

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



ERA21FA233

AIRWORTHINES

Helicopter Specialist's Factual Report

May 24, 2022

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A. ACCIDENT

Location: Leesburg, FL
Date: May 25, 2021
Time: 1745 Eastern daylight time (EDT)
2145 Universal coordinated time (UCT)
Helicopter: BHI H60 Helicopters LLC, UH-60A / N9FH

B. AIRWORTHINESS SPECIALIST

Helicopter Specialist Van S. McKenny IV
NTSB / AS40
Washington, DC

C. DETAILS OF THE EXAMINATION

1.0 Helicopter Information

The BHI H60 Helicopters LLC, UH-60A (Blackhawk) is a twin turboshaft engine, single rotor, semimonocoque fuselage helicopter (Figure 1). Primary mission capability of the helicopter is tactical transport of troops, supplies and equipment. Secondary missions include training, mobilization, development of new and improved concepts, and support of disaster relief. The main rotor system has four blades made of titanium/fiberglass. The drive train consists of a main transmission, intermediate gear box, and tail rotor gear box with interconnecting shafts. The propulsion system has two General Electric (GE) T700-GE-701D turboshaft engines operating in parallel. The nonretractable landing gear consists of the main landing gear and a tailwheel.¹

The Supplemental Type Certificate (STC) Firefighting System installs a 925-gallon internal water tank in the main cabin. The water tank itself is constructed mostly of carbon fiber material. The water tank is built with the internal floor that is laterally sloped approximately 14 inches downward from the right side to the left side. Due to floor loading limits, the tank is limited to 895 gallons when the snorkel is installed and 910 gallons when the snorkel is not installed.²

¹ BHI H60 Helicopters, LLC, Operator's Manual, Restricted Category Model BHI UH-60A, Ch-2, 2-1.

² BHI UH-60A Rotorcraft Flight Manual Supplement, Internal Water Tank & Snorkel Installation, Ch-4, 4.1.



Figure 1. Accident helicopter on May 25, 2021.

2.0 On-scene Wreckage Documentation

The wreckage was located in a localized swamp approximately 1,000 feet southeast from the approach end of runway 3 of the Leesburg Airport (LEE), Leesburg Florida (Figure 2). The terrain was flat, and the localized swamp was populated with mature oak trees with a dense underbrush of scrub oak, and the soil was soft mud to a depth of 1.5 feet in some locations. The wreckage was contained in a 31-foot diameter vertical impact crater and had been consumed by fire (Figure 3). The wreckage was oriented on a tail-nose bearing of 055° magnetic. Sections of all 4 rotor blades were contained with the main wreckage. The orientation of the main wreckage indicates that the helicopter impacted with its left side partially inverted. The right engine (No. 2) was exposed, and the left engine (No. 1) was not visible under the debris. The main gearbox had been completely consumed by fire exposing the internal main drive gear assemblies. The vertical tail, tail rotor, stabilator, and aft portion of the empennage was located about 50 yards away on a bearing 020° magnetic from the main wreckage (Figures 4 & 5). The tail section had not been exposed to fire and all tail rotor and stabilator components were present.



Figure 2. Wreckage debris map.

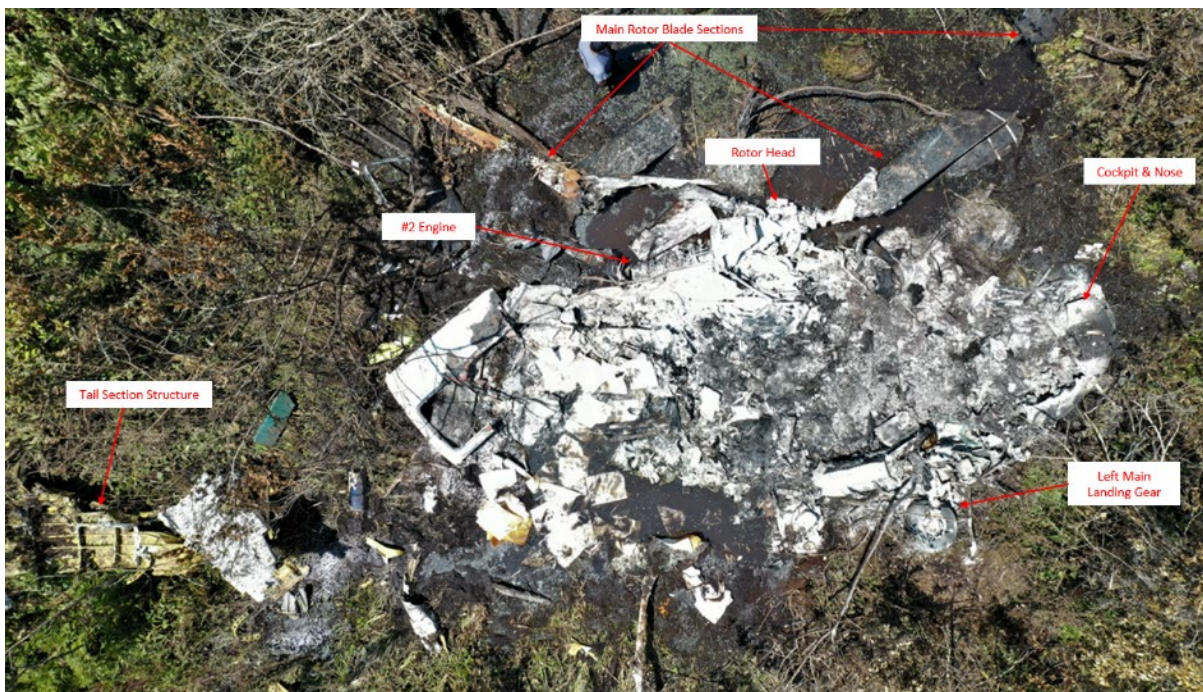


Figure 3. Overhead view of wreckage.



