National Transportation Safety Board
Aviation Accident Final Report

Location:	Bloomington, IL	**Accident Number:**	CEN15FA190
Date & Time:	04/07/2015, 0006 CDT	**Registration:**	N789UP
Aircraft:	CESSNA 414A	**Aircraft Damage:**	Substantial
Defining Event:	Loss of control in flight	**Injuries:**	7 Fatal
Flight Conducted Under:	Part 91: General Aviation - Personal		

Analysis

The twin-engine airplane, flown by an airline transport pilot, was approaching the destination airport after a cross-country flight in night instrument meteorological conditions. The destination airport weather conditions about 1 minute before the accident included an overcast ceiling at 200 ft and 1/2-mile visibility with light rain and fog. According to air traffic control (ATC) data, the flight received radar vectors to the final approach course for an instrument landing system (ILS) approach to runway 20. As shown by a postaccident simulation study based on radar data and data recovered from the airplane's electronic horizontal situation indicator (EHSI), the airplane's flight path did not properly intercept and track either the localizer or the glideslope during the instrument approach. The airplane crossed the final approach fix about 360 ft below the glideslope and then maintained a descent profile below the glideslope until it leveled briefly near the minimum descent altitude, likely for a localizer-only instrument approach. However, the lateral flight path from the final approach fix inbound was one or more dots to the right of the localizer centerline until the airplane was about 1 nautical mile from the runway 20 threshold when it turned 90° left to an east course. The turn was initiated before the airplane had reached the missed approach point; additionally, the left turn was not in accordance with the published missed approach instructions, which specified a climb on runway heading before making a right turn to a 270° magnetic heading. The airplane made a series of pitch excursions as it flew away from the localizer. The simulation study determined that dual engine power was required to match the recorded flight trajectory and ground speeds, which indicated that both engines were operating throughout the approach. The simulation results also indicated that, based on calculated angle of attack and lift coefficient data, the airplane likely encountered an aerodynamic stall during its course deviation to the east. The airplane impacted the ground about 2.2 miles east-northeast of the runway 20 threshold and about 1.75 miles east of the localizer centerline.

According to FAA documentation, at the time of the accident, all components of the airport's ILS were functional, with no recorded errors, and the localizer was radiating a front-course to the correct runway. Additionally, a postaccident flight check found no anomalies with the instrument approach.

An onsite examination established that the airplane impacted the ground upright and in a nose-low attitude, and the lack of an appreciable debris path was consistent with an aerodynamic stall/spin. Wreckage examinations did not reveal any anomalies with the airplane's flight control systems, engines, or propellers. The glideslope antenna was found disconnected from its associated cable circuit. Laboratory examination and testing determined that the glideslope antenna cable was likely inadequately connected/secured during the flight, which resulted in an unusable glideslope signal to the cockpit avionics. There was no history of recent maintenance on the glideslope antenna, and the reason for the inadequate connection could not be determined.

Data downloaded from the airplane's EHSI established that the device was in the ILS mode during the instrument approach phase and that it had achieved a valid localizer state on both navigation channels; however, the device never achieved a valid glideslope state on either channel during the flight. Further, a replay of the recorded EHSI data confirmed that, during the approach, the device displayed a large "X" through the glideslope scale and did not display a deviation pointer, both of which were indications of an invalid glideslope state.

There was no evidence of cumulative sleep loss, acute sleep loss, or medical conditions that indicated poor sleep quality for the pilot. However, the accident occurred more than 2 hours after the pilot routinely went to sleep, which suggests that the pilot's circadian system would not have been promoting alertness during the flight. Further, at the time of the accident, the pilot likely had been awake for 18 hours. Thus, the time at which the accident occurred and the extended hours of continuous wakefulness likely led to the development of fatigue.

The presence of low cloud ceilings and the lack of glideslope guidance would have been stresses to the pilot during a critical phase of flight. This would have increased the pilot's workload and situational stress as he flew the localizer approach, a procedure that he likely did not anticipate or plan to conduct. In addition, weight and balance calculations indicated that the airplane's center of gravity (CG) was aft of the allowable limit, and the series of pitch excursions that began shortly after the airplane turned left and flew away from the localizer suggests that the pilot had difficulty controlling airplane pitch. This difficulty was likely due to the adverse handling characteristics associated with the aft CG. These adverse handling characteristics would have further increased the pilot's workload and provided another distraction from maintaining control of the airplane. Therefore, it is likely that the higher workload caused by the pilot's attempt to fly an unanticipated localizer approach at night in low ceilings and his difficulty maintaining pitch control of the airplane with an aft CG contributed to his degraded task performance in the minutes preceding the accident.

