main rotor hydraulic actuators. The airframe mount to the piston of the left hydraulic actuator was fractured but the mounts for the right and center hydraulic actuators were whole. The aft mounts for the hydraulic actuators remained attached to the support assembly. The data plate for the right main rotor hydraulic actuator was not present.[7] The data plate for the left and collective main rotor hydraulic actuators were present and showed S/N HR012 and HR011, respectively.

The stationary swashplate was fractured and two large pieces of stationary swashplate were recovered (**Figure 8**). One piece contained the left control arm with a fractured portion of a control tube rod end connected to it. The second piece contained a portion of the right control arm but the outer portion of the arm was fractured, with pieces of wood embedded in the right control arm.

[5] The PRCS restricts tail rotor authority at higher airspeeds by automatically adjusting the left pedal [forward] stop. When the helicopter accelerates above 55 knots indicated airspeed (KIAS), the PRCS solenoid energizes, engaging a cam which limits forward travel of the left pedal by 25%. When the helicopter decelerates below 50 KIAS, the PRCS solenoid de-energizes, disengaging the cam, allowing full forward travel of the left pedal. Pulling the emergency release cable for the PRCS allows for manual disengagement of the PRCS pedal stop. The emergency release cable has a copper witness wire to prevent inadvertent disengagement of the PRCS pedal stop.

[6] The broom closet is a vertical structure behind the cockpit seats which house a portion of the flight control push-pull tubes.

[7] According to the maintenance records for N191SF, the right main rotor hydraulic actuator installed was part number (P/N) 206-076-062-107 and S/N HR010.

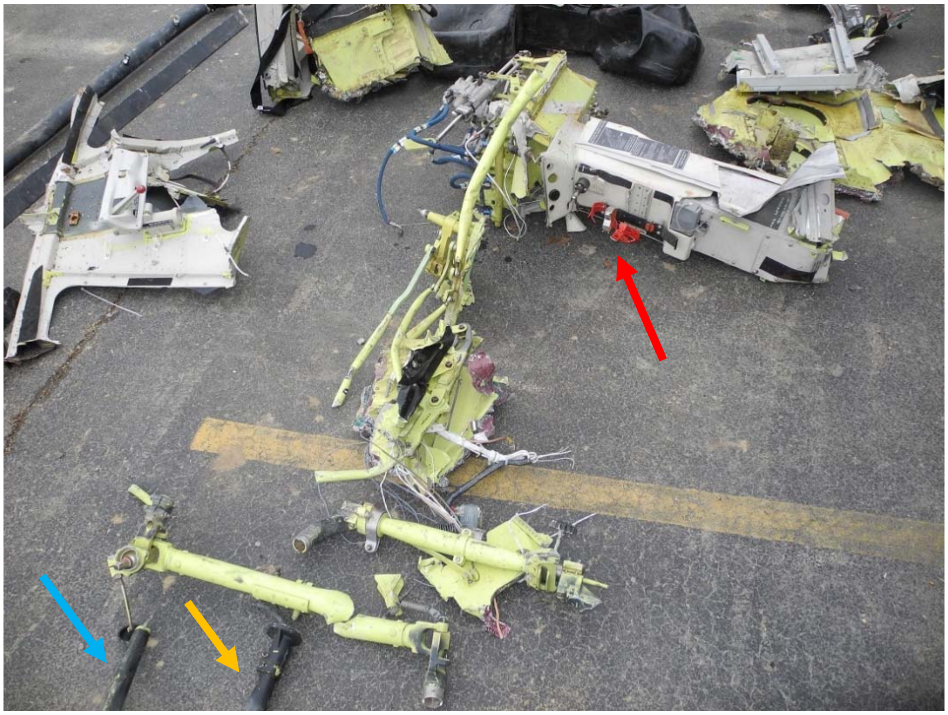

Figure 7. The recovered flight controls. The red arrow points to the broom closet structure with the main rotor hydraulic actuators to the left of it. The blue and orange arrows point to the cyclic and collective, respectively.

Figure 8. The two pieces of the stationary swashplate. The red arrow points to embedded wood on the right control arm.

The tail rotor control tube was fractured but the bell crank leading up to the tail hydraulic actuator piston remained installed on a separated piece of airframe. The tail hydraulic actuator piston was fractured and separated from the actuator body, and the remainder of the piston remained within the actuator body. The tail hydraulic actuator remained installed at its aft end to the walking beam. The tail hydraulic actuator and walking beam were found installed on a piece of intermediate fuselage and tail boom support. The data plate for the tail rotor hydraulic actuator was not present.[8] The tail rotor

[8] According to the maintenance records for N191SF, the tail rotor hydraulic actuator installed was P/N 206-076-062-105 and S/N HR010.

control tube was continuous from the walking beam through the intercostal support until a break in the tail boom about 2 feet aft of the intercostal support. Six pieces of tail rotor control tube were found in the wreckage, one of which still remained within the tail boom section containing the horizontal stabilizer. The tail control bell crank was found with the tail rotor gearbox and the linkage to the tail rotor control lever remained installed but bent. Due to a bend in the tail rotor output shaft, the control lever could not be moved. The tail rotor control linkages remained installed between the tail rotor head and the tail rotor blade pitch horns.

