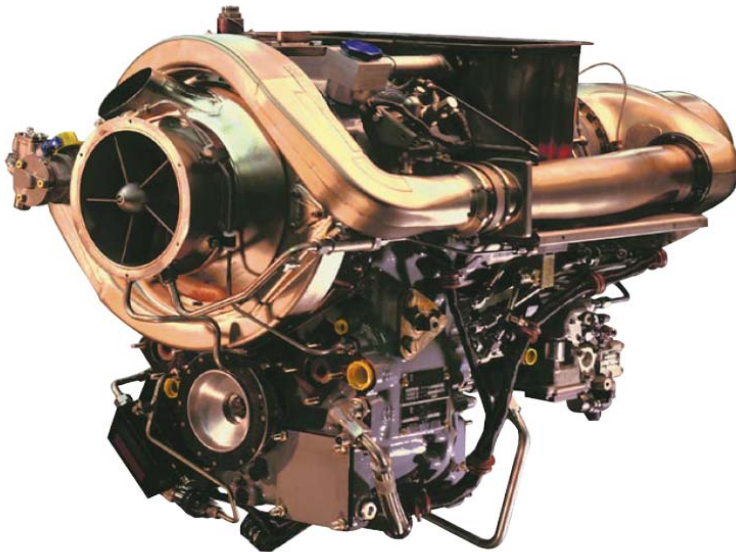




Rolls-Royce

Engine Investigation Report

**Rolls-Royce Corporation
Model 250-C47M
Engine CAE-847837**



**Nick Shepler
Air Safety Investigations**

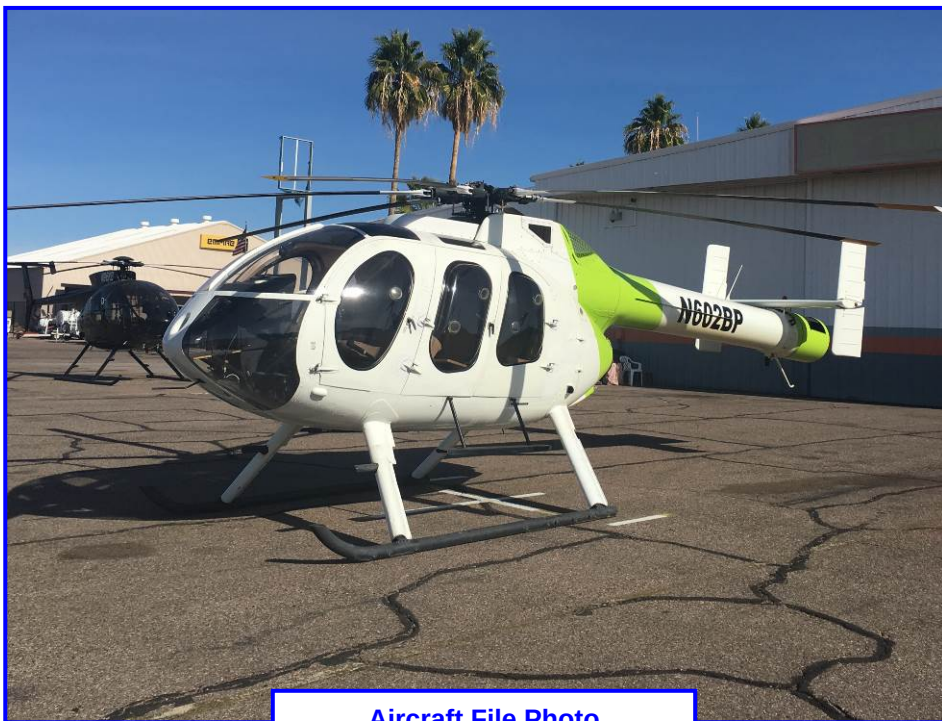
**High Line Helicopters, LLC
Smethport, Pennsylvania**

**Accident date: 8 April 2018
Wreckage exam date: 17-18 May 2018
Report date: 20 June 2018**

Background

On April 8, 2018, at approximately 5:11PM eastern daylight time, an MD Helicopter 600N, N602BP, operated by High Line Helicopters, LLC, was destroyed when it collided with a wooden power line support structure and terrain in Smethport, Pennsylvania.

The commercial pilot was seriously injured and two linemen were fatally injured. Visual meteorological conditions prevailed, and no flight plan was filed for the power line construction flight, which was conducted under the provisions of Title 14 Code of Federal Regulations Part 133.



Aircraft File Photo

The aircraft was recovered to Anglin Aircraft Recovery Services, LLC in Clayton, Delaware.

This report presents the observations made during the investigation.

Aircraft Information

Model	MD600N
Serial Number	RN025
Registration Number	N602BP
Airframe Total Time	5204.2 (as of 7 April 2018)
Hobbs	5201.9 (as of 7 April 2018)
Last Inspection (100 Hr)	4 February 2018

Engine Information

Engine Model	Rolls-Royce 250-C47M
Rating:	650 HP
Serial Number	CAE 847837
Engine Total Hours/Cycles	4475.5 Hours / 6076 Cycles (as of 7 April 2018)
Last Inspection (150 Hr)	4 February 2018

