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

September 25, 2018

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT

NTSB No: WPR18MA087

A. ACCIDENT

Operator:	Papillon Airways, Inc.
Aircraft:	Airbus Helicopters EC130 B4, Registration N155GC
Location:	Peach Springs, Arizona
Date:	February 10, 2018
Time:	1719 mountain standard time

B. GROUP

Group Chairman:	Chihoon Shin National Transportation Safety Board Washington, District of Columbia
Member:	Michael Hemann Federal Aviation Administration Fort Worth, Texas
Member:	Luis Garcia Papillon Airways, Inc. Boulder City, Nevada
Member:	Yann Torres Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile Le Bourget, France
Member:	Seth Buttner Airbus Helicopters, Inc. Grand Prairie, Texas
Member:	Bryan Larimore Safran Helicopter Engines Grand Prairie, Texas

LIST OF ACRONYMS

ALF	aft-looking-forward
ARAC	aviation rulemaking advisory committee
ATT	aircraft total time
AZ	Arizona
CFR	Code of Federal Regulations
CSN	cycles since new
EBCAU	emergency backup control ancillary unit
FAA	Federal Aviation Administration
FADEC	full-authority digital engine control
FAR	Federal Aviation Regulations
FLI	first limit indicator
FOD	foreign object debris
GOM	general operations manual
HMU	hydromechanical unit
MST	mountain standard time
NTSB	National Transportation Safety Board
NV	Nevada
PCL	pitch control link
RFM	rotorcraft flight manual
SAIB	Special Airworthiness Information Bulletin
STC	supplemental type certificate
TCDS	type certificate data sheet
TRDS	tail rotor drive shaft
TSN	time since new
VEMD	vehicle engine management display

C. SUMMARY

On February 10, 2018, about 1719 mountain standard time (MST), an Airbus Helicopters EC130 B4 helicopter, N155GC, was destroyed when it impacted a canyon wash while on approach to land at Quartermaster landing zone near Peach Springs, Arizona (AZ). The commercial pilot and one passenger sustained serious injuries and five passengers were fatally injured. The air tour flight was operated by Papillon Airways, Inc. under the provisions of 14 *Code of Federal Regulations* (CFR) Part 136. The helicopter departed Boulder City Municipal Airport, Boulder City, Nevada (NV) at 1642 MST and had intended to land at Quartermaster landing zone, a group of unimproved landing pads within Quartermaster canyon. Visual meteorological conditions prevailed and a company flight plan had been filed.

A review of the recorded radar data showed that the helicopter departed Boulder City and continued on the Green 4 standard helicopter route prescribed in the Grand Canyon West Special Flight Rules Area 50-2. Witnesses reported that as the helicopter neared the vicinity of Quartermaster, they observed it on a flight path consistent with the pilot aligning to make a landing to a pad on the west side of the Quartermaster landing zone. The helicopter began to slow after it passed over the river and maintained a southern course as it entered a canyon wash adjacent to the Quartermaster landing zone. While maintaining the same altitude, the helicopter entered a nose-high attitude and then began a left turn toward the Quartermaster landing zone. During the turn, the helicopter transitioned into a nose-low attitude and as it began to face the landing pads it began to slightly drift aft. The helicopter then maneuvered into a nose-level attitude and continued in the left turn. Subsequently the helicopter continued to yaw, with one witness reporting the helicopter yawed at least two complete revolutions, as it descended into the wash below where it impacted terrain. A postcrash fire ensued.

The majority of the helicopter was found at the main wreckage site. The main wreckage site contained the main fuselage, main rotor, and engine. The tail boom and fenestron were found adjacent to the main wreckage site. A postcrash fire thermally damaged or consumed the majority of the components contained within the main wreckage site. Pieces of the helicopter, including the tail stinger, skid step toe, and the fenestron hub cover, were found on a hillside to the south-southeast of the main wreckage site.

D. DETAILS OF THE INVESTIGATION

1.0 HELICOPTER INFORMATION

1.1 HELICOPTER DESCRIPTION

The Airbus Helicopters EC130 B4 has a three-bladed main rotor system that provides helicopter lift and thrust.[1] A 10-bladed fenestron tail rotor system provides anti-torque and directional control. The helicopter cyclic and collective flight controls are hydraulically assisted by a dual hydraulic system. The helicopter was equipped with a skid-type landing gear and a Safran Helicopter Engines Arriel 2B1 turboshaft engine. The EC130 B4 helicopter is type certificated under Federal Aviation Administration (FAA) Type Certificate Data Sheet (TCDS) No. H9EU as a normal category (14 CFR Part 27) helicopter.

