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

March 20, 2019

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT

NTSB No: CEN18FA391

A. ACCIDENT

Operator:	Chinilna Equipment, LLC
Aircraft:	Airbus Helicopters AS350 B3e, N907PL
Location:	Gustavus, Alaska
Date:	September 28, 2018
Time:	1057 Alaska daylight time

B. GROUP

Group Chairman:	Chihoon Shin National Transportation Safety Board Washington, District of Columbia
Member:	Daniel Figueroa Federal Aviation Administration Juneau, Alaska
Member:	Seth Buttner Airbus Helicopters Grand Prairie, Texas
Member:	Bryan Larimore Safran Helicopter Engines Grand Prairie, Texas
Member:	Stéphane Veillon Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile Le Bourget, France

LIST OF ACRONYMS

agl	above ground level
AK	Alaska
ALF	aft-looking-forward
CFR	Code of Federal Regulations
DC	District of Columbia
EBCAU	emergency backup control ancillary unit
EDR	engine data recorder
FAA	Federal Aviation Administration
FADEC	full authority digital engine control
GPS	Global Positioning System
HMU	hydromechanical unit
JNU	Juneau International Airport
mm	millimeter
NTSB	National Transportation Safety Board
SAS	stability augmentation system
S/N	serial number
TRDS	tail rotor drive shaft
TX	Texas
USCG	United States Coast Guard
YAK	Yakutat Airport

C. SUMMARY

On September 28, 2018, about 1057 Alaska daylight time, an Airbus Helicopters AS350 B3e helicopter, N907PL, impacted shallow water on a beach in Glacier Bay National Park about 60 miles northwest of Gustavus, Alaska (AK). The co-pilot was fatally injured, one passenger sustained serious injuries, and the pilot and one other passenger are missing. The helicopter was registered to Chinilna Equipment LLC and operated by a private individual under the provisions of Title 14 *Code of Federal Regulations* (CFR) Part 91 as a personal flight. Visual meteorological conditions prevailed at the time of the accident and no flight plan had been filed. The flight departed from the Juneau International Airport (JNU) Juneau, Alaska, and was en route to Yakutat Airport (YAK), Yakutat, Alaska.

According to the family members, the purpose of the trip was to deliver the helicopter from the Airbus Helicopters factory in Grand Prairie, Texas (TX), to Anchorage, AK, which required multiple stops. The left seat pilot was onboard for insurance coverage purposes. The owner/pilot planned to drop off the left seat pilot in Wasilla, AK, then proceed to Anchorage.

The accident flight departed Juneau and proceeded west over the mountains 3,000 to 4,000 feet above ground level (agl) and then north along the coast line about 500 to 700 feet agl. The last recorded Global Positioning System (GPS) point was 8.5 nautical miles southeast of the accident site and 500 feet agl while flying above the beach.

In a post-accident interview, the surviving passenger stated that the pilot "reached down and rolled the throttle off." He added that the pilot left the collective up and the helicopter entered a free fall from about 500 feet agl, then about 30 feet agl he increased the throttle again. He felt helicopter impact the water and noticed water splash in the cabin, then went unconscious.

The helicopter impacted the water and came to rest partially embedded in the sand. The investigative team arrived at the accident site about 1100 local time on September 30, 2018, to photo document the accident site and locate the Appareo Vision 1000 image recording device, the engine data recorder (EDR), and full authority digital engine control (FADEC) unit; they were all recovered and transported to the National Transportation Safety Board (NTSB) Vehicle Recorders Laboratory in Washington, District of Columbia (DC), for examination and download.

The tail boom, tail rotor assembly, and most of the instrument panel were not found. The wreckage was recovered to a secure location for a post-accident examination.

D. DETAILS OF THE INVESTIGATION

1.0 HELICOPTER INFORMATION

1.1 HELICOPTER DESCRIPTION

The Airbus Helicopters AS350 B3e, also known as the H125, has a three-bladed main rotor system that provides helicopter lift and thrust.[1] A two-bladed tail rotor system provides anti-torque and directional control. The helicopter flight controls are hydraulically assisted by a dual hydraulic system. The helicopter was equipped with a high skid-type landing gear and a Safran Helicopter

[1] The main rotor blades rotate in a clockwise direction when looking down at the main rotor disc from above.

Engines Arriel 2D turboshaft engine. The AS350 B3e and H125 are marketing designations; the helicopter is type certificated under Federal Aviation Administration (FAA) Type Certificate Data Sheet (TCDS) No. H9EU as an AS350 B3 equipped with the Arriel 2D turboshaft engine.

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) 8471, was manufactured in 2018. Engine S/N 53116 was installed at the time of the accident. According to Airbus Helicopters, the airframe and engine had accumulated a total time of 13.7 hours when ownership transferred from Airbus Helicopters to Chinilna Equipment LLC. The total flight hours accumulated during the ferry flight from Grand Prairie, TX to the accident site near Gustavus, AK could not be determined.

2.0 WRECKAGE EXAMINATION

The United States Coast Guard (USCG) provided the NTSB with photos of the wreckage when it was initially located (**Photos 1 and 2**). From September 30 to October 1, 2018, representatives from the NTSB, FAA, Airbus Helicopters, and Safran Helicopter Engines convened at the accident site to document the wreckage. The wreckage was recovered from October 1-2, 2018 to a hangar at JNU and the wreckage was documented further.