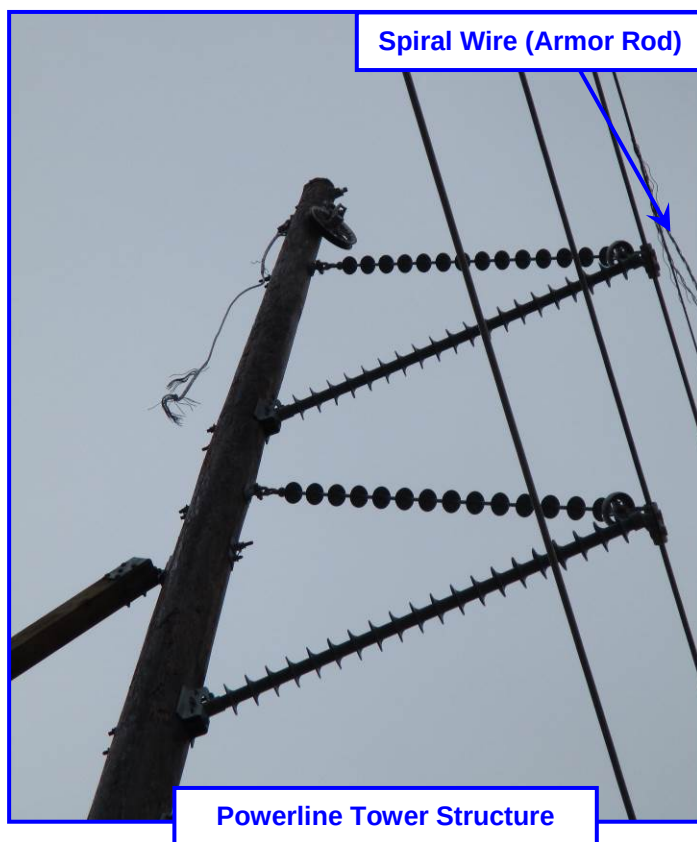
Accident Flight

The helicopter was engaged in hanging new power lines along a series of recently constructed high-tension power line towers. The power lines were newly installed in mountainous terrain and were oriented approximately east/west. They were supported by a series of structures of either wood (dual pole, H-frame) or steel (single pole) construction. A static line (non-current carrying wire) was affixed to the top of the structures above the power lines.

The purpose of the flight was to remove the static line from a wheeled, pulley device (dolly) that temporarily secured the static line and permanently attach the static line to the tower structure. One lineman completed the task from the skid of the hovering helicopter, while a second lineman passed tools and equipment back and forth from inside the helicopter.

The steps taken to complete the task included wrapping the line with a spiraled wire coating (armor rod), attaching a safety strap (safety) and ratcheting chain lifting device (hoist); each of which were attached to the top of the structure pole. Lastly a static line connecting device (shoe) was attached to the line. The line was then hoisted into position and bolted to the structure. The safety, hoist, and dolly were then removed from the structure and static line after which the helicopter repositioned to the next structure to repeat the task.

In an interview, the pilot reported that the entire crew met earlier in the day, and flew to a structure to assess the work and tools required to complete the assigned task. They landed, refueled, and departed on the accident flight. The crew completed one structure, and the pilot hovered the helicopter into position to complete the work on the next structure. The lineman attached the first half of the armor rod ahead of the dolly, and manipulated the line and dolly to complete the wrap.

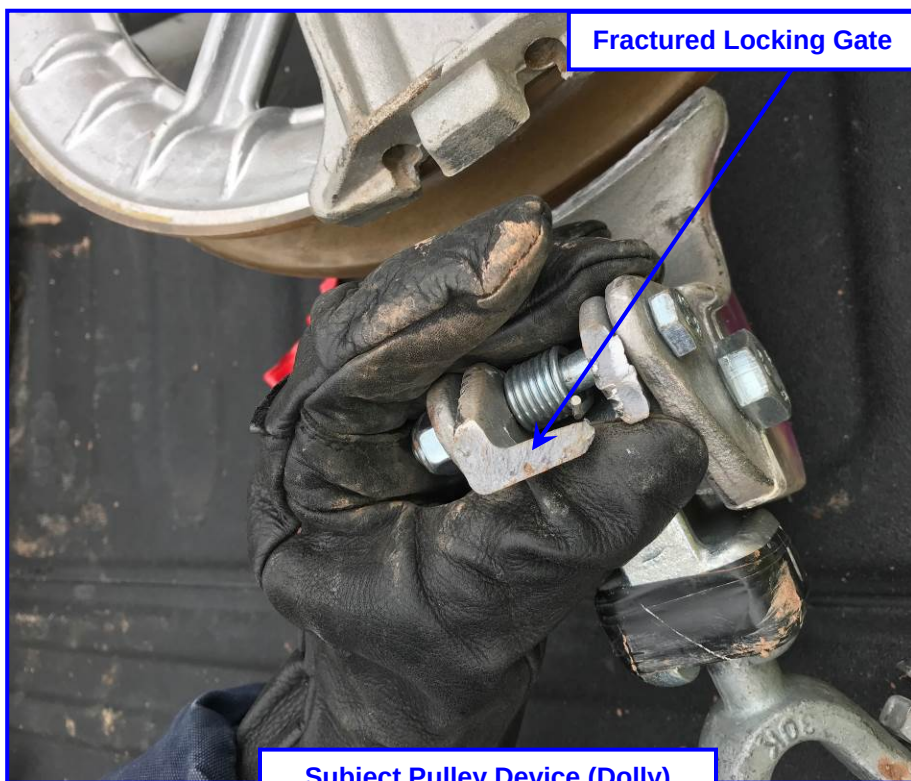


According to the pilot, the lineman opened the spring-loaded locking gate on the dolly above the static line to wrap the second half of the armor rod, which was "normal," and prior to the attachment of the safety. About that time, the pilot felt the helicopter was "pulled" toward the structure. The pilot stated that he made cyclic and pedal inputs to avoid the structure, but all he could remember was rolling over the structure.