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

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) 7091, was manufactured in November 2010. According to helicopter records, the airframe had accumulated an aircraft total time (ATT) of about 9,629.1 flight hours around the time of the accident. The engine installed on the accident helicopter, S/N 23056, had accumulated about 15,505.4 hours time since new (TSN), about 22,688.65 gas generator cycles since new (CSN), and about 9,364.70 power turbine CSN around the time of the accident.

2.0 WRECKAGE DOCUMENTATION AT THE ACCIDENT SITE AND AFTER RECOVERY

On February 11, 2018, members of the Airworthiness Group viewed the accident site and adjacent terrain from a helicopter. On February 12, 2018, members of the Airworthiness Group convened at the accident site to document the wreckage. On February 13, 2018, the wreckage was recovered via helicopter long line and transported to Air Transport in Phoenix, AZ. On February 14, 2018, members of the Airworthiness Group convened at Air Transport to further document and lay out the wreckage.

2.1 STRUCTURES

2.1.1 OVERVIEW

The helicopter structure comprises 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 fenestron drive shafts, horizontal stabilizer, and fenestron.

2.1.2 MAIN FUSELAGE

The main fuselage came to rest upright on rocky terrain at a heading of 222 degrees magnetic (**Figure 1**). The majority of the main fuselage was consumed by the postcrash fire. A boulder was found protruding between the front and aft skid crosstubes. The skids were fractured and separated from the main fuselage, but were found in the general vicinity of where they are normally installed with respect to fuselage orientation. The left-front crosstube, normally connected to the front portion of the left skid, was fractured and found rotated forward about 90 degrees. The rear-left crosstube and fairing were upright. All skid segments were thermally damaged, and surviving fracture surfaces undamaged by postcrash fire exhibited signatures consistent with overload. The left and right skids exhibited fractures about 1/3 of its length behind the front of the skid. A segment of the right skid, from its midpoint back to the skid heel, was missing. One of the forward attachments for the forward crosstube was found as a completed assembly, but loose within the wreckage. **Figure 2** shows a reconstruction of the recovered pieces of the landing gear. The fuel tank and the airframe surrounding the fuel tank were consumed by the postcrash fire.

Figure 1. The helicopter wreckage as seen when the Airworthiness Group arrived on scene.

Figure 2. A reconstruction of the landing gear.

The engine was found on the engine deck with the engine cowling still installed, but thermally damaged. The engine, engine deck, and engine cowling were found resting on its right side. The fuel tank fueling cap was found on a slope to the west of the main wreckage. The majority of the fuel system was consumed by the postcrash fire.

The left(-rear) sliding door was found resting on the ground to the immediate left of the main fuselage. Pieces of a door frame were observed in the vicinity of the cyclic control and instrument panel; these pieces were thermally damaged and its door frame position could not be positively identified. The left-front door was found resting on the ground to the forward-right of the main fuselage. A seat and its frame were found adjacent to the left-front door. A door jettison rod was found laying next to the left-front door. The right-front door and right-rear door were not found.

Portions of seats and restraints were found within and around the main wreckage. For additional information on the seats and restraints, see the Survival Factors Group Chairman's Factual Report in the docket for this investigation.

2.1.3 TAIL BOOM AND EMPENNAGE

The tail boom, with fenestron still attached, was separated from the main fuselage at its forward circular attachment frame (adjacent to the aft end of the engine deck). The tail boom came to rest upright to the front-left of the cockpit. The tail boom was angled upward, with the aft end resting on a mound of rocks. The tail rotor drive shaft cover exhibited circular impact marks protruding outboard in the location where the steel and aluminum tail rotor drive shafts connect (**Figure 3**). A rotating tail rotor drive shaft flange contacting the interior surface of its cowling can produce circular impact marks protruding outboard. On the tail boom-side of the circular attachment frame, the majority of the rivets were missing and none of the rivet holes exhibited missing material; the lower half of the frame was deformed consistent with impact damage. On the main fuselage-side of the circular attachment frame, the majority of the rivet heads were present but the frame was deformed, fractured on its right side, and exhibited thermal damage. A puncture about 3 inches in length (in the helicopter longitudinal axis) was observed on the upper left skin of the tail boom, adjacent to the forward end of the fenestron drive shaft cover and about 35 inches from the circular attachment frame.

