Aviation Investigation Final Report

Location:	Hertford, North Carolina	**Accident Number:**	ERA17MA316
Date & Time:	September 8, 2017, 11:20 Local	**Registration:**	N146DU
Aircraft:	EUROCOPTER DEUTSCHLAND GMBH MBB BK 117	**Aircraft Damage:**	Destroyed
Defining Event:	Loss of engine power (partial)	**Injuries:**	4 Fatal
Flight Conducted Under:	Part 135: Air taxi & commuter - Non-scheduled - Air Medical (Discretionary)		

Analysis

The pilot was conducting an air ambulance flight to transport a patient to another hospital located about 130 nautical miles away. About 8 minutes after takeoff, at a GPS altitude of about 2,500 ft mean sea level (msl) and a groundspeed of about 120 knots, the helicopter began a left turn toward the south. Although the precise timing and order of events could not be determined, the No. 2 engine experienced a bearing seizure; the engine continued to run. This likely resulted in several cockpit indications described below. It is likely that the pilot then errantly shutdown the No. 1 engine and continued to fly for a brief period utilizing the No. 2 engine. About 1 minute after the left turn began, the last data point was recorded, which indicated that the helicopter was at a GPS altitude of about 1,200 ft msl and a groundspeed of 75 knots. It is likely that the No. 2 engine subsequently lost all power. The helicopter then impacted a shallow turf drainage pathway between fields of tall grass on a farm, and a postcrash fire ensued, which consumed most of the helicopter structure. The lack of any ground scars leading toward or away from the main wreckage indicated that the helicopter was in a near-vertical descent before impacting the ground. One rotor blade was found intact resting in undisturbed 8-ft-tall grass, consistent with little or no rotation of the main rotor system. Neither engine exhibited damage consistent with rotation at the time of impact.

Detailed examination of the No. 2 engine revealed that its gas generator shaft rear bearing was seized and damaged. Specifically, all the roller elements were flattened and none of the roller elements would rotate. Several bearing components showed damage consistent with friction between the seized rollers and the inner race and ensuing overheating. These signatures were not observed in the No. 1 engine gas generator shaft rear bearing. The lack of rotation of the roller pins and the damage to the gas generator spool indicated that the No. 2 engine's rear bearing had failed during the accident flight.

The No. 2 engine's oil return strainer/chip detector was partially obstructed with crystalline carbon-like and metallic debris, and debris was found downstream of the strainer in the oil pump inlet, consistent with some oil flow through the normal path exiting the rear bearing housing. The No. 2 engine 3-way deck fitting was unobstructed; however, it had been exposed to significant heat that could have decomposed the elastomeric tubing and any excess shrink tubing material, if it had been present and blocking the fitting's ports. Excess shrink tubing material was found obstructing the ports in the No. 1 engine 3-way deck fitting. No liquid oil remnants were found on engine No. 2 components to indicate that engine oil had migrated through the engine's main air path and through the exhaust. Had oil been present, it might have been consumed by the postimpact fire.

The root cause of the No. 2 engine's bearing failure could not be determined due to the damage it sustained while continuing to operate before impact, and due to impact and subsequent post-crash fire damage.

Accident Sequence and Cockpit Indications

A lack of recorded flight data precluded determining the precise timing, duration, and order of each event that likely occurred during the accident flight, to include the cockpit indications provided to the pilot; however, based on available evidence, it is possible that the pilot may have encountered the following indications during the final minutes of the flight.

Engine Chip Detector Indication

Metallic debris found in the No. 2 engine oil return strainer/chip detector downstream of the rear bearing housing likely resulted in an ENG CHIP message on the helicopter's Caution and Advisory Display (CAD).

The helicopter's flight manual (FLM) listed two procedures for engine chip detection: either shut down the affected engine or slowly reduce power to idle on the affected engine and monitor the engine parameters. The second option was intended to allow the pilot to potentially use the affected engine during landing.

Engine Parameter Discrepancy Indication

A cockpit display simulation prepared by the airframe manufacturer and an analysis prepared by the engine manufacturer revealed that, during the degradation of the rear bearing, the No. 2 engine experienced an increase in turbine outlet temperature (TOT). This likely triggered an engine parameter discrepancy (ENG PA DIS) caution message that would have appeared in both the left (engine 1) and right (engine 2) columns on the CAD, indicating that a discrepancy was detected in one of the parameters between engine Nos. 1 and 2. The CAD message would not have indicated which parameter had a discrepancy; however, the affected parameter's numeric value (TOT in this case) would change from white to yellow on the First Limit Indicator (FLI), described below.

The FLM procedure for the ENG PA DIS message was, "do not try and match needles, avoid using maximum power, compare the numeric values on the FLI to verify the affected parameter, and land as soon as practicable." The FLM procedures did not request the pilot to shut down the engine.

Other Indications

Additional caution messages may have also appeared on the CAD. If a difference in torque between the two engines was detected at greater than 15%, a VAR NR caution message would appear in the center “MISC” column of the CAD, advising the pilot to manually match the engines’ torque values. If a difference in N1 between the two engines of greater that 10% was detected, the ENG SPLIT caution message would appear in both engine columns of the CAD. The FLM procedure for an ENG SPLIT caution message was to adjust the collective lever to one-engine inoperative (OEI) limits or below, turn off bleed air consumers, and analyze engine conditions.

First Limit Indicator Display During Bearing Failure

A simulation of the primary engine display instrument, the first limit indicator (FLI), revealed that as the bearing degraded, the FLI might have presented data in a way that was unfamiliar to the pilot, possibly causing confusion.

Specifically, as the bearing failed, the FLI needle for the No. 2 engine would have changed from indicating torque (TRQ), to indicating turbine outlet temperature (TOT) due to a sudden rise in TOT in the No. 2 engine. Such a switch would have been unusual, because the needles normally reflect TOT during engine start only. The change in the position of the No. 2 FLI needle would have resulted in a large split between both needles.

In normal cruise flight, with the FLI needles both representing TRQ, a large split during cruise flight would indicate a difference in TRQ between the engines; thus, the pilot may have erroneously thought that the split was showing that the No. 1 engine was producing much less TRQ than the No. 2 engine, which might have contributed to his decision to shut down the No. 1 engine.

The FLI should have indicated, in the numeric section of the display, that the No. 2 needle was indicating TOT, and if appropriate, that the No. 2 engine’s TOT had reached its limit. Despite the split needles, the numeric values for each engine’s TRQ may have at least initially been similar, which could be confirmed by cross-checking the triple tachometer located above the FLI on the instrument panel.

The specific condition of the FLI needles showing one engine limited by TRQ and the other engine limited by TOT during cruise flight was not reviewed or practiced as part of the operator’s or the helicopter manufacturer’s training programs. However, depending on operating conditions, the engines could be limited by TRQ, N1, or TOT, which was covered in those training programs, as were engine failures and typical “needle split” conditions that occur during an engine failure.

