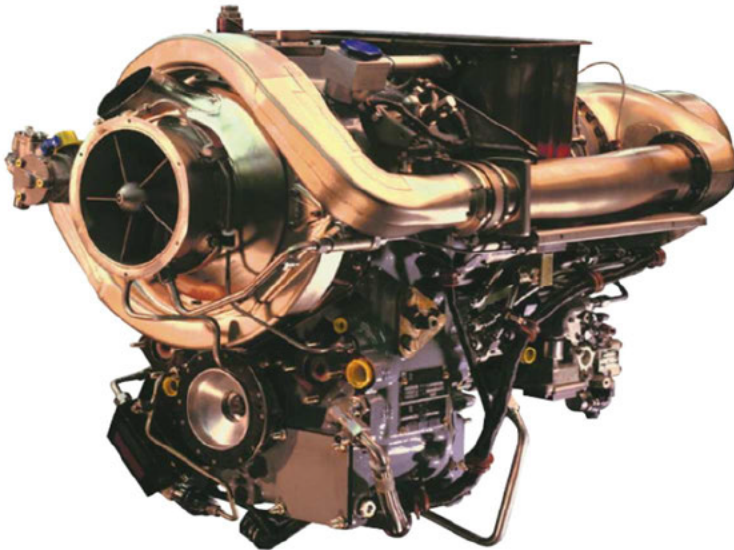




Rolls-Royce

Engine Investigation Report

**Rolls-Royce Corporation
Model M250-C47B
Engine CAE-848351**



**Nick Shepler
Air Safety Investigations**

**Operator: Air Methods Corporation
Location: Mount Baldy, LA County, California**

**Accident date: 4 September 2022
Wreckage exam date: 22 September 2022
Engine exam date: 2 November 2022
Report date: 13 December 2022
NTSB Case: WPR22LA33**

Background

On September 4, 2022, at 0808 Pacific daylight time, a Bell 407 helicopter, N687AM, was substantially damaged when it was involved in an accident near Mount Baldy, Los Angeles County, California. The pilot was seriously injured. The helicopter was operated as a Title 14 Code of Federal Regulations Part 91 flight.



Aircraft File Photo

The helicopter was being used to shuttle water and equipment in support of a local charity event. The pilot had completed four shuttle flights and was approaching the main, off airport landing zone to land when the low rotor RPM (revolutions per minute) warning sounded. He aborted the approach and attempted to increase power. The engine power did not recover, and the pilot performed an autorotation to a nearby road. The helicopter rolled upon landing, which resulted in substantial damage.

This report presents the observations made during the investigation.

Aircraft Information

Model	Bell 407
Serial Number	53497
Registration Number	N687AM
Airframe Total Time	6942:49 Hours (as of 1-Sep-2022)
Last Inspection (300 Hr/12 Month)	0 Hrs since (as of 30-Aug-2022)