3.0 Wreckage Examination

Parts of what remained of the wreckage (Figure 6) were transported to Florida Air Recovery, Jacksonville, Florida, on May 28, 2021, to facilitate further examination.

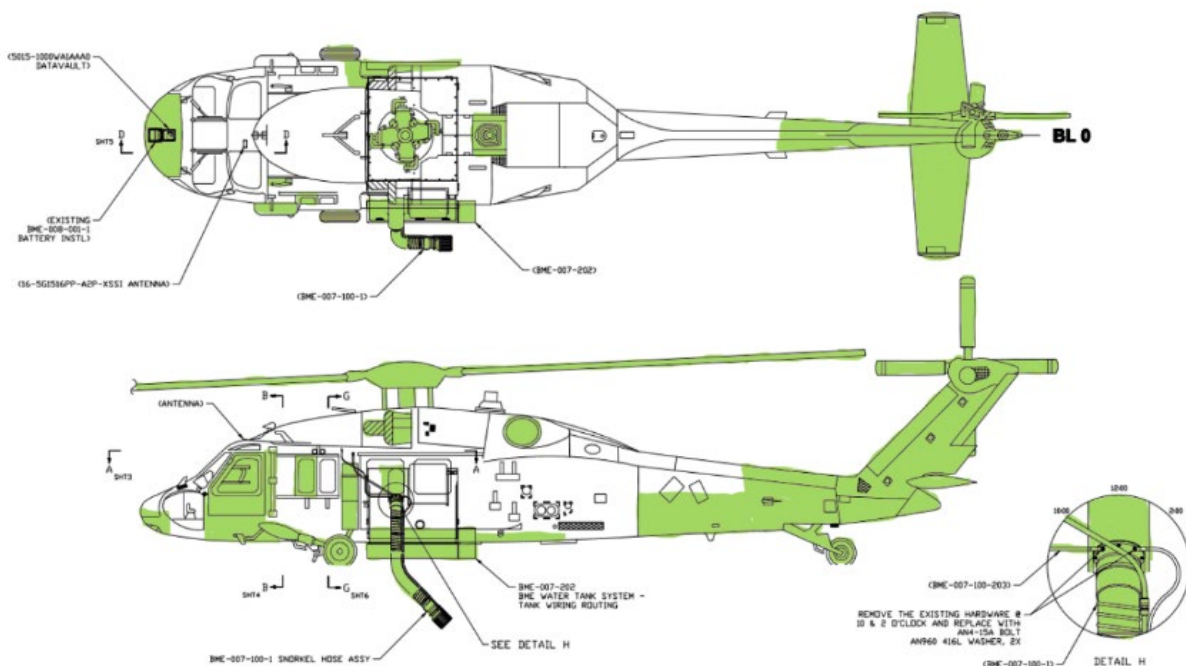


Figure 6. Green areas indicate the sections of the helicopter that were recovered and examined.

3.1 Fuselage

The entire fuselage (except for the empennage, vertical tail, & tail rotor) were contained with the main wreckage. The outboard halves of two rotor blades (yellow & black) were not at the main wreckage location. The left forward section of fuselage including landing gear mount was recovered. Next to the landing gear was a section of the fire water tank with the hose connection. The entire water gate box mechanism, which is attached to the bottom of the water tank was present. Sections of the snorkel hose was located underneath this section of the wreckage. The left cockpit door was recovered. Portions of the carbon-epoxy water tank structure were identified. The end of the snorkel was located, missing the motor, impeller, and cage. The cockpit section inside the fuselage had been heavily fire damaged. Fire damaged portions of the fuel bladder were recovered. The majority of the aft fuselage area had been consumed by the post-crash fire. Portions of the left and right tail skins were recovered, along with the empennage, vertical tail, stabilator, and tail rotor. The right main landing gear mount had extreme fire damage. The majority of the right side of the forward fuselage and cabin had been consumed by the post-crash fire. Right side main cabin door was recovered and had been liberated from the fuselage. The majority of the upper engine deck, both engines, and auxiliary power unit (APU) were present. Three tail rotor driveshaft segments were recovered. The fire bottles were attached to their respective frame, and bottle gages indicated 650 psi on both. The hydraulic pressure accumulator and APU were recovered. The tail section had separated at station 640, 4 feet forward of the tail pylon bulkhead. The stabilator was connected and relatively undamaged. The Section III and IV tail rotor driveshafts were in their respective positions. Section III had separated from both hanger bearings (See Figure 12 for tail rotor drive system schematic).

3.2 Cockpit

The cockpit was contained within the main wreckage but fragmented and subjected to extreme fire damage. The instrument panel had separated into right (copilot), left (pilot), and portions of the center console. The overhead panel and engine control levers were not located. The cockpit had been completely destroyed by the post-crash fire. Both cyclics, antitorque pedals, and one collective control were identified. All linking control tubes had been consumed by the fire. The collective trim actuator and yaw trim actuators were identified. One pilot seat frame was identified. The cushion, seat covering, and seat harness webbing had been consumed. One 5-point restraint buckle was located.

Both sides of the instrument panel had video displays attached (video cameras located in the cargo hook area to view the external/long line cargo). One center display unit (CDU) was identified that had been destroyed by heat/fire.

Table 1. Left side (pilot) instruments.

Airspeed	Unreadable
Attitude Indicator	Unreadable
Horizontal Situation Indicator (HSI)	075°
Absolute (ABS) Altimeter/Radar Altimeter	0 feet
Altimeter	600 feet
Vertical Speed Indicator (VSI)	7,000 foot per minute (fpm) climb

Table 2. Right side (copilot) instruments.