When asked, the pilot said he neither felt nor heard anything unusual prior to the helicopter being pulled to the structure.

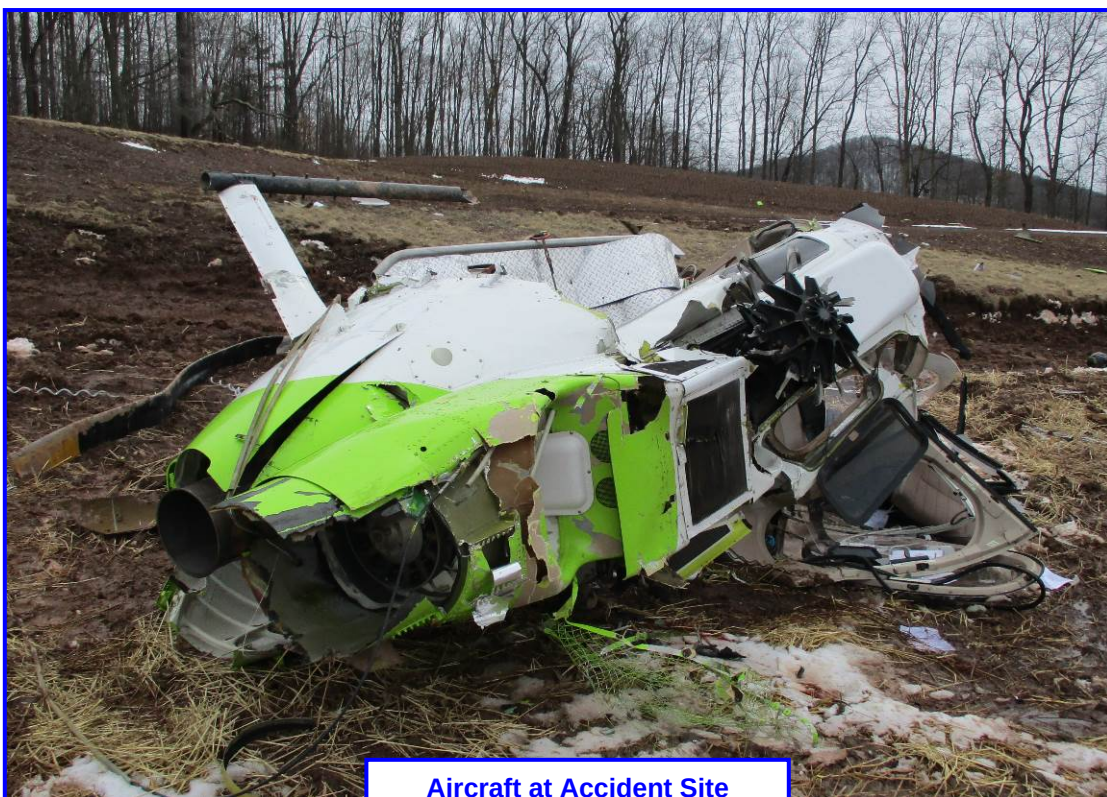
The safety strap was suspended from a cross-brace of the H-structure, and the hoist was found next to the fuselage; each appeared undamaged. Examination of the structure poles and the static line revealed signatures consistent with main rotor blade strikes. The dolly was in its swiveling mount and facing 180° from its operational position. Damage signatures to the pole above its mounting matched the dimensions of the dolly. The dolly was recovered from the top of the structure, and examination revealed it was intact except for the locking gate, which was fractured. The fracture surface displayed features consistent with overload. The dolly was retained for further examination at the NTSB Materials Laboratory.

The helicopter descended vertically between and adjacent to the two-pole structure. The tailboom and all six rotor blades separated from the helicopter during the descent. Portions of the structure required replacement due to damage incurred from the impact with the helicopter.



Fractured Locking Gate

Subject Pulley Device (Dolly)



Aircraft at Accident Site

Accident Site Examination

The helicopter was examined at the accident site about 1,600 ft elevation, and all major components were accounted for at the scene. The wreckage was contained largely at the bottom of the wooden H-structure that was struck, with the six rotor blades separated at the hub and scattered at various distances on the south side of the power lines. One rotor blade travelled approximately 300' down the hill (west) of the structure. The tailboom separated and was about 70' west of the structure. Striation marks consistent with wire contact were visible on top of the left skid forward of the front cross tube.

The airframe was resting on its right side. The forward lower fuselage and cockpit structure was extensively damaged. The cabin section lower fuselage was extensively crushed. The NOTAR tailboom was separated from the main fuselage aft of the attachment fitting. The composite tailboom was fragmented mid-span. The aft end of the tailboom contained the direct jet thruster, horizontal and vertical stabilizers. The horizontal and vertical stabilizers were impact damaged. The NOTAR fan shroud was crushed and deformed. There were multiple fractures of the flight controls.

Access to the right side of the helicopter and engine compartment was limited due to the positioning of the aircraft. Therefore, a complete visual assessment of the entire engine, particularly the right hand side, could not be achieved. Based on what was visible of the engine it appeared to be properly secured within the engine bay with no immediate evidence of external damage. The NTSB stated that the engine was still running when the first responders arrived on scene nearly 20 minutes after the accident occurrence.



Engine Condition at Accident Site

ECU (Engine Control Unit):

The ECU (S/N: JG7ALW0048) was undamaged and removed from the wreckage at the authorization of the NTSB.