Engine Information

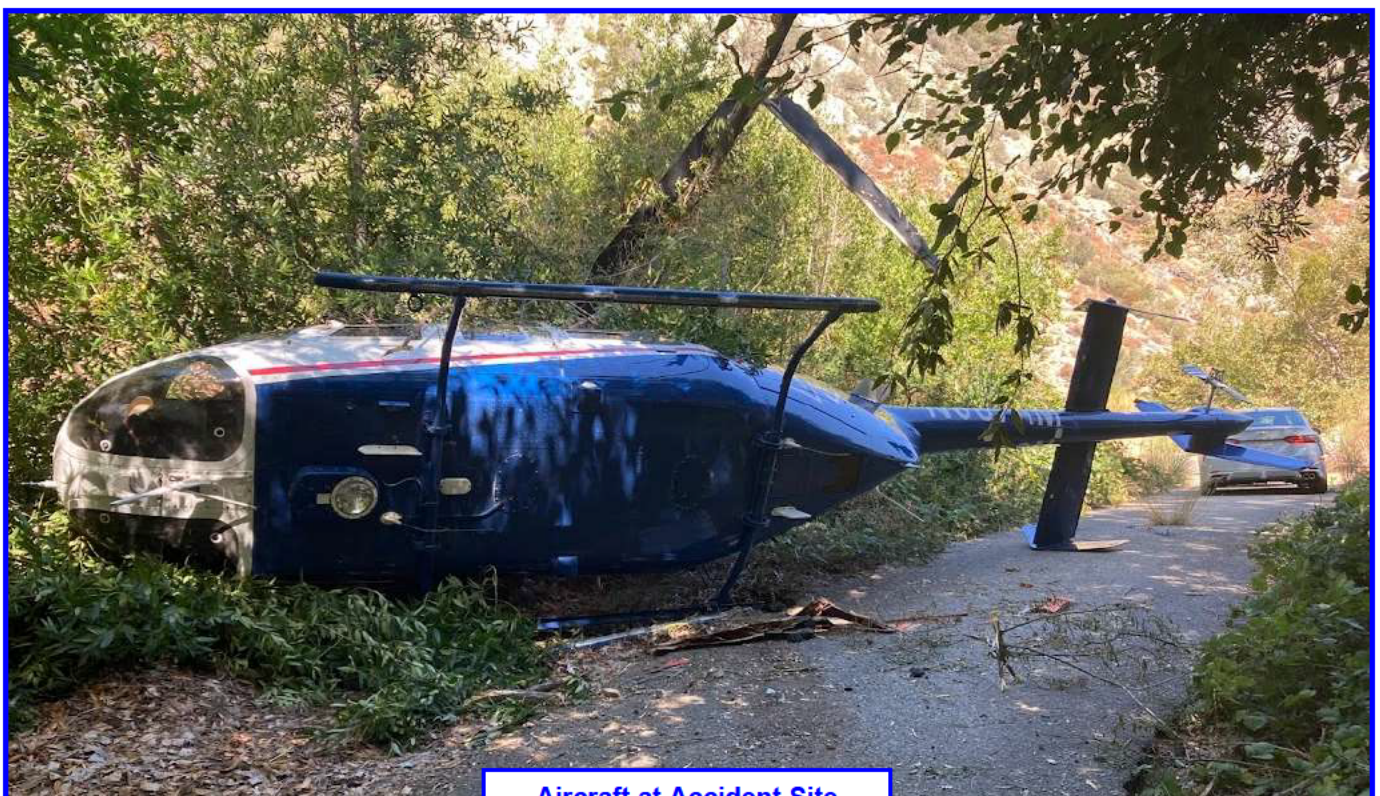
Engine Model	Rolls-Royce M250-C47B
Rating:	650 HP
Serial Number	CAE-848351
Engine Total Hours/Cycles	2815:18 Hours / 8438 Cycles (as of 1-Sep-2022)
Last Inspection (150/300 Hr/12 Mo)	0 Hrs since (as of 30-Aug-2022)

Accident Flight

The aircraft was supporting a public relations event with a local fire department. The event consisted of flying water, supplies, & personnel from a base camp at 4300' MSL to the summit of Mount Baldy, approximately 4 NM away, at just over 10,000' MSL. The pilot estimated that the amount of work required would necessitate a total of 5 flights to the summit.

The first flight was flown successfully with no operational issues. Upon landing at the summit, while off-loading supplies & 2 people, the main rotor was kept 100% RPM. After landing back at the base camp, the engine was kept at idle while 200 LB of cargo & 1 person was loaded. On the second landing on the summit, the main rotor RPM was again left at 100% while off-loading. On the return flight to the base camp, with only the pilot & approximately 375 LB of fuel on board, the pilot set up for a steep approach to the confined landing zone. While slowing from 60 to 40 knots & turning on final approach, the low rotor RPM warning light illuminated along with the low rotor RPM warning horn. No other lights or audio annunciations were present and the engine sounded normal. (Note: The low rotor warning light illuminates at 95% RPM.)

Upon observing the light, the pilot lowered collective, increasing main rotor speed to 100%. The pilot does not recall observing the throttle position on the collective yoke. At that point the pilot aborted the approach, made a mayday, and continued down the canyon looking for a place to land. The pilot alerted awaiting firefighters that he had a partial engine failure. He attempted to raise collective and again got the low rotor light & horn. The FADEC was kept in AUTO mode throughout the flight. The pilot's options for suitable landing locations diminished as he continued down the canyon. He opted not to attempt an autorotation but used what power the helicopter had for landing. He flared the helicopter into the top of a tree on the down canyon side of a clearing. Full collective pull was initiated to cushion the impact. The helicopter came to rest on its right side. The pilot rolled the throttle to the OFF position to shut down the engine & turned the battery switch off.

