Aviation Investigation Final Report

Location:	Hickory, Kentucky	**Accident Number:**	ERA16FA248
Date & Time:	July 11, 2016, 11:23 Local	**Registration:**	N427TV
Aircraft:	BELL HELICOPTER TEXTRON CANADA 407	**Aircraft Damage:**	Substantial
Defining Event:	Flight control sys malf/fail	**Injuries:**	1 Fatal
Flight Conducted Under:	Part 91: General aviation		

Analysis

The pilot was performing a visual approach to a landing zone to board an additional crewmember. A witness reported that there were no abnormalities in the helicopter's sound or position, until it was approximately 75 to 100 feet above the ground. Suddenly, the main rotor tilted to the right. Immediately after, the entire helicopter banked to its right and fell to the ground on its right side, where it came to rest. The main rotor blades broke apart during the impact sequence. The engine continued to run after the accident, and was subsequently shut down by responding personnel.

An examination of the wreckage revealed that the collective lever, located at the front and bottom of the swashplate support, was disconnected from the pivot sleeve. The collective lever was designed to move the pivot sleeve vertically on the swashplate support, via direct linkage from the cockpit collective control, to change the pitch on all the main rotor blades simultaneously. The collective lever pins and screws that attached the collective lever to the pivot sleeve were missing; they were later found loose, near the main rotor area. The safety wires intended to secure the screws to the pins were missing. Examination of the hardware at the NTSB Materials Laboratory revealed that the safety wires not present, and the screws backed out over time, resulting in the complete loss of collective control in flight.

Maintenance on the helicopter was performed about 38 flight hours prior to the accident. The maintenance included a 24-month inspection that required examination of the flight control bolts and nuts. The collective lever pins were not specifically included in that inspection. Two mechanics and a maintenance foreman, all employees of the operator, performed the maintenance, and all reported during postaccident interviews that they did not recall removing the safety wire or examining the pins. However, the foreman added, "I could see why it [examination of the collective lever pins] could have been done. The 24-month flight control bolt inspection was being performed, why not pull them and look at them too. I've done it before." Two of the mechanics reported that they would occasionally be "pulled off" one aircraft to work on another, and there was no work interruption policy in place. Thus, given that the safety wires were missing, it is likely that they were removed and not replaced during the

most recent maintenance and that maintenance personnel did not recall taking that action due to possible work interruptions.

Subsequent to the accident, the operator implemented numerous safety initiatives to prevent recurrence, including two independent safety audits, a formal fatigue risk management program, a Safety Management System, a formal tool/material accountability program, new work interruption policies, creation of a formally-trained Safety Officer position, and a formal process for the communication of safety-critical information.

Probable Cause and Findings

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

Company maintenance personnel's inappropriate removal without replacement of the safety wires on the collective lever pin screws during a recent maintenance inspection, which resulted in the screws backing out and led to a loss of collective control in flight.

Findings

Aircraft	Main rotor control - Incorrect service/maintenance
Aircraft	Fasteners - Incorrect service/maintenance
Aircraft	Prop/rotor parameters - Attain/maintain not possible
Personnel issues	Scheduled/routine inspection - Maintenance personnel

Factual Information

History of Flight

Prior to flight	Aircraft maintenance event
Approach-VFR pattern final	Flight control sys malf/fail (Defining event)
Approach-VFR pattern final	Loss of control in flight
Uncontrolled descent	Collision with terr/obj (non-CFIT)

On July 11, 2016, at 1123 central daylight time, a Bell 407, N427TV, collided with terrain during the approach to landing at the Tennessee Valley Authority (TVA) Mayfield Customer Service Center, Hickory, Kentucky. The commercial pilot was fatally injured, and the helicopter was substantially damaged by impact forces. The helicopter was registered to and operated by the TVA under the provisions of 14 *Code of Federal Regulations* Part 91 as a business flight. Day visual meteorological conditions prevailed, and no flight plan was filed. The flight originated from Outlaw Field Airport (CKV), Clarksville, Tennessee at 1048.

According to TVA personnel, the pilot flew the helicopter from Knoxville, Tennessee, to CKV, refueled, and then flew to the TVA Customer Service Center to pick up a maintenance lineman for the purpose of inspecting power lines and equipment.

