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

September 13, 2019

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT

NTSB No: ERA17MA316

A. ACCIDENT

Operator: Duke University Health System

Aircraft: N146DU / Eurocopter Deutschland GMBH MBB-BK-117-C2

Location: Herford, NC

Date: September 8, 2017

Time: 1120 EDT

B. GROUP

Group Chairman:	Van S. McKenny IV National Transportation Safety Board Washington, DC
Member:	Nancy McAtee National Transportation Safety Board Washington, DC
Member:	Seth Buttner Airbus Helicopters Grand Prairie, TX
Member:	Chris Meinhardt Air Methods Corp Englewood, CO
Member:	Bryan Larimore Safran Helicopter Engines Grand Prairie, TX

LIST OF ACRONYMS

cw	clockwise
ccw	counterclockwise
FAA	Federal Aviation Administration
FCU	Fuel Control Unit
FOD	Foreign object damage
JNX	Johnston Regional Airport
N1	Gas generator turbine speed (% rpm)
N2	Power turbine speed (% rpm)
PN	Part number
SEMA	Smart Electro-Mechanic Actuator
SN	Serial number

C. SUMMARY

On September 8, 2017, about 1120 eastern daylight time, a Eurocopter Deutschland GMBH MBB BK117-C2 helicopter, N146DU, was destroyed when it crashed on a wind turbine farm in Hertford, North Carolina. The commercial pilot, two flight nurses, and one patient were fatally injured. Day visual meteorological conditions prevailed at the time, and a company flight plan was filed for flight that departed the Sentara Albemarle Regional Medical Center Heliport (NC98) about 1108. The flight was destined for the Duke University North Heliport (NC92). The helicopter was operated by Air Methods Corporation under the provisions of 14 *Code of Federal Regulations* Part 135.

According to the operator the helicopter, pilot and both medical crew were based at the Johnston Regional Airport (JNX), Smithfield, North Carolina. At 1108, the pilot radioed the company operations center and advised that that they were departing Albemarle Regional Medical Center (NC98) for Duke University North Heliport (NC92) with 2 hours of fuel and four people on board. There were no further communications with the helicopter. Tracking data transmitted by the helicopter showed that it departed and headed on a westerly course at 2,500 ft mean sea level (msl). About 8 minutes later the track turns southerly and descents to 1,200 ft msl. The wreckage was located in the vicinity of the final track data point. Witnesses reported seeing smoke trailing from the helicopter prior to ground impact.

On-scene examination was conducted on September 9th, where the wreckage was documented. All helicopter airframe and engine components were accounted for, cockpit avionics were separated out of the wreckage and collected, and the engine-transmission remained attached to the engine deck and was separated by the recovery crew from the wreckage as one unit. The wreckage was removed and transported to Atlanta Air Salvage, Griffin, GA, for the wreckage examination layout. Wreckage examination and documentation continued through September 12-13 at Atlanta Air Salvage.

D. DETAILS OF THE INVESTIGATION

On September 9, 2017, the Airworthiness Group was formed consisting of representatives from Airbus, Safran Helicopter Engines, Air Methods Corp, and FAA. Field documentation of the wreckage was conducted on-scene. The wreckage was transported to Atlanta Air Salvage, and a full wreckage examination was conducted on September 12-13, 2017.

An examination of the helicopter's main gearbox transmission, rotor head, and freewheel units was conducted on November 13, 2017, at the Airbus Helicopter facility in Grand Prairie, TX.

E. FACTUAL INFORMATION

1.0 HELICOPTER INFORMATION

1.1 HELICOPTER DESCRIPTION[1]

The BK 117 C-2 is a multi-purpose helicopter, utilizing a four-bladed hingeless main rotor system with fiber-reinforced composite blades, and a semi-rigid, two-bladed tail rotor.

The pilot's seat is on the right hand side. The primary structure consists mainly of sheet metal and composite material. The helicopter is accessible through six doors: two hinged doors for the crew/front occupant, two sliding doors for the rear passengers, and two aft clam shell doors for the rear compartment. The tail boom can be separated from the fuselage, and consists of the horizontal stabilizer, vertical stabilizer, vertical fin, intermediate gearbox, tail rotor gearbox, tail rotor and fairing. The non–retractable type landing gear consists of two cross tubes, two skids and two boarding/maintenance steps. The pilot control inputs, applied through the cyclic stick and the collective lever, are transmitted to three ball bearing control cables (flexballs). These flexballs are leading to the nose section and then up to the hydraulic boost unit on the overhead structure. These three ball bearing control cables are controlling the input control levers of the hydraulic boost unit. There, the control signals become force amplified. The amplified signals, which leave the boost unit at the output boost pistons, are transmitted via control rods to the mixing lever assembly. They are combined in to a input that tilts the swash plate in the desired direction (cyclic stick input), or moves the sliding sleeve up or down, which creates the desired simultaneous variation of the angle of incidence on all four rotor blades (collective lever input). The collective lever is equipped with several switches and buttons and with twist grips for manual engine control.