It was connected to a Rolls-Royce computer for downloading and examination of the ECU's memory. Data download was completed and a cursory review showed primary exceedance messages for Torque, followed almost immediately by Np (power turbine) & Nr (main rotor) speed exceedances. The control system responded by initiating Overspeed Activation sensing the overspeed of Np. The torque spike tracks along with a rapid rise in collective pitch.

Immediately following, the data shows a steep drop off in torque presumably from the loss of drive shaft connection between the engine and main rotor transmission resulting from the main rotor blades impacting static structure (power lines and/or utility stanchions).



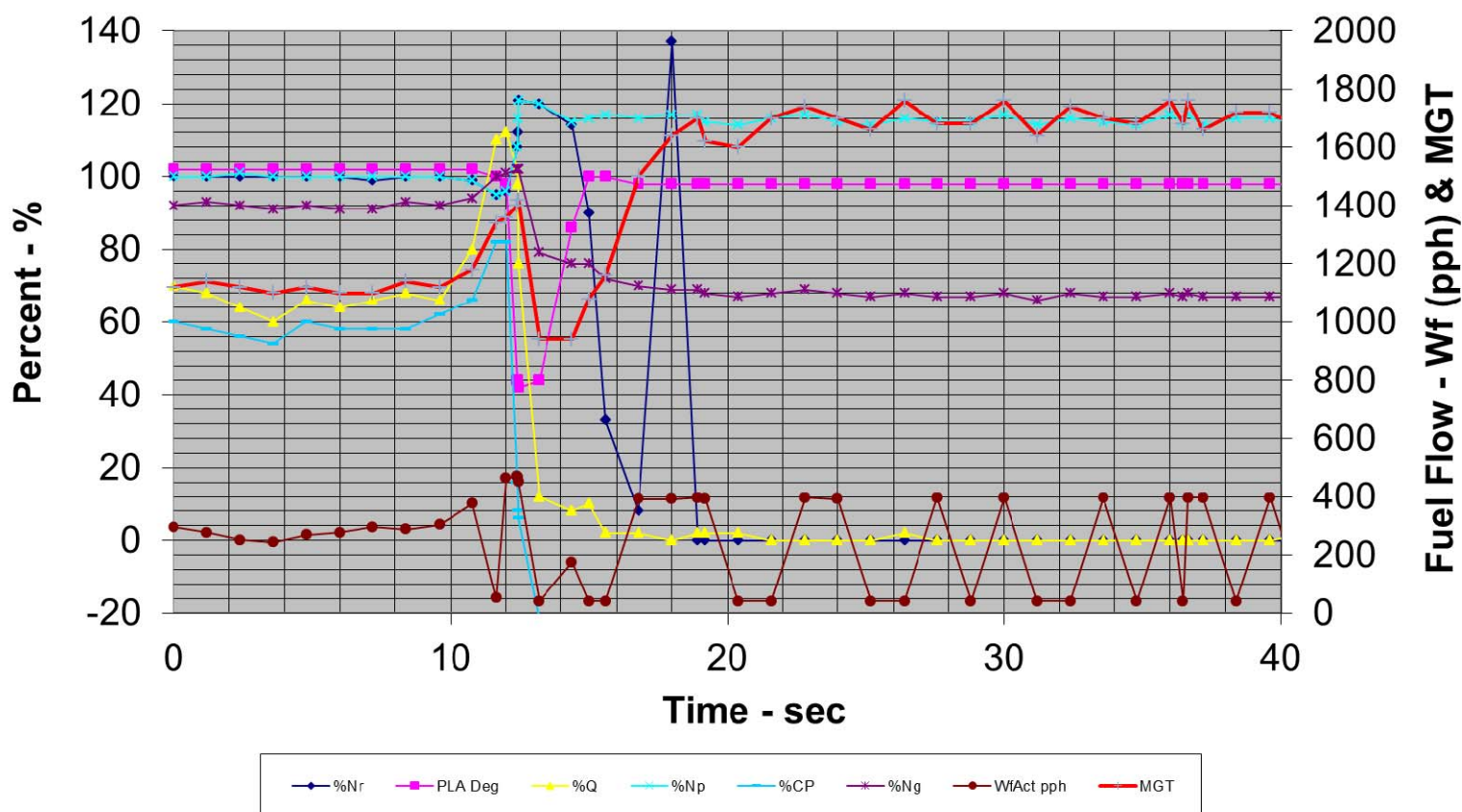
The ECU data also showed drastic changes in throttle (PLA – power lever angle) position and at the same time a change in ECU control mode from Auto to Manual. The MD600N has an ECU AUTO/MANUAL switch on the collective pitch control. Although not confirmed, it's possible that the pilot's reactions to the helicopter's violent behavior were reactionary at that moment. This may also explain the abrupt drop in collective pitch at the same time the control mode was switched and the torque bottoming out.

Following impact with the ground the engine continued to run at a slightly higher than idle speed throughout the remainder of the incident data capture and beyond. The Np overspeed activation system controlled the engine during this period as indicated by the repeated spikes in fuel flow and MGT. This is also consistent with the 1st responders stating that the engine was still running nearly 20 minutes prior to their arrival at the accident site. It is unclear as to how the engine was eventually shut down since the fuel cutoff control was still in the engaged (ON) position during the on-site examination.

The ECU exceedances triggered the Incident Recorder (IR) function of the ECU, which captured at least 10 "snapshot" lines of data as well as an additional 150 IR lines of data.