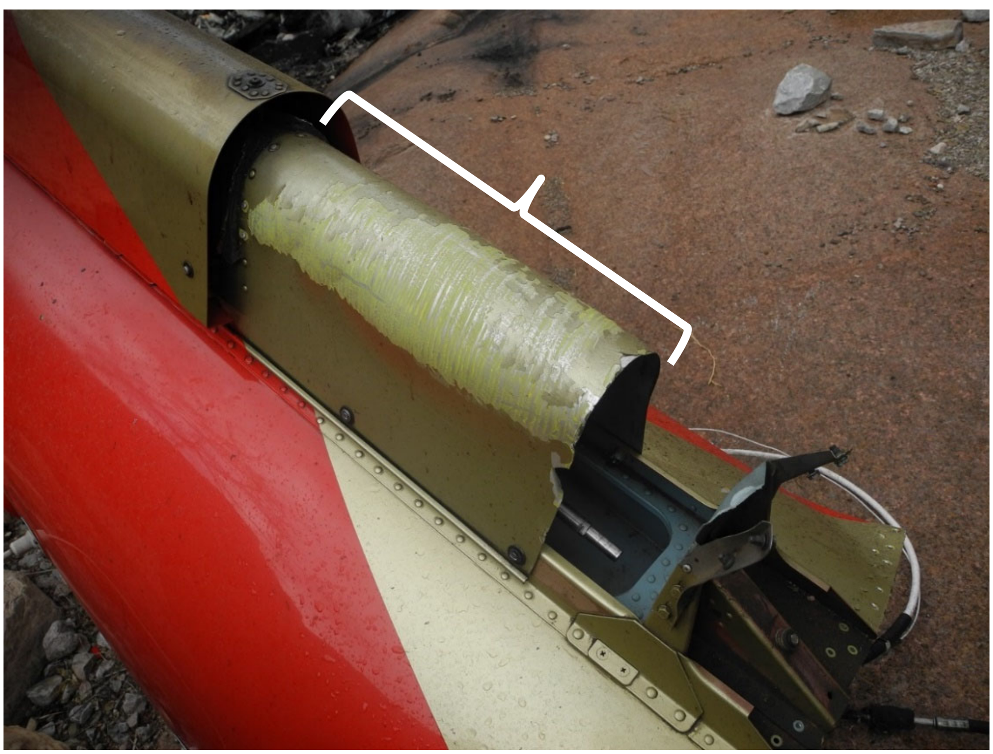

Figure 3. Circular impact marks (white bracket) on the fenestron drive shaft cover.

The fenestron vertical fin was missing from its normally installed location. Thermally damaged material from the aft end of the vertical fin, including a portion of the fenestron shroud, was found on the ground immediately below the fenestron. A portion of the vertical fin was found southwest of the main fuselage and exhibited linear cut marks consistent with main rotor blade contact; one cut mark was about 3 inches below the upper surface and a second cut mark was about 17 inches below the upper surface. The tail stinger was found on a canyon slope about 175 feet to the east of the main wreckage. A portion of the lower vertical fin remained attached to the tail stinger. The aft end of the tail stinger was deformed with an up-left directionality.

The left horizontal stabilizer was attached to the tail boom and exhibited an impact mark about 16 inches from its outboard end, resulting in the outboard portion of the horizontal stabilizer to be deformed upward. The outboard trailing edge exhibited an impact mark with an upward directionality. The right horizontal stabilizer was attached to the tail boom and was resting on a rock. The stabilizer exhibited minimal damage.

The fenestron hub cover was found on a canyon slope about 115 feet to the east-southeast of the main wreckage. The anti-collision light box was found to the northeast of the main wreckage and exhibited deformation consistent with main rotor blade impact.

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 Starflex is attached to the main rotor shaft 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’. The

EC130 B4 helicopter identifies each main rotor blade with a unique colors using colored tape on the blade sleeve and pitch control link (PCL).

2.2.2 MAIN ROTOR OBSERVATIONS

All three main rotor blades were found at the main wreckage site (**Figure 4**). The color of the blades could not be identified due to thermal damage. With the cockpit forward heading at the 12 o'clock position, one blade was at a 1 o'clock heading (identified as "blade 1" for this report); another blade was at the 2 o'clock heading ("blade 2"); and the third blade was at the 6 o'clock heading ("blade 3"). All three main rotor blades remained attached at their root ends to their respective main rotor blade sleeves. All three main rotor blade sleeves remained attached to the Starflex. The elastomeric thrust bearing, located between the sleeve and the Starflex, for all three blades were thermally damaged. All three pitch horns remained attached to their respective sleeves. All three Starflex arms were fractured at an angle across their width. Blades 1 and 2 were heavily sooted with most of the blade afterbody missing.[2] Loose pieces of the leading edge abrasion strip were found in the main wreckage. Blade 3 was partially sooted and contained most of its afterbody. Small pieces of main rotor skin and foam core were found in the area surrounding the main wreckage site. Additionally, the tip ends of blades 1, 2, and 3 were fractured and broomstrawed. The main rotor vibration absorber remained installed at the top of the main rotor head.