[1] Helicopter description extracted form the BK-117 C-2 Flight Manual

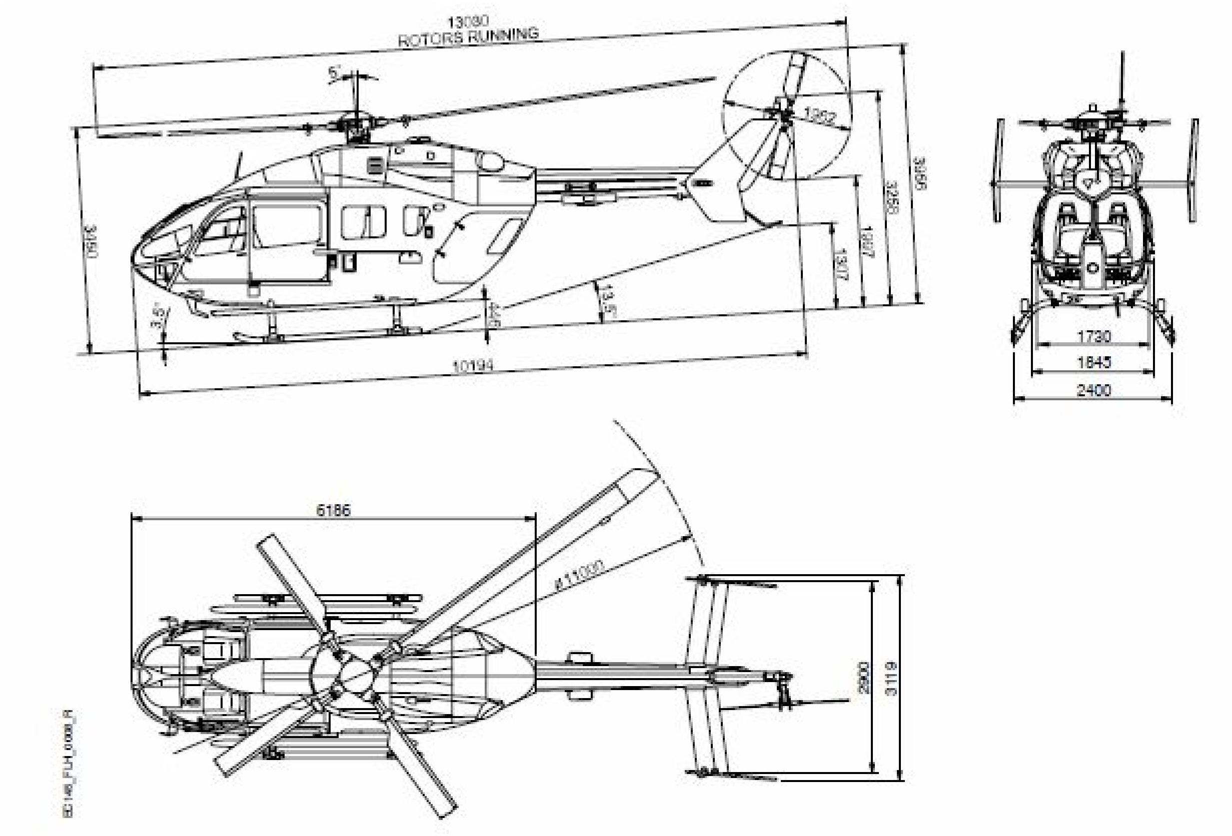

Figure 1 - BK-117-C2 3-view drawing.

The helicopter is powered by two Turbomeca Arriel 1E2 turboshaft engines of the free turbine type. Engine power is transmitted to the main transmission via independent drive systems. Each engine is equipped with a fully-separated fuel system, a tandem hydraulic system, dual electrical systems and a redundant lubrication system for the main transmission.

The engines are located in separate fireproof compartments aft of the main transmission and above the passenger/cargo compartment. The engines are turbo shafts, with single-stage axial and centrifugal compressors, annular combustors, a two-stage gas producer and a single-stage free power turbine. The engines are equipped with an independently operating engine ignition system. The starting and ignition system is activated by the respective START switch (ENG1/ENG2) on the main switch panel. Each engine gets controlled via the twist grip setting on the collective lever. The twist grips, which are adjustable through the OFF, IDLE and FLIGHT positions and EMER range, operate independently of each other. The twist grip for the number 1 engine had longitudinal grooves along the grip and was positioned forward of the number 2 engine twist grip, which had gnarled/checker pattern on the grip. The different twist grips were intended to aid the pilot in identifying each engine control by tactile feel.

Fuel flow is regulated and maintained within limits established by the parameters of the gas producer turbine speed, the power turbine speed, the compressor pressure, the position of the twist grips and the collective pitch. To stabilize the power turbine speed N2 the N2 governor is connected with the collective pitch through a mechanical linkage. This prevents N2 rpm droop and enables the increased power requirements of the helicopter to be met. Installed in the mechanical linkage are two electrical actuators which are driven by signals from a control unit so that the appropriate rotor rpm is set within the variable rotor rpm range and simultaneously, the torque of both engines is matched.

1.2 HELICOPTER HISTORY

The accident helicopter, serial number (S/N) 9474, was manufactured in December 2011. The medical gurney and other related medical equipment was installed in April 2012. The helicopter had accumulated an aircraft total time (ACTT) of 2,714 hours at the time of the accident. According to the helicopter maintenance records, both engines, engine #1 S/N 47292, and engine #2 S/N 47346, were the originally installed engines at the time of manufacture, and had accumulated 2,714 hours each. The most recent inspection was the 300-hour completed on September 3, 2017, at ACTT 2,710+23 hours.[2]

2.0 WRECKAGE DOCUMENTATION

The wreckage was located 12 miles west of Elizabeth City, NC, in a field of 8-foot-tall switch grass, and populated with approximately 300 foot tall electric power wind farm towers. The area immediately around the wreckage had been maintained by mowed grass along a 7-foot-wide and 2.5 foot deep drainage ditch which was oriented along a 310º - 130º magnetic bearing. The helicopter was positioned directly over the drainage ditch oriented from tail to nose on a 261º magnetic bearing. The helicopter had been involved in a postcrash fire that consumed the majority of the cockpit, cabin, engine & transmission bays, and fuselage. The tail boom aft of the rear portion of the main fuselage remained oriented with the centerline of the helicopter and had experienced less thermal damage. The rotor blades radiated from the center of the wreckage and the green blade laid in 8 foot tall switch grass that was undisturbed on either side of it.

The cockpit and cabin were completely consumed by a postcrash fire. The upper fuselage had collapsed in to the cabin area. The tail boom was in line with the fuselage and exhibited thermal damage at the interface at the transition between the aft fuselage and tailboom, which appeared to effectively separate the tail boom from the postcrash fire. The surviving components of the landing skids were splayed outward and fragmented. Two fire bottles were heat damaged. Each bottle had two discharge ports. The squib on the right discharge port on each had been melted away, and remnants of each squib were near the bottles. The squibs on the left port of each bottle were still attached to their ports.

[2] Hours + minutes.

