Aviation Investigation Final Report

Location:	Palm Bay, Florida	**Accident Number:**	ERA16FA311
Date & Time:	September 6, 2016, 13:40 Local	**Registration:**	N805AR
Aircraft:	Sikorsky S61	**Aircraft Damage:**	Destroyed
Defining Event:	Loss of engine power (total)	**Injuries:**	3 Fatal
Flight Conducted Under:	Part 91: General aviation - Flight test		

Analysis

The helicopter flight crew, consisting of a pilot, copilot, and maintenance crewmember, was performing 20-knot rearward flight about 200 ft above ground level as part of a post-maintenance functional check flight (FCF). While the pilot was flying and recovering from the first rearward flight maneuver, unusual sounds were heard, which the flight crew identified as a compressor stall. The pilot then told the maintenance crewmember that they were returning to their home airport; however, after discussing compressor stalls and engine exhaust gas temperatures with the copilot, the pilot changed his mind and told the maintenance crewmember that they were going to try the maneuver again in a different direction relative to the wind (with the wind off the nose). While the pilot was recovering from the second rearward flight maneuver, there was a change in background noise, which the maintenance crewmember identified as a compressor stall. About 2 seconds later, there was another change in background noise, consistent with a decay in drivetrain rpm, which was followed by the helicopter descending and impacting the ground.

Although the crew identified the sounds and loss of power as compressor stalls, a sound spectrum study could not characterize the gas generator speed (Ng) behavior, due to overdriven audio on the CVR, to determine the engine anomaly the crew identified as a compressor stall. It is likely that the cause of the overdriven audio is related to an engine anomaly. At the same time the engine anomaly occurred, the sound spectrum revealed Nr quickly decayed due to a dual loss of engine power coupled with a high collective setting. Because main rotor speed (Nr) decayed at the same time the overdriven audio occurred, it is likely both engines lost power nearly simultaneously. No anomalous damage to the engines was found that would have explained the dual loss of engine power and the main rotor drive system did not exhibit evidence of preimpact mechanical malfunction. Fuel exhaustion was unlikely given the estimated fuel load at the time of the accident. After the overdriven audio, the rate of Ng decay for each engine appeared similar to engine Ng decay when at a lower power setting. Due to a lack of a flight data recorder or a cockpit image recorder, the behavior of the engines as well as the position of the cockpit engine control levers at the time of the anomaly could not be determined.

During postaccident examination, the left (No. 1) freewheeling unit (FWU) was found to rotate freely in both directions of rotation instead of rotating freely in only one direction as it was designed to do. Had the left FWU failed in flight resulting in a loss of drive between the No. 1 engine and the main gearbox, the No. 1 engine power turbine would have experienced an overspeed due to the sudden loss of load. A No. 1 engine power turbine overspeed would also have resulted in an overspeed of the AC generators due to a through shaft connecting the left FWU and the AC generators. However, during the accident loss of power event, the frequencies of the main gearbox planetary mesh and the AC generators did not diverge but remained synced, which is not consistent with a left FWU overspeed. Therefore, the anomalous finding of rotation in both directions for the left FWU is likely a postaccident artifact.

Review of the rotorcraft flight manual (RFM) emergency procedures revealed, "2. If an abnormal engine conditions occurs such as engine stall, flame-out, or overtemperature, transition to single engine flight or landing…."

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:
A dual loss of engine power for undetermined reasons after the pilot's improper decision to attempt another maneuver after recovering from a perceived compressor stall, rather than returning to the airport.

Findings

Aircraft	(general) - Not specified
Not determined	(general) - Unknown/Not determined
Personnel issues	Decision making/judgment - Pilot

Factual Information

History of Flight

Maneuvering-low-alt flying	Loss of engine power (total) (Defining event)
Uncontrolled descent	Collision with terr/obj (non-CFIT)

On September 6, 2016, about 1340 eastern daylight time, a Sikorsky S-61N, N805AR, was destroyed when it impacted a field after experiencing a dual loss of engine power while in a hover near Palm Bay, Florida. The airline transport pilot, the commercial-rated copilot, and the maintenance crewmember were fatally injured. The helicopter was registered to EP Aviation LLC and was being operated by AAR Airlift Group under the provisions of Title 14 *Code of Federal Regulations* Part 91 as a post-maintenance flight. Visual meteorological conditions prevailed, and a company visual flight rules flight plan was filed for the local flight that departed Melbourne International Airport (MLB), Melbourne, Florida, at 1324.