NOTE: Snapshot data is recorded each time a given parameter is exceeded; IR data records 10 lines of data prior to an exceedance and continues recording data for at least 48 seconds following the last exceedance. In this event, the IR recorded data for the entire event and stopped recording only after the ECU hit its max 3 minute recording capability. Data is recorded at a rate of 1 line every 1.2 seconds.

N602BP Incident Data



Incident Recorder Data Plot

%Nr = Main Rotor Speed

%Np = Power Turbine Speed

WfAct pph = Fuel Flow (lb/hr)

PLA = Power Lever Angle

%CP = Collective Pitch

MGT = Measured Gas Temp (°F)

%Q = Torque

%Ng = Gas Generator Turbine Speed

The ECU data indicated the engine was performing normally prior to the accident sequence. All relevant engine parameters (torque, Ng/Np speeds, fuel flow, and temperature) were normal prior to the sequence and responded as expected during the accident sequence.

Examination of the engine at the accident site revealed no immediate evidence of pre-impact fire, damage, or malfunction. The ECU data suggests the engine was producing sufficient power and responding to throttle inputs.

Wreckage Recovery Examination

On 17-18 May 2018, the aircraft was presented for examination at Anglin Aircraft Recovery Services, LLC in Clayton, Delaware. The examination was attended by Rolls-Royce, MD Helicopters, Boeing, Highline Helicopters, NTSB and FAA representatives.

The helicopter was positioned on its right side in the same manner as the accident site. Therefore, only limited access to the engine was available. The engine remained within the engine compartment and the engine mounts showed no immediate signs of damage. Initial inspection of the engine exterior did not reveal any obvious signs of damage from impact forces, internal engine failure, or evidence of fire. All accessible B-nuts were found to be at least hand tight and were orange torque stripe painted.

Examination of the compressor inlet revealed the impeller blades to be normal with no evidence of foreign object (FOD) type damage.

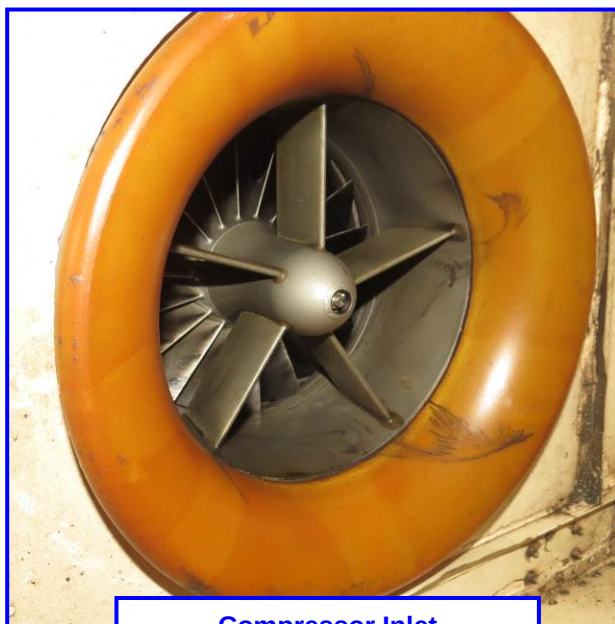
The exhaust duct was not removed but a borescope was inserted inside the exhaust collector support to view the 4th-stage turbine blades and surrounding areas. The 4th-stage blades appeared undamaged as did the surrounding turbine sections and exhaust plenum.

The engine to main rotor transmission drive shafting was fractured at both KAflex® coupling ends. Continuity of the N2 drive system could not be achieved by hand turning the output drive forward of the freewheeling unit. A pry bar inserted into the fractured KAflex® straps was used to apply considerable force. Drive continuity was thereby confirmed back to the 4th-stage power turbine wheel.

N1 rotor continuity was confirmed from the compressor impeller to the starter-generator cooling fan. Rotation was smooth and continuous.