Shutdown of No. 1 Engine

Examination of the wreckage at the accident site revealed that the No. 1 engine twist-grip throttle control in the cockpit was found in the OFF position (which matched the indicator on the No. 1 engine fuel control unit). In order for the control to be placed in this position, the pilot would have had to press a release button on the grip to rotate it below the IDLE position. The No. 2 engine twist-grip throttle control was found in the FLIGHT position (which matched the indicator on the No. 2 engine fuel control unit). This evidence indicated that the pilot likely shut down the No. 1 engine and that the helicopter continued to fly for some time with power being provided only by the No. 2 engine.

According to the helicopter's FLM there were three events that might prompt a pilot to shut down an engine in flight; an engine fire, an engine CHIP indication, or low engine oil pressure.

It is possible that the pilot inadvertently shut down the engine No 1. in response to the No. 2 engine ENG CHIP caution. However, the available evidence did not indicate why he might have chosen to shut down an engine rather than reduce the engine power to idle. It is also possible that the pilot erroneously shut down the No. 1 engine after receiving one or more of the above-mentioned cockpit indications, which may have been unexpected and/or confusing.

Single Engine Performance

Performance calculations indicated that, given the takeoff weight and ambient conditions, the helicopter would have been able to fly to a suitable landing location with only one engine operative without exceeding maximum continuous power. However, the helicopter would not have been able to hover to land, which would have required the pilot to make a running landing onto a smooth, firm surface.

The GPS tracking data from the helicopter were not recorded at a sufficient frequency to determine the helicopter's track, speed, and descent profile before impact. As a result, the investigation could not determine if the pilot maneuvered for an immediate landing or a diversion to an alternate location, nor could it be determined if the pilot established the appropriate speed for a one-engine-inoperative (OEI) condition. However, witness reports indicated that the helicopter appeared to be in control with the main and tail rotors turning at an estimated altitude of about 300 ft above the ground with little or no forward speed just before the helicopter's rapid final descent. Thus, it is possible that the pilot was attempting an emergency OEI landing when the loss of power in the No. 2 engine occurred. While the helicopter's flight manual provided a procedure for a dual engine failure, it did not provide autorotation performance data to compute height and speed combinations that should result in a successful autorotation with both engines inoperative. Nevertheless, the helicopter might have been at an altitude that was too low and/or an airspeed that was too slow to allow for a successful autorotative landing when the loss of power in the No. 2 engine occurred.

Assessment of Potential Fire in No. 2 Engine Compartment

Filaments in all four bulbs in the No. 2 engine fire warning light were found stretched, consistent with their illumination at the time of impact. Each engine's electrically operated airframe fuel shutoff valve was found in the open position. Because each valve would close if its respective fire indication button was pressed, the pilot likely did not press either fire indication button. This suggests that the pilot did not inadvertently shut down the No. 1 engine in response to a potential No. 2 engine fire indication, and that the No. 1 engine shutdown occurred at some point before the illumination of the No. 2 engine fire warning light. With the No. 1 engine already shut down, the pilot would likely not have pressed the No.

2 engine fire indication button, because it would have automatically shut down the helicopter's remaining source of engine power.

Although witnesses reported that during the final moments of the accident that smoke had been trailing behind the helicopter that was black and/or blue in color, the investigation could not determine if the origin of the smoke was from an active engine compartment fire, engine oil exposed to hot engine components, poor combustion in the No.2 engine, and/or another source. Although a plume of smoke can emanate from an engine's exhaust if the engine is shutdown using the engine fire button, the open airframe fuel shutoff valves suggest that neither fire button was pressed. The investigation could also not determine if any smoke was present in the cockpit and if that could have affected the pilot's visibility inside or outside of the helicopter.

Although reports of erroneous fire indications in BK117 C2 helicopters have occurred in the past, based on the fire indication light bulb filament stretching, and the multiple witness reports of smoke emanating from the helicopter in flight, it is possible that an in-flight fire occurred in the No.2 engine compartment; however, the impact damage and post-crash fire precluded a conclusive determination of the presence and origin of an in-flight fire.

The postaccident condition of the No.2 engine and the rotor system indicated that prior to impact, the No.2 engine lost all power. The cause of the ultimate complete loss of power in the No. 2 engine could not be determined. Although it is reasonable to consider that it may have been the result of effects of the rear bearing failure, or as a consequence of an unmitigated in-flight fire, there was insufficient evidence to conclude if or how either of these conditions led to the complete loss of power in the No. 2 engine.

Possible Indication of Impending Bearing Failure

A review of records from engine oil tests performed in the 9 months preceding the accident revealed that metallic contaminants were detected in the No. 2 engine oil at levels considerably higher than in the No. 1 engine. Although the contaminant levels did not exceed those specified by the engine manufacturer to warrant action, the contamination levels fluctuated significantly between tests. In one case, the concentration of iron, which could be an indicator of impending bearing failure, doubled between tests. The oil test evaluation procedures did not include steps to monitor trends of contaminant concentration levels over time. If the engine manufacturer's procedures had included appropriate trend monitoring criteria, the impending bearing failure in the No. 2 engine might have been detected and mitigated.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

A failure of the rear bearing in the No. 2 engine, which (1) created multiple and likely unexpected and confusing cockpit indications, resulting in the pilot's improper diagnosis and subsequent erroneous shutdown of the No. 1 engine, and (2) the resulting degraded the performance of the No. 2 engine, until it ultimately lost power. The complete loss of engine power likely occurred at an altitude and/or airspeed that was too low for the pilot to execute a successful emergency autorotative landing.

Findings

Aircraft	Turbine section - Failure
Environmental issues	Warnings/alarms - Response/compensation
Personnel issues	Identification/recognition - Pilot
Personnel issues	Incorrect action selection - Pilot
Aircraft	Altitude - Attain/maintain not possible
Aircraft	Prop/rotor parameters - Attain/maintain not possible

Factual Information

History of Flight

Enroute-cruise	Loss of engine power (partial) (Defining event)
Emergency descent	Loss of engine power (total)
Uncontrolled descent	Collision with terr/obj (non-CFIT)

On September 8, 2017, about 1120 eastern daylight time, an Airbus (formerly Eurocopter) Deutschland GmbH MBB BK117 C-2 helicopter, N146DU, powered by two Safran Helicopter (SafranHE) Arriel 1 E2 turboshaft engines, was destroyed when it was involved in an accident near Hertford, North Carolina. The commercial pilot, two flight nurses, and one patient were fatally injured. The helicopter was operated as a Title 14 *Code of Federal Regulations* Part 135 air ambulance flight.