Probable Cause and Findings

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

The pilot's failure to maintain control of the airplane during the instrument approach in night instrument meteorological conditions, which resulted in the airplane exceeding its critical angle of attack and an aerodynamic stall/spin. Contributing to the accident were pilot fatigue,

the pilot's increased workload during the instrument approach resulting from the lack of glideslope guidance due to an inadequately connected/secured glideslope antenna cable, and the airplane being loaded aft of its balance limit.

Findings

Aircraft	Pitch control - Not attained/maintained (Cause) Angle of attack - Not attained/maintained (Cause) CG/weight distribution - Capability exceeded (Factor)
Personnel issues	Aircraft control - Pilot (Cause) Circadian rhythms or jetlag - Pilot (Factor) Task monitoring/vigilance - Pilot (Factor) Cognitive overload - Pilot (Factor)
Environmental issues	Below VFR minima - Effect on operation (Cause) Dark - Effect on operation (Cause)

Factual Information

History of Flight

Approach-IFR initial approach	Nav system malfunction/failure
Approach-IFR missed approach	Loss of control in flight (Defining event) Aerodynamic stall/spin

On April 7, 2015, about 0006 central daylight time, a Cessna 414A twin-engine airplane, N789UP, collided with terrain following a loss of control during an instrument approach to Central Illinois Regional Airport (BMI), Bloomington, Illinois. The airline transport pilot and six passengers were fatally injured, and the airplane was substantially damaged. The airplane was registered to Make It Happen Aviation, LLC, and operated by the pilot under the provisions of 14 *Code of Federal Regulations* Part 91 on an instrument flight rules (IFR) flight plan. Night instrument meteorological conditions (IMC) prevailed for the cross-country flight that departed Indianapolis International Airport (IND), Indianapolis, Indiana, at 2307.

According to Federal Aviation Administration (FAA) air traffic control (ATC) data, after departure, the flight climbed to a cruise altitude of 8,000 ft mean sea level (msl) and proceeded direct to BMI. At 2344:38, the flight was about 42 nautical miles (nm) south-southeast of BMI and entered a cruise descent to 4,000 ft msl. At 2352:06, the pilot established contact with a controller at the Peoria Terminal Radar Approach Control facility, reported being level at 4,000 ft msl, and requested the instrument landing system (ILS) runway 20 instrument approach to BMI. According to radar data, at the time of the request, the flight was located about 21 nm south-southeast of BMI and was established on a direct course to BMI at 4,000 ft msl. The controller told the pilot to expect radar vectors for the ILS runway 20 approach. At 2354:18, the controller told the pilot to make a right turn to a 330° heading. The pilot acknowledged the heading change. At 2359:16, the controller cleared the flight to descend to and maintain 2,500 ft msl. At 2359:20, the pilot acknowledged the descent clearance.

At 0000:01, the controller told the pilot to turn left to a 290° heading, and the pilot acknowledged the heading change. At 0000:39, the controller told the pilot that the flight was 5 nm from EGROW, the final approach fix, cleared the flight for the ILS runway 20 approach, issued a heading change to 230° to intercept the final approach course, and told the pilot to maintain 2,500 ft msl until established on the inbound course. The pilot correctly read back the instrument approach clearance, the heading to intercept the localizer, and the altitude restriction.

At 0001:26, the flight crossed through the final approach course while on the assigned 230° heading before turning to a south heading. The plotted radar data showed the flight made course corrections on both sides of the localizer centerline as it proceeded inbound toward EGROW. At 0001:47, the controller told the pilot to cancel his IFR flight plan on the approach control radio frequency, said that radar services were terminated, and authorized a change to the airport's common traffic advisory frequency (CTAF). At that time, the flight was 3.4 nm

outside of EGROW and established inbound on the localizer, at 2,400 ft msl. At 0002:00, the pilot transmitted over the unmonitored airport CTAF, "twin Cessna seven eight nine uniform pop is coming up on EGROW, ILS runway 20, full stop." No additional transmissions from the pilot were recorded on the airport CTAF or by Peoria Approach Control.