The main rotor and tail rotor hydraulic actuators were retained for further examination. (See section 5.0 of this report.)

2.4.3 COCKPIT FLIGHT CONTROL OBSERVATIONS

The cockpit flight controls exhibited fractures in multiple locations. The left pedal set, with the lockout kit installed, was recovered but only the left pedal remained attached. The lockout kit was fractured in multiple locations. The right pedal set was recovered with both pedals attached. The pedal linkages from the right pedals to the bell crank remained intact but bent. The lateral control tube, to the left of the center bell crank, had fractured in overload. The PRCS remained installed on a fragmented section of the cockpit structure and the emergency release cable remained attached.

The cyclic and collective controls were recovered separated from their mounts (**Figure 9**). The pilot collective control-mounted engine twist grip control was found between “FLY” and “95” (**Figure 10**). The pilot cyclic mount was found installed on the cyclic jackshaft and its friction knob remained installed. The friction knob mount exhibited a gap. The cyclic jackshaft was fractured in two pieces, with each piece containing the left and right cyclic mounts. The pilot collective mount remained installed on the collective jackshaft. The left collective mount was fractured and separated.

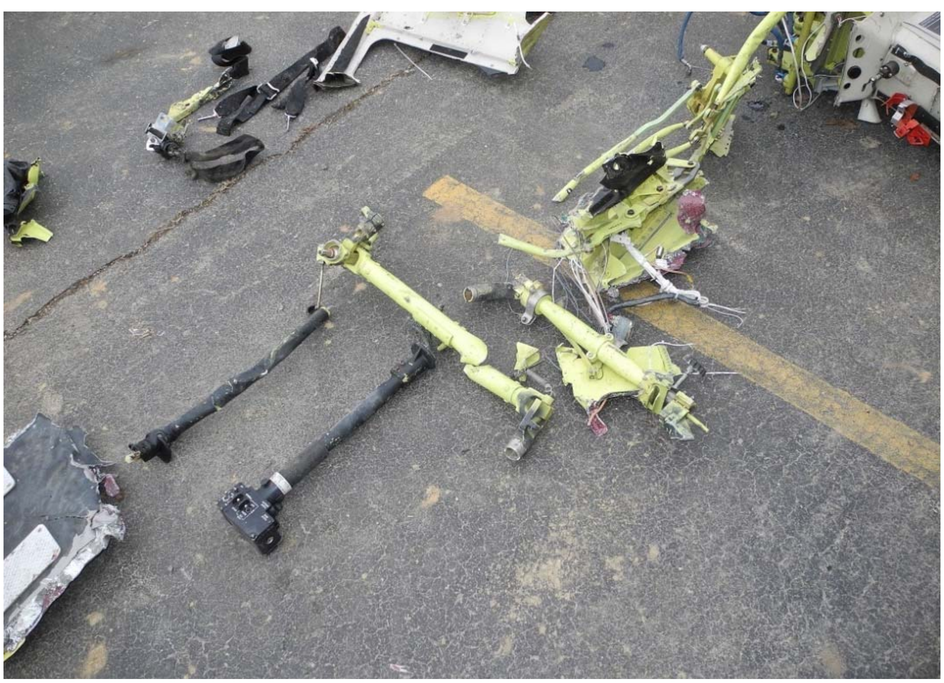

Figure 9. The recovered cyclic, collective, and their respective jackshafts.

Figure 10. The pilot collective control-mounted engine twist grip control.

2.5 COCKPIT INSTRUMENTS AND AVIONICS

A group of cockpit instruments and avionics were found in wreckage containing structure and electrical wiring. The engine gas generator speed (Ng), engine measured gas temperature (MGT), and engine torque gauges were removed from this wreckage and retained for further evaluation. (See section 4.0 of this report.) Additionally, one Garmin GTN-650 navigation unit was found in this wreckage. A second GTN-650 navigation unit was found in a tree in the wreckage path and recovered.

The accident helicopter was equipped with an Outerlink satellite communication and flight data monitoring system.[9] The Outerlink processor module was found in the aft cabin wreckage. The Outerlink dialer module was found in the cockpit avionics wreckage; the Secure Digital (SD) data card was not present in the dialer module. The Outerlink dialer and processor modules were sent to the NTSB Recorders Laboratory in Washington, District of Columbia (DC).[10]

2.6 ENGINE

2.5.1 ENGINE DESCRIPTION

The Rolls-Royce Model 250-C47B is a turboshaft engine that comprises a single-stage centrifugal compressor, a single can-type combustor, and a turbine assembly that incorporates a two-stage gas producer turbine and a two-stage power (free) turbine. The gas producer turbine and the power turbine are not mechanically connected and rotate

[9] The Outerlink system was installed under the provisions of Supplemental Type Certificate (STC) No. SR00365BO.
[10] For additional information on the Outerlink dialer and processor modules, see the Flight Data Monitoring Group Chairman's Factual Report in the docket for this investigation.

independently of each other. The gas producer turbine drives the compressor as well as most of the engine-mounted accessories. The power turbine delivers power to the helicopter rotor system via the engine accessory gearbox. The accessory gearbox front and rear drive splines deliver power to the main rotor and tail rotor drive trains, respectively.