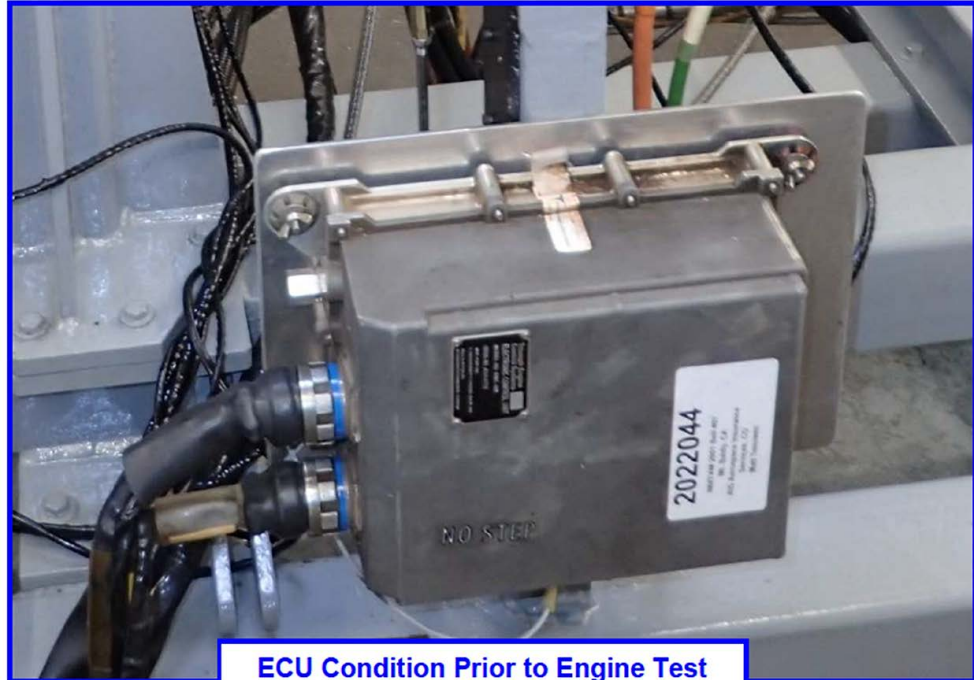


Aircraft at Accident Site

ECU (Engine Control Unit)

The ECU (S/N: JG1ALK0702) 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.



of the ECU, which captured 3 “snapshot” lines of data as well as an additional 51 complete 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 measurable data for nearly 62 seconds. Incident data is recorded at a rate of 1 line every 1.2 seconds. Snapshot data is continuously monitored and recorded instantaneously.

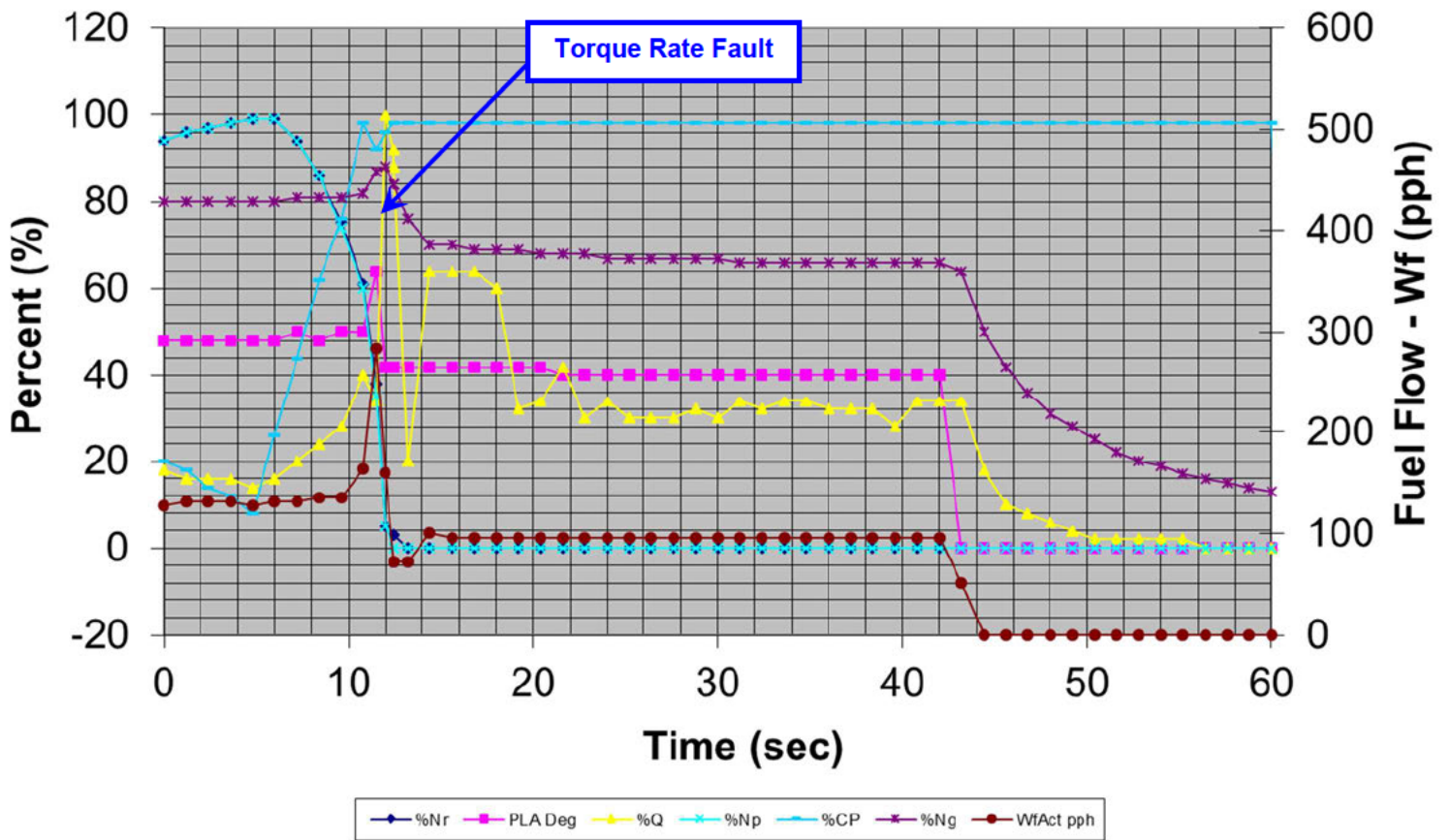
Control continuity was established from the collective twist grip to the engine hydro-mechanical unit (HMU). As previously stated, the throttle was found in the OFF position. When the throttle was manipulated by hand, it could be felt that the throttle went into the Fly detent. When the throttle was rotated upwards from Fly to Max Ng, it could be felt going out of the detent. When the throttle was rolled down out of Fly towards Idle, the feeling of rolling out of the detent was hard to feel.