According to the operator, the helicopter's fore/aft pitch servo had recently been removed and replaced. Subsequently, three functional check flights (FCF) were required to be completed. Two FCFs were completed uneventfully the day of the accident, and the crewmembers were conducting the final FCF when the accident occurred. One of the maneuvers to be performed during the final FCF was rearward flight at a computed airspeed of 20 knots. According to the cockpit voice recorder (CVR), the flight crew performed two of these rearward FCF maneuvers during the accident flight.

Video taken by a ground witness recorded the helicopter performing the first rearward maneuver about 200 ft above ground level. Correlation of the video to the CVR showed the helicopter flying rearward at 1337:25, when the copilot stated the rear speed was 15 knots. At 1337:40, the helicopter continued to fly rearward as the copilot stated the rear speed was 20 knots. Two thumping sounds were recorded on the CVR at 1337:42 and 1337:44, when the rear speed was about 31 knots, but corresponding sounds could not be identified in the ground witness video. The ground witness video then showed the nose of the helicopter pitch down as the helicopter transitioned from rearward flight to a forward left 90° turn and continued forward in straight and level flight. During the recovery maneuver, an event occurs which caused a 2-second region of overdriven audio to be recorded on the CVR. This occurred during the left pedal turn and while the helicopter was approaching 90° to the rearward flightpath. The helicopter then flew an orbit in increasing altitude, and the video ended.

According to the CVR, the pilot took over control of the helicopter at 1336:41 and the copilot, who was receiving flight training on the day of the accident, identified the thumping sounds as a compressor stall, and the pilot agreed. The pilot then told the maintenance crewmember that they were returning to MLB. At 1338:02, the flight crew discussed the perceived compressor stall and engine exhaust gas temperatures. Then at 1338:26, the pilot told the maintenance crewmember that they were going to try the maneuver again in a different direction relative to the wind (with the wind off the nose), and the maintenance crewmember stated that it was okay with him. At 1339:46, the pilot was recovering from flying rearward when there was a change in background noise, which the maintenance crewmember identified as a compressor stall. The audio for the cockpit area microphone was overdriven again from about 1339:45 to 1339:48. At 1339:48, the copilot stated that the "AFCS is back on" while there was another change in background noise consistent with a decay in drivetrain rpm. The recording ended at 1339:55.

There were no known witnesses to the impact.

Pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	57,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane; Helicopter	**Second Pilot Present:**	Yes
Instructor Rating(s):	Helicopter; Instrument helicopter	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 None	**Last FAA Medical Exam:**	December 5, 2015
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	May 18, 2016
Flight Time:	6347 hours (Total, all aircraft), 1780 hours (Total, this make and model), 4754 hours (Pilot In Command, all aircraft), 114 hours (Last 90 days, all aircraft), 25 hours (Last 30 days, all aircraft), 0 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Commercial	**Age:**	45,Male
Airplane Rating(s):	None	**Seat Occupied:**	Right
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	4-point
Instrument Rating(s):	Helicopter	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	May 16, 2016
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	4090 hours (Total, all aircraft), 1 hours (Total, this make and model), 3419 hours (Pilot In Command, all aircraft), 1 hours (Last 90 days, all aircraft), 1 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

The pilot in the left seat held an airline transport pilot certificate with a rating for rotorcraft helicopter and commercial privileges in airplane single- and multi-engine land and instrument airplane. In addition, the pilot held a flight instructor certificate with ratings for rotorcraft helicopter and instrument rotorcraft. The pilot's most recent Federal Aviation Administration (FAA) first-class medical certificate was issued on December 5, 2015. According to the operator, the pilot was hired in 2012 and completed all required company training. At the time of the accident, he had accrued a total flight experience of about 6,347 hours of which 5,743 hours were in helicopters and 1,780 of those hours were in the same make and model as the accident helicopter. The pilot had flown 114 hours and 25 hours during the 90-day and 30-day periods preceding the accident, respectively; all of these hours were flown in the same make and model as the accident helicopter.