The engine incorporates a full authority digital engine control (FADEC) system. The FADEC system is composed of an airframe-mounted ECU and an engine-mounted hydromechanical unit (HMU). The ECU, manufactured by Triumph Engine Control Systems, monitors engine parameters and performance, as well as the helicopter's power demands, and delivers the necessary control commands to the HMU. As a result, the HMU delivers a metered fuel flow to the engine in accordance with ECU control commands. The ECU continuously monitors the FADEC system for faults and will alert the pilot of specific faults that could significantly impact engine performance. Faults that are considered minor will not be alerted to the pilot during flight, but will be recorded and displayed during engine shutdown. The recorded fault history can be retrieved by maintenance personnel using a computer with the requisite software. Additionally, whenever certain engine parameters are exceeded, the ECU will record the exceedance in a separate incident recorder dataset; this dataset is only accessible by the engine and ECU manufacturers.

2.5.2 ENGINE OBSERVATIONS

The engine was found resting inverted on the aft cabin structure (**Figure 11**). The left, right, and bottom engine mounts remained attached to the engine but its linkages to the airframe were fractured. Several of the first stage compressor blades exhibited leading edge tip curls. The deformation was consistent with soft body foreign object debris (FOD) ingestion.[11] The outer combustion case and the compressor discharge tubes were separated from the engine and found about 20 feet downhill of the engine. The exhaust remained attached to the engine but exhibited crushing deformation. The engine accessory gearbox remained attached to the engine. The engine accessories remained attached to the accessory gearbox. The inlet guide vanes remained attached and did not exhibit deformation. When the compressor was rotated by hand, the starter generator also rotated, confirming continuity of the gas producer turbine-to-compressor (N1) drivetrain. Rotation of the power output shaft resulted in rotation of the power turbines, confirming continuity of the power turbine-to-pinion gear (N2) drivetrain. There was no evidence of binding on either the N1 or the N2 drivetrain. The upper and lower magnetic chip detectors were removed and exhibited no ferrous debris. Residual oil from the engine exhibited a clean appearance with a bright tan coloration. The ECU was found in the wreckage debris path and was retained for data extraction. (See section 3.0 of this report.)

[11] Soft body impact damage is characterized by a large radius of curvature or curling deformation to the blade and can cause curling deformation of the blades in the direction opposite of normal rotation. Soft body impact damage can result from impacts with pliable objects such as birds, ice, tire rubber, and plastic objects.

Figure 11. The engine (red arrow) and aft cabin (blue arrow) at the accident site.

3.0 ECU DOWNLOAD

The ECU for the Rolls-Royce 250-C47B contains NVM which records faults and exceedances. The ECU records data from multiple parameters at a 1.2 second interval. (Each interval containing recorded parameters is referred to as a 'line' in this section.) When a fault or an exceedance[12] occurs, the ECU will record the last 10 lines prior to the exceedance and 40 lines after the fault or exceedance.

On April 16, 2019, the Airworthiness Group chairman and representatives from Rolls-Royce and Triumph convened at Triumph Engine Control Systems facilities in West Hartford, Connecticut to attempt to retrieve information that may have been stored within the ECU. A dent was observed on the ECU cover. The cover was removed and the circuit card assembly (CCA) containing the U40 chip[13], also known as the computer board, was removed from the ECU. The computer board was examined under a microscope; no physical damage was observed. The computer board was installed into a test unit. The test unit was connected to a terminal and powered. The terminal successfully read the U40 chip contents, which included engine fault history, engine history, and engine incident recording data.

In the downloaded data, zero faults and two exceedances were recorded. The first exceedance was defined as a high torque exceedance that was recorded at timestamp 223:58:14.304.[14][15] The second exceedance was defined as a torque rate limit exceedance that was recorded at timestamp 223:58:17.304. In the incident data, a total of 150 lines were downloaded from the incident history. Lines 1 through 12 contained recorded parameters. Lines 13 to 150 contained all zeros. Line 1 of the incident data was at timestamp 223:58:03.408. Line 12 of the incident data was at timestamp 223:58:16.608.

[12] A fault is an error that may preclude normal operation of the ECU. An exceedance is when a parameter, such as torque or gas generator speed, operates outside of a predefined limit.
[13] The U40 chip was the NVM to which faults and exceedances are written.
[14] The timestamps are listed in HH:MM:SS.mmm, interpreted as hours:minutes:seconds.miliseconds.
[15] According to the downloaded data, the engine operating time was 223.87 hours.