As part of the ECU investigation process, the throttle was manipulated through various positions (Off, Idle, Fly, Max Ng, 48 PLA). The observations made when observing the corresponding HMU pointer positions and the PLA 1 sensor reading on the ECU with a Rolls-Royce computer plugged into the ECU (FADEC) port in the cockpit correlated & were consistent with throttle rigging expectations.

The IR data indicated PLA readings between 48-50 degrees. The normal PLA reading when the throttle is in the FLY position is 70 degrees.

The data further showed that the engine was performing normally, in accordance with the lower PLA position, and was responding to throttle inputs as expected during the accident sequence.

N687AM - Incident Data



Incident Recorder Data

%Nr = Main Rotor Speed

%Np = Power Turbine Speed

WfAct pph = Fuel Flow (lb/hr)

PLA = Power Lever Angle

%CP = Collective Pitch

%Q = Torque

%Ng = Gas Generator Turbine Speed

EXAMINATION DETAILS – WRECKAGE

A wreckage examination was conducted September 22, 2022 at the Air Salvage of Dallas in Lancaster, Texas. The examination was conducted under the auspices of the NTSB. Additional party members included the Denver FAA-FSDO, Air Methods, Bell Flight Safety, and Rolls-Royce Air Safety. The following observations were made:



As-Recovered Condition of Helicopter

Visual examination of the airframe & engine revealed no evidence of any pre-existing mechanical damage or malfunction. The engine was removed for ease of further examination and testing.

The aircraft sustained damage consistent with vertical impact and rollover. The right-hand skid was fractured from the support struts. The left-hand skid was mechanically severed, and the struts were removed to facilitate wreckage transportation.

The main rotor showed signs of low rotational inertia as indicated by the vertical fracture damage at the rotor head as well as the spanwise bending/buckling damage to the main rotor blades. All 4 main rotor blades remained securely attached to their respective blade grips but were removed prior to ground transportation.

The tailboom remained securely attached to the fuselage with no indication of main rotor blade contact damage.



Main Rotor Head Condition

The engine remained securely attached at all 3 mount points as well as their respective connections on the airframe in the engine bay. There was no visual indication of axial or lateral displacement of the engine as a result of the accident sequence.