As-Recovered Condition of Helicopter

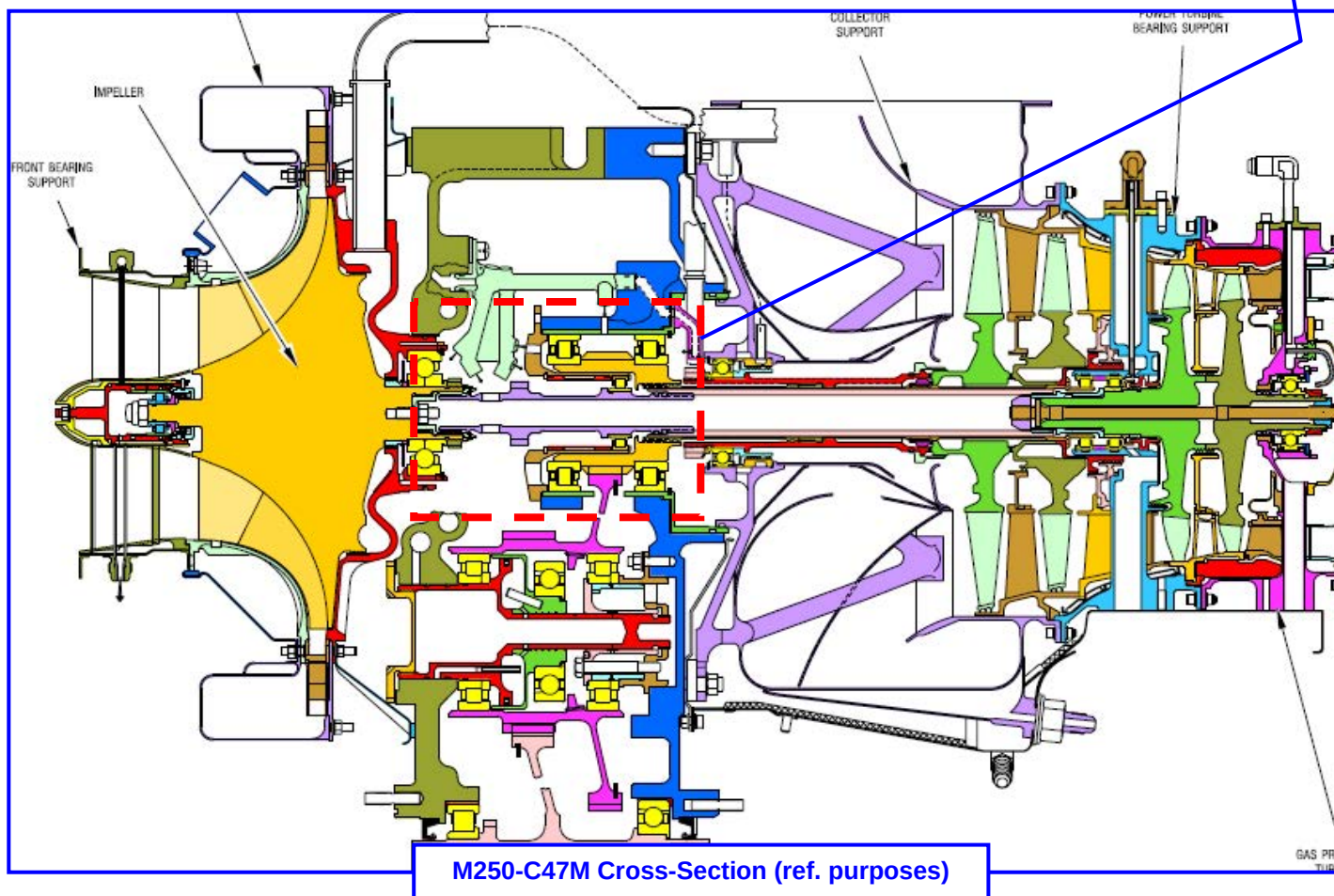
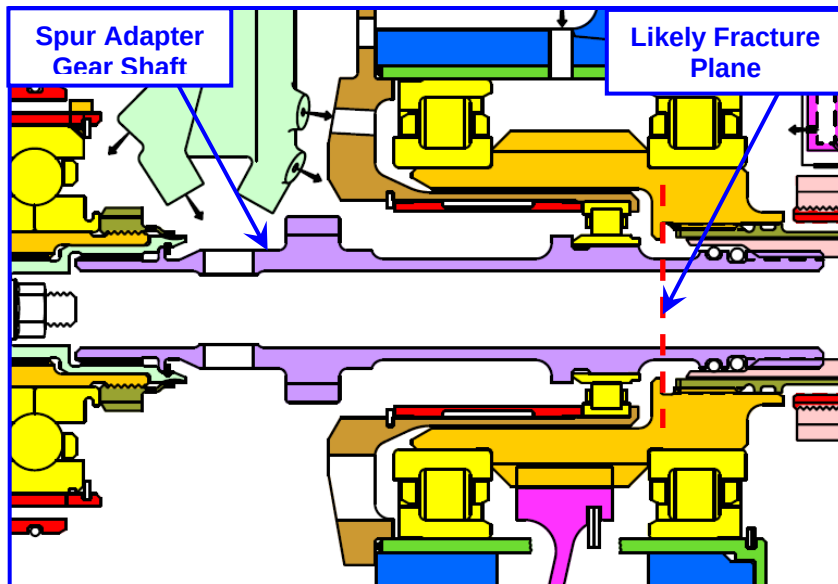


Compressor Inlet

However, while inspecting the 1st-stage gas producer turbine nozzle and 1st-stage wheel using a borescope, it was noted that the gas producer turbine was not rotating when checking N1 continuity. Although unconfirmed, this was likely due to fracture damage incurred by the spur adapter gear shaft (SAG gear) during the accident sequence.

The SAG gear likely cracked aft of the No. 2-1/2 bearing forward of its connection with the turbine to compressor coupling shaft. The ECU data (as well 1st responders) confirmed the engine continued to run following the accident. It's likely that continued running of the engine eventually lead to the SAG gear fracturing at this location thereby separating drive to the gas producer turbine and therefore lack of complete N1 continuity during the examination. Engine shutdown would have occurred following complete fracture of the SAG gear shaft.

Due to the orientation of the aircraft during the recovery exam, the engine could not be removed and therefore separation of the turbine module from the gearbox was not possible. This would have enabled visual examination of the SAG gear interface with the turbine to compressor coupling.