The copilot in the right seat held a commercial pilot certificate with ratings for rotorcraft helicopter and instrument helicopter. His most recent FAA second-class medical certificate was issued on May 16, 2016. According to the operator, the copilot was hired on July 31, 2016. He had completed company-required ground training and was in the process of completing flight training at the time of the accident. The copilot had accrued a total flight experience of 4,090 hours, all of which were in helicopters. Before the day of the accident, he did not have any flight experience in the same make and model as the accident helicopter but was qualified to act as second-in-command.

Aircraft and Owner/Operator Information

Aircraft Make:	Sikorsky	**Registration:**	N805AR
Model/Series:	S61 N	**Aircraft Category:**	Helicopter
Year of Manufacture:	1974	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	61717
Landing Gear Type:	Tricycle	**Seats:**	41
Date/Type of Last Inspection:	August 25, 2016 Continuous airworthiness	**Certified Max Gross Wt.:**	22000 lbs
Time Since Last Inspection:	1 Hrs	**Engines:**	2 Turbo shaft
Airframe Total Time:	40296 Hrs as of last inspection	**Engine Manufacturer:**	GE
ELT:	C126 installed, activated, did not aid in locating accident	**Engine Model/Series:**	CT58-140-2
Registered Owner:	EP Aviation LLC	**Rated Power:**	1500 Horsepower
Operator:	AAR Airlift Group	**Operating Certificate(s) Held:**	Commuter air carrier (135), On-demand air taxi (135)
Operator Does Business As:		**Operator Designator Code:**	39LA

The 41-seat capacity, tricycle-gear helicopter, serial number 61717, was manufactured in 1974. It was powered by two 1,500-horsepower General Electric CT58-140-2 turboshaft engines. The helicopter was maintained under a continuous airworthiness program. Its most recent inspection was a phase five check, which was completed on August 25, 2016. At that time, the airframe had accumulated 40,296.2 total hours of operation. The No. 1 engine had accumulated 708.9 hours since major overhaul (23,235 hours since new), and the No. 2 engine had accumulated 4,520.2 hours since major overhaul (26,259 hours since new). Following the phase five check, the helicopter had flown about 1.2 hours during the two previous FCFs. At the end of the second flight, prior to the accident flight, the flight crew reported total fuel onboard was 2,200 lbs.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	MLB,33 ft msl	**Distance from Accident Site:**	10 Nautical Miles
Observation Time:	13:53 Local	**Direction from Accident Site:**	15°
Lowest Cloud Condition:	Few / 5000 ft AGL	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	11 knots /	**Turbulence Type Forecast/Actual:**	None / None
Wind Direction:	70°	**Turbulence Severity Forecast/Actual:**	N/A / N/A
Altimeter Setting:	30.14 inches Hg	**Temperature/Dew Point:**	30°C / 21°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Melbourne, FL (MLB)	**Type of Flight Plan Filed:**	Company VFR
Destination:	Melbourne, FL (MLB)	**Type of Clearance:**	None
Departure Time:	13:24 Local	**Type of Airspace:**	

At 1353, the recorded weather at MLB, which was located about 8 miles north of the accident site, included wind from 070° at 11 knots, visibility 10 miles, and few clouds at 5,000 ft.

Wreckage and Impact Information

Crew Injuries:	3 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:		**Aircraft Fire:**	On-ground
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	3 Fatal	**Latitude, Longitude:**	27.940555,-80.704719

The helicopter came to rest upright in a field with no debris path noted. The wreckage was oriented on a magnetic heading of about 190°. A postcrash fire consumed the cockpit and cabin. The tail boom transition section exhibited partial thermal damage, and the tail boom remained intact. The five main rotor blades and the five tail rotor blades remained attached to their respective rotor hubs. The main and tail rotor blades exhibited signatures consistent with low rotational energy at ground impact. Four of the five main rotor blades exhibited partial thermal damage, and one main rotor blade exhibited thermal damage along its entire span. One tail rotor blade was fractured about 1 ft outboard of the attachment bolt; the outboard section of the separated blade was found on the ground next to the tailrotor. Another tail rotor blade was partially separated about 1 ft outboard of the attachment bolt, and its tip was embedded in the ground. Drivetrain continuity was confirmed between the main transmission and the tail rotor gearbox.