According to Air Methods Corporation (AMC), the operator of the flight, the pilot and both medical crewmembers departed at 0827 on the morning of the flight from their base at Johnston Regional Airport (JNX), Smithfield, North Carolina, for Elizabeth City Regional Airport (ECG), Elizabeth City, North Carolina, for refueling. The helicopter arrived at ECG about 0924 and departed for Sentara Albemarle Medical Center Heliport (NC98) in Elizabeth City about 1011. The helicopter arrived at NC98 about 1022, after which the patient was boarded onto the helicopter. About 1108, the pilot radioed the Duke Life Flight operations center and advised that that the helicopter was departing for Duke University North Heliport (NC92), which was 130 nautical miles (nm) away, with 2 hours of fuel and four people aboard. There were no further communications from the helicopter.

GPS tracking data transmitted from the helicopter every 60 seconds showed that it departed NC98 to the northwest, climbed to a GPS altitude of about 1,000 ft mean sea level (msl), and turned west. The helicopter then climbed to a GPS altitude of about 2,500 ft msl and continued on a westerly track at a groundspeed of about 120 knots. About 8 minutes after takeoff, the helicopter began a turn toward the south. When the transmitted data ended about 1 minute later, the helicopter was traveling on a southeasterly track at a GPS altitude of about 1,200 ft msl and a groundspeed of 75 knots. The helicopter wreckage was located about 15 nm west of ECG.

Several witnesses reported observing smoke trailing behind the helicopter while it was in flight. Some of these witnesses described the smoke as "heavy" and "dark," and others reported the color as "black," "dark blue," and "blue." One witness reported that the smoke was coming from under the rotor. Another witness reported that smoke was trailing about 20 ft behind the helicopter in “one single wide streak…like a truck would leave when it is burning oil, blue, not black”. One witness reported that the helicopter appeared to be "hovering" at an altitude of about 300 ft (based on its height relative to a nearby windmill) just before it descended straight down. Another witness reported hearing a "popping noise" and observing the helicopter turning left and right and then descending quickly. This witness further reported that the helicopter appeared "in control" with the rotors turning before he lost sight of it.

Pilot Information

Certificate:	Commercial	**Age:**	51,Male
Airplane Rating(s):	None	**Seat Occupied:**	Right
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	
Instrument Rating(s):	Helicopter	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 Without waivers/limitations	**Last FAA Medical Exam:**	October 6, 2016
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	May 5, 2017
Flight Time:	(Estimated) 4562 hours (Total, all aircraft), 1027 hours (Total, this make and model)		

The pilot had been employed with AMC since August 2009. He was the lead pilot and the safety officer at AMC's JNX base and an AMC maintenance test pilot in the BK117 C2 helicopter. He was also current and qualified on the twin-engine Airbus EC135 helicopter, in which he had accrued 1,100 hours of total flight experience. Before his employment with AMC, the pilot flew twin-engine Sikorsky UH-60 helicopters for the US Army, accruing about 2,300 flight hours, and the EC135 helicopter for another helicopter air ambulance provider.

AMC training records indicated that the pilot had completed all required training with no deficiencies. During the pilot's most recent recurrent training and checkride for the BK117 C2, the pilot performed one-engine-inoperative (OEI) flight procedures and a simulated OEI landing. Recurrent training typically included autorotations, which were practiced to a power recovery at a 3-ft hover, but no autorotations were specifically documented in the pilot's recurrent training records. At the time of the accident, AMC did not have a BK117 C2 simulator training program, which would allow for practice autorotations to touchdown. According to his training records, the pilot was familiar and current with the indications associated with autorotation and OEI conditions as well as for the behavior of the aircraft. (AMC had been developing a BK117 C2 simulator training program at the time of the accident, which was subsequently implemented). Simulated OEI landings were performed in the aircraft by utilizing power limits representative of OEI performance. Engine fire light procedures were discussed during the training and were the subject of oral questions during the checkride.

The pilot's most recent EC135 simulator training included OEI recoveries, OEI landings, and engine fire light procedures. The indications and procedures in the EC135 are similar to what is seen and performed in the EC145.

The pilot's work schedule included 12-hour workdays from 0800 to 2000, with a 6-days-on/6-days-off format. The accident occurred on the third flight leg of the second day of the pilot's work schedule.

According to his wife, the pilot had no issues with his sleep during the 3 days preceding the accident. He was in good health and was not taking any medications. She further reported that he was happy with his life and did not have any major life stressors. The pilot was not employed outside of AMC, enjoyed his job with the company, and had not mentioned any concerns about the company or its helicopters.

The pilot's coworkers and managers provided positive feedback about his performance. He was described as professional, well prepared, thorough, and team oriented, and he exhibited good pilot skills.

Aircraft and Owner/Operator Information

Aircraft Make:	EUROCOPTER DEUTSCHLAND GMBH	**Registration:**	N146DU
Model/Series:	MBB BK 117 C2	**Aircraft Category:**	Helicopter
Year of Manufacture:	2011	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	9474
Landing Gear Type:	Skid	**Seats:**	4
Date/Type of Last Inspection:	September 8, 2017 AAIP	**Certified Max Gross Wt.:**	7590 lbs
Time Since Last Inspection:	2 Hrs	**Engines:**	2 Turbo shaft
Airframe Total Time:	2714 Hrs at time of accident	**Engine Manufacturer:**	Turbomeca
ELT:	C126 installed, not activated	**Engine Model/Series:**	Arriel 1E2
Registered Owner:	DUKE UNIVERSITY HEALTH SYSTEM INC	**Rated Power:**	760 Horsepower
Operator:	Air Methods Corporation	**Operating Certificate(s) Held:**	On-demand air taxi (135)

Maintenance

The helicopter was maintained by the operator using a Federal Aviation Administration (FAA) Approved Aircraft Inspection Program. According to AMC maintenance records, the helicopter’s most recent 30-hour engine inspection was completed on August 15, 2017. At that time, the helicopter and both engines had accrued a total of 2,673 hours. Several routine maintenance and inspection tasks were completed on both engines during a ten-day period prior to the accident which include such items as engine power assurance checks, compressor wash, and zonal inspections; no unusual finds were reported. The most recent daily inspection occurred on the morning of the accident at which time, the helicopter and engines had accrued a total of about 2,714 hours.

According to AMC, in addition to scheduled inspections, a daily airworthiness check of the helicopter was performed by a mechanic. A review of all engine and engine indication related maintenance records for the 6 months preceding the accident revealed no discrepancies.
AMC’s maintenance program specified the time between overhaul (TBO) for different engine

components; the engine was normally not overhauled completely at one time. The TBO for the gas generator section was every 3,600 hours; the gas generator sections for the accident engines were not due to be overhauled for another 886 hours. Review of the maintenance records for the last 9 months prior to the accident revealed that AMC conducted multiple routine and scheduled gas generator oil system tasks which included rear bearing lubrication inspections, oil line inspections, and electric magnetic plugs inspections with no anomies reported. The engine manufacturer's specification for an engine oil change was every 800 hours. Maintenance records indicated that the operator replaced the engine oil at least every 300 hours. In addition, the Fuel Control Units (FCU) of both engines were last checked in mid-August with no anomalies reported.