According to a TVA lineman who witnessed the accident, there was a light wind from the south/southeast, and the helicopter appeared to be making its final approach from the north. The witness stated that there were no abnormalities in the helicopter's sound or position, until the helicopter was about 75 to 100 ft above the ground. He then observed the main rotor abruptly tilt to the right. Immediately after, the helicopter banked right, fell to the ground, and came to rest on its right side. The witness stated that he never lost sight of the helicopter and described the impact as very hard with no sliding or bouncing. He saw the rotor blades break apart. The witness then ran into the building to get help. The helicopter's engine continued to run after the accident and was subsequently shut down by responding personnel.

Initial examination of the wreckage revealed that the collective lever, which connected the cockpit collective controls to the main rotor, was disconnected from the pivot sleeve. The attaching hardware for the lever was subsequently found loose in the wreckage near the main rotor hub.

Pilot Information

Certificate:	Commercial	**Age:**	58,Male
Airplane Rating(s):	Single-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane; Helicopter	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	March 31, 2016
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	February 12, 2016
Flight Time:	18430 hours (Total, all aircraft), 850 hours (Total, this make and model)		

The pilot, who was seated in the right cockpit seat, held a Federal Aviation Administration (FAA) commercial pilot certificate with airplane single-engine land, rotorcraft-helicopter, instrument airplane, and instrument helicopter ratings. He held an FAA second-class medical certificate with a restriction to wear corrective lenses.

The pilot reported 18,430 total hours of flying experience on his latest medical certificate application, which was dated March 31, 2016. TVA personnel reported that his flight experience in the Bell 407 was about 850 hours. He completed a flight review in a MD Helicopters MD530 helicopter on February 12, 2016, and a flight review in the Bell 407 on January 5, 2016.

Aircraft and Owner/Operator Information

Aircraft Make:	BELL HELICOPTER TEXTRON CANADA	**Registration:**	N427TV
Model/Series:	407 NO SERIES	**Aircraft Category:**	Helicopter
Year of Manufacture:	2012	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	54106
Landing Gear Type:	N/A; High skid	**Seats:**	7
Date/Type of Last Inspection:	June 20, 2016 Annual	**Certified Max Gross Wt.:**	5501 lbs
Time Since Last Inspection:	38 Hrs	**Engines:**	1 Turbo shaft
Airframe Total Time:	1390 Hrs at time of accident	**Engine Manufacturer:**	ROLLS-ROYC
ELT:	C126 installed, activated, did not aid in locating accident	**Engine Model/Series:**	250-C47B
Registered Owner:	TENNESSEE VALLEY AUTHORITY	**Rated Power:**	600 Horsepower
Operator:	TENNESSEE VALLEY AUTHORITY	**Operating Certificate(s) Held:**	None

The helicopter was a Bell Helicopter model 407, serial number 54106, built in 2012 and purchased new

by the TVA. It was a single-engine helicopter of conventional construction and equipped with a four-blade, soft-in-plane design, composite hub, main rotor system, a full monocoque aluminum-skinned tail boom, and a conventional two-blade tail rotor system.

The helicopter was powered by a Rolls-Royce model 250-C47B turboshaft engine, serial number CAE-848434, with maximum takeoff and maximum continuous power ratings of 650 and 600 shaft horsepower, respectively.

The helicopter was issued a normal category standard airworthiness certificate and was maintained under an approved aircraft inspection program. Between May 31, 2016, and June 20, 2016, the helicopter was at the TVA maintenance facility at Muscle Shoals, Alabama, and the following inspections were accomplished: annual/50hr/100 hr, 150hr, 300 hr, 300hr/12 month, 600hr/12 month, 1200 hr/2 year, 12-month and 24-month inspections. From June 20, 2016, until the time of the accident, the helicopter was operated about 38.4 hours.

The collective lever was located at the front and bottom of the swashplate support. The collective lever and collective control link were designed to move the pivot sleeve vertically on the swashplate support to change the pitch on all the main rotor blades simultaneously. The collective lever was attached to the pivot sleeve with screws, washers, and pivot pins (see figure 1). Once attached, the and the specified torque was applied, locking wire would typically be affixed to the screw.