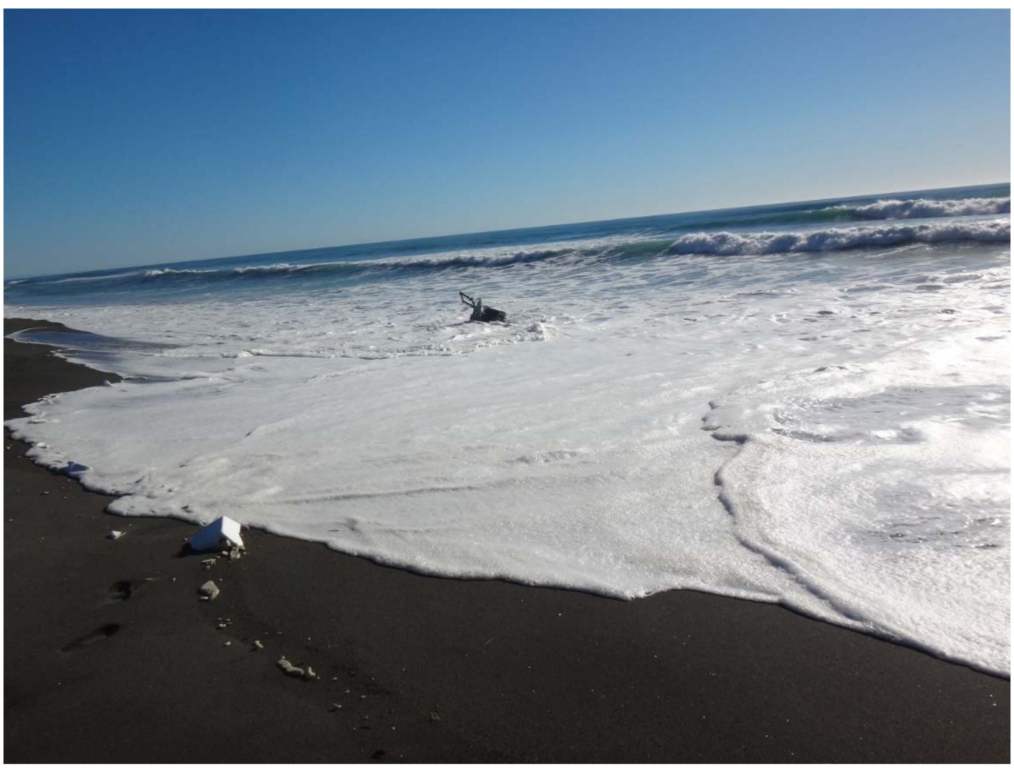

Photo 1. The helicopter wreckage during high tide. The right skid is visible. (photo courtesy of the USCG)

Photo 2. The helicopter wreckage at low tide. (photo courtesy of the USCG)

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 main fuselage was found on a beach on its left side. The main fuselage was partially buried in the sand. The structure forward of the aft cabin bulkhead had separated from the main fuselage. The left and right aft bench seat remained attached to the aft cabin bulkhead. The two longitudinal floor beams, for the cabin floor structure, were fractured about 6.5 inches (left beam) and 5 inches (right beam) forward of the aft cabin bulkhead. The rear structure of the main fuselage was crushed inward throughout its circumference. The ring frame, located about 7.5 inches forward of the tail boom attachment to the rear structure, was partially fractured and deformed forward at about the 9 o'clock position. All upper cowlings had separated from the main fuselage (**Photo 3**). The left side transmission cowling was recovered as a single piece. The right side transmission cowling was recovered in two pieces. Multiple pieces of honeycomb sandwich composites were recovered. The engine firewall remained attached to the main fuselage and its base was deformed in the aft direction and its upper portion was partially fractured. The engine deck was deformed downward. The engine air inlet barrier filter remained installed within its frame but the cowling surrounding the frame had separated. Sand was found within the barrier filter.