Attitude Indicator	50° nose up 120° right wing down
Absolute (ABS) Altimeter/Radar Altimeter	0 feet
Altimeter	450 feet, 30.16 inches of mercury (inHg)
Horizontal Situation Indicator (HSI)	050°
Vertical Speed Indicator (VSI)	1500 fpm descent

3.3 Flight Controls

The majority of the flight control push-pull connecting tubes could not be located and were presumed to have been consumed by the post-crash fire. The major remaining portions of the flight control system were the collective and yaw boost actuators, stability augmentation system (SAS) actuator, mixing unit, primary servos, tail rotor control cables, and the tail rotor control quadrant. The primary servos assembly was identified. All flight control tube connections had bolts and nuts thru their respective rod-end connections. The collective and yaw trim assemblies were identified with control arms fractured. The tail rotor cables within the empennage exhibited broomstrawed ends where the tail separated from the helicopter. The tail rotor control cable in the fuselage exhibited broomstrawed at one end, the other end was a flat separation. The other fuselage control cable was not located. Forward, aft, and lateral flight control servos were attached to their respective bell crank/walking beam and traced to the stationary swashplate linkages.

3.4 Main Rotor Drive System

The main rotor module (transmission) and rotor head were co-located with the main wreckage (Figure 7). Three blade roots remained attached to their spindles; one blade had separated from the spindle (blue). Both engine input module cases had been consumed by the post-crash fire and the majority of the main module case had been consumed. The sun gear and planetary gears were present on the main rotor shaft. One hydraulic module and one generator were recovered. The bridge beam was not present but the forward, aft, and lateral hydraulic servos and linkages to the stationary swashplate were present. The aft and lateral remained connected, the forward servo was disconnected from the swashplate because half the stationary swashplate ring was not present, presumed consumed by the post-crash fire. Both sets of rotating scissors were connected to the lower pressure plate but not connected to the rotating swashplate. Each end of the scissors had the swashplate attachment hardware still connected.

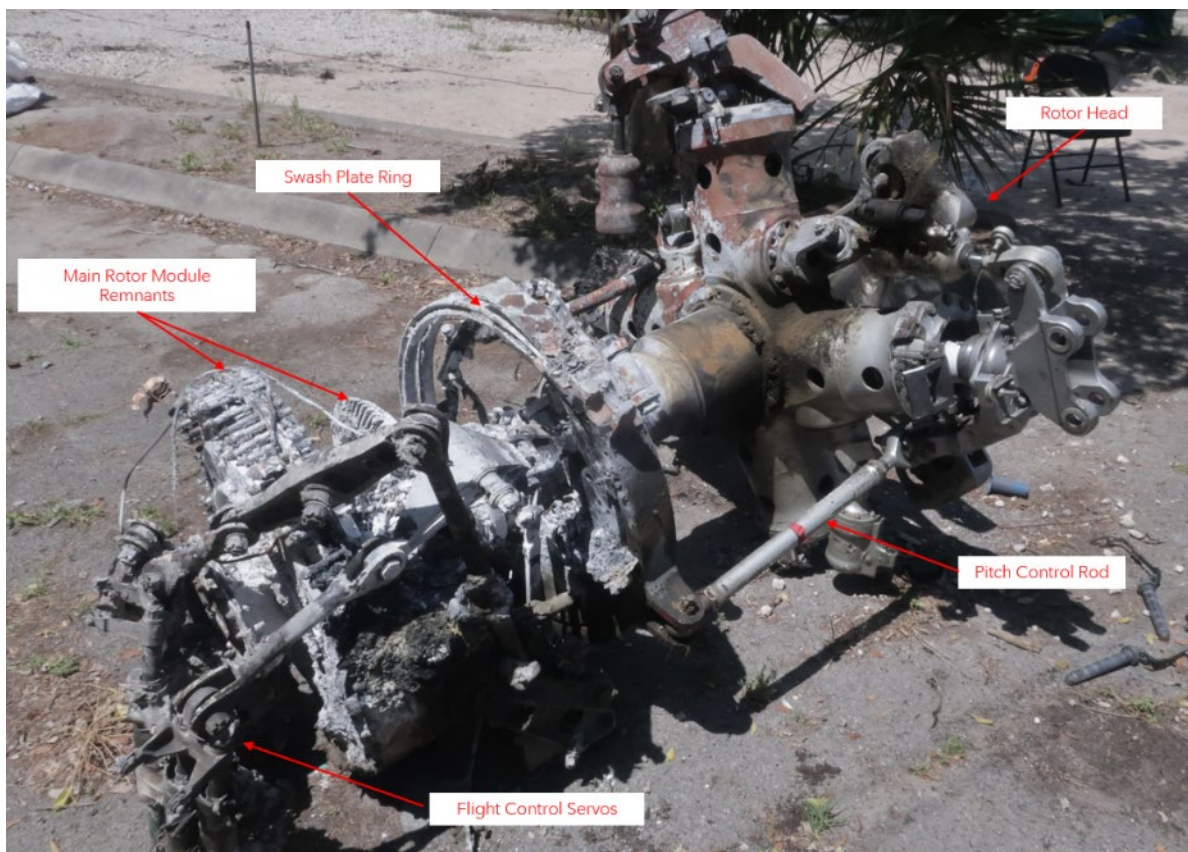


Figure 7. Main rotor module (transmission) and rotor head.

3.4.1 Main Rotor Head

The four arms of the titanium hub were present. The fairing and bifiler remained attached. The yellow, blue, and red pitch control rods (PCR) were present. The black PCR was not present and was not recovered.

The yellow spindle was connected, and the elastomeric bearing was present but heat damaged. The pitch horn and blade grip were connected to the spindle assembly. Twenty inches of the yellow blade remained attached, and the damper had separated at the rotor head end. The yellow PCR was connected at the pitch horn and disconnected from the rotating swashplate, but the rod-end and thru bolt remained attached to the PCR. The yellow PCR was bent at mid span.