Attachment 1 contains the downloaded ECU data as well as a table of acronyms and definitions for the parameters recorded in the exceedance and incident data.

4.0 COCKPIT GAUGE DOWNLOAD

On May 16, 2019, the Airworthiness Group chairman and representatives from Bell convened at Bell facilities in Fort Worth, Texas to attempt to retrieve information that may have been stored in the NVM contained within the Ng, MGT, and torque cockpit gauges. According to Bell, these gauges store exceedance information to include peak value, duration of the exceedance, and the date and time when the exceedance occurred. For each gauge readout attempt, the gauge was connected to a 28 volt power source with a current limit of 5 amperes and a laptop.

When the torque gauge was connected to power, the entire gauge face lit up an off-white color but the indicator bar was not visible and the display showed no numerical values. A download of the exceedance log was attempted but resulted in an error message that the gauge was unreadable. Power to the gauge was cycled and a second download was attempted but resulted in the same error message.

When the Ng gauge was connected to power, the entire gauge face lit up an orange color for about 1 second, after which the light extinguished. An indicator bar was not visible and the display showed no numerical values. A download of the exceedance log was attempted but resulted in an error message that the gauge was unreadable. Power to the gauge was cycled and a second download was attempted but resulted in the same error message.

When the MGT gauge was connected to power, the entire gauge face lit up an off-white color during its boot up cycle, after which the light extinguished with the exception of the indicator bar, visible at the “0” portion of the gauge arc, and the numerical value “0” visible in the display. A download of the exceedance log was attempted but resulted in an error message that the gauge was unreadable. Power to the gauge was cycled and a second download was attempted but resulted in the same error message.

5.0 HYDRAULIC ACTUATOR EXAMINATION

On May 20-23, 2019, the Airworthiness Group chairman and representatives from Woodward convened at Woodward facilities in Santa Clarita, California to examine the main rotor and tail rotor hydraulic actuators.

5.1 RIGHT MAIN ROTOR HYDRAULIC ACTUATOR (S/N HR010)

5.1.1 INITIAL VISUAL EXAMINATION

All safety cables on bolts, screws, and port covers remained installed and intact.[16] All but one of the locking tabs were flat against the jam nut on pilot input of the main control valve (MCV); one locking tab was on the edge of the jam nut flat. The torque stripe on the MCV jam nut was present but appeared partially disturbed but exhibited no evidence of rotation. Manipulation of the aft spherical bearing on the output arm revealed slight axial play of the bearing, but minimal lateral play. The forward spherical bearing of the output arm as well as the piston rod end spherical bearing exhibited no play. All three spherical

[16] According to Woodward, safety cables are not used by their facility when overhauling the Bell 407 hydraulic actuators. Instead, safety wiring is used.

bearings moved freely. Remnant pieces of tree bark was found embedded on the actuator housing.

The test port was opened and the piston was actuated by hand, resulting in residual hydraulic fluid exiting the test port. The piston was moved without difficulty. The residual fluid, collected in a glass bottle, exhibited a bright red coloration with a single black particle.

5.1.2 BENCH TESTING

Bench testing of the actuator was performed in accordance with the procedures of Paragraph 40 of the Woodward acceptance test and inspection procedure (AT&IP) for P/N 41011400-103 hydraulic actuators, except for Paragraphs 40.17 (set rod end) and 40.18 (install protective covers) which were not performed.[17] Additionally, Paragraphs 40.4 (proof pressure and low pressure leak tests), 40.5 (servovalve check), and 40.6 (dynamic leakage check) were performed as the last steps of the bench test.

The bench testing results for the right main rotor hydraulic actuator were within the requirements of all tests performed in Paragraph 40 of the AT&IP.

5.1.3 DISASSEMBLY

The input lever was removed and did not exhibit anomalous damage. The piston rod end (still containing its spherical bearing), jam nut, and locking key were removed. The rod end threads exhibited no anomalous damage. The housing output end and end cap were removed to facilitate removal of the piston. Residual hydraulic fluid exited the housing as the piston was removed. The piston's external surfaces were shiny in appearance with a visible crosshatch pattern[18] on its surface except in certain areas containing typical service wear. The piston seal was present and intact. The dynamic seals and scraper seals were intact on the end glands. Debris was visible only on the exterior side of the scraper seal. The o-ring and backup ring on the end glands were intact. The cylinder bore had no anomalous damage and exhibited a clean appearance.

The MCV cover and spring were removed, revealing the MCV. There was no residual hydraulic fluid within the MCV cover. The servo spool was removed from the MCV. The lands on the servo spool and bypass spool exhibited no evidence of anomalous damage and their o-rings were intact. The o-ring and backup rings on the sleeve were intact. The sleeve and its bore exhibited no anomalous damage.