In the period February 22nd, 2017 through March 31, 2017 (at 2,406 hours), both engines were removed from the airframe during a major helicopter maintenance.

On May 22nd, 2017 (at 2,521 hours), a flight crew reported an electrical burning smell in the cabin. Maintenance troubleshooting did not reveal any discrepancies.

Engine Procedures

Each engine was equipped with four chip detectors, two of which were electric, to alert the pilot with a cockpit indication (ENG CHIP) when a metal particle is detected in the engine oil. One of the electric detectors was positioned in a strainer downstream of the rear bearing housing. The cockpit indication for a chip detection is a master caution light, an audible gong, and an amber caution message on the caution and advisory display panel showing the chip detection and the engine that was affected. The helicopter was optionally equipped with a pulse chip detector, or “fuzz burn” system. This system can clear small insignificant debris from the chip detector contacts by applying an electrical current to the detector to ‘burn’ the debris. According to the BK117 C-2 Flight Manual (FLM), with this system installed, the first procedure after receiving an ENG CHIP indication, is to depress the FUZZ BURN switch for 1 second, and monitor engine parameters. If the ENG CHIP indication extinguishes, no further action is required. If the ENG CHIP indication occurs again later in flight, the fuzz burn system may be activated a second time. If the ENG CHIP indication does not extinguish, the emergency procedures included two options for resolving the issue: either (1) perform a single-engine emergency shutdown or (2) reduce the affected engine slowly to idle power, and monitor indications. The FLM indicated that the second option would enable a pilot to use the affected engine for landing, as long as engine parameters remained within limits. A decision for this option requires the pilot to continuously monitor engine parameters N1 (gas generator speed), TOT (turbine outlet temperature), TRQ (engine torque), oil pressure and temperature, and be prepared for immediate engine shutdown.

According to the Airbus Helicopters training content and the FLM, emergency procedures in bold face with a grey background are generally memory items which shall be performed immediately without necessity of consulting either the FLM or the pilot’s checklist. The helicopter shall be operated in compliance with the certified limitations making sure that even if one engine became inoperative (OEI), the helicopter could safely continue the flight and there would be enough time for the pilot to identify and allocate the technical issue. Mission preparation requires anticipating all engines operating (AEO) and OEI performance according to the mission environment. The FLM also prescribes that if one engine became inoperative, the pilot must determine if the situation will allow for OEI flight, and if not, to land as soon as possible. Conditions that affect the ability of the helicopter to sustain OEI flight include the helicopter’s weight, the outside air temperature, and the pressure altitude.

A review of weight and balance records revealed that, at the time of takeoff, the accident helicopter weighed between 7,524 and 7,590 pounds. A review of performance calculations revealed that, based on that weight range and the ambient temperature, the helicopter had an OEI climb rate of about 300 ft per minute at a speed of 65 knots, with maximum continuous power, at an altitude of 1,000 ft. The review of performance calculations also revealed that the helicopter did not have enough power to hover to land with one operating engine. The FLM indicated that landing in these conditions would require, in part, an approach speed of 65 knots (reduced to 40 knots at an altitude of 50 ft), necessitating a "running" landing in which the helicopter would land with some forward airspeed. An FLM height-velocity diagram, which was applicable for OEI landings to a smooth, firm surface, indicated that, for the accident helicopter’s takeoff weight and the ambient temperature, a successful OEI landing could be performed from an altitude of about 180 ft above ground level and with no initial forward speed. The FLM did not provide a height-velocity diagram with guidance for autorotation conditions with both engines inoperative.

According to the FLM, if the engine fire detection system sensed heat, an engine fire indication button would illuminate on the warning unit for the affected engine. The warning unit indication is arranged with the fire indication light for the No. 1 engine on the left edge of the unit, and the light for the No. 2 engine on the right edge of the unit. The fire detection initiating the illumination on the warning panel is accompanied by a warning bell. The FLM procedure for a fire indication includes: establish OEI flight by reducing the airspeed below 100 knots and pressing the fire indication button, which would automatically close the airframe fuel shutoff valve for that engine and cause the engine to shut down by fuel starvation. According to Safran, this can result in a plume of smoke from the engine exhaust. The engine fire detection system did not have the capability to sense smoke.

Vehicle and Engine Multifunction Display

The helicopter was equipped with a Vehicle and Engine Multifunction Display (VEMD), which is an electronic display in the center of the helicopter’s instrument panel and is the pilot's primary reference for engine power management. The central focus on the VEMD is the First Limit Indicator (FLI) displaying an analogue indication (tachometer-like) of the limiting parameter associated with the helicopter engine primary limitations. The dial scale of the analogue display is arbitrary and does not represent a percentage value.

The VEMD’s FLI presents a needle dial gauge (needle “I” is for the No. 1 engine, and needle “II” is for the No. 2 engine) and digital numeric values for engine torque (TRQ), turbine outlet temperature (TOT), and gas generator rotational speed (N1) for each engine. Figure 1 depicts the FLI and describes the display’s various indications.