The blue spindle had fractured and separated from the rotor head. The elastomeric bearing was present. The blue blade damper had separated at the rotor head connection and the blue PCR remained attached at the pitch horn and swashplate.

The red spindle was in place and the elastomeric bearing intact. The damper remained connected at both ends. Twenty-four inches of the red blade remained attached to the spindle. The red PCR remained attached at the pitch horn and swashplate.

The black spindle was connected, the elastomeric bearing present but heat damaged. The pitch horn and blade grip were connected to the spindle assembly. Thirty-three inches of the black blade remained attached. The damper had separated at the rotor head end. The pitch horn had fractured at the PCR connection and the PCR was not present.

3.4.2 Main Rotor Blades

Portions of all four rotor blades were recovered (Figure 8).



Figure 8. Overhead view of the main rotor blades laid out for examination.

Yellow Blade, Serial Number (SN): A007-04434

The blade was fractured 10-inches outboard of the blade grip. Blade afterbody separation was in two halves from 6 feet to 19 feet 8 inches. A leading-edge witness mark from the copilot's pilot tube was located at 8 feet 9 inches. The spar was fractured at the 13 feet 2 inch location. A 7-inch diameter semicircular deformation with witness indentations consistent with the spacing of the nozzle cage rods was evident (Figure 9). The spar fracture's leading-edge bottom was curled up and aft. The fracture characteristics include 45° shear lips along the edge. Blue paint transfer was observed on the upper leading edge at the 11-to-12-foot location, and the blade tip aft outboard edge was damaged.



Figure 9. Yellow blade exhibiting semicircular shaped leading-edge separation and the snorkel pump basket deformed in the shape of the blade leading edge.

Red Blade, SN: A007-04436

The blade root was attached to the grip. The blade was fractured at 9 feet 7 inches with an approximately 20° inboard to outboard leading to trailing edge fracture line. The blade was also fractured at 14 feet 3 inch location in downward bending, with the fracture line along the chord line. There was a leading-edge buckle at the 16 feet 10 inch location. A 20° angle crease leading to trailing edge inboard to outboard at the 19 feet 3 inch location. The blade tip was not present. There was a leading-edge impact mark near the blade tip.

Blue Blade, SN: A007-13043

The blade was attached to the blade grip and the leading edge was bent 45° aft at the 2 feet location and the trailing edge had damage at 6 feet. The blade was fractured at 10 feet 10 inch location with a 20° inboard to outboard aft tear. There was a trailing edge hole between 9 and 15 feet. There was blade tip damaged with the tip cap missing. The bottom of the blade had blue paint transfer parallel to the blade chord between 5 and 6 feet.

Black Blade, SN: A007-02738

The blade was fractured at 2 feet with a 45° inboard to outboard spar fracture. The fracture characteristics include upward bending and shear lips along the fracture surface. There was heat damage along its length out to 8 feet. Upper skin delamination out to 12 feet 7 inches. There was a midspan fracture at 12 feet 10 inches, with spar upward bending characteristics, 45° fracture line, and shear lips along the fracture surface. The remaining outboard section of blade was not recovered.

3.5 Tail Rotor Drive System

A diagram of the tail rotor drive shafts recovered for examination is depicted in Figure 12. The Section IV drive shaft remained in place on the vertical stab, the Section III drive shaft remained in situ on the tail boom and intermediate gear box but had separated at both Thomas couplings. The Section IV remained attached to the intermediate gearbox and tail rotor gearbox. The Section III drive shaft was intact, unbent, had rotational scoring along its length at multiple locations. Both Thomas couplings exhibited overload torsional separations. The Section II-C drive shaft was not located. Section II-B (mid) drive shaft had an impact crease lengthwise 36 inches from the aft end, about 6 inches of mid shaft were missing, and 18 inches of the forward end was located. Both Thomas couplings exhibited fractures consistent with torsional overload. Section II-A was missing 19 inches of the aft end including the end fixture and Thomas coupling. A dent and rotational score marks were observed at the same location. The forward end and Thomas coupling had separated in torsional overload. The oil cooler drive shaft had separated from the cooler fan assembly in overload at the coupling, and the opposite end Thomas coupling has separated in torsional overload. The Section I short shaft, between main transmission and the fan assembly was not located. The intermediate gear box had no damage, and the input-output was smooth when rotated by hand. The tail rotor moved in concert smoothly with no binding.

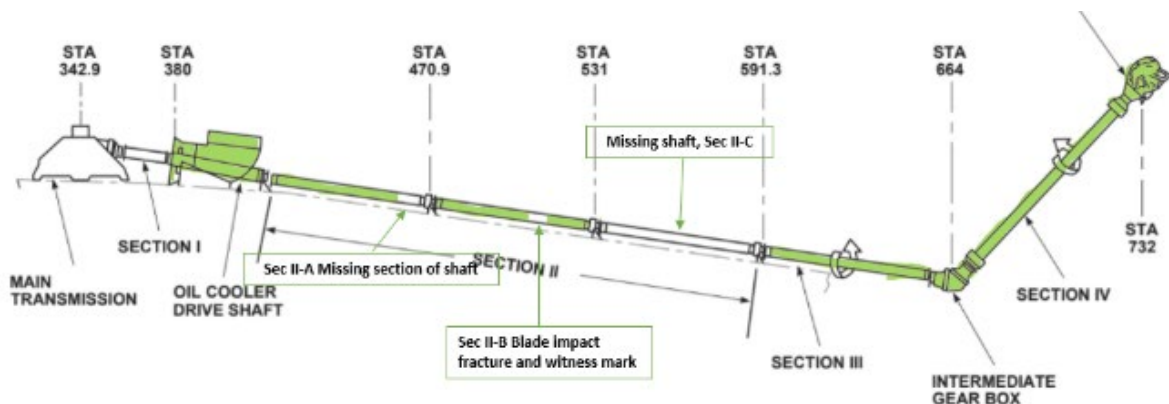


Figure 10 Tail rotor drive system schematic. Sections annotated in green were recovered and examined.