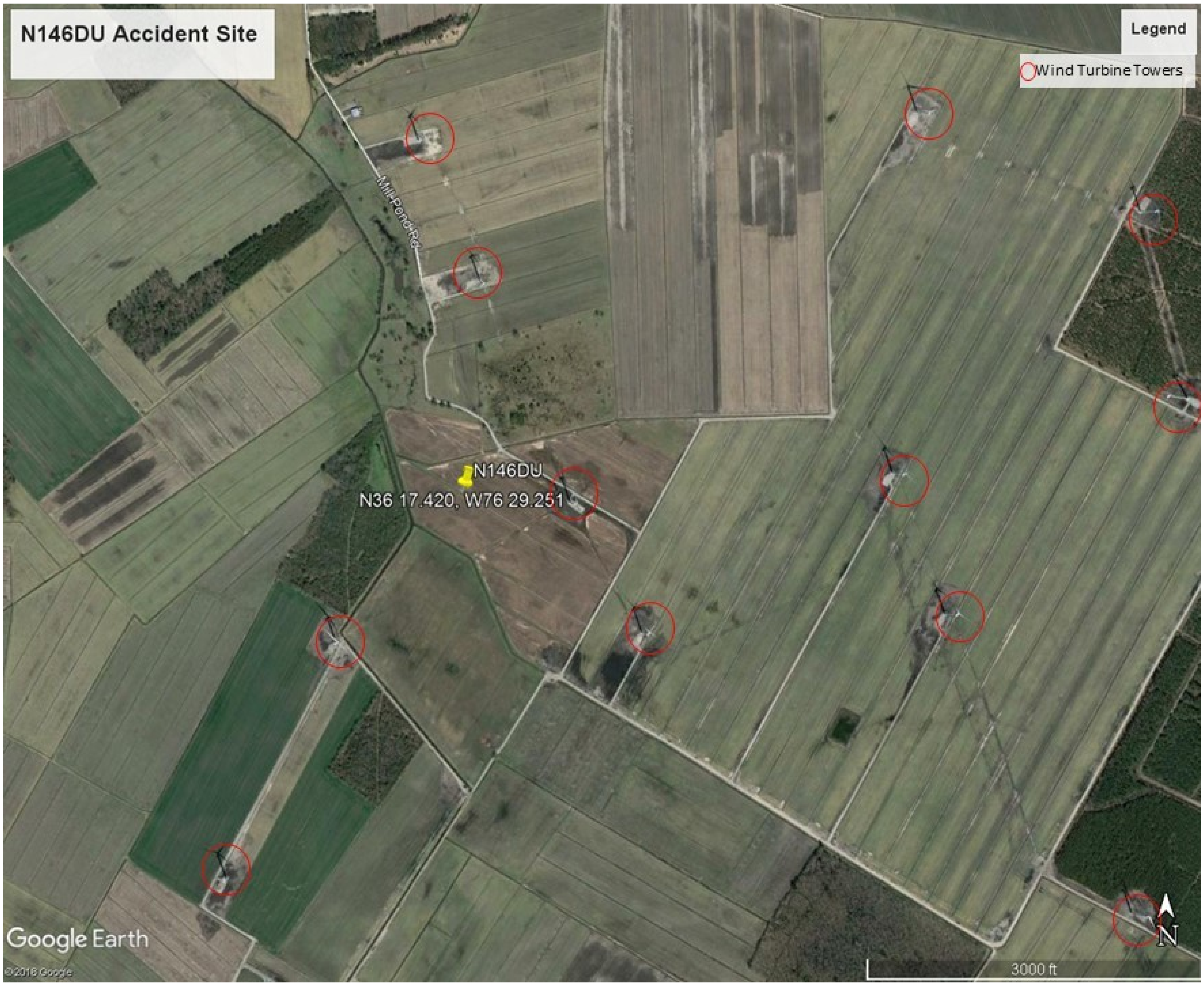

Figure 2 - Map of accident area.

Photo 1 - Main wreckage viewed from the front of the helicopter.

Photo 2 - Main wreckage viewed from the aft left quadrant.

Photo 3 - Wreckage overhead view.

Photo 4 - Terrain surrounding accident site.

2.1 Main Rotor System

2.1.1 Rotor Head

The rotor head remained attached to the transmission vertical shaft; it was discolored with black soot and exposed to extreme heat from the postcrash fire. The rotor head/main transmission could not be rotated by hand. All 4 blade grips and pitch varying housings were present. The blade grips and blades were arbitrarily numbered by investigative personnel from 1-4 in a counter clockwise direction[3]. The pitch links from the rotating swash plate to the pitch change arms from blades 1 (yellow), 2 (red), 3 (blue) were attached. The pitch link for blade 4 (green) was fractured mid length with the rod end remaining attached to the pitch change arm and appeared bent with shear lips consistent with overload. The opposing rod half was attached to the rotating swash plate. The collective pitch arm was fractured near the control rod end. The right longitudinal control lever was fractured at the control rod attaching end. The left short rod was present and attached to the stationary swash plate, with the opposite end retaining remnants of the longitudinal control lever and attach bolt. The right arm of the stationary swash plate was fractured 180º across the bore where the short rod attaches, and the right side short rod was not attached. The short control rod had separated from the lever and swash plate but was located in the wreckage with both attach bolts in place. The right side lever arm was not present, although remnants of the arm were contained around the through bolt. The left lever arm and forked lever assembly was in place. The drive scissors were in place between rotating swash plate and the rotor head.

2.1.2 Yellow Rotor Blade

The entire blade length was accounted for. Thermal damage was evident along the entire length of the blade. The trailing edge was destroyed by fire. The vibration absorber (weights) remained attached to the blade. Both primary and secondary blade attach pins were present, bolted, and cotter-keyed. The pitch link was attached to the rotating swash plate and pitch change arm. The leading edge was oriented in the direction of rotation (ccw) and no leading edge damage was visible. The spar had fiber bundles that were separated into "groups" from the blade grip to 4 feet outboard. About 4.5 feet of the blade tip including the trailing edge were present.

2.1.2 Red Rotor Blade

The entire blade length was accounted for. The inboard 4 feet of the spar and the trailing edge section was destroyed by fire. The vibration absorber remained attached to the blade. The leading edge faced the direction of rotation (ccw). No leading edge blade damage was visible. The primary and secondary blade attach pins were in place, bolted and cotter-keyed. The pitch link was attached between the swash plate and pitch change arm. About 4.5 feet of blade tip was undamaged with the trim tab attached. The trailing edge section of the remaining portion of the blade was destroyed by fire.

2.2.3 Blue Rotor Blade

The entire blade length was accounted for and remained attached to the rotor head via the blade grip. The primary and secondary blade attach pins were in place, bolted, and cotter-keyed. 5 feet of the inboard portion of the blade exhibited thermal damage and charring. The blade vibration

[3] Blade numbers in this report do not correspond with blade numbers referenced in the Airbus Maintenance Manuals.

absorber was present and attached to the blade. The pitch link remained attached to the rotating swash plate and blade pitch change arm. No significant leading edge blade damage was observed. The blade leading edge faced the direction of rotation (ccw).