At 0003:12, the flight crossed EGROW at 2,100 ft msl, continued to descend, and was right of the localizer centerline. At 0003:46, the flight was about 3.5 nm north of the runway 20 threshold when it descended below available radar coverage at 1,500 ft msl. Subsequently, at 0004:34, radar coverage was reestablished with the flight about 1.7 nm north of the runway 20 threshold at 1,400 ft msl. The plotted radar data showed that, between 0004:34 and 0005:08, the flight climbed from 1,400 ft msl to 2,000 ft msl while maintaining a south course. At 0005:08, the flight began a descending left turn to an east course. The airplane continued to descend on the east course until reaching 1,500 ft msl at 0005:27. The airplane then began a climb while maintaining an east course. At 0005:42, the airplane was 0.75 nm east of the localizer centerline at 2,000 ft msl. At 0005:47, the flight descended below available radar coverage at 1,800 ft msl. Subsequently, at 0006:11, radar coverage was reestablished at 1,600 ft msl about 0.7 nm southeast of the previous radar return. The next two radar returns, recorded at 0006:16 and 0006:20, were at 1,900 ft msl and were consistent with the airplane on an east course. The final radar return was recorded at 0006:25 at 1,600 ft msl about 2.2 nm east-northeast of the runway 20 threshold and was coincident with the accident site location.

Numerous individuals reported being awoken shortly after midnight by the sound of a low-flying airplane over their respective residences. Additionally, several of these witnesses saw dense fog and/or rain after the airplane had overflown their positions.

Pilot Information

Certificate:	Airline Transport	**Age:**	51, Male
Airplane Rating(s):	Multi-engine Land; Single-engine Land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	Lap Only
Instrument Rating(s):	Airplane	**Second Pilot Present:**	No
Instructor Rating(s):	Airplane Multi-engine; Airplane Single-engine; Instrument Airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 With Waivers/Limitations	**Last Medical Exam:**	02/02/2015
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	03/11/2015
Flight Time:	(Estimated) 12100 hours (Total, all aircraft), 1150 hours (Total, this make and model)		

According to FAA records, the 51-year-old pilot held an airline transport pilot certificate with single-engine land, multi-engine land, and instrument airplane ratings. The single-engine land rating was limited to commercial privileges. The pilot was type-rated for the Cessna Citation,

Learjet 35, Rockwell Sabreliner, Dassault Falcon 10, and Embraer Phenom business jets. He also held a flight instructor certificate with single-engine, multi-engine, and instrument airplane ratings. His most recent FAA second-class medical certificate was issued on February 2, 2015, with a limitation for corrective lenses. On the application for his current medical certificate, the pilot reported having accumulated 12,000 hours of total flight experience, of which 500 hours were flown within the previous 6 months. A search of FAA records showed no previous accidents, incidents, or enforcement proceedings.

A current pilot logbook was not located during the investigation; the pilot's most recent logbook entry was dated February 15, 2005. A portfolio was found in the airplane wreckage that contained numerous pilot training certificates, fleet management documents, and airplane insurance applications. According to an insurance application that was submitted for the operation of the airplane, dated May 12, 2014, the pilot reported having a total flight experience of 12,100 hours with 9,850 hours in multiengine airplanes, 8,575 hours in turbine-powered airplanes, and 1,150 hours in Cessna 414A airplanes. The portfolio also contained documentation for simulator-based proficiency training in the Cessna 414A that was completed on August 14, 2013, at Recurrent Training Center, Inc., Savoy, Illinois. According to available information, the pilot's last flight review and instrument proficiency check were completed on March 11, 2015, in conjunction with simulator-based recurrent training for a Dassault Falcon 10 business jet at FlightSafety International, Dallas, Texas.