3.5.1 Tail Rotor

The empennage and tail rotor were located about 50 yards north of the main wreckage. All four blades were attached to the hub, the red blade was broken at the root (Figure 13). The pitch change beam was connected to the drive shaft, all pitch links were connected to their respective blade pitch horns. The tail rotor control quadrant was undamaged. Tail rotor control cables connected to the quadrant and moved the pitch beam when manipulated by hand. The control cables were traced up to the tail boom separation, cable ends were broomstrawed at the ends.

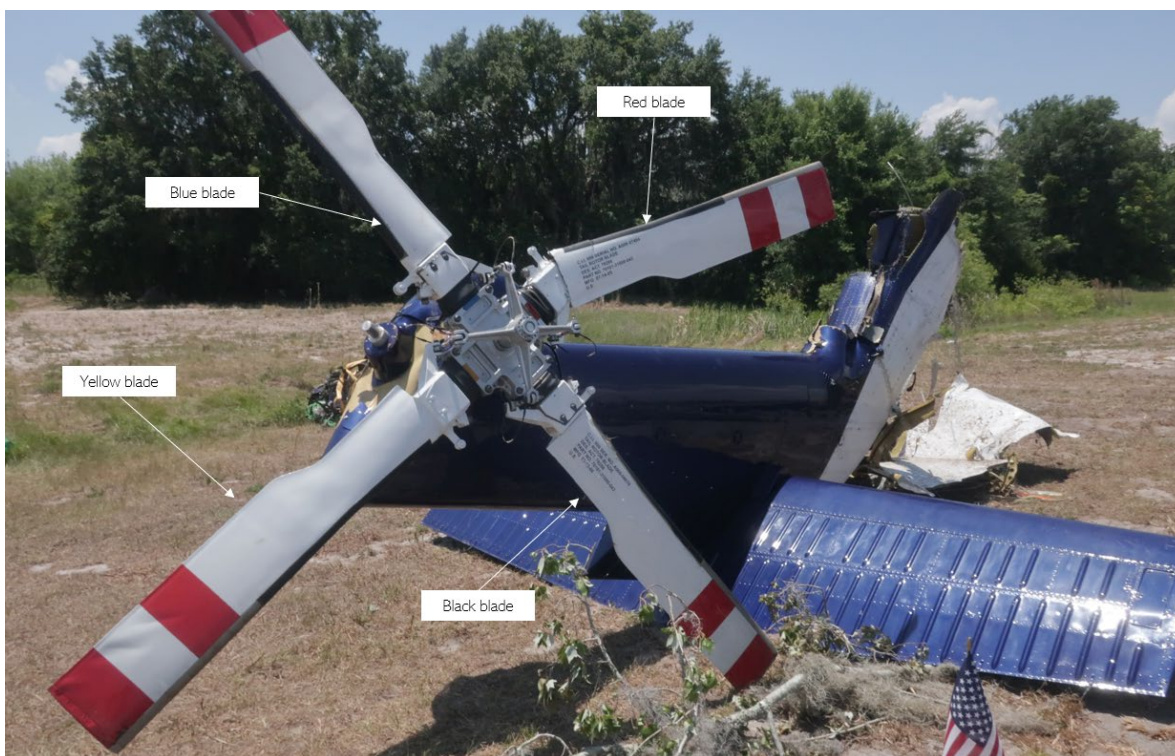


Figure 11. Tail rotor, vertical fin, and stabilator.

The empennage and tail rotor were found about 50 yards north of the main wreckage. All four tail rotor blades were attached to the hub, the red blade was broken at the root (Figure 13). The pitch change beam was connected to the drive shaft, all pitch links were connected to their respective blade pitch horns. The tail rotor control quadrant was undamaged. Tail rotor control cables connected to the quadrant and moved the pitch beam when manipulated by hand. The control cables were traced up to the tail boom separation, cable ends were broomstrawed at the ends.

Table 3. Tail rotor blade information.

Red blade	SN: A009-07494	Broken at the blade grip.
Black blade	SN: A009-09078	Leading edge damage about 6 inches outboard for root. Tip cap missing. Chordwise scratches on the inboard side of the blade.
Yellow blade	SN: not marked	Skin oil canning on outboard half of blade.
Blue blade	SN: not marked	Blade tip cap missing, blade tip damage.

3.6 Powerplants

The left engine (No. 1) was a GE T700-GE-701D turboshaft engine, SN GE-L613214. The inlet duct was crushed around the intake, and the accessory gearbox was intact. The fuel control was present (Woodward Hydromechanical Control Unit) on the engine. The combustion section and turbine section were intact. Turbine blades were visible from the tailpipe end with no blade damage or missing blades. When the turbine rotor was turned by hand, movement could be heard in the forward section of the engine.

The right engine (No. 2) was a GE T700-GE-701D turboshaft engine, SN GE-L613215, had extreme fire damage. The swirl frame and intake duct had been completely consumed by fire. The compressor blades were loose in their mounts and the accessory gearbox including the fuel control unit had been completely consumed by fire. The combustion section and turbine section remained connected and no holes in either case were identified. The highspeed power output shaft was connected to the power turbine. The power turbine turned in concert with the power output shaft when turned by hand. Visual examination of power turbine wheel showed no blade damage.

3.7 Firefighting System STC

The water tank is constructed of carbon-epoxy composite material and holds up to 925 gallons of water or fire retardant and is positioned in the main cabin area of the helicopter (Figure 14). A programable metal water gate is attached to the left

bottom of the tank that extends outside the helicopter. A 15 foot, 6 inch diameter, flexible hose hangs from the left side of the tank with a 130 pound water pump and screen assembly attached to the bottom of the hose. An electrical power cable runs down the hose from the helicopter to the pump providing 115 alternating current voltage to the 7.5 horsepower pump. An electrical bonding wire also is attached to the outside of the hose to the motor/pump assembly to provide electrical grounding and lightning protection.