2.2.4 Green Rotor Blade

The entire blade length was accounted for and the blade remained attached to the rotor head. The entire blade and pitch housing had rotated approximately 180 degrees with the blade leading edge facing opposite the direction of rotation (cw). The pitch change link had separated in the middle, with the rod end remaining attached to the pitch arm. The rod end threads were bent and the fracture surface exhibited shear lips consistent with overload. A leading edge blade ground witness mark was next to and parallel to the blade as it rested on the ground. No leading edge damage was evident, the erosion strips were attached and two trim tabs were present on the outer trailing edge. Thermal damage and charring was observed 6 feet from the blade root to outboard. Spar buckling was evident 4 feet from the blade root.

2.1.5 Tail Rotor

The tail rotor output drive shaft was attached to the main transmission gearbox. The flex coupling between the short shaft and the long shaft was connected. The flex coupling between the long shaft and the 42º gear box was separated with bent flex coupling plates and sheared bolts. The 42º gear box rotated freely by hand. The shaft between the 42º gear box and the 90º gear box was connected and the 90º gear box rotated freely by hand. The flexball cable was connected to the tail rotor actuator bell crank. The tail rotor SEMA (Smart Electro-Mechanic Actuator) control rod had sheared from the SEMA unit in bending. The tail rotor head was undamaged, both of the pitch links were present and attached. Tail rotor blades were attached to the rotor head. Both rotor blades exhibited no leading edge damage. One blade had been bent aft and the trailing edge was split. Oil was drained from the tail rotor gearbox, and the magnetic chip detector drain plug was clean of debris.

2.2 Transmission

The main transmission gear box was manufactured by Kawasaki, PN: B632K1001-051, SN: KA-1068. The transmission had been exposed to extreme heat, deforming and distorting attached hardware, and discoloring the entire exterior. All four transmission mounts were present with upper and lower attach points and bolts installed. The forward left, rear left, and forward right upper and lower airframe mount arms were fractured/separated and heat damaged. The right rear airframe mount was intact with the upper arm buckled and heat damaged; the attach bolts were in place. The two forward horizontal braces were attached to the engine deck. Both numbers 1 and 2 engine drive shafts were attached. The right side lateral mount was connected to the engine deck. The transmission was seized and not movable by hand. The rotor brake disk was attached to the transmission and showed no unusual wear. The rotor brake hardware was fire damaged, the brake pads had detached from the mount, and were located below the disk and showed moderate brake pad wear. The oil filler cap was in place. Both engine drive shafts were connected to the freewheel unit housing with intact Bendix coupling flanges.

2.3 Flight Controls

The collective control end was attached to the flexball cable bell crank. The flexball cable was traced to the end. The No. 1 twist grip throttle had extreme heat damage to the head end of the twist grip making the position marking unreadable. The No. 2 twist grip throttle position was in the F (fly) position. Set screws on each twist grip were not aligned, and the circumferential distance between the two set screws was 40mm. Measurements made from the twistgrip set screw established that the No. 1 throttle position was OFF. The cyclic stick was attached to floor deck structure. The push-pull tubes connecting the cyclic to the forward flight control converter was destroyed. The 2 flexball cables from the flight control converter were traced aft to their cable ends. The flight control hydraulic pack had extreme thermal damage; control rod ends to the three actuators were attached to the actuator cylinders. Fragments of the antitorque pedals were identified in the wreckage. The flexball cable was traced from the pedal area to the tail rotor control/servo assembly.

2.4 Engines

A detailed Maintenance Records and Powerplant Factual Report is contained in the official docket of this investigation.

2.4.1 Engine No. 1

The number 1 engine (left engine) was a Safran Helicopter Engines, Arriel 1E2, SN: 47292, and was contained in the engine bay, connected to the transmission via the input shaft. No evidence of torsional damage or rotational scoring was observed on the input shaft. The entire engine exhibited extreme thermal damage with most aluminum engine accessories partially damaged or consumed. Heavy thermal damage was evident on the upper portion of the engine. The gas generator could not be turned by hand (module 3). The free turbine could be slightly rotated by hand (module 4). No apparent FOD damage to the axial compressor was evident. The flexball cables remained attached to both the anticipator and throttle, however the anticipator was broken away from the fuel control unit (FCU). The throttle position was in cutoff (0 degrees). Module 5 (reduction gearbox) was removed from the engine by investigators. No displacement of the input pinion slippage mark was observed. Module 5 could be turned by hand and good continuity through the gear train was observed. The free turbine could be turned by hand. The free turbine nozzle guide vane and rear bearing was removed. The rear bearing was heavily coked. The gas generator could be turned by hand from the starter input pinion. The gas generator was removed from module 1 (transmission shaft and accessory gearbox). The rear of the second stage turbine had no remarkable damage or marks. An optical borescope was used to examine the first stage turbine with nothing remarkable noted. No loose b-nuts were found on the engine. The engine magnetic drain plugs did not have a significant amount of debris collected on the magnetic probe. Fuel was drained from the fuel control and the fuel control removed from module 1. Gear train continuity through module 1 was verified. The rear bearing oil return line magnetic chip detector and oil screen were found to be clear of debris or metal particles. The number 1 engine fuel shut off valve was removed from the airframe for further examination.

2.4.2 Engine No. 2

The number 2 engine (right engine) was a Safran Helicopter Engines, Arriel 1E2, SN: 47346, and was contained within the engine bay, connected to the transmission via the transmission shaft. There was no evidence of torsional damage or rotational scoring to the transmission shaft. The entire engine exhibited extreme thermal damage with most aluminum engine accessories partially damaged or consumed. Heavy thermal damage was evident on the upper portion of the engine. The gas generator (module 3) could not be turned by hand. The free turbine could be moved about 0.5 inches by hand, with further movement being restricted. No apparent FOD damage was evident to the axial compressor. The flexball cables remained attached to both the anticipator and throttle, however the anticipator was broken away from the FCU. Throttle position was at 62-degrees. The reduction gearbox (module 5) was removed from the engine by investigators. No displacement of the input pinion slippage mark was observed. The reduction gearbox gear train could be turned by hand, good continuity throughout was observed. The free turbine nozzle guide vane and rear bearing were removed. Inspection of the rear bearing and bearing rollers were found to have been ground down flat even with the race. The turbine shaft of the gas generator had been riding on the cage and deformed the end of the turbine shaft. No anomalies were noted on the second stage turbine. The first stage high pressure turbine was optically borescoped with nothing remarkable noted. The fuel control was removed from module 1. Gear train continuity through module 1 was verified. No loose b-nuts were found on the engine. The engine magnetic drain plugs did not have any significant debris collected. The rear bearing strainer/chip detector housing was removed and disassembled (TU208). Black carbon like debris and particles were emptied on to clean paper and collected. Some of the particles reacted to a magnet that was placed near the debris. The number 2 engine fuel shut off valve was removed from the airframe for further examination.