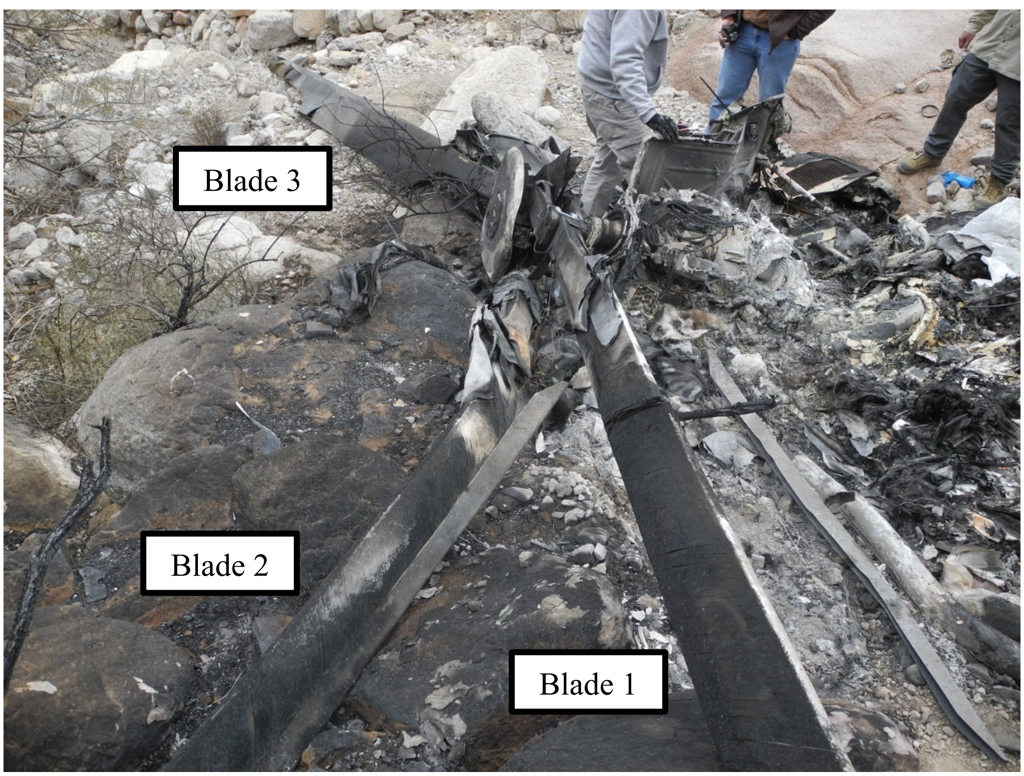

Figure 4. The main rotor blades, main rotor head, and main transmission.

[2] The afterbody is the structure behind the spar. On the EC130 B4 main rotor blades, the afterbody comprises a composite sandwich of fiberglass upper and lower skin with a foam core in between.

2.2.3 MAIN ROTOR DRIVE SYSTEM OBSERVATIONS

The Starflex remained attached to the main rotor mast; both Starflex and main rotor mast exhibited thermal damage. The main transmission lower housing was partially consumed by the postcrash fire, exposing the internal transmission gears. The conical housing remained attached to remnant portions of the lower housing. The four suspension bar upper rod ends remained attached to the upper housing but the suspension bars were fractured and consumed by the postcrash fire. Two of the suspension bar lower rod ends, normally installed to the airframe, and their attaching hardware were found loose in the recovered wreckage.

The rotor brake and its control cable were found in their normally installed location, between the engine-to-transmission drive shaft and the main transmission input pinion. The rotor brake and its control cable exhibited thermal damage. The engine-to-transmission drive shaft was thermally damaged and the flexible couplings on both ends of the drive shaft did not exhibit evidence of splaying. The engine-to-transmission drive shaft remained within the support tube (also known as a “liaison tube”) between the main transmission and engine. The support tube was thermally damaged and its forward end was consumed by the postcrash fire. The gimbal ring was consumed by the postcrash fire. The forward casing, attached to the main transmission and gimbal ring, was thermally damaged and partially consumed by the postcrash fire.

2.3 FLIGHT CONTROLS

2.3.1 OVERVIEW

The cyclic and collective control inputs are transmitted from the pilot controls to the stationary swashplate through a series of push-pull tubes and bell cranks. The main rotor cyclic and collective controls are hydraulically assisted via three dual-cylinder main rotor servo controls: fore/aft, right-roll, and left-roll. Each main rotor servo control comprises two cylinders that are stacked in tandem. The main rotor servo controls are mounted to the transmission upper housing and the stationary swashplate. The pedal control inputs are transmitted directly to the fenestron, without hydraulic assistance, via a control cable. The pilot seat is normally located on the left side of the helicopter.