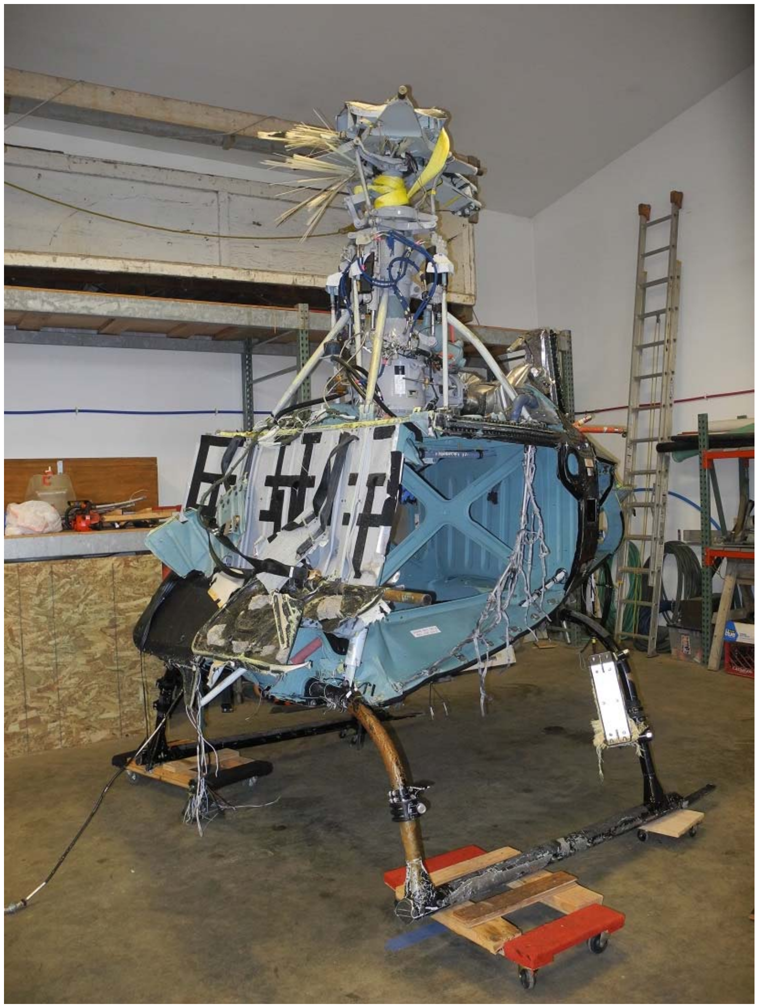

Photo 3. The recovered main fuselage with the main transmission and main rotor head attached. The fuel tank was previously separated for the recovery effort and remained uninstalled.

The left crossbeam of the central body structure, to the left of the fuel tank, was mostly intact but exhibited deformation on its lower-forward member with fractures near where it connects to the frame. No fractures were observed on the left crossbeam. The right crossbeam exhibited fractures on its lower-forward and lower-aft members. The lower-forward member exhibited a partial fracture and the lower-aft member exhibited a complete fracture through its width. The right crossbeam and lower frame were deformed in the outboard direction. The bulkhead forward and behind the fuel tank was generally intact but exhibited slight bulging at the lower portion of the bulkhead. The fuselage skin behind the aft cross tube was deformed in the up and aft directions. The fuel tank[2] remained installed within the center fuselage. The fuel tank was removed at the accident site by the investigation team in support of the wreckage recovery. The brackets attaching the fuel tank to the center fuselage were intact except for the aft-right bracket, whose forward

[2] The accident helicopter was equipped with a crash-resistant fuel system.

attachment flange was fractured. About 25 gallons of fuel was removed from the fuel tank on scene; additional fuel was removed after recovery of the fuel tank. Evidence of salt water was observed from the fuel removed from the fuel tank.

The helicopter was equipped with a high skid landing gear. The landing gear remained attached to the main fuselage at its forward and aft cross tubes. For both the left and right skids, the forward skid tube had separated at the forward cross tube and was not recovered. The skid tube heel struts were present on both left and right skids. The left and right oleo strut remained attached to the main fuselage and the forward cross tube. For the right oleo strut, the main fuselage attachment point itself had partially separated from the main fuselage. The helicopter was also equipped with a cargo pod on its left skid; a portion of the cargo pod fairing was found separated from the wreckage.

The cockpit floor, with the front seats attached, was recovered (**Photo 4**). The cockpit and cabin roof structure, about 5.5 feet in length measured from the upper windshield attachment, was also recovered. The Appareo Vision 1000 image recorder remained attached to the roof structure and was retained for further analysis.[3] For both front seats, the seat bottom and seat back cushions had separated but were recovered.

Photo 4. The separated cockpit with front seats still attached.

The upper portion of the left seat back was fractured and had separated from the wreckage. The left seat back had a vertical fracture from its top end to the shoulder restraint inertia reel; the shoulder restraint was impinged within the bottom end of the vertical fracture. The two upper bolts connecting the left seat to the vertical energy attenuating track remained connected to the seat but were deformed in the forward direction. The left upper bolt was displaced about 1.25 inches down the track and the right upper bolt was

[3] For additional information on the Appareo Vision 1000 image recorder, see the Onboard Image and Data Recorder Factual Report in the docket for this investigation.

displaced about 1.5 inches down the track. The fuse for the attenuation coil was fractured on the right attenuation track and the fuse for the left attenuation coil was not fractured. All four restraints remained connected to the central rotary buckle and all four restraints remained attached to their anchor points. The two shoulder restraints were routed through a cutout in the seat back cushion. The left seat was located about 5 inches aft on the longitudinal seat track when measured from the forward end of the track.

The upper portion of the right seat back was fractured and had separated from the wreckage. The two upper bolts connecting the right seat to the vertical energy attenuating track remained connected to the seat but were deformed in the forward direction. The left upper bolt was displaced about 2 inches down the track and the right upper bolt was displaced about 1.25 inches down the track. Both fuses for the left and right attenuation coils were fractured. Three of the four restraints remained connected to the rotary buckle; the left lap restraint had separated from the rotary buckle. All four restraints remained attached to their anchor points. The two shoulder restraints were routed through a cutout in the seat back cushion. The right seat was located about 3.25 inches aft on the longitudinal seat track when measured from the forward end of the track.