Photo 5 - Engine 2 TU208 oil strainer and chip detector.

3. MAIN ROTOR AND GEARBOX EXAMINATION

The rotor head and main transmission gearbox were examined by the Airworthiness Group on November 13, 2017, at the Airbus facility in Grand Prairie, TX. The rotor head and transmission were removed from the shipping crate and placed on a transmission stand. The rotor head hub cap was removed.   The 3 remaining pitch links that were attached to the rotor head were disconnected from the blade grip by technicians. The pitch link for blade 4 (green) was thermally deformed and had separated at mid length from the blade grip at the rod end consistent with overload bending. The rod end attached to the swash plate also exhibited bending and thermal damage. The nuts were removed from the 12 main rotor head attach studs. All stud/nut combinations had washers. All the nuts had retained torque. The rotor head was lifted off the main rotor mast.

3.1 Rotor Head

All 4 blade mounting forks were in their respective rotor arm. The number 4 blade (green) was rotated 150º counterclockwise (ccw), as viewed from the rotor blade tip towards the rotor head. The blade mounting fork was wedged into the circular end of the rotor arm. The rotor head cover, o-ring, lower cover, nut plate, and nut were removed. The main bolt was removed. No evidence of oil leakage was observed on the exterior of the rotor hub. Oil was observed to drain out of the rotor head. No signs of moisture were observed in the oil. The tension-torsion (T-T) strap retaining pins were removed from all 4 rotor arms. The inner sleeve and blade mounting forks for blades 1,2, and 3 were removed. The T-T strap for each was in place. All T-T strap exterior plastic coatings exhibited some localized melting. The No. 4 blade mounting fork was moved out of its jammed position by using a mallet. The inner sleeve was removed. The T-T strap retained an 80º-90º ccw set twist (as viewed from the blade end looking towards the rotor hub). All blade grip sleeve bearings and rotor arm needle bearings were undamaged and coated with oil.

Photo 6 - Rotor head removed from rotor mast for examination[4].

[4] Image has been digitally modified to remove incorrect rotor head arm identification.

Photo 7 - Main rotor inner sleeve assemblies & T-T straps.

3.2 Main Transmission Gearbox

The left hydraulic pump and cooling fan/blower housing had been destroyed by post-crash fire, the inner hydraulic pump components were present near the hydraulic pump mounting pad. The right side hydraulic pump and cooling fan/blower were attached to the transmission at the mounting pad. The right engine (No. 2 engine) drive input pinion, input quill, and freewheel unit was removed. The freewheel unit could be turned by hand in the opposite direction to power application. The freewheel unit could not be turned by hand in the direction of power application. All teeth on pinon and bevel gears were present with witness marks only on the face of the teeth that were in contact with each other at the time of impact. Black soot dust was on the input pinion bearing and gear teeth. The left engine (No. 1 engine) drive input pinion, input quill, and freewheel unit was removed. The freewheel unit could be turned by hand in the opposite direction to power application, the unit could not be turned by hand in the direction of power application. All teeth on pinon and bevel gear were present with witness marks only on the teeth that were in contact with each other at the time of impact. Black soot dust was on the input pinion bearing and gear teeth. After the power input pinion assemblies were removed, torque was applied to the main mast by using a 3-foot lever in an attempt to rotate the transmission gears, however, the transmission remained seized. The right and left transmission oil filters were removed. The filter elements were discolored but no foreign debris or metal particles were identified. No particles were identified on chip detectors. The tail rotor drive pinion and rotor brake disk were removed. The bevel and pinion gear teeth were undamaged. The lower bearing cover was removed. Black sludge had accumulated on the bottom of the cover. The sludge contained no particles that were sensitive to a magnet. The lower nut was removed. The collective, lateral, and longitudinal pitch arms were removed from the rotor mast. The rotor mast was pulled out of the transmission. No unusual wear was noted. All bearings that were visible were examined. The upper rotor mast bearing was removed from the transmission case. The bearing was seized, and the inner or outer race could not be moved by hand. The roller bearings were all present with no localized discoloration or mechanical damage, however approximately a 160º portion of the outer race appeared to be darker, consistent with exposure to heat. The roller bearings exhibited light rusty colored surface oxidation. Seventeen of the roller bearings in the transmission were visually inspected, and revealed no mechanical damage, no damaged rollers, races, or cages. The gear teeth examined on the left and right intermediate gears exhibited no mechanical damage, corrosion, or witness marks indicating abnormal gear to gear interfacing.

3.3 Left Freewheel Unit

The bevel gear was discolored black with a flat dull surface appearance. The input bevel gear rotated in freewheel direction when rotated ccw by hand from the drive flange. The drive locked the bevel gear when rotated in the cw direction. The interior lip seal was melted. No oil was observed in the casing or on the bearings. The sprag bearing was removed. No scoring or damaged observed on the outer race with a smooth surface. The sprag elements were all present and held in place by the cage. No indications of sprag cage deformation were observed. No scoring was observed on the sprag elements. The interior retaining spring was in place and appeared undamaged. All interior roller bearings and ball bearings were visually examined and were seized.

3.4 Right Freewheel Unit

The bevel gear was discolored black with a flat dull surface appearance. The input bevel gear rotated in freewheel direction when rotated ccw by hand from the drive flange. The flange could not be rotated in the cw direction. The interior lip seal was melted and fragmented. No oil observed in the casing or on the bearings. The sprag bearing was removed and no scoring or damaged observed on the outer race, outer race surface was smooth. Sprag elements were all present and held in place by the cage. No indications of sprag cage deformation were observed. No scoring was observed on the sprag elements. The interior retaining spring was in place and appeared undamaged. All interior roller bearings and ball bearings were visually examined, all (?) bearings were seized.