Both engines remained attached to the airframe and exhibited fire damage. Examination of the engines revealed that the first stage compressor blades of both engines exhibited little or no leading-edge damage. Both engine fuel control units were found with their respective control shafts in the "FLIGHT" position. Both engines were separated from the main gearbox at the aft end of the high-speed shaft. A boresope inspection of the helicopter's main gearbox was performed. No evidence of thermal damage was observed on the internal components of the main gearbox, and the interior coatings appeared in good condition. The gear teeth exhibited normal wear patterns consistent with typical service wear. No anomalous damage was observed with the gears and bearings. Additionally, the main rotor drive system was evaluated for continuity and all components operated normally. Manual rotation of the rotor brake disk resulted in corresponding movement of the main rotor head, tail takeoff pinion, No. 1 tail rotor drive shaft, and the two input pinion splined couplings (normally attached to the aft end of the high-speed shafts).

Freewheeling Units (FWU)

The left and right FWUs were subsequently examined at the manufacturer's facility. The ramp-roller clutch engaged on the right FWU when rotated in the drive direction and disengaged when rotated in the freewheeling direction. No anomalous damage was observed on the right FWU.

When the left FWU was rotated, the ramp-roller clutch remained disengaged and freewheeled in both directions of rotation. The splined nut was removed and exhibited no anomalous damage. Additionally, the ramps, roller elements, bearing cage, and bearing outer race did not exhibit anomalous damage. Further examination of the left FWU revealed that both bearing cage pins were observed to be in the retracted position. The bearing cage pin housings were labeled "A" and "B" for identification purposes. When both pin assemblies were removed from the bearing cage, each pin remained contained (and retracted) within its sleeve. Circumferential scoring was observed within the inner diameter of the bores that housed the bearing cage pin sleeves. Pin "A" was removed from the sleeve by pushing an Allen key through the hole at the rear end of the sleeve. Resistance was felt when pushing the pin out of the sleeve. Once the pin was pushed out, the spring exited the sleeve. The pin and spring were reinstalled into the sleeve, and subsequent compression of the pin resulted in normal operation of the pin-and-spring mechanism. Pin "B" was not disassembled and remained in its compressed position for X-ray examination. Circular contact marks were seen on the bearing cage tangs, consistent with bearing cage pin contact with the tangs during impact forces. The circular contact marks were more pronounced compared to those observed on the right FWU.

No. 1 Engine

A teardown examination of both engines was performed at an independent helicopter facility.

Application of 25 foot-pounds (ft-lbs) of torque on the No. 1 engine starter dog (jaws) did not result in any movement of the engine core. Removal of the stator vane actuator (SVA) pilot valve cover revealed that the feedback cable remained connected to the pilot valve arm. The pilot valve exhibited no anomalous damage. The SVA pilot valve internal housing exhibited witness marks consistent with contact with the helical exterior of the feedback cable. The feedback cable could not be manually actuated and was found in a position consistent with the SVA in the closed position. The SVA housing was melted off from its piston, and remnants of the melted actuator housing were observed below its normally installed location.

After removal of the accessory gearbox (AGB), application of 25 ft-lbs of torque on the starter dog did not result in any movement of the engine core. Attempting to manually rotate the AGB using the radial drive shaft was unsuccessful. The centrifugal fuel purifier (CFP) was removed from the AGB, and its external drive splines exhibited no anomalous damage. After removal of the CFP, manual rotation of the AGB resulted in minimal rotation with evidence of binding. The lubrication pump was removed, and both its internal and external splines exhibited no anomalous damage. The lubrication pump was not able to be manually rotated. The fuel control was removed, and the splined connection between the fuel control and fuel pump exhibited no anomalous damage. Thermally degraded O-rings were observed when the fuel control was removed from the fuel pump. After removal of the fuel control, manual rotation of the AGB resulted in limited rotation and a corresponding rotation of the drive splines to the lubrication pump and the CFP but not to the fuel pump-to-fuel control drive splines. During removal of the fuel pump from the AGB, one of the six studs separated and was retained in its mounting flange. The fuel pump could not be manually rotated. After fuel pump removal, manual rotation of the AGB was successful and resulted in a corresponding rotation of the drive splines for the fuel pump, lubrication pump, and CFP. The fuel pump external splines exhibited no anomalous damage. The front frame accessory drive gears did not exhibit anomalous damage. At this point in the engine disassembly, manual rotation of the starter dog was successful and resulted in corresponding rotation of the accessory drive internal spline (normally mating to the AGB radial drive shaft).