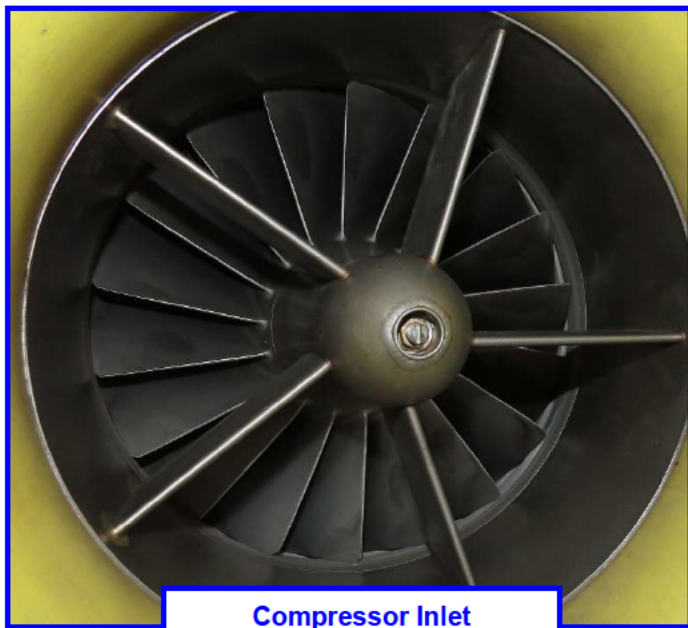
Engine Compartment – General Condition

General visual inspection of the engine's various fuel, oil, air, and electrical connections including B-nuts were found hand tight and painted with torque stripe. The engine did not reveal any obvious signs of damage from impact forces, internal engine failure, fluid leakage, or evidence of fire.

The aircraft was equipped with an inlet barrier filter. The compressor front support, guide vanes (struts), and impeller vanes were void of any noticeable impact damage or FOD.

The 4th-stage turbine blades appeared undamaged and void of thermal distress as did the surrounding turbine sections and exhaust plenum. The 1st-stage gas producer turbine blades & vanes were borescope examined and appeared visually normal & unremarkable.

The engine to transmission drive shafting was intact at the KAflex® coupling forward of the freewheeling unit as was the tail rotor draft shaft connection at the rear of the engine gearbox.



Compressor Inlet

Both N1 and N2 rotors could be rotated by hand and were smooth and quiet. Continuity from the 4th-stage power turbine wheel to the power output shaft and through to the main rotor head was established. Continuity was also confirmed throughout the N1 rotor system from the compressor impeller to the starter-generator cooling fan.

Fuel was detected up to the fuel spray nozzle. Approximately 2 teaspoons of fuel were drained from the flex line between the fuel flow meter and the fuel spray nozzle. The fuel smelled fresh and appeared visually clear with no sign of settling water, foreign debris, or dirt.

The airframe fuel filter canister was removed for examination & to facilitate engine removal. The bypass indicator on the top of the filter body housing was not extended. The canister was full of clean, clear fuel. Fuel was drained from the canister revealing no evidence of residual debris in the bottom. The internal fuel filter was clean and void of any captured debris within the pleats.



Airframe Fuel Filter & Collected Fuel

The Combined Engine Filter Assembly (CEFA) fuel filter was not removed and inspected.

Aircraft battery power was applied, and the instrument panel powered up. The ENGINE CHIP light did not illuminate on the annunciator panel. The upper and lower magnetic chip detectors were not pulled and inspected. The airframe oil tank level indicator showed full. The CEFA oil filter and engine pressure oil filter were not removed and inspected during the wreckage examination. The bypass indicator on the CEFA oil filter was not extended.

The fuel spray nozzle was removed and inspected. There was no evidence of obstruction in the fuel spray nozzle inlet. The fuel nozzle contained a uniform carbon layer across the air shroud. The nozzle was otherwise visually normal in appearance and not disassembled further.

In preparation for further examination the engine was removed and prepared for shipment for further examination.