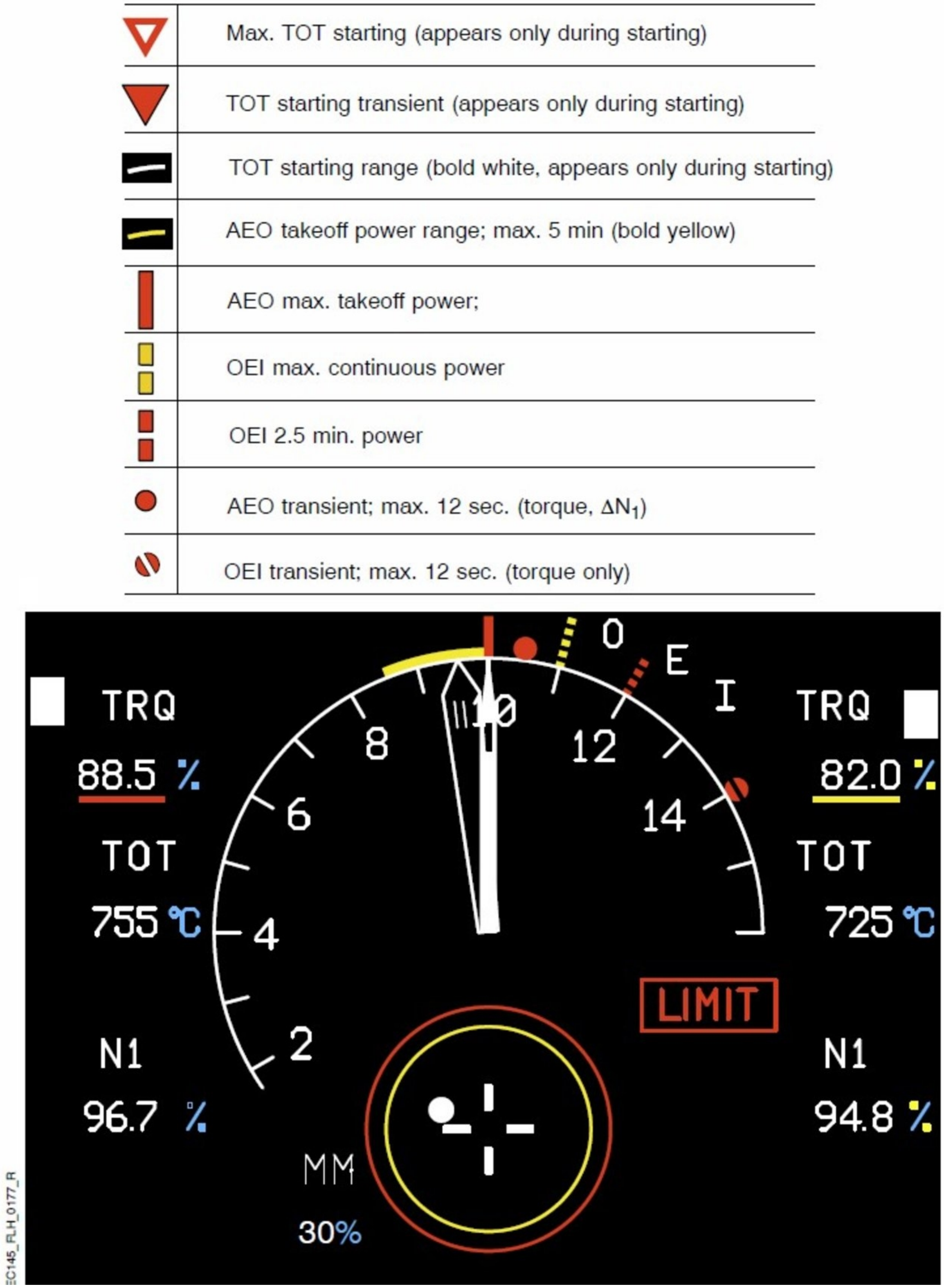

Figure 1 - First limit indicator. (Information from rotorcraft flight manual.)

The needles can represent TRQ, TOT, or N1, depending on which of these parameters is the closest to its operating limitation for each engine given the conditions at the time. For example, during cruise flight on the day of the accident, the needle for each engine (operating normally) would have corresponded to torque. In normal operation, both engines would have also remained torque matched by an automated variable rotorspeed and torque matching system (VARTOMS). In this case, the "first limit" for both engines would be torque. The first limiting parameter is the parameter that is closest to its limit and does not mean that parameter has reached a limit. For example, as the pilot adds power, the engines would eventually reach one of the torque operating limits before reaching any of the turbine outlet temperature or gas generator speed limits. In different ambient conditions, such as operation at higher pressure altitudes, the first limiting parameter can instead be N1. Normally, both engines are limited by the same parameter.

The needles do not depict the value of the first-limited parameter (the scale inside the arc, numbered 2 through 14 in figure 1, is unitless, and standardized for comparison of the three limiting parameters) but rather the relationship of the parameter to several different limits that are shown on the outside of the arc as colored lines and symbols. These limits, including those for the OEI condition, are always displayed. The digital numeric values arranged vertically on the left side of the display show the values of TRQ, TOT, and N1 for the No. 1 engine; the numbers on the right side show the values for the No. 2 engine. These numbers, and the white boxes showing which parameter is currently closest to a limit for each engine, are also always displayed.

Should an engine be first limited by torque, its needles would depict engine torque with the various torque limits shown on the outside of the dial arc as red and yellow lines and circles. The white boxes that indicate the first-limit parameter for each engine (which in the example on Figure 1 is TRQ for both engines) also indicate that the respective needle is displaying that particular parameter. The needles in figure 1 show the No. 2 engine TRQ is in the yellow "AEO takeoff power range" and that the No. 1 engine TRQ is at the red "AEO max. takeoff power" limit. Additionally, the numeric value for the No. 1 engine TRQ is underlined with a red bar, indicating that it has reached the TRQ limit and is arriving to the transient range (meaning it can safely operate at that torque for a limited amount of time).
If both engines are operating normally in cruise flight, both needles would indicate TRQ and would be positioned closely to one another with the same or about the same value, indicating that each engine is producing about the same amount of power. Small deviations in TRQ can be addressed manually by the pilot.

A large deviation, or "split," between the needles during flight would indicate an unusual situation, which may be associated with an issue with the torque matching system (VARTOMS), other disparate conditions between the two engines (not necessarily due to a malfunction), or in an engine failure. If a large split between needles is visible, it would be one of the indications that a pilot could use to confirm the failure of an engine and determine which engine had failed. Airbus Helicopters performed a simulation to determine what would happen with a split between the needles if they were not indicating the same parameter for each engine, as discussed later in this report.

Triple Tachometer

Located above the FLI, is a triple tachometer which is an analog gauge with three needles. One needle depicts the main rotor RPM, the other two depict the power turbine speed (N2) in percent of the respective engine. This instrument can aid the pilot in determining which engine may be experiencing a problem, if the problem results in a variance in one of the engine's power turbine speed. Additionally, an aural pulsed tone warning occurs and the ROTOR RPM light will illuminate on the warning unit when the rotor RPM is less than 95%.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KECG,13 ft msl	**Distance from Accident Site:**	15 Nautical Miles
Observation Time:	11:54 Local	**Direction from Accident Site:**	97°
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	6 knots / None	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	350°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.18 inches Hg	**Temperature/Dew Point:**	24°C / 12°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	ELIZABETH CITY, NC (NC98)	**Type of Flight Plan Filed:**	Company VFR
Destination:	DURHAM, NC (NC92)	**Type of Clearance:**	None
Departure Time:	11:08 Local	**Type of Airspace:**	Class G

Wreckage and Impact Information

Crew Injuries:	3 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:	1 Fatal	**Aircraft Fire:**	Both in-flight and on-ground
Ground Injuries:	N/A	**Aircraft Explosion:**	Unknown
Total Injuries:	4 Fatal	**Latitude, Longitude:**	36.290279,-76.487503

The helicopter impacted a shallow turf drainage pathway, which was about 30 ft wide and 2,000 ft long, located between two fields of 8-ft-tall grass near a wind turbine farm. The fuselage came to rest in a 7-ft-wide ditch in the center of the pathway and was oriented on a magnetic heading of 261°. There were no ground scars leading to or from the main wreckage.

Examination of the wreckage revealed that all of the major helicopter components were present at the accident site. The cabin had collapsed downward and was partially consumed by a postcrash fire. The tailboom remained largely intact. Flight control continuity was established from the cockpit area to the rotor systems and engines. The four main rotor blades and the two tail rotor blades remained attached to their rotor hubs. The No. 4 main rotor blade was found rotated about 180° in its hub with the pitch links fractured and partially melted. The outboard 4 ft of the No. 3 main rotor blade came to rest in the 8-ft-tall grass adjacent to the drainage path, and the grass on both sides of the blade was undisturbed. None of the main or tail rotor blades exhibited leading edge damage, chordwise scratches, or other evidence of rotation. The tail rotor shaft remained attached to the transmission, which could not be manually rotated.