The sequence valve and back-to-back check valve were removed and their components, including their respective o-rings and backup rings, exhibited no anomalous damage. The filter (screen) on the pressure port exhibited no evidence of blockage or debris. The differential relief valve was removed and the valve components, including o-rings, did not exhibit anomalous damage. Debris, with the appearance of wood, was embedded within the threads on the outside of the differential relief valve cap. The inlet

[17] The AT&IP is normally used to check the quality of condition and performance of newly manufactured and overhauled hydraulic actuators.
[18] According to Woodward, the piston has a crosshatch pattern on its surface at the time of its manufacture. The crosshatch pattern on the surface of the piston is part of the piston design.

check valve was removed and did not exhibit anomalous damage. The o-rings and backup rings on the inlet check valve were intact.

Figure 12 shows the completed disassembly of the right main rotor hydraulic actuator.

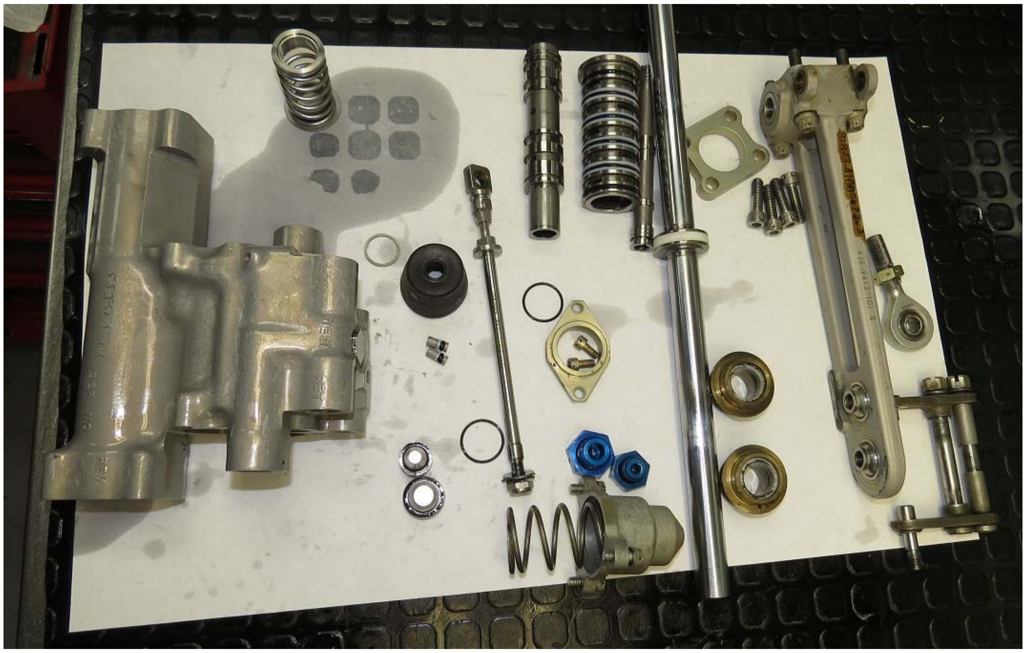

Figure 12. The completed disassembly of the right main rotor hydraulic actuator. (photo courtesy of Woodward)

5.2 COLLECTIVE MAIN ROTOR HYDRAULIC ACTUATOR (S/N HR011)

5.2.1 INITIAL VISUAL EXAMINATION

All safety cables on bolts, screws, and port covers remained installed and intact. All locking tabs were flat against the jam nut for the MCV pilot input. The torque stripe on the MCV jam nut was present and undisturbed. The spherical bearings on the output arm and piston rod end moved freely and did not exhibited play.

The test port was opened and the piston was actuated by hand, resulting in residual hydraulic fluid exiting the test port. The piston was moved albeit with difficulty. The residual fluid, collected in a glass bottle, exhibited a bright red coloration with a single black particle.

5.2.2 BENCH TESTING

Bench testing of the actuator was performed in accordance with the procedures of Paragraph 40 of the Woodward acceptance test and inspection procedure (AT&IP) for P/N 41011400-103 hydraulic actuators, except for Paragraphs 40.17 (set rod end) and 40.18 (install protective covers) which were not performed. Additionally, Paragraphs 40.4 (proof pressure and low pressure leak tests), 40.5 (servovalve check), and 40.6 (dynamic leakage check) were performed as the last steps of the bench test.

Except for the sequence valve leakage test (Paragraph 40.13) and the proof pressure and low pressure tests (Paragraph 40.4), the collective hydraulic actuator met the requirements for the remaining tests within Paragraph 40 of the AT&IP. During the sequence valve leakage test, the pressure port leaked at a rate of about 24 cubic centimeters (cc) per minute; no more than two drops[19] are allowed from the pressure port. However, no leaks were observed from the return port. Additionally, the MCV cover (also known as the "3-screw cover") exhibited a slight leak during both the proof pressure and low pressure tests; no evidence of external leakage was allowed during this test.