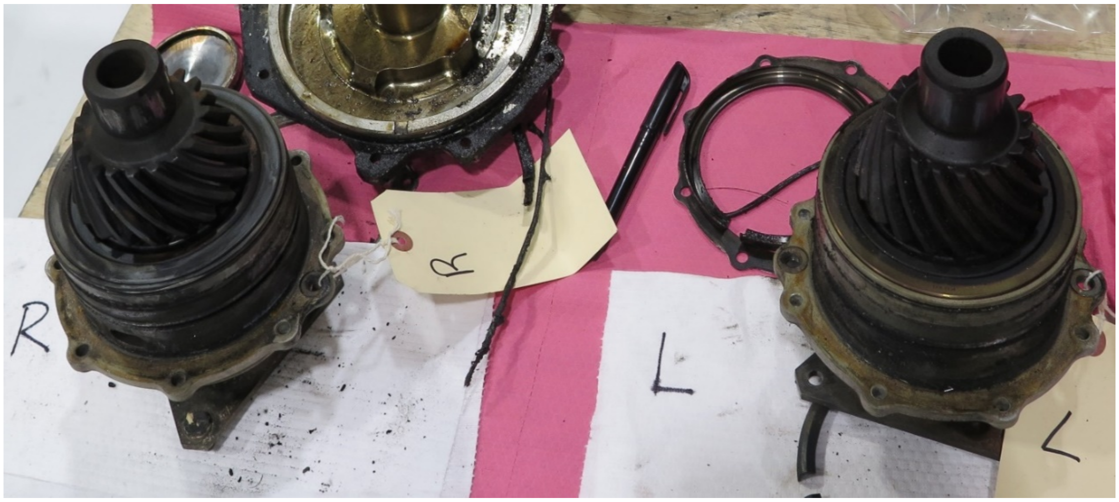

Photo 8 - Right & left freewheel units.

2 AIRFRAME FUEL SHUT-OFF VALVE EXAMINATION

There are two airframe fuel valves that are mounted in the left and right side of the airframe immediately beneath the engine deck. Each fuel valve services the engine on its side of the helicopter. The valves are electrically activated from the cockpit via the FIRE push button switch. The valves are ball type with a electronic solenoid actuator that remains in its last position when de-energized.

The fuel shutoff valves were submitted to the Materials Laboratory for examination as shown in Photo 9.

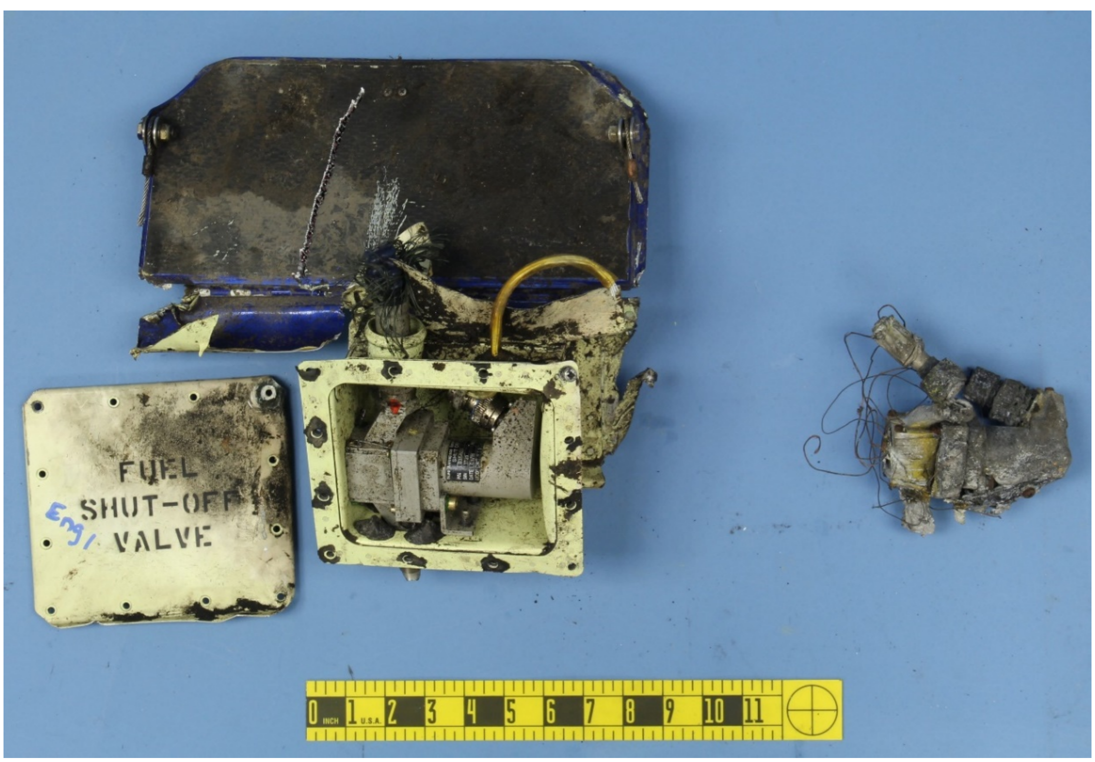

Photo 9 - Fuel Shutoff Valves

The intact fuel shutoff valve, labeled Fuel Shut-Off Valve #1, was removed from the surrounding structure. Fuel Shutoff Valve #2 exhibited melting and other fire related damage. Both valves were x-rayed to determine the valve position. Both valves were found to be in the same position as shown in the radiograph in Photo 10. Both valves appear to be in the OPEN position.