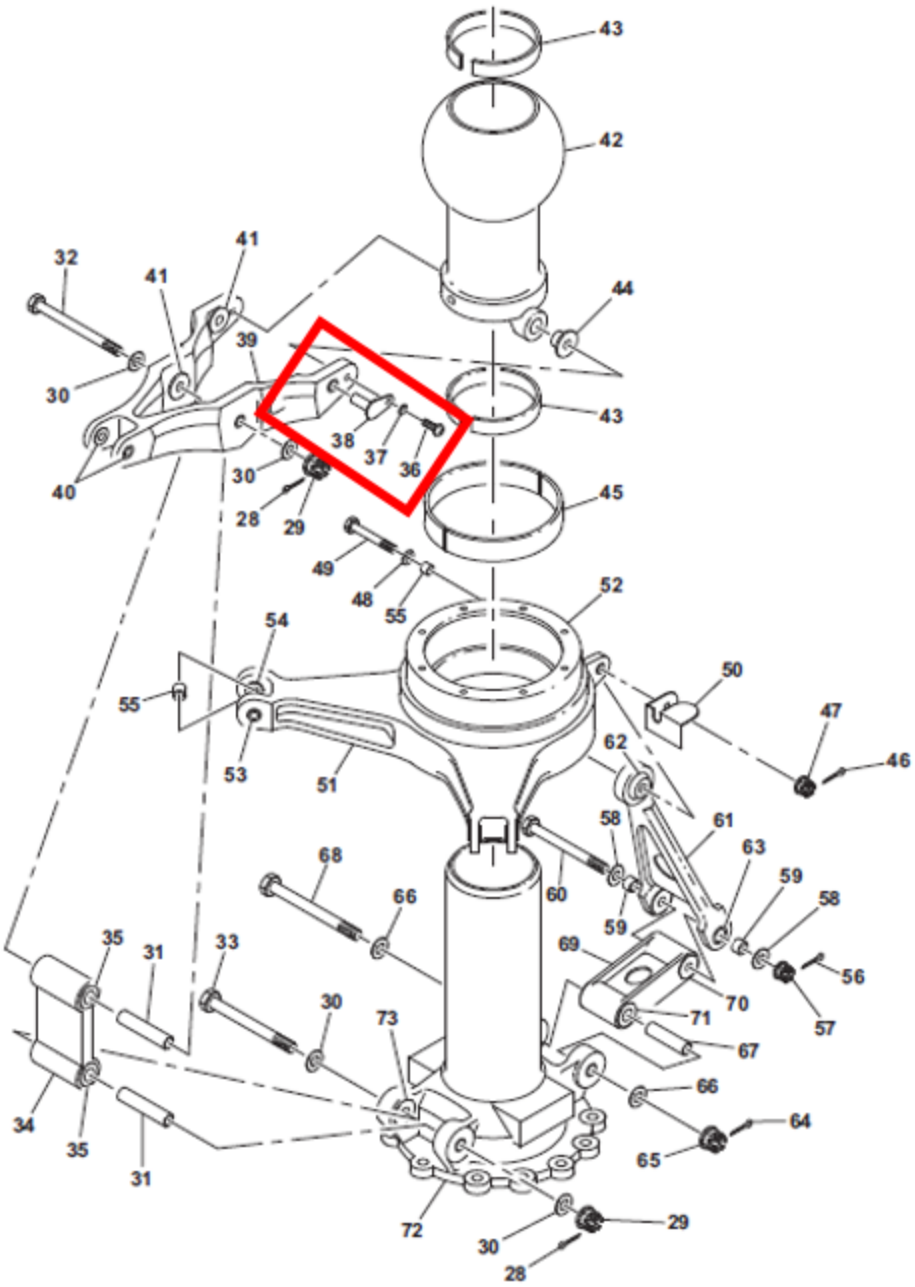

Figure 1 - Swashplate support assembly, with collective pitch lever attaching hardware outlined in red.

The maintenance tasks performed during the inspections between May 31, 2016, and June 20, 2016, did not require the removal of the collective lever or the disconnection or inspection of the collective lever pins or screws. Although an inspection of the condition of the flight control bolts and nuts was one of the maintenance tasks performed, an inspection of the collective lever pins, screws, and corresponding lockwire was not included in that inspection.

The maintenance and inspections of the helicopter's flight controls, including the collective control, were

performed by two TVA airframe and powerplant mechanics and one TVA foreman, who assisted in the work and supervised the operation. All three employees were interviewed by FAA inspectors following the accident.

One of the mechanics re-installed an anti-drive lever assembly. He did not recall removing the lockwire on the collective lever pin screws or removing the pins. He stated that the other mechanic performed the 24-month inspection of the flight control bolts and nuts. He further stated that the collective lever pins were not part of that inspection.