5.2.3 DISASSEMBLY

Residual fluid from the actuator was drained by opening the test port and actuating the piston. The input lever was removed and did not exhibit anomalous damage. The piston rod end (containing the spherical bearing), jam nut, and locking key were removed. The rod end threads exhibited no anomalous damage. The housing output end and end cap were removed to facilitate removal of the piston. The piston was removed and its external surfaces were shiny in appearance with a visible crosshatch pattern on its surface except in certain areas containing typical service wear. The piston seal as well as the dynamic seals and scraper seals on the ends glands were intact. Debris was visible only on the exterior side of the scraper seal. The o-ring and backup ring on the end glands were intact. The cylinder bore had no anomalous damage and exhibited a clean appearance.

The MCV cover and spring were removed and residual hydraulic fluid was visible within the cover. The pilot input and shaft assembly were removed and exhibited no anomalous damage. The o-rings and backup rings on the sleeve had no anomalous damage. The sleeve and its bore exhibited no anomalous damage. The servo and bypass spools were removed from the sleeve, neither of which exhibited anomalous damage. The o-rings on the servo and bypass spools were intact.

The sequence valve and back-to-back check valve were removed and their components, including their respective o-rings and backup rings, exhibited no anomalous damage. The filter (screen) on the pressure port exhibited no evidence of blockage but had captured a small, brown-colored piece of debris. The filter and its retainer were removed and attempting to remove the debris with a metal pick resulted in breakup of the debris. Compressed air was used to remove the broken up debris, but the air obliterated it. The differential relief valve was removed and the valve components, including o-rings, did not exhibit anomalous damage. The inlet check valve was removed and did not exhibit anomalous damage. The o-rings and backup rings on the inlet check valve were intact.

Figure 13 shows the completed disassembly of the collective main rotor hydraulic actuator.

[19] 20 drops is estimated to be about 1 cc.

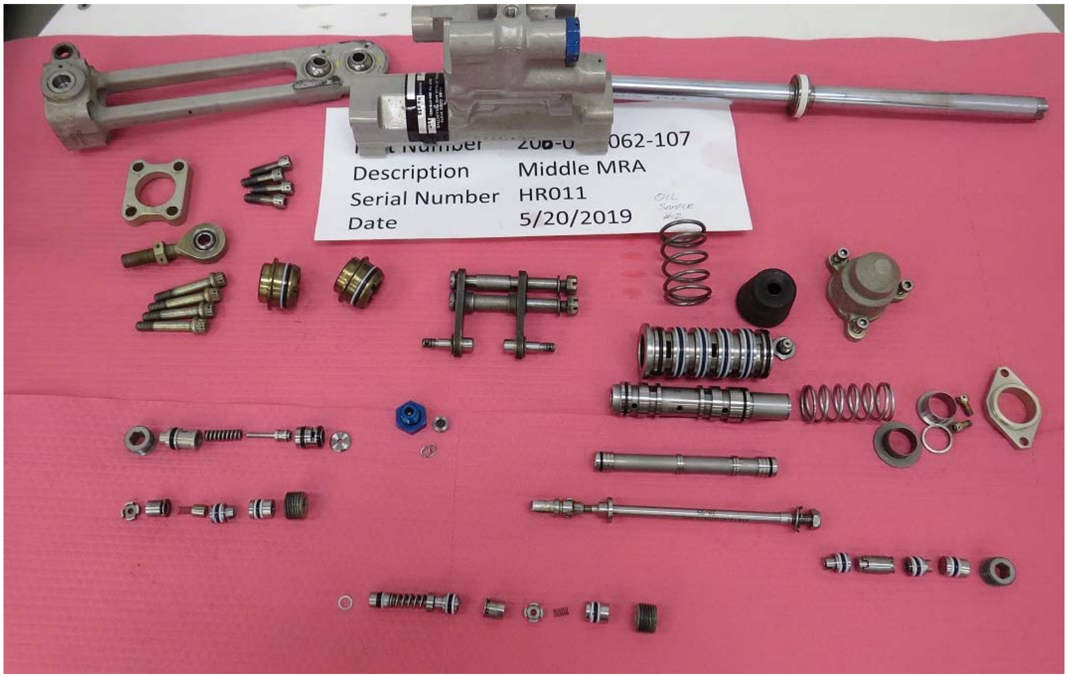

Figure 13. The completed disassembly of the collective main rotor hydraulic actuator. (photo courtesy of Woodward)

5.3 LEFT MAIN ROTOR HYDRAULIC ACTUATOR (S/N HR012)

5.3.1 INITIAL VISUAL EXAMINATION

All safety cables on bolts, screws, and port covers remained installed and intact. All locking tabs were flat against the jam nut for the MCV pilot input. The torque stripe on the MCV jam nut was present and undisturbed. The spherical bearings on the output arm and piston rod end moved freely and did not exhibited play.

The test port was opened and the piston was actuated by hand, resulting in residual hydraulic fluid exiting the test port. The piston was moved with slight difficulty. The residual fluid, collected in a glass bottle, exhibited a bright red coloration with no visible particles.