2.3.2 OBSERVATIONS

The helicopter was equipped with a single-pilot, left-side flight controls. The cyclic stick was found in the wreckage at its normally installed location (**Figure 5**). The cyclic stick head was not attached to the cyclic stick and was not observed in the main wreckage. The lateral torque tube was found in its normally installed location and was bent about midspan. The collective stick was found in the wreckage in its normally installed location. The collective stick was found in a nearly full-up position. The engine twist-grip throttle was found to be in the “flight” gate. The left and right pedals were separated from their respective posts and found loose in the main wreckage near their normally installed locations. The pedal control bellcrank was found in its normally installed location. The control mixing unit was found in its normally installed location. The mixing unit push-pull tubes and the push-pull tube attachment points were fractured and thermally damaged. All cyclic, collective, and pedal control components observed in the main wreckage were thermally damaged.

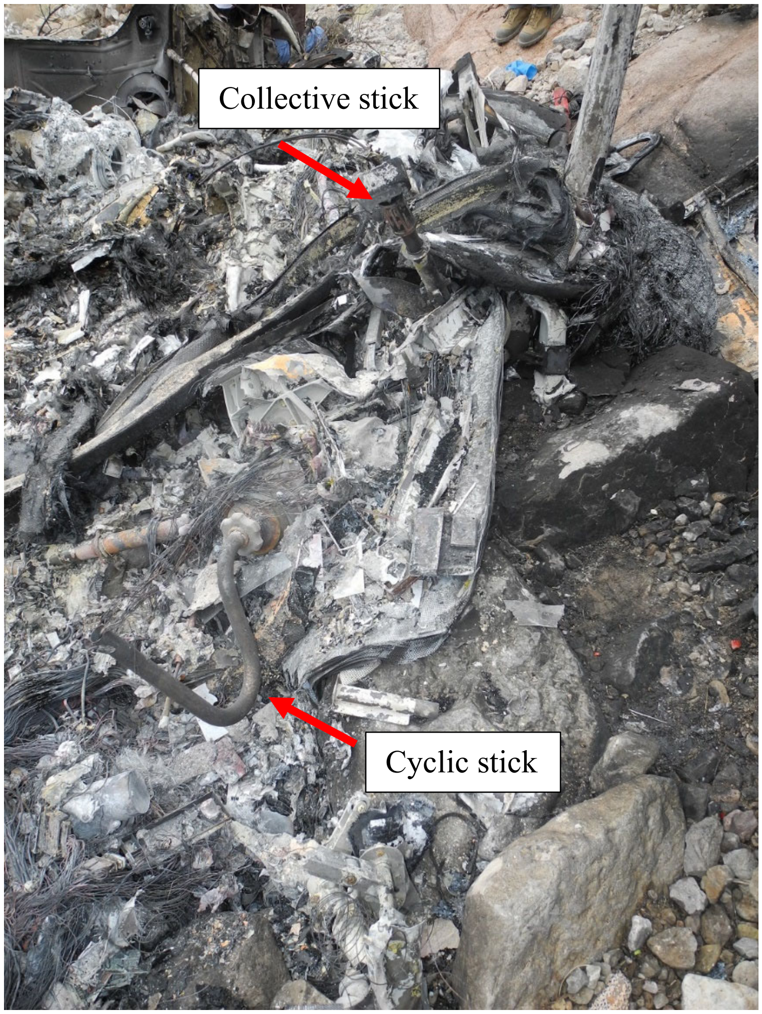

Figure 5. The pilot cyclic and collective sticks (viewed forward-looking-aft).

All three main rotor servo controls were found in their normally installed locations. The lower rod end for the left-roll and right-roll servo controls remained attached to the transmission housing; the lower rod end of the fore-aft servo control contained its attaching hardware but the transmission housing attachment location was consumed by the postcrash fire. The upper rod ends for all three servo controls remained attached to the stationary swashplate.

Two of the three PCLs were found in their normally installed position; these PCLs remained attached to their respective pitch horns and the rotating swashplate attachment points, but their link body was fractured. A segment of the third PCL body was found near its normally installed location but its rod ends remained attached to its respective pitch horn and rotating swashplate attachment points. The rotating scissor link remained installed but was thermally damaged. The stationary scissor link remained attached to the swashplate and transmission housing, but was fractured and partially melted at its pivot point.

The belt-driven aircraft hydraulic pump and the gear-driven hydraulic pump were found loose in the main wreckage. The hydraulic fluid reservoir was consumed by the postcrash fire. The servo control hydraulic lines were thermally damaged but remained connected.