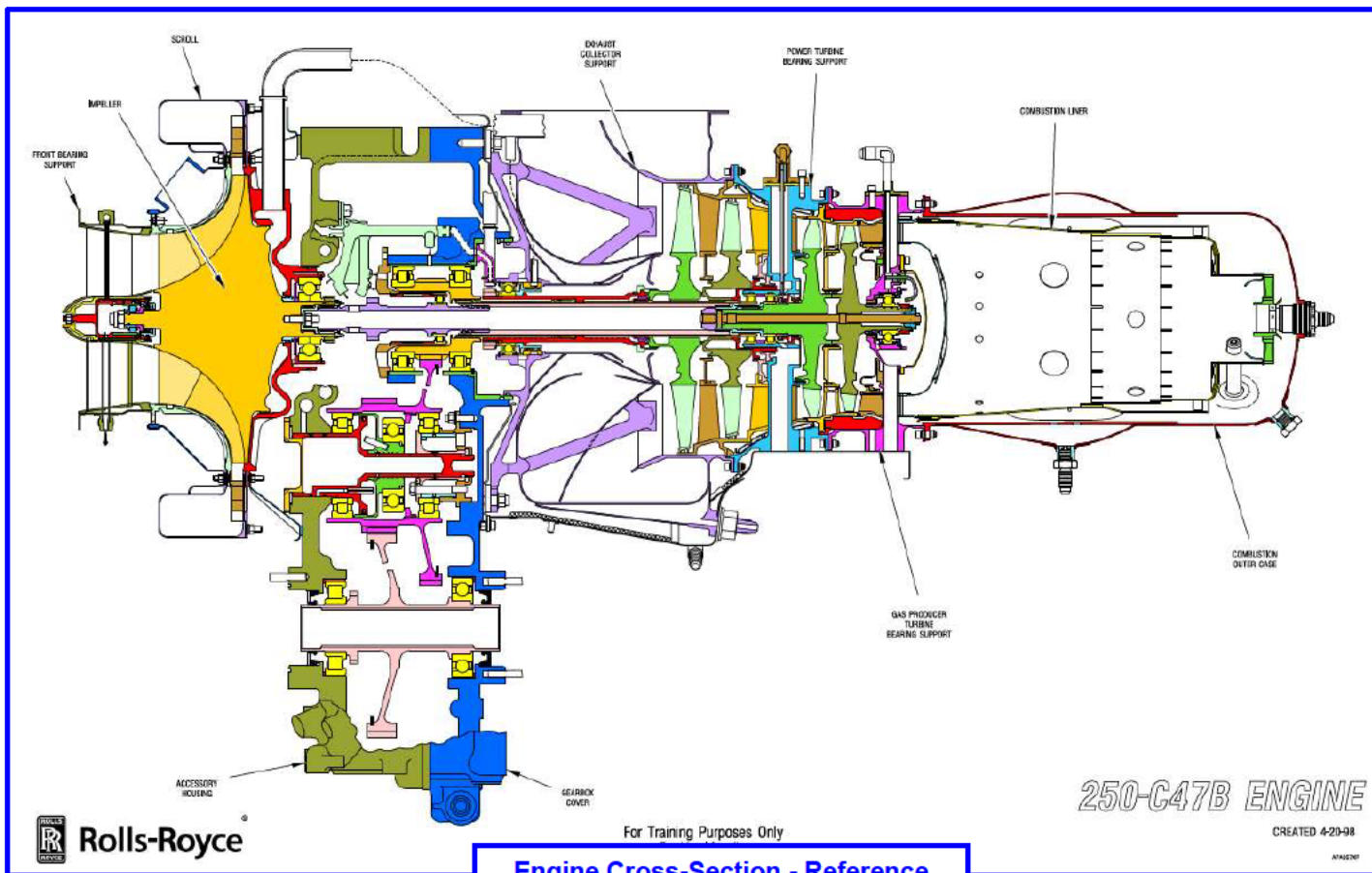
Per the direction of the NTSB, the engine was installed in a Rolls-Royce supplied shipping container. The engine was then delivered to Arrow Aviation in Broussard, LA, which is a Rolls-Royce Authorized Maintenance Repair & Overhaul Center (AMROC).