The second stage turbine rotor was removed, and its blades exhibited no anomalous damage or erosion. All blades were present, and both sides of the blades exhibited evidence of soot deposits. The first stage turbine rotor was removed, and its blades exhibited no anomalous damage or erosion. All blades were present, and both sides of the blades exhibited evidence of soot deposits with heavier soot deposits observed on the blades around the 12 o'clock position. Separation of the compressor case halves revealed all 10 stages of the compressor rotors, after which the compressor spool (with the front frame and rear frame still attached) could be manually rotated. All compressor blade surfaces exhibited soot deposits. The compressor blades did not exhibit evidence of damage consistent with hard or soft body foreign object debris ingestion or severe erosion. The six compressor stator stages exhibited no evidence of anomalous damage. Soot deposits were observed on the inlet guide vanes (IGV), all three stages of variable guide vanes (VGV), and the six stages of stators. From the 3 o'clock to the 6 o'clock region, the VGV tips were scored in the area between the second, third, and fourth stages. Impressions of the stator vanes were observed on the soot deposits on the compressor spool surfaces. Very light impressions of the last two stages of the VGV were observed on the soot deposits on top of the spool surfaces but impressions of the first stage of VGV and IGV were not observed on the soot deposits on the compressor spool surfaces. The power turbine blades did not exhibit evidence of anomalous damage or severe erosion; the blades exhibited discoloration, and the surfaces exhibited a rough appearance in areas that were not coated with soot.

The fuel pump cover was removed, revealing a thermally degraded gasket underneath the cover. The front coupling external and internal splines exhibited no evidence of wear. The internal splines exhibited a rust-colored residue on a portion of its outer diameter. The front (muff) coupling adapter splines exhibited no anomalous damage. Removal of the front cover revealed white-colored deposits consistent with corrosion; however, all components were subject to postcrash firefighting efforts and then stored in an open hangar before examination. A thermally degraded gasket was observed underneath the front cover. Two small, metallic globules were found underneath the front cover. A plug covering a port normally used for testing was removed, and a thermally degraded O-ring was found underneath the head of the plug.

The rear cover was removed, revealing corrosion and thermal discoloration within the interior surfaces of the pump. Red-colored deposits were seen on the boost drive gear outer surfaces and about half of the gear web surfaces. The three shear posts were intact. The internal splines of the rear coupling, connected to the boost drive gear, exhibited no anomalous damage. The rear coupling was removed, and the retaining ring was still in its installed position. The driveshaft splines mating to the rear coupling exhibited no anomalous damage. Red-colored deposits were observed on the contact surface of the boost driven gear teeth, but none were observed on the non-contact side of the gear teeth. The booster driven gear bearing support contained white-colored deposits consistent with corrosion. The pump drive gear and driven gear teeth contained red-colored deposits. Small, metallic globules were found throughout the inner surfaces of the drive and driven gear body and cover bearings (where the gear face contacts its bearings). Removal of the drive and driven gear resulted in axial scoring of the pump housing. The drive gear splines exhibited no anomalous damage.

The impeller, with the boost driven gear still attached, could not be removed from the pump housing. A borescope was inserted through the fuel inlet port to examine the impeller. The leading edge of an impeller blade was visible along with red-colored deposits adjacent to the visible impeller blade.

No. 2 Engine

After removal of the AGB, the application of 25 ft-lbs of torque on the No. 2 engine starter dog did not result in movement of the engine core.

The lubrication pump was removed and the internal and external pump drive splines exhibited no anomalous damage. The lubrication pump was not able to be manually rotated. The fuel control was removed, and the fuel pump-to-fuel control drive splines (both internal and external splines) did not exhibit anomalous damage. Thermally degraded O-rings were found when the fuel control was removed from the fuel pump. The fuel pump drive splines did not exhibit anomalous damage. A gasket on the fuel pump flange of the accessory gearbox exhibited impressions that mirrored the contact surface of the fuel pump. After removal of the fuel pump, neither the fuel pump nor the accessory gearbox were able to be manually rotated by hand. The front frame accessory drive gears did not exhibit anomalous damage. At this point, the starter dog was able to be manually rotated and exhibited continuity of drive to the accessory drive internal splines (which mates to the AGB radial drive shaft).