The fenestron control cable was fractured near the tail boom attachment frame separation (**Figure 6**). The aft portion of the fenestron control cable was found within the tail boom; continuity of control was confirmed from its fracture (at its forward end) to the fenestron blades. The control cable junction box (triangular flanges which are bolted together) was disassembled revealing the junction, a circular dovetail connection, which remained connected. The flex-ball control cable was fractured but a portion of it remained within the forward junction box. The dovetail, the aft portion of the forward flexball cable, and the forward junction housing were retained for further examination.[3] Evidence of the forward portion of the fenestron control cable was observed in the main wreckage, including the mating fracture to the aft portion of the fenestron control cable. Control continuity of the forward portion of the fenestron control cable could not be determined due to melted and crushed airframe.

Figure 6. The fenestron control cable near the aft end of the main fuselage.

2.4 FENESTRON

2.4.1 OVERVIEW

Engine power is transferred to the fenestron gearbox via two fenestron drive shafts: forward and aft. The forward fenestron drive shaft, made of steel, is connected to a flange connected to the aft end of the freewheel shaft. The aft fenestron drive shaft, made of aluminum, connects to the forward fenestron drive shaft via a splined, steel flange adapter. Flexible couplings are located between each drive shaft attachment point to allow for minor misalignment. Five ball bearings (also known as "hanger bearings"),

[3] For additional details of the fenestron control cable findings, see the Materials Lab Factual Report No. 18-041 in the docket for this investigation.

mounted within support brackets along the tail boom, support the fenestron drive shafts. The fenestron gearbox provides gear reduction and changes the direction of drive.

The fenestron comprises a 10-bladed rotor whose blades are unevenly spaced. The fenestron blades are connected at a central pitch change mechanism, at the hub of the fenestron, for collective pitch changes.

2.4.2 FENESTRON OBSERVATIONS

The fenestron remained attached to the tail boom but was thermally damaged from the postcrash fire (**Figure 7**). Three stators from the lower portion of the fenestron were found on the ground immediately below the fenestron. All but one of the fenestron blades remained attached to the fenestron hub. One fenestron blade was fractured at its root and the blade was found on the ground immediately below the fenestron. Four consecutive fenestron blades from the lower half of the fenestron were bent in the direction opposite of normal rotation. The fenestron hub cover was found on a slope to the south-southeast of the main wreckage.

Figure 7. The fenestron as observed on scene.

2.4.3 FENESTRON DRIVE SYSTEM

The steel fenestron drive shaft was found at the aft end of the main fuselage. The steel fenestron drive shaft forward flange was fractured; the three forward flange lobes remained attached to the flexible coupling and fenestron output drive flange (found on the aft side of the engine reduction gearbox). The fenestron output drive flange lobes exhibited slight deformation in the aft direction. The splined adapter and flexible coupling remained attached to the steel fenestron drive shaft aft flange; these components exhibited minor damage. The internal splines of the splined adapter exhibited no evidence of anomalous wear.

The aluminum fenestron drive shaft remained within the tail boom and was continuous from its forward splined end (normally mated to the splined adapter at the aft end of the steel fenestron drive shaft) to its aft attachment to the fenestron input pinion. No anomalous damage was observed on the aluminum fenestron drive shaft. The external splines on the forward end of the aluminum fenestron drive shaft exhibited no evidence of anomalous wear.

The five hanger bearings were found within the tail boom. The hanger bearings were visually in good condition but were ejected from their respective hanger bearing mounts. The upper portion of the aft-most hanger bearing mount was tilted forward but the remaining four hanger bearing mounts remained intact. All five hanger bearings remained attached to the aluminum fenestron drive shaft.

2.5 COCKPIT INSTRUMENTS

Three avionics boxes and two dial indicators were found loose in, and subsequently separated from, the main wreckage site. All recovered items exhibited thermal damage. The caution and warning annunciator panel was also found but was thermally damaged. The vehicle engine management display (VEMD) could not be identified in the main wreckage site. No usable information could be read from the cockpit instruments observed on scene.

2.6 POWERPLANT

2.6.1 OVERVIEW

The Arriel 2B1 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[4] 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

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

the power transmission shaft. An accessory gearbox is driven off of a gear coaxial to the shaft between the axial and centrifugal flow compressors.

2.6.2 OBSERVATIONS

The aft-left engine mount was separated at its bushing and thermally damaged, but the two mount halves were aligned. The aft-right engine mount remained installed on the engine deck but was thermally damaged. The full-authority digital engine control (FADEC) was found adjacent to the underside of the engine deck and was thermally damaged. The fuel lines remained attached to the hydromechanical unit (HMU) and oil lines remained attached. The emergency backup control ancillary unit (EBCAU) was removed from the HMU and the key, an operational position indicator for the EBCAU, was found in the 12 o'clock position. A 12 o'clock position of the key is consistent with non-emergency operation of the EBCAU. The starter generator remained attached to the engine and exhibited signatures of thermal damage. The starter generator output cables to the master electrical box was thermally damaged and the master electrical box was found loose in the wreckage.