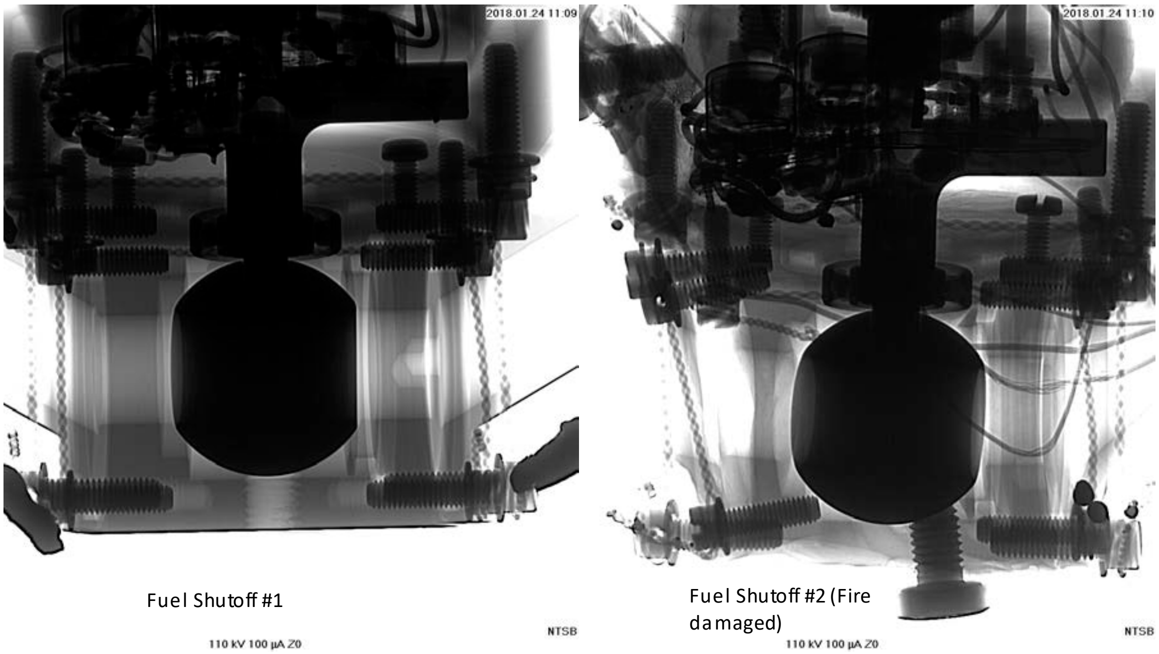

Photo 10 - Radiograph of Fuel Shutoff Valves.

3 FIRE SUPPRESSANT BOTTLES

The fire suppressant bottles from then engine fire suppression system were submitted to the Materials Laboratory for examination as shown in Photo 11.

Photo 11 - Fire Suppressant Bottles.

The inlet/overpressure valves (the same valve performed both functions) were examined using x-ray. The valves could not be fully visualized in the radiographs. A boroscope was sent through the valve openings on both bottles. On one bottle, the inlet valve was hollow all the way into the bottle indicating the internal components missing and likely destroyed by fire. The second bottle had an obstruction. It could not be determined if the obstruction was part of the valve or melted debris. Therefore, the overpressure valve condition for both bottles could not be determined.

The bottle outlet valves were removed from each bottle. There was considerable fire damage in the interior of the valves indicating that fire/heat got inside of the bottles and destroyed the burst disc or disc remnants (if the bottles discharged). Therefore, the condition of the outlet valves could not be determined.

4 INSTRUMENT PANEL #2 FIRE LIGHT EXAMINATION

A recovered portion of the warning unit was submitted to the Materials Laboratory for examination. The four light bulbs for the engine #2 fire indicator were x-rayed to examine the filament in each bulb. The radiographs for the FIRE annunciator bulbs showed that the filaments for all the light bulbs were stretched. The radiographs also showed that all but one of the bulb filaments were intact. The bulb 1 filament was broken and stretched while bulbs 2-4 filaments were intact and stretched. The bulb numbering is arbitrary because the bulb positioning could not be determined due to fire damage. Radiograph images of all four bulbs are contained in the official docket. No light bulbs were identified by radiograph in the BOT 1 & BOT 2 button located next to the FIRE light/button.

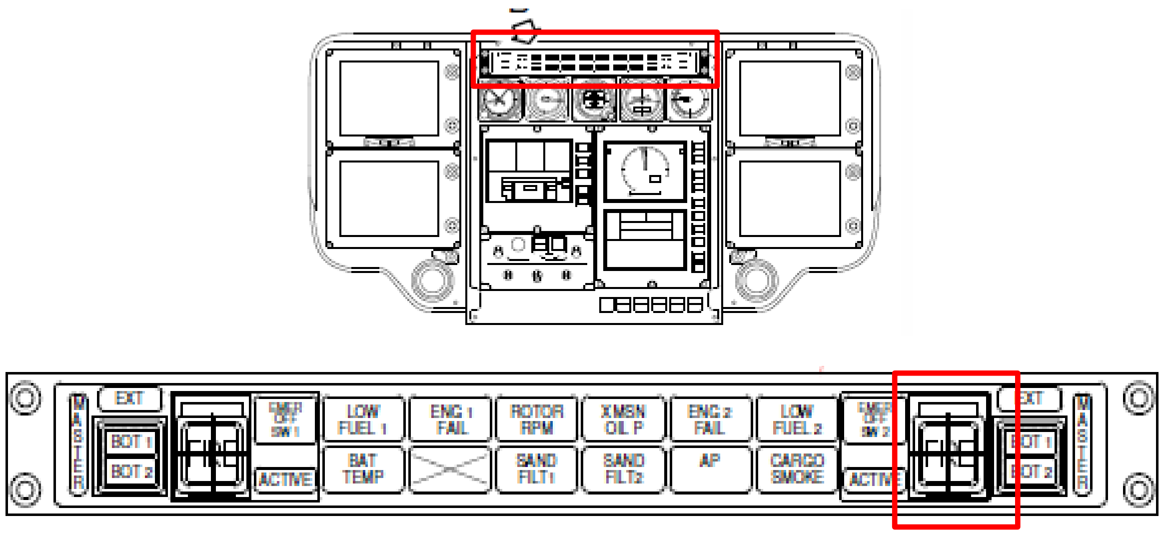

Figure 2 - Caution and Warning Unit[5]

The No. 1 FIRE light/button was not located during the wreckage examination, and therefore the light bulbs on that side were not available to be examined.