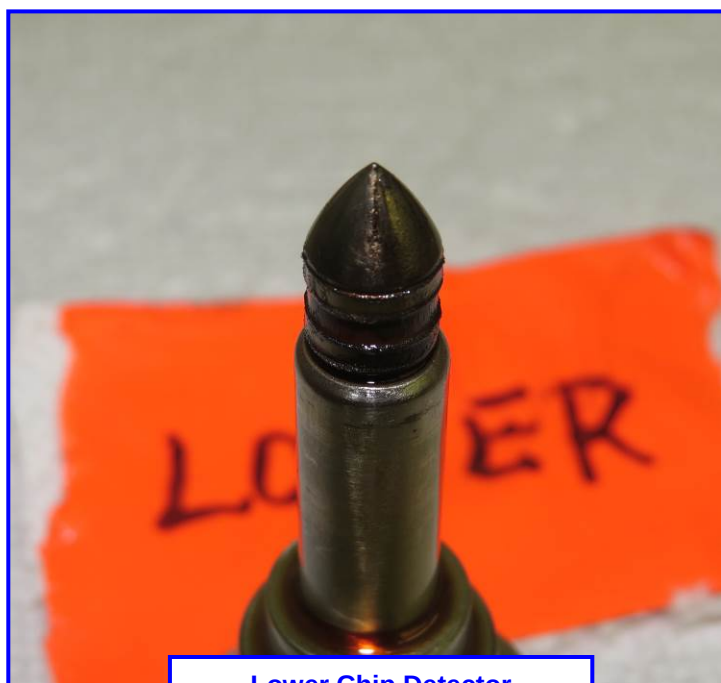
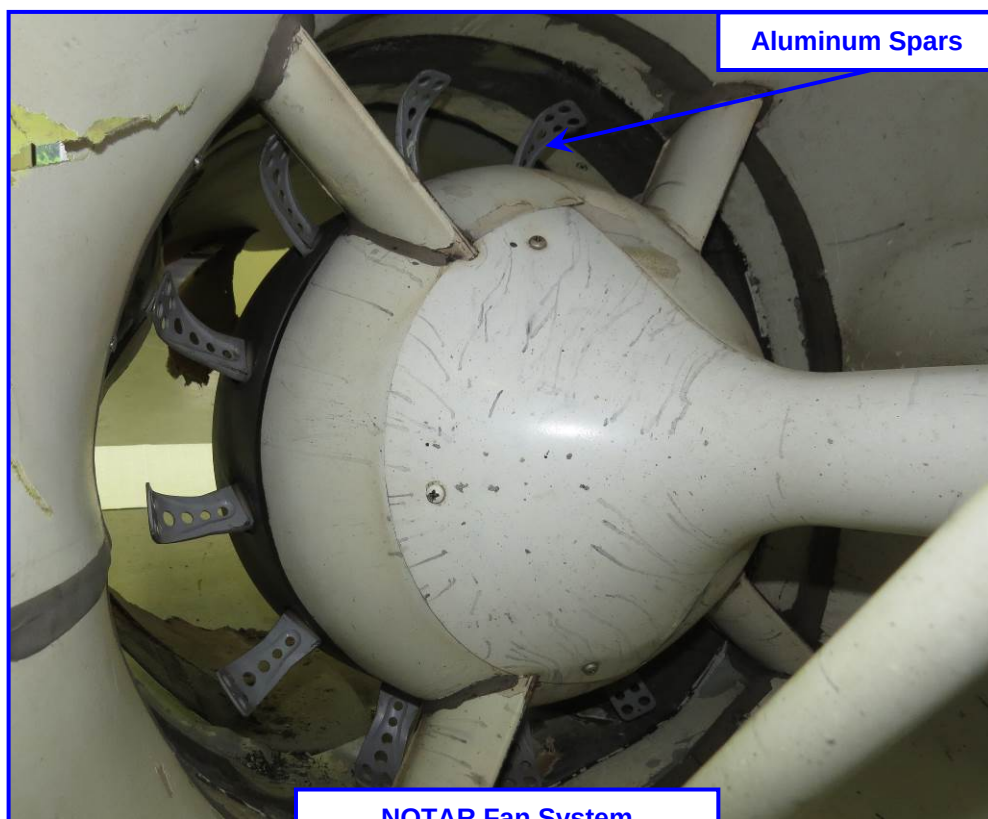


Rotational signature was evident on the NOTAR system. Only the aluminum spars remained of the fan blades. The polypropylene plastic was completely separated from the spars. The NOTAR blade spars were bent opposite the direction of rotation.

Fuel was detected up to the fuel spray nozzle. Approximately 1 teaspoon of fuel was drained from the flex line between the turbine fire shield check valve and the fuel spray nozzle. The fuel appeared clean and clear with no unusual odor.

The lower magnetic chip detector was pulled and inspected free of ferrous metal debris. Due to accessibility issues, the upper magnetic chip detector and engine pressure oil filter in the gearbox were not removed and inspected. The Combined Engine Filter Assembly (CEFA) oil and fuel filters were not removed and inspected.

The fuel spray nozzle was removed and inspected. There was no evidence of obstruction in the fuel spray nozzle inlet. The nozzle tip contained a uniform thin layer of carbon build up but was otherwise visually normal in appearance and not disassembled further.