The second stage turbine blades exhibited no evidence of anomalous damage. The first stage turbine case was removed, and the shroud did not exhibit evidence of rubbing or blade contact marks. Staining of the shroud, in the shape of turbine blade airfoils, was observed around the circumference of the shroud. The second stage nozzle was removed and exhibited cracks near the leading edge root end of the nozzle vanes. The cracks were more extensive on three vanes centered about the 12 o'clock position. A crack was also observed on the trailing edge tip end of the nozzle vane. The cracks were measured to be about 3/8 inch in length. The first stage turbine blades did not exhibit anomalous damage. Separation of the compressor case halves revealed all 10 stages of the compressor rotors. Slight bending deformation in the direction opposite of normal rotation was observed on several compressor blades from various stages. Corrosion was observed on the vanes of the IGV and all three stages of the VGV. The spool face for the third stage VGV, between compressor stages 3 and 4, exhibited evidence of rubbing; corresponding rub marks were observed on seven of the vanes on the third stage VGV. The rubbing on the spool face was of negligible depth and could not be measured with calipers. Additionally, the spool face between compressor stages 5 and 6 exhibited evidence of rubbing of negligible depth. The remaining six stages of stators did not exhibit anomalous damage.

The front coupling splines and muff adapter did not exhibit anomalous damage. Remnants of a thermally degraded gasket and bellows were observed after removal of the front coupling from the fuel pump housing. After the pump cover was removed, a thermally degraded O-ring as well as small metallic globules on the cover bearings were found. The O-rings around the pump cover bearings were thermally damaged and exhibited a tackiness when touched. The rear cover was removed from the pump housing. The booster drive and driven gears showed no anomalous damage. All three shear posts on the booster drive gear remained intact. The drive gear hub exhibited areas of red discoloration. The driveshaft exhibited no anomalous damage. No evidence of blockage was found on the pressurized fuel outlet. Small metallic globules were found on the pump gears and bearings. The pump gears and the impeller exhibited no anomalous damage, but the gear teeth exhibited an iridescent coloration.

No.1 Fuel Control

Soot was present on the exterior of the fuel control housing. There was no evidence of cracks, fractures, or melting of the housing. The retaining clip for the pressure regulating valve (PRV) housing was fractured at one of its ends, but lockwire remained attached to the fractured retaining clip end. Lockwire was present on the bolts securing the PRV housing to the fuel control. The fuel density adjustment dial tab was bent upward, and the tab was offset from the dial hard stop by about 40°. The PRV dial was at the JP-5 setting.

The gas generator speed (Ng) governor splines remained intact and the shaft exhibited axial and radial play when manipulated by hand. The disassembly technician noted that the shaft play was typical for the fuel control. When the power turbine speed (Nf) tachometer drive cable was manually rotated, the rotation was limited to twisting of the drive cable, and the drive cable would not rotate freely.

The SVA rod protrusion from the housing was measured to be about 0.883 inches. The position of the emergency throttle was measured to be about 1.695 inches in depth. The flattened surface between the two emergency throttle rack gears was observed between the rack gear housings. The rack gears remained pinned together. The rack and pinion gears exhibited corrosion on its surfaces, but their gear teeth exhibited no other anomalous damage. Additionally, the cam did not exhibit anomalous damage.

The end cap was removed, revealing the minimum flow stop. The metering valve support was able to be rotated by hand; the metering valve support is normally torqued to 110 inch-pounds (in-lbs) at overhaul. The metering valve support inner diameter surfaces exhibited corrosion. The metering valve support was removed, revealing the metering valve. The metering valve surfaces exhibited corrosion. The position of the metering valve relative to the housing was about 3.56 inches, consistent with a lower power setting or engine spooldown. An attempt was made to move the metering valve by hand, but the metering valve appeared seized. Removal of the metering valve revealed the flow window opening was consistent with the metering valve being at the minimum flow stop. The spool and sleeve of the metering valve exhibited corrosion on its surfaces, and the spool was seized within its sleeve.

The cover of the fuel control was removed, revealing the internal components of the fuel control. Generally, corrosion was visible throughout the surfaces of the internal components, but the visible components did not exhibit fractures or disconnection. All components exhibited freedom of movement except for the three-dimensional (3D) cam and the Ng governor gear. According to the disassembly technician, the internal configuration and condition of the fuel control appeared typical aside from the corrosion and thermal damage. The 3D cam was about at the ground idle position. The rack gear that rotates the 3D cam was found positioned to the end of the rack gear consistent with elevated ambient temperatures. The compressor discharge pressure (P3) bellows was vacuum tested and successfully held a vacuum for 1 minute.