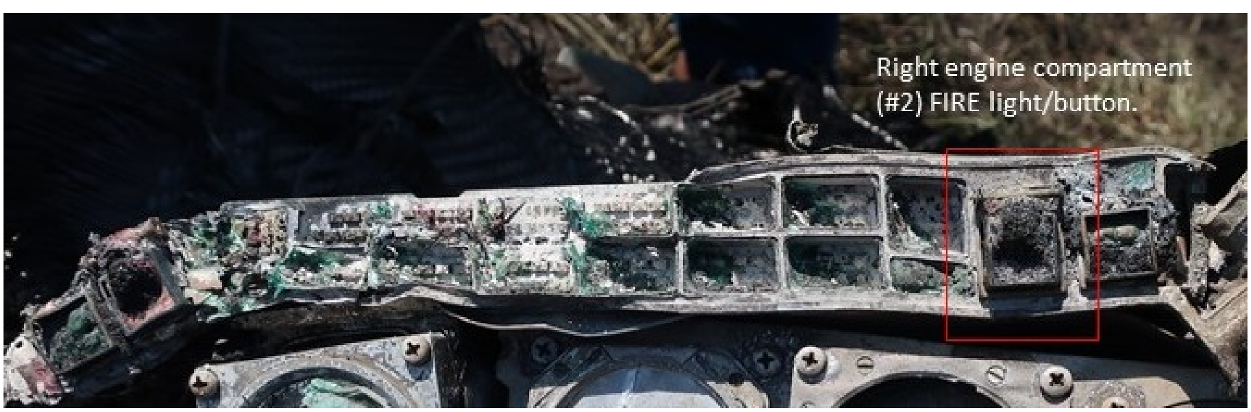

Photo 12- Cockpit warning panel, #2 fire light identified.

[5] Drawings extracted from Airbus Aircraft Maintenance Manual (AMM) MBB BK117-C2

Photo 13 - Fire light bulbs, 20x magnification.

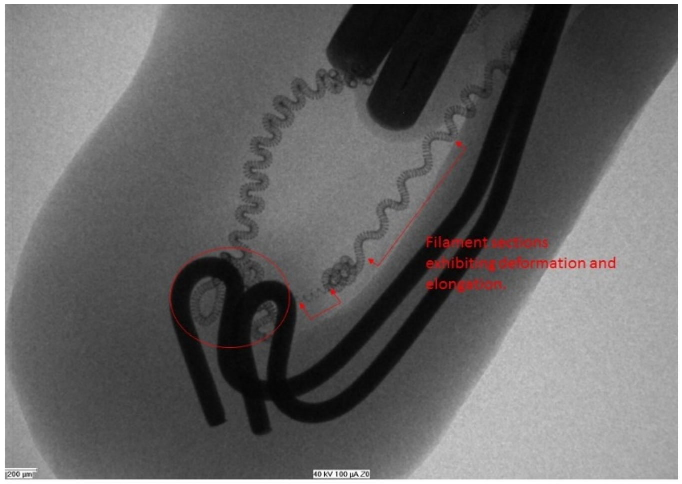

Photo 14 - Typical radiograph of stretched bulb filament.

The engines are equipped with independent fire warning systems. Each system consists of three fire detectors, one installed to the engine, the other two installed to the aft fire wall, the fire warning logic circuitry, located in the warning unit, and visual / audio warning. Electrical power is supplied by the essential bus, via the circuit breaker FIRE D.

The systems can be checked for continuity and lamp function by test switches in the overhead panel. The system is tested as part of the prestart checklist.[6] A single detector will trigger the system for the related engine compartment. The red FIRE light will be illuminated on the cockpit warning panel and an audio alarm bell is heard in the headsets. The FIRE light/button itself contains four light bulbs for redundancy purposes, all of which will illuminate in the event of a triggered fire detector.

Trigger temperatures: Engine Accessory Gear Box - 210ºC, and Rear Fire Wall - 315ºC.

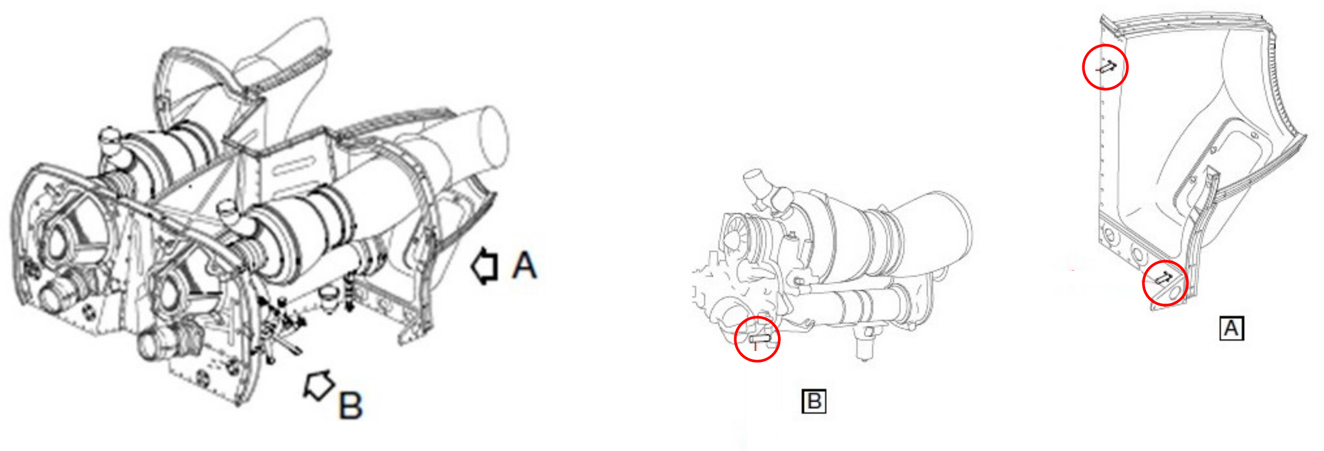

Figure 3 - Engine Compartment Fire Detector Locations[7]

[6] Flight Manual BK-117 C-2, Rev 15, page 4-13

[7] Drawings extracted from Airbus Aircraft Maintenance Manual (AMM) MBB BK117-C2

5 IMPACT LOADS

An impact load analysis was performed by Airbus based on the observation that 3 of the 4 main gear box vertical load struts were fractured. The structural failure pattern of these struts indicated that loads imparted were a result of a mostly vertical impact. The design standard for the transmission mount was the ability to sustain a downward vertical loading of 20g's.

Two scenarios were examined that would calculate the most extreme strut loading possibilities. The first was a perfectly horizontal impact that distributes the load equally between the 4 struts, which would require a 130g impact load to fail all 4 struts. The second was the helicopter was inclined so that only 1 strut must sustain the impact load, which would require a 32g impact to fail the strut. Based on these two values, two drop heights were calculated. For the helicopter to impact at such an angle to impart the load entirely into one strut, the drop height would be 80 meters. For the helicopter to impact completely horizontally it would impart the load into all four struts equally, the drop height would be 300 meters.

Van S. McKenny IV
Aerospace Engineer – Helicopters