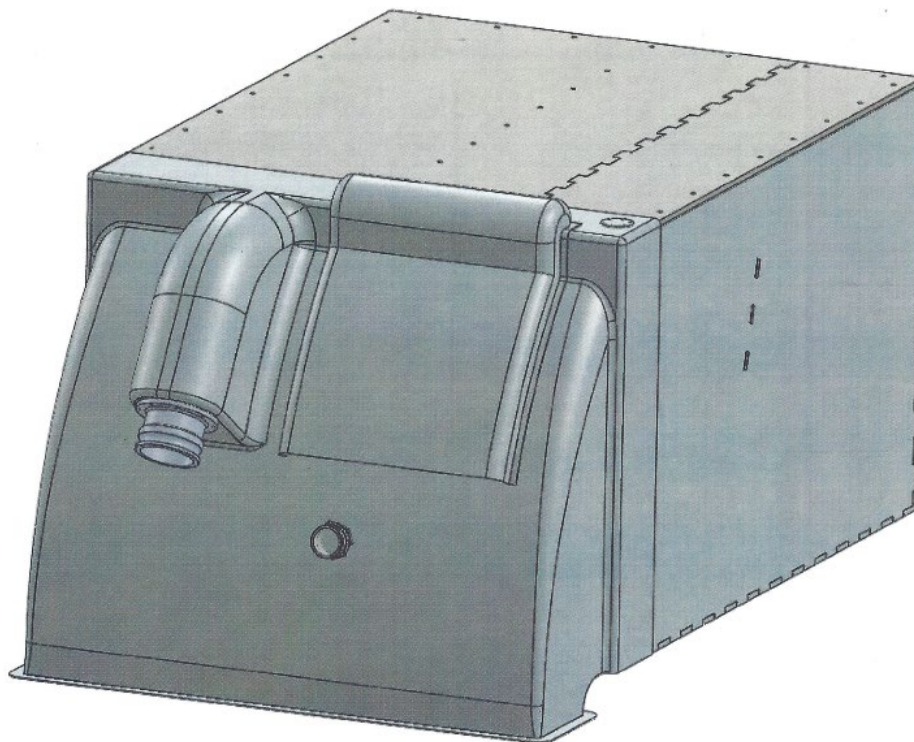


Figure 12. Fire tank engineering drawing.

Portions of the water tank and snorkel hose connecting port were found next to the left main landing gear within the main wreckage. A 10 foot section of the hose assembly (minus the suction pump) was found once the forward left side of the fuselage had been lifted. The upper hose remained attached to the tank nozzle; however, portions of the hose had torn away from the tank nozzle and the edges were melted (Figures 15 and 16). The suction pump and cage were not present on the end of the hose, the recuperator and fragmented sections of the crown housing remained attached.

The upper section of the hose that was clamped to the tank nozzle was examined and disassembled. One-third of the hose was attached to the tank snorkel support and coupler, while two-thirds had been torn away with the tear line coincident with the hose coupler plate. The hose coupler was discolored black and

brown consistent with exposure to extreme heat (Figure 15). Both hose coupler locking levers were in the down (locked) position, one lever had thermal damage and the other was undamaged. Portions of a zip tie encircling the entire coupler that restrained the locking levers was present. The flapper valve inside the tank nozzle was attached and functioned by returning to the close position when opened by hand. A 10 inch braided bonding wire was connected to the tank nozzle and frayed at the opposite end. A second 3 feet of bonding wire was attached to the tank nozzle and routed under one of the coupler's locking handles and had a frayed end. Fire tank nozzle support structure had torn away from the aft side of the coupler assembly, revealing a ripped and deformed portion of nut plate. The nut-bolt fastener were in place but had ripped through the nut plate material (Figure 16).



Figure 13. Forward side of the fire tank nozzle support and the snorkel hose connection.



Figure 14. Aft side of the fire tank nozzle support and the snorkel hose connection.

The lower section of the hose clamp assembly was examined and disassembled. The hose nozzle clamp and plate were present at the opposite end of the hose. The fragmented end of the motor/pump crown housing was attached. The nuts securing the lock plate were attached to the clamp rod, one side had a washer, nut, and nyloc locking nut, the other side had a washer and nut. The side with the nut only, did not exhibit any break-away torque when removed. The nyloc locking nut was in good condition with the locking feature evident as it was removed. The hose clamp rod was not aligned with the grooves of the hose.

D. VIDEO REVIEW

During the time period just prior to the accident, numerous witnesses from the operator were present at the airport. Some of these witnesses were videoing the helicopter's practice water drops. Twenty-two video clips were reviewed, with nineteen of the clips showing the helicopter performing water drops before the accident water drop pass, and three clips of the accident water drop pass.

In the nineteen video clips before the accident pass, the helicopter is seen flying straight and level at a constant airspeed and releasing water over a specific point in the airport infield. As the helicopter approached the water release area, the snorkel hose can be seen hanging in a stable condition off the left side of the helicopter in each case. As water is released from the water tank gate, water can be seen to impinge on the snorkel hose, and the hose remains in a stable condition in each case.

In the three video clips showing the accident water drop and pass, the snorkel hose is seen making large and slightly erratic oscillations as the helicopter approached the water drop area. The helicopter comes to a hover, releases the water from the tank gate, and water impinges on the hose, as it had during the previous passes. No witness video captured the helicopter's transition to forward flight or climb out immediately prior to the accident.