5.3.2 BENCH TESTING

Bench testing of the actuator was performed in accordance with the procedures of Paragraph 40 of the Woodward acceptance test and inspection procedure (AT&IP) for P/N 41011400-103 hydraulic actuators, except for Paragraphs 40.17 (set rod end) and 40.18 (install protective covers) which were not performed. Additionally, Paragraphs 40.4 (proof pressure and low pressure leak tests), 40.5 (servovalve check), and 40.6 (dynamic leakage check) were performed as the last steps of the bench test.

During the manual operation test (Paragraph 40.3), the actuator moved in the extend direction at 60 pounds, above the maximum allowable of 26 pounds. During the sequence valve leakage test (Paragraph 40.13), the pressure port leaked about 4.4 cc per minute; no more than two drops are allowed at the pressure port. There was no evidence of leakage from the return port during this test. During the thermal relief valve test (Paragraph 40.15), the cracking pressure was about 240 pounds per square inch (psi); the allowable cracking pressure was 125 to 200 psi. During the servovalve check (Paragraph 40.5), the bypass stroke in the retract direction was 0.010 inches, below the minimum of 0.011 inches. The actuator met the requirements for the remaining tests within Paragraph 40 of the AT&IP. At the conclusion of the AT&IP, the manual operation test (Paragraph 40.3) was performed again to determine if the manual operation forces would change after the dynamic leakage test was performed; there was no change from the initial results of the manual operation test.

5.3.3 DISASSEMBLY

Residual fluid from the actuator was drained by opening the test port and actuating the piston. The input lever was removed and did not exhibit anomalous damage. The piston rod end (containing the spherical bearing), jam nut, and locking key were removed. The rod end threads exhibited no anomalous damage. The housing output end and end cap were removed to facilitate removal of the piston. The piston was removed and its external surfaces were shiny in appearance with a visible crosshatch pattern on its surface except in certain areas containing typical service wear. The piston seal as well as the dynamic seals and scraper seals on the ends glands were intact. The land of the piston diameter exhibited a localized area of roughness; the location of the roughness was in the area where the piston head contacts the piston bore. Debris was visible only on the exterior side of the scraper seal. The o-ring and backup ring on the end glands were intact. Circumferential witness marks were seen in the cylinder bore, near the end where the piston head would reside when the piston is at full retraction. The witness marks were about 1.4 to 2.0 inches from the bore end face (to which the end cap mates to the housing). The remainder of the cylinder bore had no anomalous damage and exhibited a clean appearance.

The MCV cover and spring were removed; no hydraulic fluid was visible within the cover. An orange-colored material, similar in appearance to torque stripe material, was seen on the exterior end face between the sleeve and the bypass spool, on the input-lever side of the sleeve. The pilot input and shaft assembly were removed and exhibited no anomalous damage. The o-rings and backup rings on the sleeve had no anomalous damage. The sleeve and its bore exhibited no anomalous damage. The servo and bypass spools were removed from the sleeve, neither of which exhibited anomalous damage. The o-rings on the servo and bypass spools were intact.

The sequence valve was removed and its components, including the o-rings and backup rings, exhibited no anomalous damage. The back-to-back check valve was removed and the output-side seat had an indentation on its contact surface that normally contacts the plug, opposite the sealing surface. The indentation was hemispherical and had an appearance similar to those produced during hardness testing of materials. The remaining components from the back-to-back check valve, including the o-rings and backup rings, exhibited no anomalous damage. The differential relief valve was removed and the valve components, including o-rings, did not exhibit anomalous damage. The inlet check valve was removed and the poppet cage exhibited radial chatter marks on its end face that mates to the spring retainer. The remaining components from the inlet check valve did not exhibit anomalous damage. The o-rings and backup rings on the inlet check valve were intact. The filter (screen) on the pressure port exhibited no evidence of blockage or debris.

Figure 14 shows the completed disassembly of the left main rotor hydraulic actuator.

Figure 14. The completed disassembly of the left main rotor hydraulic actuator. **(photo courtesy of Woodward)**

5.4 TAIL ROTOR HYDRAULIC ACTUATOR (S/N HR010)

5.4.1 INITIAL VISUAL EXAMINATION

The safety cables on the actuator housing end cap, adjacent to the piston's rod end, was broken. The remaining safety cables on bolts, screws, and port covers were intact. All locking tabs were flat against the jam nut for the MCV pilot input. The torque stripe on the MCV jam nut was present and undisturbed. The spherical bearing on the output arm moved freely and exhibited no play. The spherical bearing on the output piston rod end exhibited no play but was difficult to move by hand.

The test port was opened and the piston was actuated by tapping the fractured end using a plastic hammer and drift. No residual hydraulic fluid exited the test port.

5.4.2 BENCH TESTING

Damage sustained by the tail rotor hydraulic actuator during the accident, including fracturing of the piston, precluded bench testing of the actuator.