All four seat back and seat bottom cushions for the rear seats were recovered. Two of the four seat back cushions were missing their fabric covers. All four shoulder harnesses for the aft seats remained attached to the aft cabin bulkhead wall down to the inertia reels. One half of the lap belt and male buckle for the aft far-left seat remained attached to the seat bottom anchor; the other half of the lap belt and female buckle for the aft far-left seat was not recovered and its anchor had separated from the aft cabin bulkhead. For the aft middle-left seat, the lap belt and buckle remained attached to the structure; the buckle remained clasped and the belt remained attached to both the aft cabin bulkhead anchor and the seat bottom anchor. For the aft middle-right and aft far-right seats, the lap belt and buckle remained attached to the structure; the buckle was unclasped but the belt remained attached to both the aft cabin bulkhead anchor and the seat bottom anchor.

The tail boom, including the empennage and tail rotor, was not found. Various pieces of cowling, access panel doors, and the baggage doors were found separated from the main wreckage.

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. 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 remained attached to the main rotor shaft. The Starflex arms were intact with no evidence of fractures. The three frequency dampers had separated from the Starflex arms. The sleeve assembly for the 'yellow' main rotor blade remained attached to the Starflex via its spherical thrust bearing; the sleeve assembly was offset from its Starflex arm in the direction opposite of normal rotation. The upper sleeve exhibited fractures on its surface. Remnants of the 'red' and 'blue' main rotor blade sleeve assembly remained attached to their respective spherical thrust bearing and the Starflex; the remnant sleeves exhibited a broomstrawed appearance. Remnants of the 'red' and 'blue' sleeve assemblies remained attached to the 'red' and 'blue' main rotor blades, respectively, but the remainder of these sleeve assemblies were missing.

The 'yellow' main rotor blade was fractured into two large sections: the inboard section and outboard section (**Photo 5**). The inboard section of the blade spanned from its root end to about 55 inches outboard where the blade was fractured, measured from the root end. The outboard section of the blade spanned from the fracture to the blade tip end. The inboard section remained attached to its sleeve assembly. The afterbody for the inboard section of the blade was present until about 31 inches outboard of the root end, beyond which the afterbody had separated and was missing. The spar exhibited a broomstrawed appearance at the blade fracture location. For the outboard section of the blade, the afterbody had separated and was missing at the inboard and outboard ends but was present at the midsection. The blade tracking tab remained installed but was deformed.

The 'red' main rotor blade was fractured into two large sections: the inboard section and outboard section. The inboard section of the blade spanned from its root end to about 106 inches outboard where the blade was fractured, measured from the blade retention pin bushings. The outboard section of the blade spanned from the fracture to the blade tip end; this section exhibited a slight upward bend. The spar exhibited a broomstrawed appearance at the blade fracture location. The afterbody had separated and was missing on the outboard half of the inboard section and along the entire span of the outboard section. The outboard portions of the sleeve assembly remained attached to the root end of the blade and exhibited a broomstrawed appearance. Part of the frequency adapter remained installed between the upper and lower sleeves. The blade tracking tab remained installed and did not exhibit significant deformation.

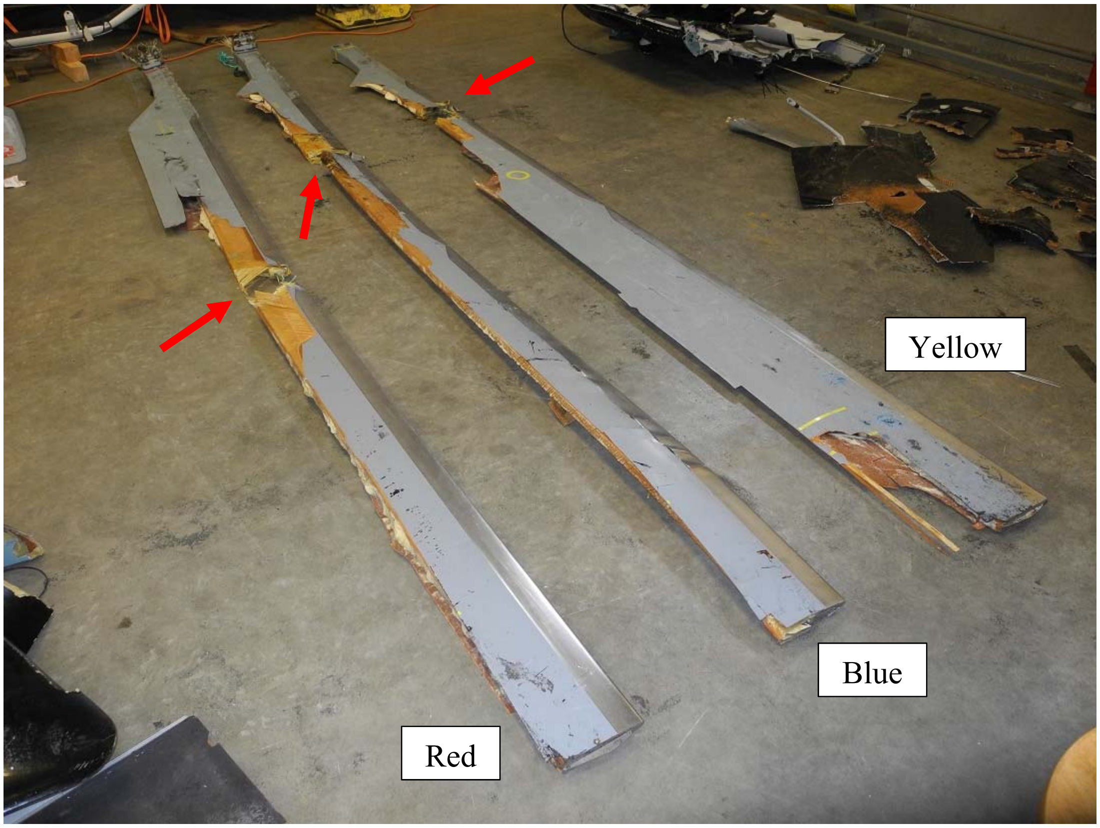

Photo 5. The recovered main rotor blades. Red arrows indicate the fractures separating the blade into two sections.