E. EXEMPLAR FIRE TANK EXAMINATION³

An examination of an exemplar water tank system installed in a Sikorsky S-70A helicopter was performed to document the production firefighting water tank installation, and the structural aspects of the nozzle support (Figure 17). The exemplar water tank that was examined was Production Tank No.1. The tank that was installed in the accident helicopter was Production Tank No. 2. Production Tank No. 1 was the tank that underwent the flight testing as part of the STC application process.

³ See Attachment 8, BME Fire Tank Examination Report for details.



Figure 15. Exemplar fire tank installed for examination purposes.

The water tank, snorkel, and water release gate are combined into a single system that can be placed in the cabin area of a UH-60A/S-70A helicopter (Figure 17). It is secured in place by a square tube steel external frame that attaches to the helicopter's existing upper cargo tie down points and to the existing floor tie-down points. The tank is constructed of half inch honeycomb panel with two ply carbon face sheet and Nomex core. The molded front section consists of 12 plies of carbon fiber cloth, and contains the snorkel attachment port, motorized water gate assembly (Trotter Controls), and vent. It was designed and manufactured by Leading Edge Composites. Leading Edge Composites also assembled the tank side panels, integrated the molded front section to the tank, installed the water gate assembly, and associated controls.

The 15 foot long and, 6-inch diameter snorkel hose was attached to the water tank using a metal nozzle port secured to the tank via a carbon fiber flange with a flapper valve by eight AN4 bolts fastened to a backing nut plate. The snorkel connects to the tank port using two lever cam-locks (coupler). The water pump is attached to the free end of the snorkel. A power cable for the pump and a lightning protection cable run down the length of the snorkel and are secured using nylon zip ties. The snorkel hose and pump assembly weighs 137.5 pounds. The snorkel hose is not secured by any other means other than the tank attachment point nor is it retractable.

The tank port had been fastened in place with 12 (AN4) bolts and torqued. The snorkel was attached to the tank using the coupler snorkel fixture cam-locks as designed. A dial gauge was positioned at various points around the tank port. The snorkel was placed on a wheeled dolly and manually pulled in one of three directions (forward, lateral, and aft). The deflection of the tank port structure was measured as the snorkel was manually pulled away from the port and then released back to a static position. The maximum deflection recorded was 0.05 inches at the tank structure between the snorkel attachment fixture and the tank wall when the snorkel was pulled out laterally from the tank. These test loads were applied manually and represented a fraction of the load that the snorkel support structure would be subjected to during flight and operation of the snorkel system.

F. FIREFIGHTING SYSTEM STC CERTIFICATION REVIEW

A STC is the Federal Aviation Administration's (FAA) approval of a major change to the type design of a previously type certificated product. An FAA Aircraft Certification Office (ACO) issues the STC. Blackhawk Mission Equipment LLC STC for the UH-60A and S-70A/C model helicopter Internal Water Tank and Snorkel installation, STC No. SR00933DE, was approved May 21, 2020, by the Denver ACO.

Guidance for applying for and approving an STC is contained in Advisory Circular (AC)-21-40A. The FAA ACO establishes a Project Team that generally consists of a project manager, engineers, or technical specialists required based on the project, flight test engineers and pilots, manufacturing inspectors, and operations inspectors. The FAA Project Team coordinates with the STC applicant to develop a Project Specific Certification Plan (PSCP) (Attachment 1). Blackhawk Mission Equipment LLC hired a program manager and numerous FAA Designated Engineering Representatives (DER) to design the water tank and snorkel system, to conduct testing, and provide associated documentation to the FAA Project Team.

The PSCP for the accent internal water tank and snorkel application listed the following technical disciplines involved in the STC application: structures (FAA DER), electrical systems (FAA DER), mechanical and structures systems (FAA DER), flight analyst and pilot (FAA DER), Designated Airworthiness Representative for Manufacturing (FAA DARF), coupon fabrication (FAA DAR), and electrical systems and equipment (FAA DER). The Denver ACO assigned a project officer, electrical systems engineer, structures engineer, flight test engineer, flight test pilot, and flight standards representative to the project. It is stated in Section 4 of the PSCP, titled Project Type, the following:

This project is a Supplemental Type Certificate for 14 CFR part 29 regulations as determined by the Administrator, for installation of the internal water tank & snorkel install on the BHI H60A/L & S-70A/C model helicopters. The

modifications are used in rotorcraft performing "External Load Operations & Carriage of Cargo" per 14 CFR Part 21.25(a)(2), (b)(1)(2) and (7).

However, the PSCP application and the approved STC No. SR00933DE did not specify the type of rotorcraft-load combination⁴ that would be applicable to the STC. According to the Denver ACO, the airworthiness standards for external loads for a transport category rotorcraft (14 CFR Part 29.865) were not applied because the standard was directed towards human and non-human external cargo and the PSCP did not have 14 CFR Part 29.865 included as part of the certification basis for the project. Additionally, the PSCP did not include the airworthiness standards for rotor blade clearances from rotorcraft structure per 14 CFR Part 29.661.

A review of the Blackhawk Mission Equipment STC application package included a Structural Analysis of the Water Tank Installation report (Attachment 2), Hose Test Report, Flight Test Report (Attachment 3), and a Functional Hazard Assessment & System Safety Assessment (Attachment 4).

The Structural Analysis quantitatively evaluates the water tank design and structural materials for emergency landing load cases per 14 CFR 29.561(a)(c) Amendment 0⁵. The review of the analysis report identified that an inaccurate value of 100 pounds was used for snorkel and pump weight when the actual value of the snorkel and pump weight was 137.5 pounds. The 100-pound vertical load was applied to the tank snorkel support and a margin of safety⁶ of +1.25 the maximum calculated load was applied. However, the calculations only considered a static vertical load applied to the snorkel support. The structural analysis of the snorkel support did not account for the type of dynamic loading that would be seen in operation, such as, air loads imparted by the snorkel, lateral loads imparted by the snorkel, water loads imparted by tank filling operation, water loads imparted by movement of the snorkel and pump horizontally through the water or loads imparted by the snorkel if the assembly was snagged. The FAA ACO stated that:

Subpart C-Strength Requirements in the PSCP, for General (29.301, 29.305(a), 29.307(a)), for flight loads (29.321-29.251, & 29.561(a)(c)) were part of the certification basis. This would have required determination of the lateral and dynamic forces on the snorkel to be used in the analysis.