Aircraft and Owner/Operator Information

Aircraft Manufacturer:	CESSNA	**Registration:**	N789UP
Model/Series:	414A	**Aircraft Category:**	Airplane
Year of Manufacture:	1980	**Amateur Built:**	No
Airworthiness Certificate:	Normal	**Serial Number:**	414A0495
Landing Gear Type:	Retractable - Tricycle	**Seats:**	7
Date/Type of Last Inspection:	10/01/2014, Annual	**Certified Max Gross Wt.:**	7087 lbs
Time Since Last Inspection:	43 Hours	**Engines:**	2 Reciprocating
Airframe Total Time:	8390.2 Hours	**Engine Manufacturer:**	Continental Motors
ELT:	C91 installed, activated, aided in locating accident	**Engine Model/Series:**	TSIO-520-NB
Registered Owner:	Make It Happen Aviation, LLC	**Rated Power:**	325 hp
Operator:	Make It Happen Aviation, LLC	**Air Carrier Operating Certificate:**	None

The airplane was a 1980 Cessna 414A (Chancellor), serial number 414A0495. Two turbo-charged Continental TSIO-520-NB reciprocating engines provided thrust through constant-speed, full-feathering, three-blade, Hartzell PHC-C3YF-2UF/FC7663DB-2Q propellers. The low-wing airplane was of conventional aluminum construction, was equipped with a

retractable tricycle landing gear, and had a pressurized cabin that was configured to seat seven people. The airplane was equipped for night operations in IMC conditions. The airplane had been modified by supplemental type certificates (STCs) to include winglets, vortex generators, and wing spoilers. Additionally, the maximum continuous horsepower of each engine had been increased to 325-horsepower by an STC modification. The airplane had a total fuel capacity of 213.4 gallons (206 gallons usable) distributed between two wing fuel tanks.

The airplane was originally issued an FAA export certificate of airworthiness on May 22, 1980. The airplane was issued a Canadian registration number, C-GFJT, and was based in Canada until September 1986 when it was imported back into the United States and issued a standard airworthiness certificate and a new registration number (N144PC) on October 1, 1986. On April 12, 1993, the registration number was changed to N789UP.

According to an airplane utilization log found in the wreckage, the airplane's hour meter indicated 2,109.7 hours before the previous flight leg (BMI to IND). The airplane's hour meter was not located during the accident investigation. Calculations indicated that the airplane had accumulated about 1.9 hours during the final two flights (the previous flight from BMI to IND and the accident flight from IND to BMI).

According to available maintenance documentation, at the time of the accident, the airframe had accumulated a total service time of 8,390.2 hours since new. The last annual inspection of the airplane was completed on October 1, 2014, at 8,346.9 total airframe hours. The airplane had accumulated 43.3 hours since the annual inspection. The static system, altimeter system, automatic pressure altitude reporting system, and transponder were last tested on December 2, 2013. A postaccident review of the maintenance records found no history of unresolved airworthiness issues. Additionally, there was no record of recent maintenance to the airplane's glideslope antenna.

At the time of the accident, the left engine, serial number 503140, had accumulated a total service time of 4,881.5 hours since new and 556.7 hours since being overhauled on March 20, 2008. The left propeller, serial number EB1994, had accumulated a total service time of 6,936.4 hours since new and 165.3 hours since being overhauled on November 23, 2010.

At the time of the accident, the right engine, serial number 519303, had accumulated a total service time of 5,591 hours since new and 1,699.9 hours since being overhauled on June 13, 2000. The right propeller, serial number EB1993, had accumulated a total service time of 6,936.4 hours since new and 691.3 hours since being overhauled on February 10, 2006.

Weight and Balance

The airplane's weight and balance for the accident flight and the preceding flight (BMI to IND) were calculated using the reported weights and seat positions for the pilot and the six passengers, maintenance records that established the airplane's basic empty weight and moment, fueling receipts/invoices, and recent flight tracking data.

According to the current weight-and-balance record, dated November 27, 2013, the airplane had an empty weight of 5,226.6 pounds (lbs) and a useful load of 1,860.4 lbs. The empty weight

center-of-gravity (CG) was 156.52 inches aft of the datum. At maximum takeoff weight, 7,087 lbs, the forward and aft CG limits were 152.2 inches and 159.04 inches, respectively. At maximum landing weight, 6,750 lbs, the forward and aft CG limits were 151.2 inches and 160.04 inches, respectively.

The average fuel consumption rate was estimated to be 47.36 gallons per hour based on the accumulated flight time between known fuel tank top-offs. Based on this estimated fuel consumption rate and fuel receipts/invoices, the airplane departed BMI for IND with about 114.5 gallons of usable fuel. After landing at IND, the airplane was fueled with 60 gallons of fuel and subsequently departed on the accident flight with an estimated 133.4 gallons of usable fuel.