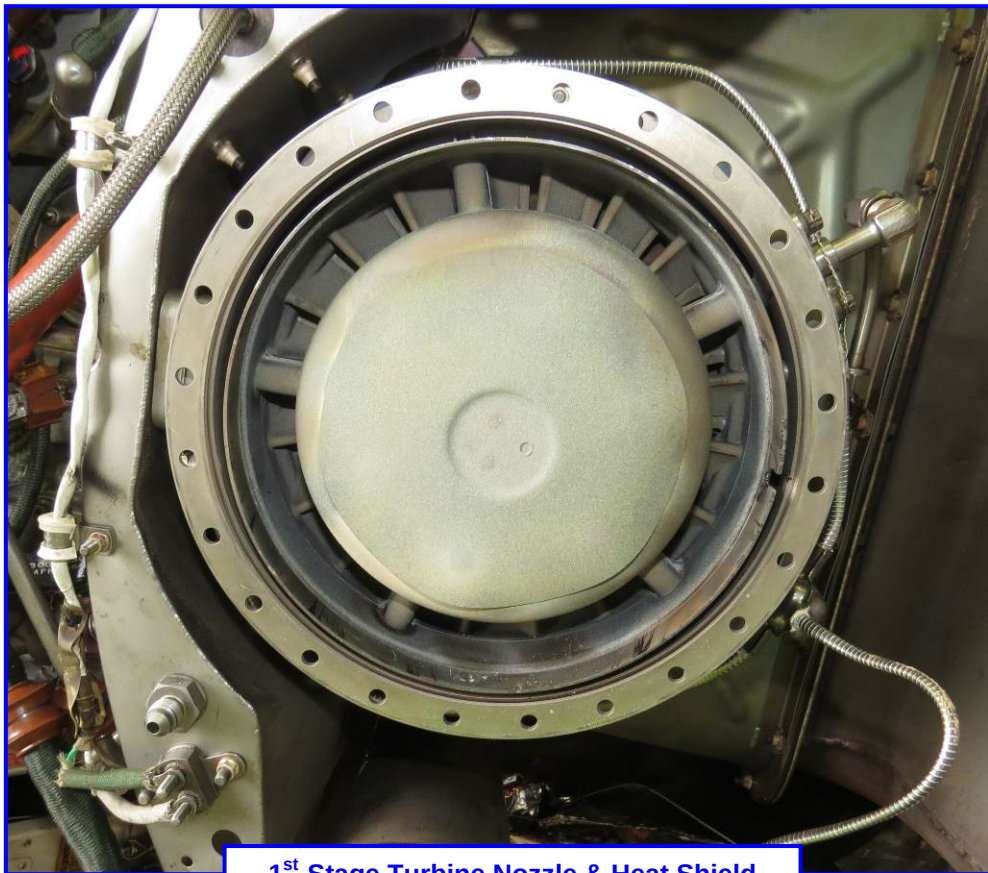


The Outer Combustion Case (OCC) was removed to facilitate visual access and assessment of the 1st-stage nozzle and wheel. Both appeared to be in good condition with no sign of missing material, impact damage, or heat related distress.

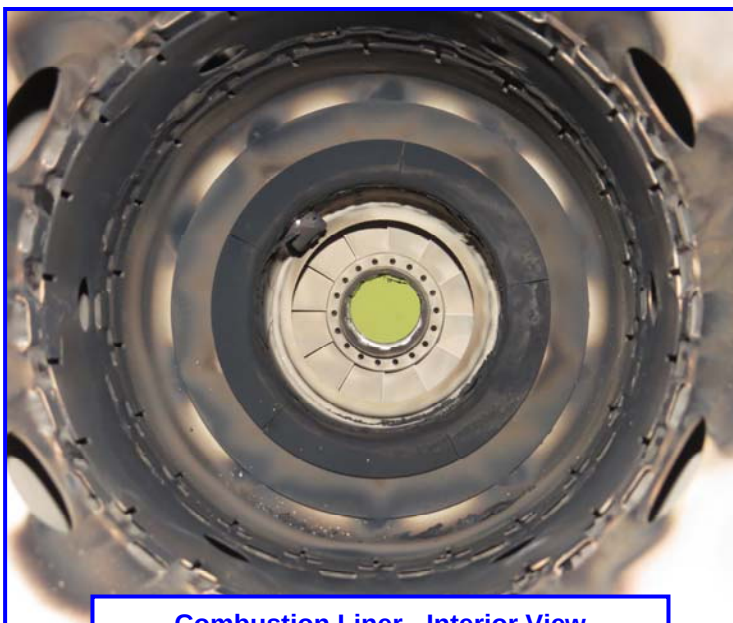
Following visual examination, the 1st-stage wheel was accessed through the nozzle guide vane. The gas producer turbine rotated freely while observing a lack of rotation of the starter-generator cooling fan & compressor impeller.

Following removal of the OCC, the combustion liner was removed for examination. The liner showed no evidence of abnormal combustion patterns or streaking. The entire OCC was visually unremarkable.

The igniter was removed, visually examined, and deemed unremarkable.



1st-Stage Turbine Nozzle & Heat Shield



Combustion Liner - Interior View



Combustion Liner - Exterior View

Engine Maintenance and Records

Component	Serial Number	Part Number	TSO (hrs)	Total Time (hrs)
Engine	CAE-847837	23065460	N/A	4475.5
Gearbox	CAG-47837	23066745	N/A	4475.5
Compressor	CAC-44367	23065593	N/A	4475.5
Turbine	CAT-44357	23063354	467.2	3849.0
HMU	JGALM0682	23078031	2106.4	4527.3
ECU	JG7ALW0048	23089311	N/A	4475.5
Bleed Valve	FF43546	23073353	1081.3	Unknown
Fuel Nozzle	0269	23077067	New	83.4

Summary of Findings

- There was no evidence of pre-impact fire, damage or malfunction of the engine.
- The N2 rotor system was continuous but required considerable force to be applied to the fractured KAflex® straps forward of the freewheeling unit.
- The N1 rotor system was continuous from the compressor impeller to the starter-generator cooling fan. Borescope inspection revealed the gas producer turbine rotor was not rotating with the entirety of the N1 rotor system.
 - Although unconfirmed, this was likely due to fracture damage incurred by the spur adapter gear shaft (SAG gear) during the accident sequence.
 - The turbine module could not be separated from the gearbox to confirm SAG gear fracture due to lack of engine accessibility and aircraft positioning during the recovery examination.
- The ECU data suggests the engine was operating normally prior to the accident and was producing sufficient power and responding to throttle inputs.
- There was no evidence observed that would indicate the engine was not capable of producing power during the event flight.