The 'blue' main rotor blade was fractured into two large sections: the inboard section and outboard section. The inboard section of the blade spanned from its root end to about 69 inches outboard where the blade was fractured, measured from the blade retention pin bushings. The outboard section of the blade spanned from the fracture to the blade tip end; this section of blade exhibited bowing with its tip end exhibiting an upward bend. The afterbody had separated and was missing for the majority of the entire span of the blade. The leading edge strip exhibited wrinkling deformation from the blade tip end to about 50 inches inboard. Red-colored contact marks were observed on the underside of the leading edge strip, about 19 inches from the blade tip end. The outboard portions of the sleeve assembly remained attached to the root end of the blade and exhibited a broomstrawed appearance. Part of the frequency adapter remained installed between the upper and lower sleeves. The blade tracking tab end plate had separated and was missing.

The three main rotor blade pitch horns remained attached to the lower end of their respective spherical thrust bearings. The 'red' and 'yellow' pitch change link bodies were bent inward. The 'blue' pitch change link did not exhibit visual evidence of deformation. The stationary and rotating scissors remained attached to the stationary and rotating swashplates, respectively. No anomalous damage was observed on the stationary and rotating swashplates and scissors.

2.2.3 MAIN ROTOR DRIVE SYSTEM OBSERVATIONS

The main gearbox remained installed on the main fuselage via four suspension bars. The aft-left suspension bar was deformed upward and outward. The remaining three suspension bars did not exhibit visual evidence of deformation. The bi-directional crossbeam remained installed but the crossbeam and rubber mounts were shifted downward about 0.5 inches. The crossbeam and the rubber mounts did not exhibit visual evidence of anomalous damage.

The engine-to-transmission drive shaft remained attached between the freewheel shaft splines and the main transmission input pinion. The flexible couplings remained attached to the forward and aft ends of the engine-to-transmission drive shaft with no evidence of fractures or visual deformation. The rotor brake turnbuckle bracket was bent forward. Small gaps were seen on the rotor brake disc, consistent with a non-actuated rotor brake, when viewed through the actuation handle window. The engine forward support tube (also known as the “liaison tube”) remained attached to the forward end of the universal joint mounted to the main gearbox housing. An oil level was not visible within the main gearbox oil sight gauge, but sand was visible within the sight gauge. Manual rotation of the main rotor head was attempted but the main rotor drive train was seized.

2.3 TAIL ROTOR SYSTEM

2.3.1 SYSTEM OVERVIEW

Engine power is transferred to the tail rotor via two tail rotor drive shafts (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 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 bellcrank. 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 tail rotor was not found at the accident site.

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 output flange lobes were deformed aft. The attaching hardware remained installed within the lobes along with remnant pieces of flexible coupling laminates.

The remainder of the tail rotor drive system was not found at the accident site.

2.4 FLIGHT CONTROL SYSTEM

2.4.1 OVERVIEW

The cyclic and collective control inputs are transmitted to the stationary swashplate through a series of push-pull control tubes, bellcranks, and a mixing unit. Control tubes connected to the cockpit controls are routed underneath the cockpit floor to a mixing unit located behind the aft cabin bulkhead. Vertical control tubes transmit control inputs from the mixing unit to three dual-cylinder main rotor servo controls[4] that provide hydraulic assistance to the cyclic and collective controls. The three main rotor servo controls are identified as: fore/aft, right-roll, and left-roll. 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, bellcranks, and a flexible ball control cable. A yaw load compensator, with an associated 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 bellcrank mounted to the tail gearbox. The accident helicopter was equipped with both pilot and co-pilot controls. In this report, the pilot controls refer to the right set of controls while the co-pilot controls refer to the left set of controls. The accident helicopter was also equipped with a Genesys Aerosystems HeliSAS autopilot and stability augmentation system (SAS).

2.4.2 OBSERVATIONS

The pilot cyclic control was fractured from its lower attachment but remained with the wreckage via electrical wiring through its post. The grip remained attached to the pilot cyclic control. The co-pilot cyclic control and grip remained installed but exhibited deformation in multiple locations. Fractures were observed on multiple control tubes between the pilot and co-pilot cyclic controls to the mixing unit (**Photo 6**). All fractures exhibited signatures consistent with overload. The lateral and longitudinal cyclic SAS actuators remained attached to the underfloor structure.

The pilot and co-pilot collective controls remained installed. The pilot collective head was present on the control stick but was partially separated and rotated to the right. The co-pilot collective head had separated and was missing from the control stick. The engine throttle twist grip was present on the pilot and co-pilot collective controls and both twist grips were in the “flight” position. An attempt to manually rotate the twist grip was unsuccessful. Fractures were observed on multiple control tubes between the pilot and co-

[4] Servo controls are also known as servo actuators.

pilot collective controls to the mixing unit. All fractures exhibited signatures consistent with overload.