The other mechanic performed the 24-month inspection of the flight control bolts and nuts. When asked if he removed the collective lever pins, he responded, "No, I don't remember doing it. If anyone would have done it, it would have been me, but I don't remember doing it."

The foreman inspected the work performed in the area of the flight controls. He reported that the removal of the collective lever pins "…was not part of the required maintenance performed." He was not aware that the pins were removed or that any lockwire was removed. He added further, "I could see why it could have been done. The 24-month flight control bolt inspection was being performed, why not pull them and look at them too. I've done it before."

Both mechanics reported that they would occasionally be "pulled off" an aircraft to perform work on another project. One mechanic stated that there was a lack of documentation of what parts were removed, such as a continuation sheet.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	M25,522 ft msl	**Distance from Accident Site:**	8 Nautical Miles
Observation Time:	16:35 Local	**Direction from Accident Site:**	150°
Lowest Cloud Condition:	Scattered / 1000 ft AGL	**Visibility**	10 miles
Lowest Ceiling:	Overcast / 10000 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	5 knots /	**Turbulence Type Forecast/Actual:**	/ None
Wind Direction:	120°	**Turbulence Severity Forecast/Actual:**	/ N/A
Altimeter Setting:	30.05 inches Hg	**Temperature/Dew Point:**	26°C / 22°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Clarksville, TN (CKV)	**Type of Flight Plan Filed:**	None
Destination:	Hickory, KY (NONE)	**Type of Clearance:**	None
Departure Time:	10:48 Local	**Type of Airspace:**	Class G

Mayfield - Graves County Airport (M25), Mayfield, Kentucky, was the closest official weather station, which was 8 miles from the accident location. The M25 weather at 1135 included wind from 120° at 5 knots, visibility 10 statute miles, scattered clouds at 1,000 and 2,200 ft, overcast ceiling at 10,000 ft, temperature 26°C, dew point 22°C, and altimeter setting 30.06 inches of Mercury.

Airport Information

Airport:	Gravel Lot NONE	**Runway Surface Type:**	Gravel
Airport Elevation:	460 ft msl	**Runway Surface Condition:**	Dry
Runway Used:		**IFR Approach:**	None
Runway Length/Width:		**VFR Approach/Landing:**	Full stop

Wreckage and Impact Information

Crew Injuries:	1 Fatal	**Aircraft Damage:**	Substantial
Passenger Injuries:		**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 Fatal	**Latitude, Longitude:**	36.882778,-88.678886

General

The helicopter came to rest on its right side, about 220 ft west of the intended landing zone (LZ). The LZ was a level, open, gravel-covered storage area for power transmission equipment. All four main rotor blades separated from the main rotor hub during the impact sequence. The aft section of the tail boom severed from the fuselage, and the tail rotor assembly remained attached to the aft section of the tail boom.

Fuel and Hydraulic Systems

The helicopter's fuel system was not compromised and contained about 695 pounds of fuel. No fuel leaks were observed, and all fuel hoses and lines were secure. The airframe-mounted fuel filter was clean, and the fuel inside was clear with no particulates noted. Hydraulic fluid was observed in the hydraulic system reservoir. All lines and hoses were secure, and there were no leaks noted.

Landing Gear

The right skid of the landing gear was fractured fore and aft, above the saddle. The right step was separated due to fractured brackets. There was an impact mark on the aft portion of the right skid that matched the general size and shape of a ground scar at the point of initial ground impact. The front cross tube remained attached to the fuselage by one bracket, and the rear cross tube was not attached to the fuselage due to fractures at the support brackets.

Fuselage

The forward fuselage exhibited crushing damage on its right side along the bottom of the fuselage. The center post of the windscreen was fractured at the bottom. The battery cover on the nose was damaged near the hinged area near the bottom of the center post. The transmission deck exhibited minor damage to its right side.

Main and Tail Rotor Systems

Examination of the main rotor blades revealed that all four rotor blades were fractured. The yoke exhibited fracturing near all four inner elastomeric shear bearings with "strawing" signatures on the flexures. The blue pitch link was bent outward towards the top with all pitch link hardware present and all cotter keys installed. The red and orange pitch change links were undamaged with pitch link hardware present and all cotter keys installed. The green pitch change link was bent and fractured from impact forces and was found near the main wreckage. Each blade exhibited bending and delamination. All blades exhibited ground impact marks on the leading edges.