The portion of the warning unit in the cockpit that contained the No. 2 engine fire warning light/button was located in the wreckage. Examination by the National Transportation Safety Board's (NTSB) Materials Laboratory in Washington, DC, revealed that the filaments in all four of the No. 2 engine fire warning light/button's light bulbs were stretched. The portion of the warning panel containing the No. 1 engine fire warning light/button was identified at the accident scene but was subsequently separated from the remaining section of the warning panel during recovery. The No. 1 engine fire warning light bulbs were not examined.

No foreign object damage was found on the axial compressor blades of both engines. No damage was observed on the visible portions of the turbine blades at the aft part of the engines. The gas generator of the No. 1 engine moved freely when manually rotated, whereas the No. 2 engine gas generator did not rotate.

The helicopter was also equipped with engine throttle twist grips on the pilot's collective control stick. Each twist grip had a lockout button that prevented the grip from being inadvertently rotated from FLIGHT to IDLE and from IDLE to OFF; the button had to be pressed to rotate the grip. The No. 1 engine grip was located at the top of the collective control tube, and the No. 2 engine grip was located immediately below the No. 1 grip (and closer to the hinge of the collective tube). Each grip had a different grooved pattern to manually distinguish one from the other. The No. 1 engine twist-grip throttle control was found in the OFF position. The No. 2 engine twist-grip throttle control was found in the FLIGHT position.

The No. 1 engine fuel control unit was found in the 0° (cutoff) position. The No. 2 engine fuel control unit was found in the 62° position, which was slightly beyond the 52° (flight) position.
The No. 1 engine fuel shutoff valve was found in the open position. The No. 2 engine fuel shutoff valve was damaged, and its position could not initially be determined. X-ray images of the valve by the NTSB's Materials Laboratory revealed that the valve was in the open position.
Engine No.1 disassembly and component examination did not reveal any discrepancies other than damage due to the crash and the post-crash fire. The No. 1 engine rear bearing oil return strainer/chip detector was absent of debris.

The No. 2 engine disassembly revealed that the gas generator shaft rear bearing was mechanically damaged. A detailed examination of the bearing at the engine manufacturer's laboratory revealed that all of the bearing roller elements were found seized (that is, none of the roller elements would rotate), with the outer bearing race, and had rubbed against the inner rotating bearing race. The roller elements appeared ground down (flattened) and overheated.

All of the oil supply pipes and restrictors and jet were found clear. The tubes to and from the rear bearing chamber (the oil supply tube, scavenge tube and vent tube) each contained a thin layer of coked oil, and were not obstructed.

Figure 2 compares the No. 2 engine rear bearing with the undamaged No. 1 engine rear bearing. Turbine components and the end of the No. 2 engine gas generator shaft exhibited rotational non-uniform damage. This damage was consistent with some continued rotation of the gas generator spool after the bearing had seized. (The turbine shaft supported by the rear bearing rotates at speeds up to 53,500 rpm.)

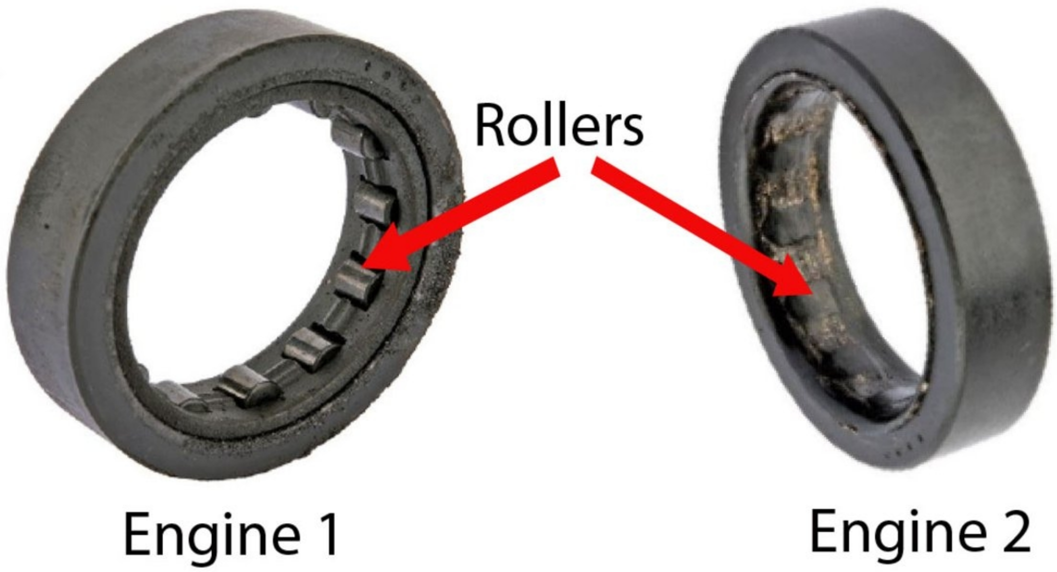

Figure 2 - Gas generator shaft rear bearings.

The No. 2 engine rear bearing oil return strainer/chip detector had carbon-like and ferrous debris in the strainer. Some debris particles were found bridging the gap between chip detector electrodes. The strainer was not completely obstructed by the debris.

Downstream of the rear bearing's casing, the oil return pipe and the suction stage of the oil pump also contained metallic debris. All the debris found in the suction stage were examined and were consistent with the constituents of components found in the oil system and in the rear bearing assembly. The oil pump, reduction gears and bearings did not show any indications of operation with lack of or insufficient lubrication.

The helicopter was equipped with two three-way union deck fittings (one for each engine bay) that routed the engines' two oil drain lines and the rear bearing housing vent line to the engine deck and then to an overboard port. The rear bearing vent line and one of the oil drain lines were attached to the ports of each fitting with elastomeric tubing and hose clamps. For these connections, an approved maintenance option allowed the installation of a shrink tubing jacket on the deck fitting nipples before the elastomeric tubing was attached over the shrink tube jacket. Damaged tubing remnants remained attached to the ports of the No. 1 engine three-way union deck fitting. The oil drain line ports and the rear bearing vent line port were completely blocked. Examination of the obstruction within each port by the NTSB's Materials Laboratory found that the material was consistent with that of the shrink tube jacket.

The No. 2 engine three-way union deck fitting ports had no obstructions. No tubing remained attached to the deck fitting ports. Examination of the fitting by the NTSB's Materials Laboratory determined that the fitting was exposed to temperature and time conditions sufficient to decompose the shrink tube jacket and elastomeric tubing materials.

Medical and Pathological Information

The North Carolina Department of Health and Human Services, Office of the Chief Medical Examiner, Raleigh, North Carolina, performed an autopsy of the pilot. His cause of death was blunt force injuries.