Fuel Spray Nozzle



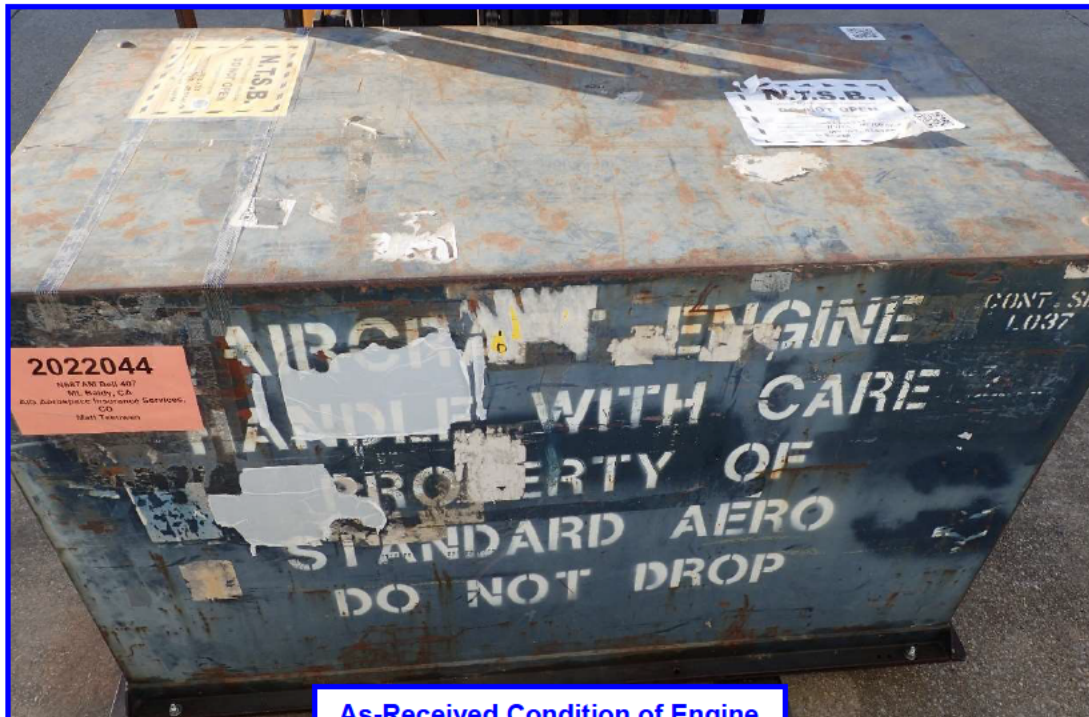
Engine Condition – Removed from Aircraft



Engine Cross-Section - Reference

ENGINE EXAMINATION DETAILS

On 2 November 2022, the subject engine was removed from the shipping container & examined at Arrow Aviation with regulatory oversight provided by the Baton Rouge, FAA-FSDO. Prior to prepping the engine for test a few additional investigative actions were performed. The pressure oil filter in the accessory gearbox was removed & inspected clean. Both magnetic chip detectors were removed with no findings. Rotational continuity of both N1 & N2 rotors was also confirmed per normal test cell induction procedures.