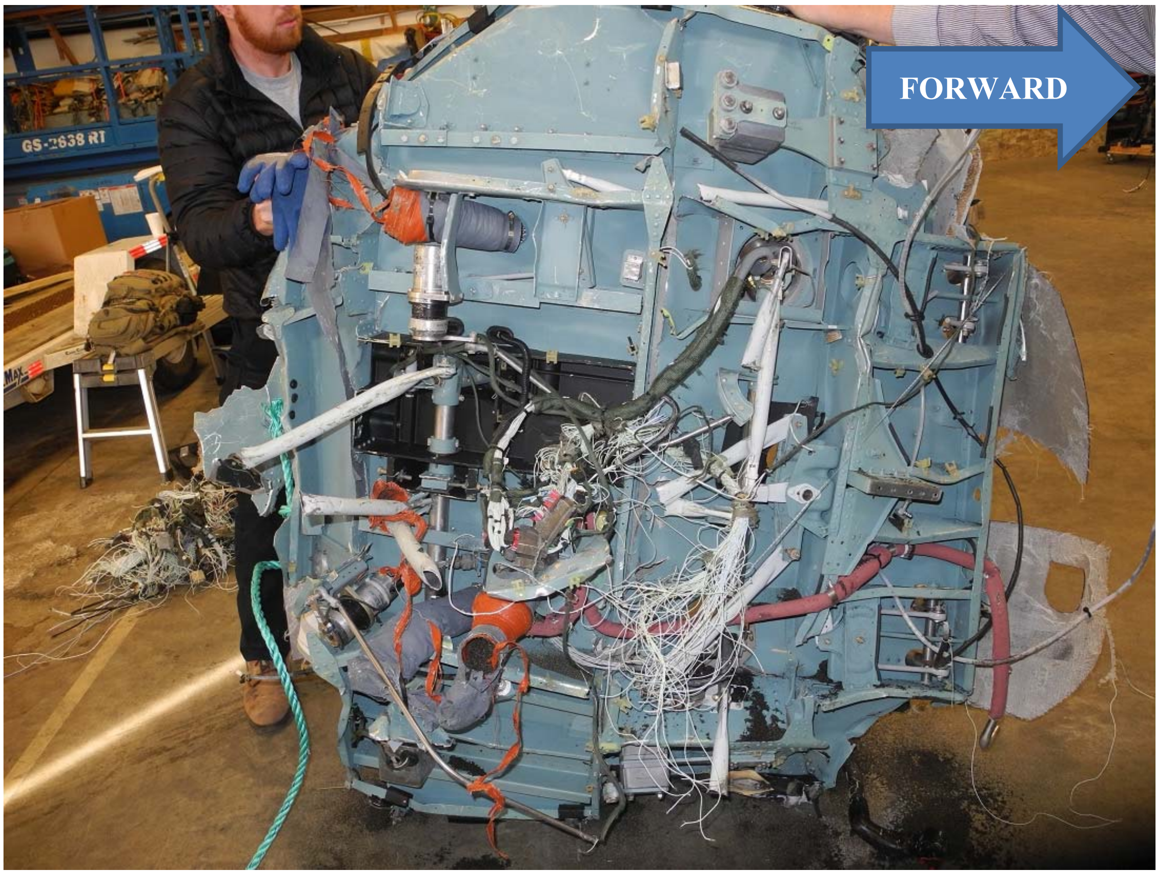

Photo 6. The underside of the cockpit floor containing the control tubes from the cyclic controls to the mixing unit.

The mixing unit remained installed behind the aft cabin bulkhead. The attachment brackets for the left lateral, right lateral, fore/aft, and collective control tubes remained connected to the mixing unit. For the right lateral servo, the right-most bracket on the mixing unit, which connects to the bottom end of the right lateral vertical control tube, was fractured from the mixing unit. The right lateral control tubes leading up to the right-roll servo control were continuous. The control tubes and connects were intact from the mixing unit to the left-roll and fore/aft servo controls. The vertical control tubes exhibited dents consistent with contact with the aft cabin bulkhead.

All three main rotor servo controls remained attached between the main transmission housing and the stationary swashplate. The input control rods remained connected and were able to be moved by hand. The hydraulic lines remained connected and secured to all three main rotor servo controls. Both forward and aft hydraulic fluid reservoirs were present but disconnected from their attaching mounts. No evidence of hydraulic fluid was observed in the sight glass for both reservoirs. Both gear-driven and belt-driven hydraulic pumps remained installed. The hydraulic pump belt was unbroken. Hydraulic lines remained connected to the hydraulic filter assembly but the filter assembly bracket was fractured from the main transmission housing. The hydraulic bypass indicator valve was observed to have extended ("popped out").[5]

The pilot and co-pilot pedals remained installed. The pilot pedals moved independently of each other; the interconnect linkages were fractured. The co-pilot pedal set remained interconnected, i.e. movement of one pedal in one direction resulted in the opposing pedal moving in the opposite direction. The longitudinal control tube remained attached to both the right pedal bellcrank and the aft-right pedal bellcrank, but was fractured about 6 inches forward of the aft-right pedal bellcrank attachment. The control linkage remained attached to the inboard side of the aft-right pedal bellcrank but was fractured at its aft end, adjacent to the nut. The mating portion of the fracture was found in the center fuselage. The link was attached to the flexible ball control cable, which was continuous to the aft baggage compartment bulkhead. The aft end of the flexible ball control cable remained attached to the linkage leading to the two bellcranks within the aft baggage compartment. The steel linkage connecting to the tail rotor servo was bent and separated from the servo at the aft spherical bearing. The tail rotor servo and yaw load compensator had separated from the fuselage and were not found. All tail rotor controls aft of this location, normally residing within the tail boom and on the tail rotor, had separated and were not found.