The power turbine blades were present with no evidence of blade shedding. The power turbine was able to be rotated by hand in the direction opposite of normal drive. The power turbine could not be rotated in the direction of drive, but the freewheeling unit was observed to move slightly when attempting this manual rotation. After removal of the engine-to-transmission drive shaft, the power turbine could be rotated in the direction of drive with a corresponding rotation of the transmission power shaft (also known as the "freewheel shaft"). The freewheeling unit remained functional. Removal of the power turbine from the engine reduction gearbox revealed the gearbox input (splined) nut and index mark. The index mark was offset about 1.5 mm in the tightening direction. The power turbine nozzle guide vane was removed, revealing the gas generator turbine. No anomalous damage was observed on the gas generator turbine.

The engine air intake duct (also known as the "bell mouth") was partially consumed by the postcrash fire but its flange remained attached to the first stage compressor cover. The first stage axial compressor exhibited no evidence of foreign object debris (FOD) damage but its blade surfaces were sooted. The gas generator was successfully rotated by hand. The helicopter was equipped with an inlet barrier filter that was partially consumed by the postcrash fire.

The module 1 and module 5 magnetic plugs were removed and revealed no evidence of magnetic debris. The electric chip detector exhibited no debris but was thermally damaged.

2.7 TERRAIN OBSERVATIONS

Reddish-orange colored markings, consistent with paint transfer marks, were observed on the ground (essentially large boulders) immediately to the south of the main fuselage. One set of these markings were primarily linear in directionality; a second set of markings exhibited an arc pattern (**Figure 8**). The accident helicopter fuselage paint scheme was a reddish-orange color.

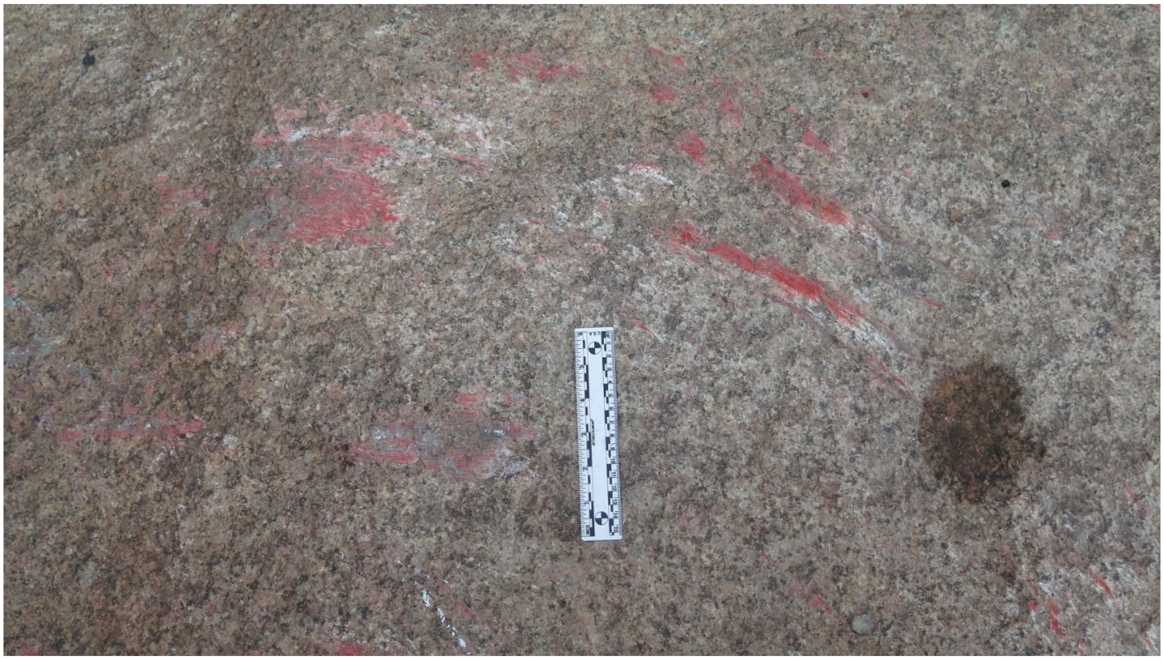

Figure 8. Reddish-orange colored markings with an arc pattern.