Toxicology testing performed at the FAA Forensic Sciences Laboratory was negative for carbon monoxide, ethanol, and all tested-for drugs.

The autopsy reports for the pilot, the medical crewmembers, and the patient did not note whether soot or smoke particles were found in their throats or respiratory systems.

Tests and Research

The helicopter's VEMD was found in the wreckage and was sent to the NTSB's Vehicle Recorders Division in Washington, DC. No usable data were recovered from the VEMD because the thermal damage to the nonvolatile memory chip precluded normal recovery procedures and additional attempts to yield usable data were unsuccessful.

Cockpit Indications

The metallic debris found in the No. 2 engine rear bearing strainer and electric chip detector was sufficient to trigger the circuit for the "ENG CHIP" caution. The "ENG CHIP" caution would have appeared in the No. 2 engine column of the Caution and Advisory Display (CAD) and associated with an audible (Gong).

Airbus Helicopters performed a computer simulation to determine what the FLI might theoretically indicate in the event of a gas generator rear bearing seizure in the No. 2 engine. The simulation assumed that the gas generator continued to rotate momentarily with damage to the high-pressure turbines and without friction in the seized rear bearing. Figure 3 shows a representation of the FLI before and during such a rear bearing seizure. Airbus Helicopters noted that this simulation depicted a snapshot of the simulated conditions and that, during operations, the needles would move and numeric values would fluctuate based on the engine parameters, the power applied, and the evolution of the bearing failure.

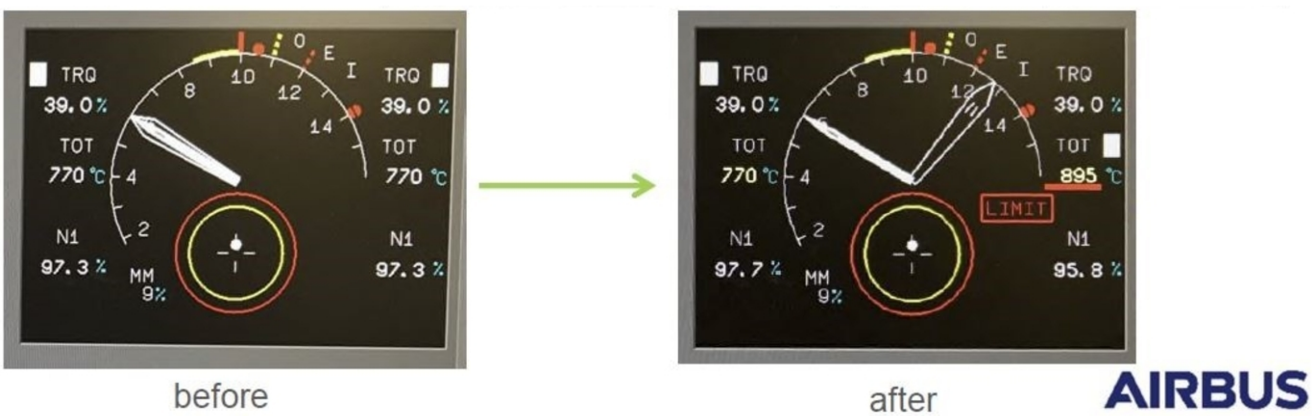

Figure 3 - Simulated FLI display before and during rear bearing seizure.

The left image of figure 3 shows the FLI with the engine operating normally, prior to a bearing seizure. Both FLI needles should depict TRQ because that would be the first limiting parameter for both engines in the flight conditions on the day of the accident. The needles would both indicate the same or nearly the same value for TRQ because both engines should produce about the same power, as the engines are TRQ balanced by the VARTOMS system. The simulation showed that, with a rear bearing seizure in the No. 2 engine, the engine's turbine outlet temperature would be elevated such that the TOT limit would be reached before the torque limit. Thus, an elevated turbine outlet temperature would result in the FLI changing to TOT for the No. 2 engine, as denoted by the white box for the No. 2 engine moving from the TRQ label (in the left image) to the TOT label (in the right image) and the position of the needle for the No. 2 engine changing. In addition, because TOT reached its limit, the digital value appeared with a red bar underneath it. The No. 1 engine would remain limited by TRQ, as indicated by the white box for the No. 1 engine next to the TRQ label (in the right image). As a result, a large split in the needles would occur because they would no longer indicate the same parameter for each engine, even though both engines would still be initially producing the same torque (39% in the figure).

The FLI page is displayed on the upper VEMD screen. The FLI zone indicates the TRQ, TOT and the N1 parameters in numerical values, along the left side of the display for engine No.1, and the right side of the display for engine No. 2. The parameter which is closest to its limit drives the analog pointer (needle) of the scale, and it is marked by a solid white rectangle next to the parameter label.

The limiting parameter adherent to the white rectangle mark is additionally underlined yellow if in the caution range. The underlining changes to a flashing red color if a limit is reached, and this is associated with a ´Gong` in order to raise attention with the pilot.

According to Airbus Helicopters, an FLI indication showing one engine limited by TRQ and the other limited by TOT in cruise flight, although accurate, would be unusual and unexpected.

Normally, the FLI needles display TOT during engine start only, at which time the symbols on the outside of the needle scale change to indicate the TOT limits and safe operating range.
This scenario, in which one of the FLI needles changes to indicate TOT while the other remains indicating TRQ during cruise flight, is not presented in the training materials created and used by Airbus for factory courses teaching pilots and maintenance technicians about the aircraft systems. It is also not specifically covered in the FLM. AMC's FAA approved Pilot Training Program utilizes information from Airbus factory courses to and the FLM to develop its courseware and content. According to AMC, this situation was also not discussed in any of the company's training materials or demonstrated during its training program because it was never covered or emphasized in any of the Airbus courseware. However, the FLM and Airbus training procedures do provide guidance for common emergencies, including FLI needle splits, engine failures, and procedures for the ENG PA DIS (engine parameter discrepancy) caution message (described below). The guidance also includes three basic airmanship rules:

1. Maintain aircraft control
2. Analyze the situation
3. Take proper action

The simulation also showed that an ENG PA DIS amber caution message may appear for both engines on the caution and advisory display panel, as shown in the left image of figure 4, due to the difference in TOT between engine Nos. 1 and 2. The ENG PA DIS caution message is displayed whenever a significant difference between each engine's TOT, TRQ, or N1 is detected, or when the signal from any of these parameters is lost. For TOT, the threshold to trigger the ENG PA DIS caution is a difference of greater that 80° C between engine 1 and engine 2. Even though the ENG PA DIS message appears in both engine columns on the CAD display, the CAD display does not indicate which parameter was detected or which engine was affected. As a result, the pilot would need to refer to the FLI parameters to determine which engine is affected, as shown in the right image of Figure 4. Figure 4 shows the TOT on the right engine is the limiting parameter, and during the event, it was likely to have appeared in the right (engine 2) column of the CAD (note that the "ENG CHIP" caution activation was not part of the simulation, and is not displayed in the figure). The FLM procedure for the ENG PA DIS message is "do not try and match needles, avoid using maximum power, compare the numeric values on the FLI to verify the affected parameter, and land as soon as practicable." The ENG PA DIS procedures do not request the pilot to shut down the engine.