Main rotor continuity was confirmed by rotating the drive shaft by hand. Movement was confirmed from the drive shaft through the transmission to the mast. The transmission was visually inspected and no pre-impact anomalies were observed. The chip detectors were removed and visually inspected with no ferrous particulate matter observed. No abnormal sounds were heard when the transmission was rotated by hand. The transmission was not disassembled.

The tail boom was fractured near the aft bulkhead, just aft of the intercostal support and the fracture surfaces were consistent with a counter-clockwise main rotor strike to the ground. The vertical fin displayed scraping damage on its lower, outboard side, and the anti-collision light remained intact. The tailskid remained attached. Both the left and right finlets on the horizontal stabilizer were fractured and missing from the stabilizer from impact forces.

Both tail rotor blades exhibited minor ground impact damage; however, no rotational scoring was observed on either blade. The tail rotor was easily rotated in both directions with no abnormal binding or noises. The pitch of the tail rotor blades was manipulated by hand with appropriate control movement noted forward to the aft end of the fractured control tube. The flapping stops exhibited compression signatures with corresponding impact marks on the yoke.

The forward end of the forward short shaft remained attached to the output end of the freewheel unit. The aft end of the forward short shaft remained attached to the forward end of the oil cooler blower shaft. The oil cooler blower shaft was rotated by hand with slight binding due to shifting of the forward end of the aft short shaft. The forward end of the aft short shaft remained coupled with the aft end of the oil cooler blower shaft. The aft end of the aft short shaft remained connected to the hanger bearing. Rotational scoring was observed on the aft short shaft with signatures indicative of contact with the engine oil tank bracket. The forward end of the #4 tail rotor drive shaft segment was separated. The #3 and #2 tail rotor drive shaft segments were separated from the tail boom and were found adjacent to the main wreckage. The forward end of the #1 tail rotor drive shaft segment was connected to the hangar bearing with the aft end of the #1 tail rotor drive shaft segment connected to the input shaft of the tail rotor gear box at the Thomas coupling. Oil was evident in the tail rotor gear box. No chips were observed on the gear box chip detector.

Flight Controls

The left collective control was not installed. Collective control continuity was confirmed through the right collective and up through the servo actuators to the disconnected collective lever. The two collective lever pivot pins and screws that attached the collective lever to the pivot sleeve were not installed. The pivot pins and screws were found on the transmission deck and on the ground underneath the right side of the helicopter. The flat washers and lockwire were missing; the washers were later found during a subsequent examination of the wreckage.

The left cyclic control was not installed. Cyclic control continuity was confirmed through the right cyclic and up through the servo actuators to the inner, non-rotating swashplate.

The left anti-torque pedals were intentionally locked in place by the operator before the accident flight. The right anti-torque pedals were fractured at the outboard bell crank of the pedal control tube; however, directional control was confirmed when the tail rotor control tube, located near the tail rotor servo, was manipulated by hand. During manipulation, there was corresponding movement of the fractured pedal control tube and the fractured control tube aft of the tail rotor servo.

Engine

The engine remained in place, and all mounts were secure. No external engine damage was noted during the inspection. The hydromechanical unit linkage was intact, and its rigging appeared normal. The helicopter was equipped with an engine inlet barrier filter, which was normal in appearance and did not appear to be obstructed.

The engine-mounted fuel filter bowl from the combined engine filter assembly (CEFA) was full of clean, normal-appearing fuel. The CEFA fuel filter element was free of debris, and the pending bypass button was not extended. The fuel nozzle exhibited no anomalies, and some carbon formation was noted on the air shroud.

The engine-mounted scavenge oil filter on the CEFA was free of debris, and the pending bypass indicator button was not extended. The oil reservoir, which was mounted on the helicopter, was compromised, which precluded determination of the oil level. Both the upper and lower magnetic chip detectors were free of ferrous particulate matter. The engine gearbox oil was not drained.

No foreign object damage was noted on the compressor inlet guide vanes or on the impeller blade leading edges. The N1 rotor turned with some resistance and was mechanically coupled from the compressor to the starter generator. The N2 system turned when manipulated by hand and was continuous to the main rotor head. Due to deformation of the exhaust stack, the fourth-stage turbine wheel could not be inspected.

All of the external air, oil, electrical, and fuel lines were secure when checked by hand. None of the b-nut connectors were loose, and torque paint was present on the connections. No red indicators were visible on the electrical connectors.