No. 2 Fuel Control

Soot was present on the exterior of the fuel control housing. There was no evidence of cracks, fractures, or melting of the housing, but several of the external bosses exhibited small dents. The retaining clip for the PRV housing was intact, and lockwire was present on the bolts securing the PRV housing to the fuel control. The fuel density adjustment dial tab was not bent, and the tab was offset from the dial hard stop by about 40° to 45°. The PRV dial was at the JP-5 setting.

The Ng governor splines remained intact, and the shaft exhibited axial and radial play when manipulated by hand. The disassembly technician noted that the shaft play was typical for the fuel control. When the Nf tachometer drive cable was manually rotated, the rotation was limited to twisting of the drive cable, and the drive cable would not rotate freely.

The SVA rod protrusion from the housing was measured to be about 0.965 inches. The SVA rod could be manually pushed downward. The SVA feedback arm was free to move and exhibited continuity to the rocker within the pilot valve assembly. On the fuel control throttle, the gap between the throttle maximum stop and throttle pad surface was measured. That measurement was replicated on an exemplar fuel control on a test bench, and the throttle position was found to be about 85°. The position of the emergency throttle was measured to be about 1.698 inches in depth. The flattened surface between the two emergency throttle rack gears was observed between the rack gear housings. The rack gears remained pinned together. The rack and pinion gears did not exhibit anomalous damage. Additionally, the cam did not exhibit anomalous damage. The pinion gear and cam rotated freely.

The end cap was removed, revealing the minimum flow stop. Based on the relative position of the pin to the minimum flow adjustment screw stop, the metering valve appeared to be at the minimum flow stop. The maximum flow stop was removed and exhibited thermal distress and corrosion on its surface. Remnants of thermally degraded packing and the backup ring were observed in the grooves in which they are normally installed. The sleeve and boss were removed and exhibited thermal distress and corrosion on its surfaces. The metering valve support was able to be rotated by hand; the metering valve support is normally torqued to 110 in-lbs at overhaul. The metering valve support was removed, revealing the metering valve. The metering valve surfaces exhibited corrosion, but relatively less corrosion compared to the No. 1 fuel control metering valve. The position of the metering valve relative to the housing was about 3.615 inches, consistent with a low power setting or engine spooldown. The spool and sleeve of the metering valve did not exhibit corrosion to the extent observed on the spool and sleeve of the No. 1 fuel control metering valve. The packing was present on the valve but was hard to the touch. The metering valve spool was seized within its sleeve.

The cover of the fuel control was removed, revealing the internal components of the fuel control. Generally, the surface condition of the internal components did not exhibit corrosion to the extent observed on the No. 1 fuel control. The internal components did not exhibit fractures or disconnection. All components exhibited freedom of movement. According to the disassembly technician, the internal configuration and condition of the fuel control appeared typical to those seen at overhaul. The 3D cam was at a relatively higher axial position compared to the 3D cam of the No. 1 fuel control. The 3D cam was also positioned about mid-travel on its rack gear. The P3 bellows was vacuum tested and successfully held a vacuum for 1 minute.

(For more information, see the Airworthiness Group Chairman's Factual Report in the public docket for this accident.)

Flight recorders

The helicopter was equipped with a Universal CVR-120 solid-state CVR that recorded 120 minutes of digital audio. Specifically, it contains a two-channel recording of the last 120 minutes of operation and a four-channel recording of the last 30 minutes of operation. The four channels that should have been recorded during the last 30 minutes of operation were; one for the pilot, one for the copilot, one for the maintenance crewmember, and one for the cockpit area microphone (CAM). However, only two channels were recorded on the accident CVR during the last 30 minutes, with one channel being the CAM and the other channel a mix of pilot, copilot, and maintenance crewmember. The helicopter was not equipped with a flight data recorder nor was it required to be.

The CVR exterior sustained heat and fire damage, but the interior crash-protected case did not sustain damage. The memory board did not exhibit heat damage; however, the ribbon cable that connected the memory module to the main circuit board sustained heat damage and was replaced. Also, several electronic components were replaced to get the memory to playback successfully. The digital audio was downloaded, and a transcript was prepared for the accident flight. Additionally, about 9 minutes preceding the accident flight was transcribed; during this time, the helicopter was on the ground, and the pilot was calculating the weight and balance and center of gravity for the accident flight.