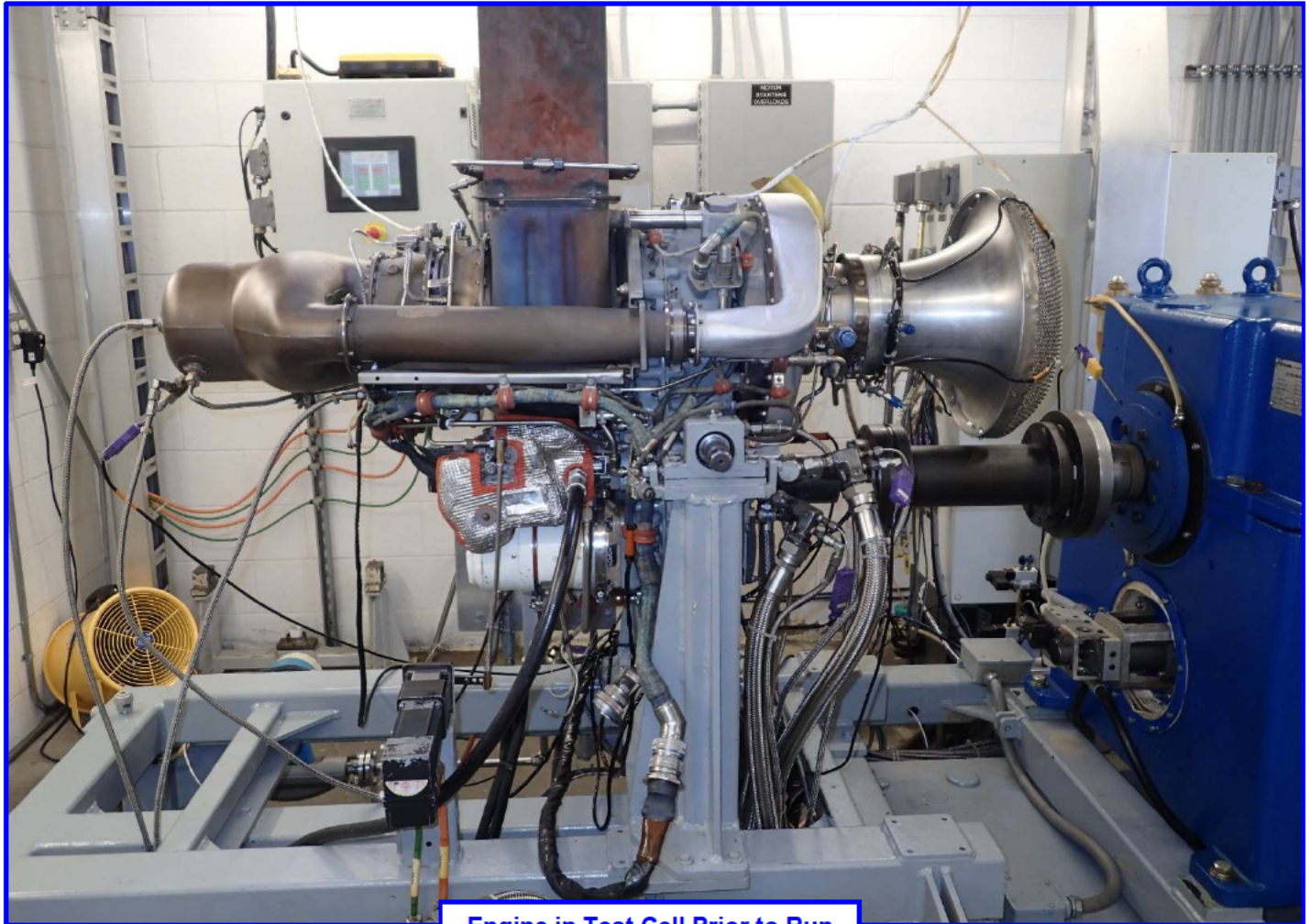


As-Received Condition of Engine



As-Received Condition of Engine

Upon completion of standard test cell preparedness tasks by Arrow Aviation technicians, the engine was considered acceptable to run on the test cell. The engine & ECU from the accident aircraft were installed on a test cell & a 6-point performance test was conducted to new engine production standards (Model M250-C47B), in accordance with Rolls-Royce M250--C40B, --C47, & --C30R/3 Series Overhaul Manual (Publication ref. CSP22001) Revision 20 dated 15 September 2019.



Engine in Test Cell Prior to Run

The engine successfully started, ran, and shut down. The engine successfully completed ground idle, flight-idle, max-continuous-power and take-off power runs. When corrected for standard atmospheric conditions, the engine yielded performance +6.9% above new-production standards at "low cruise" (450 horsepower), +5.0% above new-production standards at "high cruise" (540 horsepower), +5.0% above new-production standards at max continuous (600 horsepower), and +4.6% above new-production standards at maximum (Take-Off) power (650 horsepower).

The engine then completed "wave-off" max-power transients where the power was reduced to flight idle and then rapidly increased to take-off power. The engine responded normally and responded with maximum power without surging or hesitation. The testing was terminated following successful completion of the wave-off test and power calibration activities.

ENGINE MODULE & COMPONENT DETAILS

Component	Serial Number	Part Number	TSO (hrs)	Total Time (hrs)
Engine	CAE-848351	23063392	N/A	2815:18
Gearbox	CAG-48351	23063393	N/A	2815:18
Compressor	CAC-45467	23065593	N/A	7553:12
Turbine	CAT-45664	M250-10557	340:25	3023:30
HMU	JGALM0529	23078029	1551:53	8735:23
ECU	JG1ALK0702	M250-10696	N/A	Unknown
Bleed Valve	23073353	FF416415	88:17	3074:11
Fuel Nozzle	VN1BLH1519	M250-10604	15:54	Unknown

Summary of Findings

- There was no evidence of pre-impact fire, damage, or malfunction of the engine.
- The airframe fuel filter bowl was filled with clean, clear fuel. The filter was clean and free of foreign debris. Fuel was also present to the fuel spray nozzle.
- There was evidence of engine and drive train rotation at the time of impact.
- Continuity was established for both N1 & N2 rotors. Both could be rotated by hand and were smooth and quiet.
- Control continuity was established from the collective twist grip to the engine hydro-mechanical unit (HMU).
- The ECU data shows the engine was operating normally prior to the accident and was capable of producing sufficient power and responding to throttle inputs.
- The engine was installed in a test cell with the intent of running a 6-point performance test in accordance with Rolls-Royce M250-C47 Series Overhaul Manual procedures. The engine performed satisfactorily at all measured test points.
- All available evidence supports the engine was capable of producing sufficient power and responding to throttle inputs.
- The ECU IR data indicated the PLA was below the Bell 407 flight manual position for normal operation during the event, which would have resulted in a lower fuel flow command from the ECU.