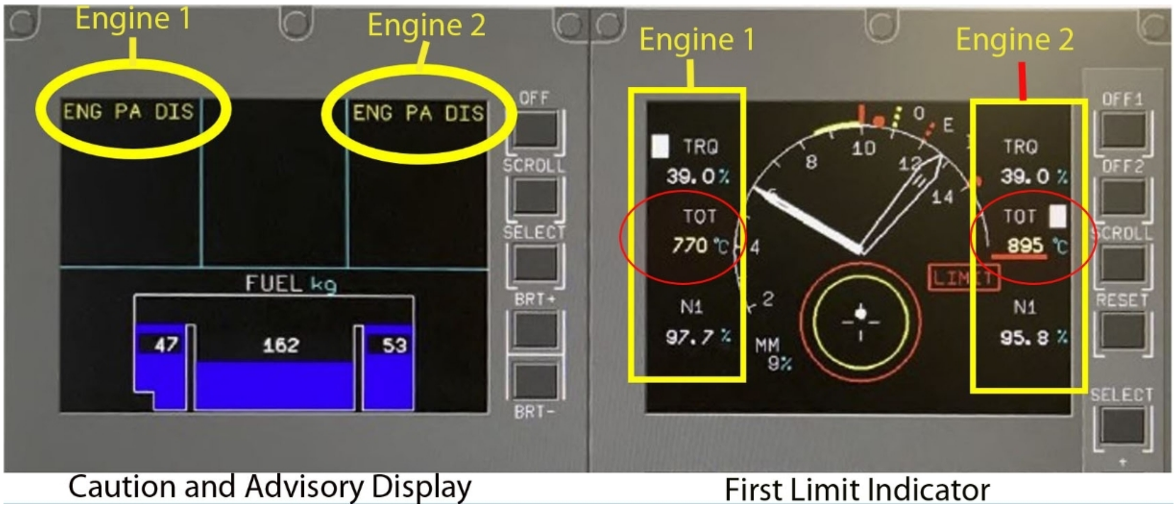

Figure 4 - Caution and advisory display panel (left) and FLI (right) showing affected engine and parameter.

When the ENG PA DIS caution is displayed in this situation, the master caution light also illuminates and simultaneously:

- The TOT rectangle turns white,
- The TOT value is underlined in red
- The LIMIT warning comes on
- An audio ´GONG´ sounds

According to Safran, a rise in TOT would be expected as the rear bearing deteriorates. The deterioration would result in excessive play in the gas generator shaft, causing components to rub, and a reduction in engine efficiency. As a result, the fuel controller would add fuel to compensate, resulting in a higher TOT. This reduction in efficiency may also result in smoke from the engine's exhaust.

The ENG CHIP and ENG PA DIS messages can be cleared from the display by the pilot via a button on the cyclic control.

Additionally, in the event that a difference in torque between the two engines is detected that exceeds 15%, the VAR NR caution message will appear in the center of the CAD, and the MAN button on the VARTOMS panel will illuminate in amber, indicating that the VARTOMS system should be switched to manual mode, and the pilot must manually match the engines torques. The VAR NR caution message will also illuminate if a problem is detected with the VARTOMS system (or other systems it is dependent upon) or if the rotor speed is not with the expected limits.

Further, if a difference in N1 between the 2 engines is detected that exceeds 10%, the ENG SPLIT caution message will appear in both engine columns on the CAD. The FLM procedure for an ENG SPLIT caution message is to adjust the collective lever to OEI limits or below, turn off bleed air consumers, and analyze engine conditions.

Additional Information

Flight Data Monitoring Device

The helicopter was equipped with a North Flight Data Systems OuterLink Voice and Video Recorder, which was designed to capture video, audio, and parametric flight data. The recorder was installed voluntarily by the operator as a flight data monitoring device.

The device was found in the wreckage and was sent to the NTSB's Vehicle Recorders Division. The device's memory card was not damaged, but no usable data could be retrieved, including recordings of the accident flight. The manufacturer of the device indicated that its internal replaceable battery might have expired, which would have prevented new data from being properly stored on the memory card.

The helicopter was not equipped, and was not required to be equipped, with a crashworthy flight data recorder or cockpit voice recorder.

Anomalous Fire Indications

A review of AMC records revealed two reports of spurious engine fire indications in other MBB BK117 C2 helicopters, one in July and the other in October 2017. In those events, the fire light illuminated either intermittently or solidly, and was accompanied by the aural warning. No evidence of an actual fire was found in either case.

Engine Oil Analysis Program

AMC's helicopter maintenance program included a spectrometric oil analysis program (SOAP). Oil samples were taken from each helicopter engine every 100 hours and sent to a laboratory for analysis. The last six laboratory reports, from November 2016 to August 2017, for each engine on the accident helicopter revealed that the No. 2 engine had consistently higher concentrations of iron than the No.1 engine. Iron is the primary constituent of bearings and gears. Specifically, examination of the laboratory results for the No. 2 engine revealed that the concentration values for iron (corrected for fluctuations in oil quantity) ranged from 2.25 to 6.75 parts per million (ppm), with the concentration values increasing and decreasing over time and nearly doubling from 3.20 to 6.20 ppm between February and May 2017 (the helicopter had accrued 91 flight hours between these two samples). The laboratory results during the same time period for the No. 1 engine ranged from 0.06 to 0.50 ppm.

The engine manufacturer's alert criteria to provide closer monitoring (such as trending analysis of SOAP results) or to perform more frequent inspections was 7.5 ppm for corrected iron concentration values. Thus, the results for the No. 2 engine were below the engine manufacturer's alert criteria.

AMC considers adding oil as normal service and does not require tracking the amount added in the record of maintenance. Mechanics may include the information in the maintenance logbook but are not required to do so, and pilots can be trained and authorized to add engine oil as well but are not required to do so or record the amount. A comparison of the SOAP test sheets with the aircraft flight logbook entries for oil additions, the quantities of oil added did not match. Accurate SOAP analyses require an accounting of oil added between successive oil samples taken for testing.

Administrative Information

Investigator In Charge (IIC):	Brazy, Douglass
Additional Participating Persons:	Matt Rigsby; FAA; Washington, DC Jason Quisling; Air Methods Corporation; Englewood, CO Bryan Larimore; SAFRAN Turbomeca; Grand Prairie, TX Seth Butner; Airbus Helicopters; Grand Prairie, TX
Original Publish Date:	January 28, 2021
Last Revision Date:	
Investigation Class:	Class 2
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=95967