The rotor brake and the emergency fuel shutoff handles remained installed on the roof and were in the stowed position.

2.5 ENGINE

2.5.1 ENGINE DESCRIPTION

The Arriel 2D turboshaft engine features a single-stage axial flow compressor and a single-stage centrifugal flow compressor, an annular combustor, a single-stage turbine rotor that drives the compressor, and a free turbine[6] rotor. A reduction gearbox is driven via a splined coupling (also known as a "muff coupling") connected to the free turbine rotor. A splined nut, within the reduction gearbox, secures the input gear and also transfers drive from the muff coupling to the input gear. After the splined nut is torqued to its required torque value, an index mark, also called a "slippage" mark, is inscribed on the splined nut and input gear. The quantity and direction of "slippage", or separation of the index mark between the splined nut and the input gear, can indicate the amount of overtorque experienced by the splined nut. The reduction gearbox provides final drive to the power transmission shaft. An accessory gearbox is driven off of a gear on the shaft between the axial and centrifugal flow compressors.

2.5.2 ENGINE OBSERVATIONS

One of the first stage compressor blades exhibited curling deformation in the direction opposite of normal rotation at its tip end (**Photo 7**). The curling deformation extended about 0.5 inches toward the root. The air intake duct had separated from the engine and was not found. The bolts for the air intake duct remained installed on its

[5] During normal operation, a hydraulic bypass indicator valve that has "popped out" indicates the filter is clogged and is being bypassed.
[6] The free turbine is also known as the power turbine.

attachment flange on the engine. The engine exhaust remained attached but exhibited deformation to the left. The exhaust extension had separated and was not found. The FADEC unit and EDR were found in their normally installed location. All engine electrical, oil, fuel, and pneumatic connections were installed and intact. These connections were separated to facilitate removal of the engine from the airframe on scene.

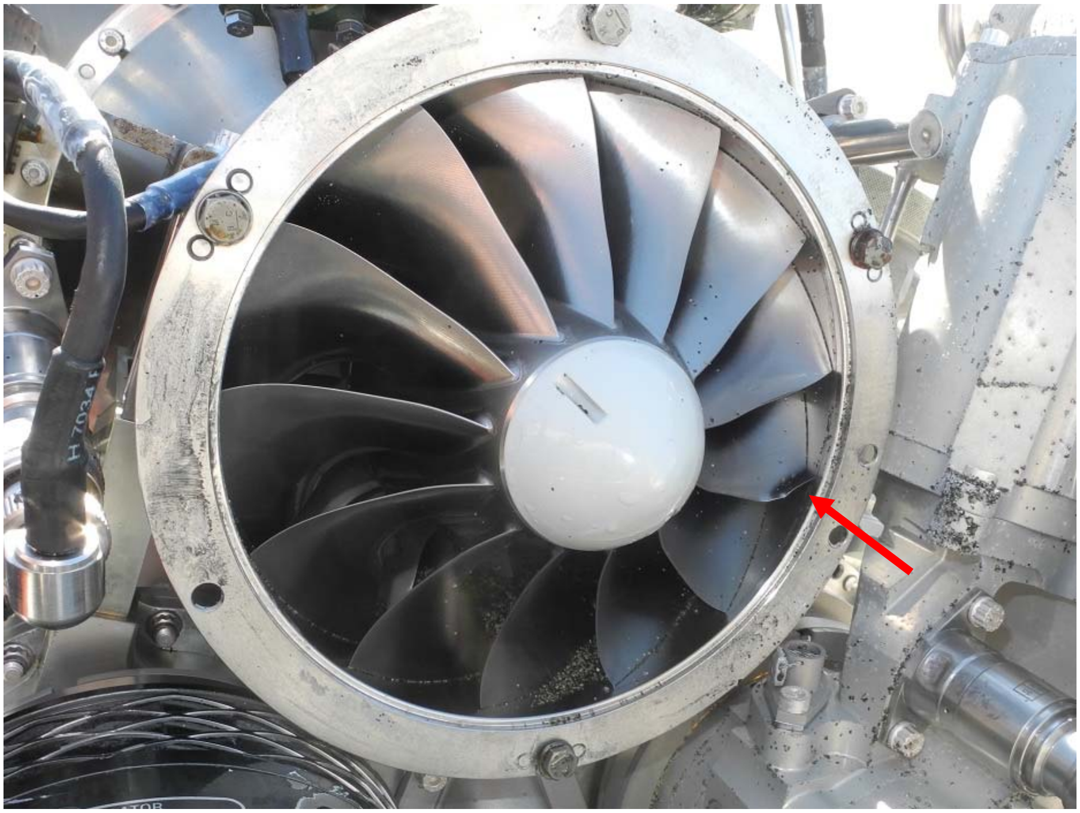

Photo 7. Curling deformation observed on one of the first stage compressor blades.