Weight and balance calculations estimated that the preceding flight (BMI to IND) departed 160 lbs over the maximum takeoff weight and with a CG aft of the permitted envelope. The calculations estimated that airplane landed 287 lbs over the maximum landing weight and with a CG aft of the permitted envelope.

Weight and balance calculations estimated that the accident flight departed 271 lbs over the maximum takeoff weight and with a CG about 4.37 inches aft of the permitted envelope. The calculations estimated that, at the time of the accident, the airplane was 366 lbs over the maximum landing weight and had a CG that was about 3.71 inches aft of the permitted envelope.

According to the FAA's Aircraft Weight and Balance Handbook, if the CG is maintained within the allowable limits for its weight, an airplane has adequate longitudinal stability and control. However, if the loaded airplane results in a CG that is aft of the allowable limits, the airplane can become unstable and difficult to recover from an aerodynamic stall. Additionally, if the unstable airplane should enter an aerodynamic spin, the spin could become flat making recovery difficult or impossible.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument Conditions	**Condition of Light:**	Night/Dark
Observation Facility, Elevation:	BMI, 871 ft msl	**Observation Time:**	0005 CDT
Distance from Accident Site:	2 Nautical Miles	**Direction from Accident Site:**	250°
Lowest Cloud Condition:		**Temperature/Dew Point:**	13°C / 13°C
Lowest Ceiling:	Overcast / 200 ft agl	**Visibility**	0.5 Miles
Wind Speed/Gusts, Direction:	6 knots, 60°	**Visibility (RVR):**	4000 ft
Altimeter Setting:	29.98 inches Hg	**Visibility (RVV):**	
Precipitation and Obscuration:	Light - Rain; Moderate - Fog		
Departure Point:	Indianapolis, IN (IND)	**Type of Flight Plan Filed:**	IFR
Destination:	Bloomington, IL (BMI)	**Type of Clearance:**	IFR
Departure Time:	2307 CDT	**Type of Airspace:**	Class E

A National Weather Service (NWS) Surface Analysis Chart issued at 0100 depicted a stationary front extending across central Iowa, northern Illinois, and Indiana; the front was immediately north of Bloomington, Illinois. A second stationary front was depicted extending over Kansas, into Missouri, and turning southeastward into Tennessee and Alabama. The station models on the chart indicated northeast winds at 10 to 15 knots north of the stationary front located across Illinois and east-southeast winds at 5 knots or less south of the front. The station models also depicted an extensive area of overcast clouds over the region with most stations along and south of the front reporting light continuous rain, drizzle, and/or mist. The station model for Bloomington indicated wind from the east-southeast at about 5 knots, surface visibility restricted in mist, overcast cloud cover, temperature and dew point at 13°C, and a sea level pressure of 29.98 inches of mercury. The station models surrounding Bloomington indicated similar conditions with overcast clouds, light continuous rain, and/or mist.

A review of weather radar data recorded at 0004 revealed no significant radar echoes greater than 15 dBZ over the greater Bloomington-Normal area. The observed radar echoes were consistent with light rain. The observed radar echoes along the recorded flight track were consistent with the airplane operating in IMC during the approach and at the time of the accident.

At 2156, about an hour before the flight departed, the BMI automated surface observing system (ASOS) reported: wind 150° at 4 knots, an overcast ceiling at 1,200 ft above ground level (agl), 10 mile surface visibility, temperature 14°C, dew point 12°C, and an altimeter setting of 29.98 inches of mercury.

At 2303, about 4 minutes before the flight departed, the BMI ASOS reported: wind 140° at 6 knots, scattered clouds at 100 ft agl and an overcast ceiling at 800 ft agl, 2 mile surface visibility with light rain and mist, temperature and dewpoint 13°C, and an altimeter setting of 29.99 inches of mercury.

At 0005, about a minute before the accident, the BMI ASOS reported: wind 060° at 6 knots, an overcast ceiling at 200 ft agl, 1/2 mile surface visibility with light rain and fog, runway visibility range (RVR) for runway 29 variable 4,000-6,000 ft, temperature and dewpoint 13°C, and an altimeter setting of 29.98 inches of mercury.