Two impact marks with a teal coloration was found on a slope about 30 feet south of the main wreckage. The elevation of these impact marks was about 10 feet above the main wreckage site. An impact mark with a teal coloration was found on a boulder about 21.5 feet east of the reddish-orange colored markings with an arc pattern. The adhesive used in the construction of the main rotor blades have a teal coloration.

A witness mark with a white coloration was found on a boulder on the hillside south-southeast of the main wreckage. A skid step toe was found adjacent to this bounder.

Pieces of transparent plastic material, similar to the helicopter windows, was found throughout the hillside to the south-southeast of the main wreckage.

On May 30, 2018, NTSB investigators performed a laser scan of the accident site to document terrain features at the accident site. **Attachment 1** of this report contains a comparison of certain accident site features to laser scan images.

3.0 MAINTENANCE

According to Papillon Airways general operations manual (GOM), the operator's helicopters are maintained under a manufacturer's recommended inspection program. According to maintenance records for N155GC, on January 25, 2018 (ATT 9594.2 hours) a combined 10-, 50-, 100-, and 150-hour airframe inspection and a combined 15-, 25-, and 30-hour engine inspection were completed. A subsequent operational check flight was performed and no discrepancies were noted, after which the helicopter was returned to service.

According to operator records, on January 28, 2018 (ATT 9,607.8 hours) a pilot flying N155GC reported an anomalous aircraft yaw and an aural alert (gong). The report stated the VEMD first limit indicator (FLI) "went down to 8 and up to yellow range in a second with another gong." According to maintenance records for N155GC, on February 4, 2018 (ATT 9,607.8 hours) the yaw anticipator potentiometer, located on the pedals, was replaced due to a bent pin on the potentiometer causing it to malfunction. After replacement of the potentiometer, a ground run check was performed with no further defects noted. A subsequent independent control check and an operational check flight were performed; no discrepancies were noted and the helicopter was returned to service. Attachment 1 contains the aircraft logbook records for the yaw potentiometer replacement on N155GC.

4.0 FUEL SYSTEM CRASH RESISTANCE

On October 3, 1994, the Federal Aviation Administration (FAA) introduced improved fuel system crash resistance standards for normal category helicopters via Amendment 27-30 to Part 27 of the Federal Aviation Regulations (FAR).[5] The standards for fuel system crash resistance, 14 CFR 27.952, are intended to minimize fuel spillage near ignition sources to improve the evacuation time needed for crew and passengers to escape a postcrash fire. However, the improved fuel system crash resistance standards were not retroactively applicable to either existing helicopters or newly manufactured helicopters whose certification basis and approval predated the effectivity of Amendment 27-30. TCDS No. H9EU was initially approved on December 21, 1977. The EC130 B4 was approved on December 21, 2000 and added to TCDS No. H9EU. The certification basis for the EC130 B4 included Amendments 27-1 through 27-32 except 14 CFR 27.952 was not adopted. The EC130 B4 is equipped with a fuel tank that is constructed of polyamide with no rubber bladder or liner, identical to the original fuel tank found in the AS350-series helicopter.[6] The EC130 T2 was approved on July 30, 2012 and added to TCDS No. H9EU; its certification basis was the same as the EC130 B4 except 14 CFR 27.952 was adopted at Amendment 27-30.

Based on NTSB safety recommendation No. A-16-10 the FAA issued Special Airworthiness Information Bulletin (SAIB) No. SW-17-31 on October 13, 2017. SAIB No. SW-17-31 notified helicopter owners and operators of a list of helicopters that are fully compliant with 14 CFR 27.952 and 29.952. As of revision 2 of the list, dated December 7, 2017, the EC130 B4 would be compliant with 14 CFR 27.952 with the installation of supplemental type certificate (STC) No. SR02492AK[7]; no other STC or modification was listed for the EC130 B4.

The accident helicopter was not equipped, nor was it required to be equipped, with a fuel system meeting the provisions of 14 CFR 27.952. From the date of manufacture of the accident helicopter until the approval of STC No. SR02492AK, there was no available modification to incorporate a fuel system meeting the provisions of 14 CFR 27.952. On February 26, 2018, the operator signed a memorandum of understanding with StandardAero[8] for 40 retrofittable crash resistant fuel tanks for AS350 B3 and EC130 B4 helicopters.

Chihoon Shin
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[5] 59 *Federal Register* 50380, October 3, 1994. The revised airworthiness standards became effective on November 2, 1994.
[6] Since 2015, newly manufactured AS350 B3e helicopters are equipped with a crash-resistant fuel system.
[7] STC No. SR02492AK is a retrofit crash resistant fuel system for several AS350-series variants as well as the EC130 B4 and was originally issued to Vector Aerospace Helicopter Services USA, Inc.
[8] Vector Aerospace was sold to StandardAero in November 2017.