A sound spectrum study was performed on recorded audio from the CVR. The study revealed that engine frequency could be correlated to Ng, and both the main gearbox planetary mesh and the AC generator electrical bleed-through noise frequencies could be correlated to main rotor speed (Nr). Additionally, CVR frequencies were compared to frequencies obtained from the witness video and provided a time correlation between the video and CVR. Plots were prepared to depict Nr and Ng through the two rearward flight maneuvers of the accident flight. The plots revealed that during the recovery from the first rearward flight maneuver, Nr decayed from about 102% to 100% and then oscillated between 104% and 101% before steadying near 102%. The Ng for both engines (average between both engines) increased from about 95% to 96% and then oscillated between 94% and 89%

before returning to 95%.

The plots for the recovery from second maneuver revealed an increase in Nr from about 100% to 101%, followed by a linear decay to about 32% over a span of 9 seconds (the end of recorded data). Just before this Nr decay began, the Ng for each engine was about 95 to 97%. The Ng could not be characterized for a 3-second portion of overdriven audio, after which the Ng for each engine decayed linearly from about 83 to 88% to 71 to 76% over a span of 6 seconds.

The engine manufacturer provided the National Transportation Safety Board with historical data of Ng reduction rates following a loss of engine power on CT58-series and CT7-series engines. The Ng reduction rate for the accident helicopter was slower compared to all but one of the previous events, which involved a CT7-9 engine where a fire handle was pulled while the engine was running at high power on the ground. Although the engine manufacturer did not have historical compressor stall data for the CT58-series engines, their compressor stall data on the CT7-series engines were not consistent with the data recorded during the two events. Lastly, the Ng reduction rate for the accident helicopter appeared comparable to that seen in an accident involving G-BBHM that the United Kingdom (UK) Air Accidents Investigation Branch (AAIB) investigated. In the accident involving G-BBHM, which was equipped with a flight data recorder (FDR), the No. 2 engine Ng decay was based on the crew retarding the cockpit engine control lever to "flight idle" after an engine fire warning light illumination, and subsequently to the "cut-off" position. Based on historical data of compressor stalls from the engine manufacturer, the plotted Ng data was not consistent with a compressor stall. (For more information, see the Spectrum Study in the public docket for this accident.)

Medical and Pathological Information

The State of Florida District 18 Medical Examiner's Office, Rockledge, Florida, performed autopsies on all three crewmembers. The cause of death for all three crewmembers was noted as multiple blunt force injuries.

The FAA Bioaeronautical Science Research Laboratory, Oklahoma City, Oklahoma, performed toxicological testing on all three crewmembers. The results were negative for alcohol and drugs for the copilot and maintenance crewmember. Review of the toxicology report for the pilot revealed detected diphenhydramine in urine and heart blood and ibuprofen in urine.

Ibuprofen is an anti-inflammatory analgesic available over the counter. Diphenhydramine is a sedating antihistamine available over the counter. The level of diphenhydramine detected in the pilot's blood was below the therapeutic range and not reported.

Tests and Research

Regarding engine failures, the rotorcraft flight manual (RFM) emergency procedures stated, in part, "if an abnormal engine condition occurs such as engine stall, flame-out, or overtemperature, transition to single engine flight or landing, confirm the malfunctioning engine has been correctly identified, and retard that engine to ground idle while proceeding as follows:…"

There was no published height velocity diagram for a dual-engine loss of power in the RFM. The RFM contained a height velocity diagram for a single-engine loss of power. Review of the diagram revealed instructions to avoid hovering below 300 ft.

The RFM did not contain procedures for a loss of dual-engine power in either a hover or during rearward flight, and according to the operator, the company's training did not include loss of dual-engine power in a hover.

Review of the FCF instructions in the maintenance manual revealed that one of the maneuvers was to fly rearward at 20 knots. The instructions allowed the maneuver to be completed at a "0 – 1000 feet altitude…"

Administrative Information

Investigator In Charge (IIC):	Gretz, Robert
Additional Participating Persons:	Ryan Bellamy; FAA FSDO; Orlando, FL Jill Browning; LMCO (Sikorsky); Stratford, CT David Gridley; GE Engines; Lynn, MA Bruce Widzgowski; AAR Arlift Corp; Melbourne, FL Glen Pruden; UTC Aerospace Systems; Windsor Locks, CT
Original Publish Date:	March 5, 2019
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=93956