5.4.3 DISASSEMBLY

The input lever was removed via tapping the screws using a hammer. The input links exhibited bending deformation. The output end was removed, revealing a white-colored powder consistent with aluminum oxide (corrosion byproduct) at the piston interface. The end cap was removed, revealing a brownish-colored residue on the exterior surface of the end gland. The piston rod end (containing its spherical bearing) remained installed with the piston and exhibited a slight bend at its threaded connection. The jam nut, locking key, and cotter pin remained installed. The remainder of the piston within the actuator was removed. The end gland on the rod end side of the piston could not be removed due to the fractured piston. The fracture surfaces of the piston exhibited signatures of overload. The end gland on the output side was removed from the piston. Both end glands exhibited evidence of corrosion on their external surfaces but their o-rings and backup rings were intact. The dynamic seal of the output-side end gland showed no anomalous damage. The piston seal was present and intact. The external surfaces of the piston exhibited a shiny appearance with a visible crosshatch pattern on its surface except in certain areas containing typical service wear. Residual hydraulic fluid was collected during removal of the piston and exhibited a bright red coloration. The piston bore exhibited no anomalous damage.

The MCV cover and spring were removed; no hydraulic fluid was visible within the cover. Torque stripe material was found on the surface between the sleeve and the bypass spool, on the input lever side of the sleeve. The o-rings and backup rings on the sleeve were intact. The sleeve and its bore exhibited no anomalous damage. The servo spool and bypass spool were removed from the sleeve. The servo spool lands and the bypass spool exhibited no anomalous damage. The o-rings on both the servo spool and bypass spool were intact.

The sequence valve was removed but its plunger and seat were stuck within the valve bore. The plunger and seat were removed using pliers; the tip of the plunger was damaged during removal but the remainder of the plunger and the seat had no anomalous damage. After removal of the valve, a small piece of black material and residual hydraulic fluid were found in the sequence valve bore and collected using a q-tip. The remainder of the sequence valve components had no anomalous damage. The back-to-back check valve retaining plug remained installed but was not tight when removed from the actuator housing. The back-to-back check valve components, including its o-rings, did not exhibit anomalous damage. The plug for the differential relief valve remained installed but was not tight when removed from the actuator housing. The differential relief valve was removed and its components, including its o-rings, exhibited no anomalous damage. The inlet check valve retaining plug remained installed but was not tight when removed from the actuator housing. The inlet check valve was removed and the poppet cage exhibited radial chatter marks on its end face that mates to the spring retainer. The remaining components from the inlet check valve, including its o-rings and backup rings, did not exhibit anomalous damage. The filter on the pressure port showed no evidence of blockage and was clear of debris.

Figure 15 shows the completed disassembly of the tail rotor hydraulic actuator.

Figure 15. The completed disassembly of the tail rotor hydraulic actuator. (photo courtesy of Woodward)

6.0 MAINTENANCE

The accident helicopter was maintained under the aircraft manufacturer's recommended inspection program. A review of the maintenance records for N191SF showed the last 12-month, 24-month, 600-hour, and 1200-hour inspections for the airframe were performed on June 11, 2018 at ATT 931.3 hours. The last 300-hour inspection for the engine was also performed on June 11, 2018. The last 150-hour airframe and engine inspections were performed on October 15, 2018 at ATT 1,078.0 hours. The operator used the Airframe Progressive Inspection Program according to the Bell 407 maintenance manual No. BHT-407-MM-1.[20] In the Airframe Progressive Inspection Program, the fifth inspection event was the most recent inspection event; the inspection was performed on December 28, 2018 at ATT 1,142.1 hours.

A review of the airframe and engine inspection logs, which also tracked Airworthiness Directives and alert service bulletins, found no overdue inspections. A review of the airframe and engine component logs found no life limited components that were overdue for overhaul or replacement.

Since the December 28, 2018 maintenance event, aside from several discrepancies noting scheduled inspections coming due, no mechanical anomalies were noted in the aircraft flight maintenance log[21], but one electrical anomaly was noted. On January 1, 2019, the helicopter intercommunication system (ICS) cord was described as inoperative; the corrective action field noted the ICS cord was

[20] The Airframe Progressive Inspection Program divides the inspection into six inspection events at 50 hour intervals. The first inspection event starts at 50 hours and the sixth inspection events starts at 300 hours, after which the program cycle resets to the first inspection after another 50 hours has elapsed.

[21] The operator's aircraft flight maintenance log was a daily log that tracked the helicopter's operations and provided fields for writing in discrepancies and their corrective actions.

replaced. The most recent noted discrepancy in the aircraft flight maintenance log was on January 24, 2019, when two discrepancies were noted on log sheet No. 19-024: 1) the Garmin GTN-650 navigation system inspection was due[22] and 2) the 30-day fire extinguisher inspection. The helicopter was recorded to have an ATT of about 1,170.3 hours. According to log sheet No. 19-024, both discrepancies were addressed, the helicopter was determined to be in an airworthy condition and subsequently released. No discrepancies were noted from January 25 to 28, 2019.

Attachment 2 contains the airframe flight maintenance log sheets from January 24 to 28, 2019.

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[22] The Garmin GTN-650 instructions for continued airworthiness document No. 190-01007-K4, for installations on the Bell 407, requires a visual inspection every 250-hours or every 12 months, whichever occurs first.