The engine was partially disassembled after recovery (**Photo 8**). The linking tube, that housed the power transmission shaft, was dented on its underside where it normally contacts the engine rear mount saddle. The reduction gearbox was removed from the engine. The index mark on the splined nut was observed to be slightly offset in the tightening direction.[7] The offset was measured to be greater than 0 millimeter (mm) but less than 1 mm. The splined nut and its mating splines did not exhibit anomalous damage. The reduction gearbox geartrain exhibited continuity but rotation was limited with evidence of binding. Sand was observed within the visible interior surfaces of the reduction gearbox.

All free turbine blades were present and did not exhibit anomalous damage. Once separated from the engine, the free turbine spun freely when manually rotated. The free turbine nozzle guide vanes were removed, revealing the high pressure turbine. All high pressure turbine blades were present and did not exhibit anomalous damage. The gas generator module was not able to be rotated by hand. Sand was observed within the gas

[7] Within the reduction gearbox is a splined nut that secures the input gear and also transfers drive from the muff coupling to the input gear. The nut is indexed by a final torque (index) mark, also referenced as a "slippage" mark. The amount of "slippage" (or amount of overtorque) can be referenced by the quantity and direction the index mark on the splined nut is offset from the index mark on the input gear.

generator module. The axial compressor and gas generator modules were subsequently removed, after which continuity of drive through the accessory gearbox was confirmed via manual rotation of the accessory gearbox input drive. The hydromechanical unit (HMU) remained attached to the accessory gearbox. The emergency backup control ancillary unit (EBCAU) was removed from the HMU and its key was found at the 12 o'clock position.[8]

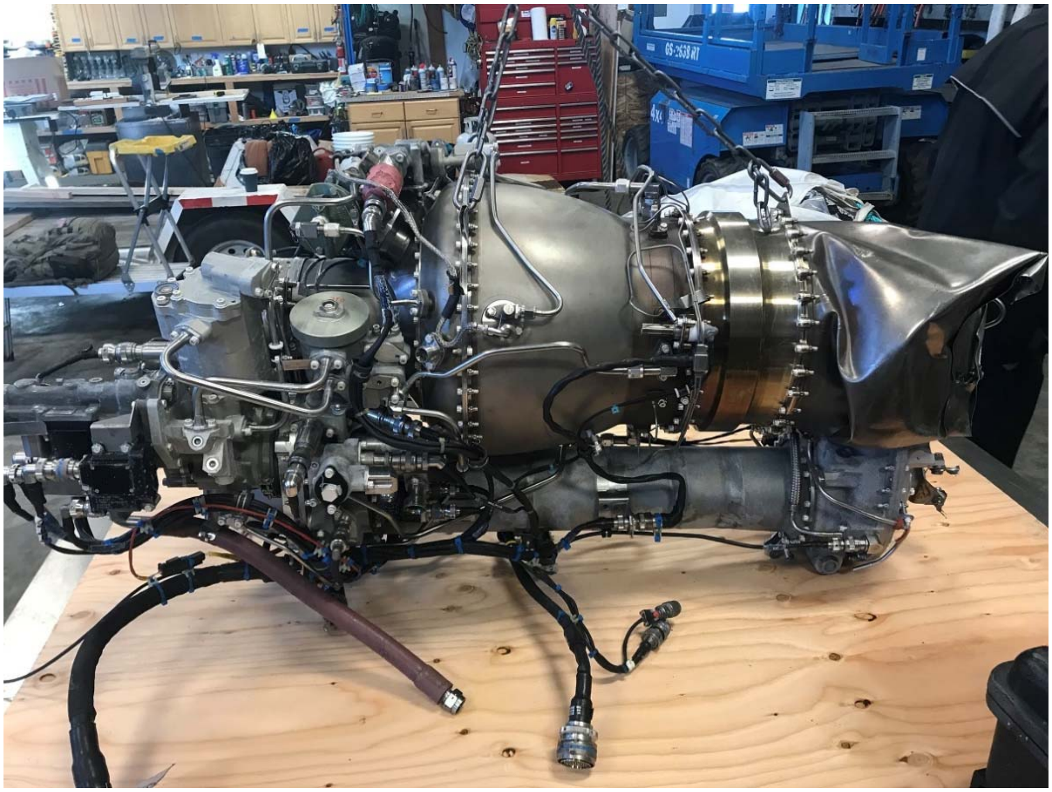

Photo 8. The recovered engine prior to disassembly.

The fuel filter was removed and the filter element appeared clean. Sand was observed in the fuel filter bowl along with residual fuel. The oil filter was removed and the filter element exhibited no evidence of debris. A residual liquid with the appearance of an oil and water mixture was observed within the oil filter bowl.

The turbine inlet temperature thermocouples were removed and exhibited no evidence of melting. Removal of the engine's two magnetic chip detectors revealed evidence of sand. Removal of the engine's electronic chip detector revealed no evidence of debris. The bleed valve port and the auxiliary port were packed with sand.

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[8] The EBCAU key is an operational position indicator. A 12 o'clock position of the EBCAU key is consistent with normal (non-emergency) operation of the HMU.