A hose test was conducted by RKG Enterprises, San Antonio, Texas ⁷ to determine the force required to fail the snorkel hose assembly in tension. The hose assembly consisted of the pump at one end and the hose coupler (mechanism that attaches the hose to the tank structure) at the other end. The coupler was attached to

⁴ CFR 14, Ch1, Subchapter A Definitions and General Requirements, 1.1 General Definitions

⁵ Amendment number is based on the certification basis of the aircraft.

⁶ Margin of safety = Factor of Safety - 1

⁷ RKG Enterprises, report number RKG5074, issued on 12/30/2019

a steel test fixture and the pump assembly was fixed to the ground. A forklift was used to lift the steel fixture with the coupled end and put tension on the hose assembly until it failed. The results were that the pump separated from the hose at 2,500 pounds of force. However, not included in the test was the water tank snorkel support where the snorkel would attach to the tank for normal operation of the snorkel-tank system, nor did it include the lighting protection cable.

The Blackhawk Mission Equipment's STC application included a flight test report (Attachment 3) that documents the details of the ground and flight test results that were conducted to demonstrate compliance with the applicable requirements. The flight tests included observation of the behavior of the tank-snorkel system at airspeeds from 0 knots up to 193 kts indicated airspeed (1.1 times the never to exceed helicopter speed (Vne)) (), angle of bank up to 30°, climbs, normal descents, and autorotative descents. Although the snorkel had been flight tested up to 30° degrees angle of bank, there was no limitation in the FAA approved rotorcraft flight manual (RFM) (Attachment 6) supplement to restrict operation with the tank and snorkel system to a maximum angle of bank of 30°. The FAA ACO was asked "why didn't flight test either test an angle of bank greater than 30° or establish a 30°-degree angle of bank limitation?" The following response was received:

Flight testing was accomplished up to 30°. [at or above] AOB in both directions....as can be found in the company flight test report BHJ-213-107, Rev A. There was not a AOB limitation created by the applicant as part of the STC.

Without an angle of bank limitation specified in the RFM supplement, normal operation of the tank-snorkel system beyond 30° angle of bank would be permitted, which would exceed the maximum angle of bank that had been demonstrated during flight test.

Functional Hazard Assessment and System Safety Assessment (FHA/SSA) (Attachment 5) was submitted to document the most likely failure conditions and mitigations for the water tank and snorkel system. The functional hazard assessment identified 13 discrete failure/hazard conditions and their effect on the rotorcraft or crew. All 13 were verified using the qualitative⁸ analysis method. Three were classified as "no safety effect", seven were classified as "minor failure condition", and two were classified as "major failure condition." The two that were classified as "major failure condition" were: (1) water tank attachments become unsecure in flight, and (2) snorkel pump becomes snagged on ground obstacle or object. It is notable that the failure condition of the snorkel hitting or getting entangled in aircraft structure (other than tail or main rotor) was classified as a minor failure condition.

⁸ Qualitative - Those analytical processes that assess system and aircraft safety in an objective non-numerical manner. Qualitative assessment is based on engineering judgement.

Additionally, the possibility of the snorkel contacting any portion of the rotor system was not addressed in the hazard analysis or system safety assessment. The FAA ACO was asked "why the FHA/SSA doesn't address snorkel contact with the rotor system?" The following response was received:

The FHA/SSA did not include snorkel contact to the rotor system due to required compliance to 29.251 - vibration, using flight testing. Flight test data showed that under normal operating parameters the snorkel structure would not create excessive vibrations to lead to the failure mode of the snorkel contacting the rotor system. This result satisfied 29.1309. 'The equipment, system, and installations whose function is required by this subchapter must be designed and installed to ensure that they performed their intended functions under any foreseeable operating condition.'

A key part of the SSA is the assessment methodology. Section 5.1 of the SSA describes the methodology as follows:

The safety assessment process begins with the FHA and ends with the verification that the design meets the safety requirements and regulatory standards. The safety assessment process can be either qualitative, quantitative, or both.

- Qualitative - Those analytical processes that assess system and aircraft safety in an objective non-numerical manner. Qualitative assessment is based on engineering judgement.
- Quantitative - Those analytical processes that apply mathematical methods to assess the system and aircraft safety.

From the flow chart (AC 29-2C)⁹ it was determined that a qualitative analysis would be appropriate because the failure conditions identified in the FHA were not hazardous or catastrophic, the dominant failure condition was Major, with the majority of failure conditions either minor or having no safety effect. The water tank system and snorkel are not complex, and the system and installation is similar to a previous design.

Additionally, the FHA Depth of Analysis flow chart (AC 29-2C) states that "Catastrophic and Hazardous/Severe-major failure conditions will likely require both qualitative and quantitative analysis, depending on the system complexity."

G. LIST OF ATTACHMENTS

Attachment 1: Project Specific Certification Plan (PSCP)

Attachment 2: Structural Analysis of the Water Tank (Nozzle Support)

Attachment 3: Flight Test Report - Snorkel Stability Testing

⁹ Advisory Circular 29-2C, Certification of Transport Category Rotorcraft, Figure AC 29.1309-5

Attachment 4: Functional Hazard Assessment & System Safety Assessment
Attachment 5: Denver ACO-NTSB Meeting Summary
Attachment 6: Interview Summaries
Attachment 7: FAA-NTSB Correspondence
Attachment 8: BME Fire Tank Examination Report
Attachment 9: Hose Test Report

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