The engine was controlled by a full authority digital electronic control(FADEC), which contained non-volatile memory in the electronic control unit (ECU). By design, when one of the predetermined parameter trip points is exceeded, the ECU begins recording incident data at a rate of one record per 1.2 seconds. The initial trigger for this event was low rotor speed (less than 92%).

The ECU was downloaded by a Rolls-Royce technical representative. A review of the data revealed no engine anomalies that would have precluded the engine from performing to specification before impact.

The ECU also retained engine maintenance history data in the maintenance terminal section. There were no pre-event faults or abnormalities noted in the maintenance terminal data. There were multiple faults recorded during the event, which corresponded to the impact sequence.

Medical and Pathological Information

The Office of the Chief Medical Examiner, Commonwealth of Kentucky, Louisville, Kentucky, performed an autopsy of the pilot. The cause of death was blunt impact injuries of the head, neck, and torso with traumatic/positional asphyxia, and the manner of death was accident.

The FAA's Bioaeronautical Research Sciences Laboratory performed toxicology testing on specimens from the pilot. The specimens tested negative for carbon monoxide, ethanol, and major drugs of abuse.

Survival Aspects

The helicopter's front seats were equipped with 4-point restraints. The outboard (right side) restraint attachment point for the pilot's lap belt was separated from the airframe wall. The rivets were pulled through and attached on one side, and the rivets were sheared on the other side. The sheared rivets were not located; however, the rivet holes were elongated from shear forces.

The pilot was not wearing a helmet at the time of the accident, nor were helmets required or provided for helicopter operations at the TVA.

Tests and Research

The collective lever and attachment hardware were sent to the NTSB Materials Laboratory for further examination. The collective lever, collective lever pins, collective lever pin screws, and washers were examined visually and by optical microscopy. All components were intact. Threads on the collective lever pin screws and the mating threaded holes in the collective lever were intact with no evidence of stripping. Holes for attaching lockwire were present in the

heads of the screws and at an adjacent area on the collective lever, but no lockwire was observed attached at either location. Deformation at the edges of the lockwire holes was noted. Circumferential scoring was present across the entire face on one side of one of the washers. On one of the screws, thread peaks were flattened near the middle of the shank on one side of the screw consistent with contact with the collective lever pin hole bore with the screw partially threaded into place.

Additional Information

Subsequent to the accident, the operator implemented numerous safety initiatives to prevent recurrence, including two independent safety audits, a formal fatigue risk management program, a safety management system, a formal tool/material accountability program, new work interruption policies, creation of a formally-trained safety officer position, and a formal process for the communication of safety-critical information.

Preventing Similar Accidents

Mechanics Manage Risk and Follow Procedures (SA-022)

The Problem

Mistakes made while performing aircraft maintenance and inspection procedures have led to in-flight emergencies and fatal accidents. System or component failures are among the most common defining events for fatal general aviation accidents.

What can you do?

- Remember that well-meaning, motivated, experienced technicians can make mistakes. Learning about and adhering to sound risk management practices can help prevent common errors that can lead to tragic consequences.

- Understand the safety hazards associated with human fatigue and strive to eliminate fatigue contributors in your life. Fatigue has been linked to forgetfulness, poor decision making, reduced vigilance, and other factors that can interfere with your ability to do your job safely.
- Pay particular attention to the safety and security of the items that undergo maintenance and any surrounding components that may have been disconnected or loosened (possibly to ease access) during that maintenance.
- Carefully follow manufacturers' instructions to ensure that the work is completed as specified. Always refer to up-to-date instructions and manuals when performing a task, and ask questions of another qualified person if something is unfamiliar to you.
- Have a qualified person, other than the person who performed the maintenance, inspect the safety and security of critical items that have received maintenance.
- Be thorough when performing routine inspections. Ensure that items needing immediate attention are addressed rather than deferred.

See https://www.ntsb.gov/Advocacy/safety-alerts/Documents/SA-022.pdf for additional resources.

The NTSB presents this information to prevent recurrence of similar accidents. Note that this should not be considered guidance from the regulator, nor does this supersede existing FAA Regulations (FARs).

Administrative Information

Investigator In Charge (IIC):	Hicks, Ralph
Additional Participating Persons:	Jamelle Poppe; FAA/FSDO; Louisville, KY Jon Michael; Rolls-Royce; Indianapolis, IN William Cronin; TVA; Chattanooga, TN Beverley Harvey; TSB; Gatineau Gary Howe; Bell Helicopter, Textron Inc.; Fort Worth, TX
Original Publish Date:	July 20, 2017
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=93579