The terminal aerodrome forecast (TAF) issued at 1826 for BMI expected marginal visual flight rules (MVFR) conditions to prevail during the forecast period with a surface visibility greater than 6 miles, an overcast ceiling at 2,500 ft agl, and rain showers in the vicinity after 0100. The terminal forecast was amended at 2048, lowering the overcast ceiling to 1,200 ft agl. At 0038, an updated terminal forecast indicated that low instrument flight rules (LIFR) conditions were expected, including an overcast ceiling at 200 ft agl, and a 1/2 mile surface visibility with light drizzle and fog.

According to available information, the pilot used a commercial weather vendor (FlightPlan.com) to obtain his preflight weather briefing. The vendor logged weather briefings at 1614, 1957, 2117, and 2228. The briefings included weather reports, forecasts, and notices to airmen for the departure, destination, alternate, and selected nearby airports and pilot reports. The final weather briefing, obtained at 2228, included the TAF for Bloomington that had been issued at 2048, which forecasted MVFR conditions. The final briefing also provided weather conditions for nearby airports that were reporting LIFR conditions with overcast ceilings ranging between 200 and 300 ft agl. The final briefing did not include the area forecast or any in-flight weather advisories. The pilot filed an IFR flight plan from IND to BMI and designated Lambert-St Louis International Airport as his alternate airport.

Airport Information

Airport:	Central Illinois Regional (BMI)	**Runway Surface Type:**	Concrete
Airport Elevation:	871 ft	**Runway Surface Condition:**	Wet
Runway Used:	20	**IFR Approach:**	ILS
Runway Length/Width:	8000 ft / 150 ft	**VFR Approach/Landing:**	None

Central Illinois Regional Airport (BMI), a public airport located about 3 miles east of Bloomington, Illinois, was owned and operated by the Bloomington-Normal Airport Authority. The airport field elevation was 871 ft msl. The airport had two runways: runway 2/20 (8,000 ft by 150 ft, concrete) and runway 11/29 (6,525 ft by 150 ft, asphalt/concrete). Although the airport was equipped with an air traffic control tower, the control tower was closed at the time of the accident.

Runway 20 incorporated a dual-mode Approach Lighting System II (ALSF-2) and Simplified Short Approach Lighting System with Runway Alignment Indicator Lights (SSALR). The SSALR system was active when the control tower was closed. The runway was also equipped with runway touchdown zone and centerline lighting and high intensity runway edge lighting.

Wreckage and Impact Information

Crew Injuries:	1 Fatal	**Aircraft Damage:**	Substantial
Passenger Injuries:	6 Fatal	**Aircraft Fire:**	On-Ground
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	7 Fatal	**Latitude, Longitude:**	40.496111, -88.868056

The accident site was located in an open harvested corn field about 2.2 miles east-northeast of the runway 20 threshold and about 1.75 miles east of the localizer centerline. The GPS altitude of the accident site was 854 ft. The main wreckage consisted of the entire airplane, which was orientated on a 074° magnetic heading. The wreckage was in an upright position, and there was no appreciable wreckage debris path. All observed airframe structural separations were consistent with impact related damage. The forward fuselage and cockpit were crushed upward and displaced aft. Flight control cable continuity was traced from the cockpit to the individual flight control surfaces. All observed flight control cable separations were consistent with overstress or were cut to facilitate recovery of the wreckage. There was no evidence of fire damage inside the cockpit, main cabin, aft fuselage, or empennage.

Both wings remained attached to the fuselage, and exhibited postimpact fire damage of their respective engine nacelles. Both ailerons were found partially separated from their respective hinge attachments. The aileron trim actuator extension measured 15/16 inch, which corresponded to the trailing-edge of the aileron trim tab being deflected up about 15°. The aileron trim indicator was damaged during impact. The right wing leading edge outboard of the engine nacelle was crushed upward and displaced aft. The right wing deice boot and winglet were damaged by the postimpact fire. The left wing aft structural attachment exhibited features consistent with an overstress separation. The left winglet had separated from the wing, and was found adjacent to the wing. The left wing leading edge outboard of the engine nacelle was crushed upward and displaced aft.

The tail section was separated immediately aft of the aft pressure bulkhead and remained attached through control cables. Both elevators remained attached to their respective horizontal stabilizers. The elevator trim actuator extension measured 1 and 11/16 inch, which corresponded to the trailing-edge of the elevator trim tab being deflected up about 5°. The elevator trim indicator was damaged during impact. The rudder remained attached to the vertical stabilizer. The rudder trim actuator extension measured 2 and 1/4 inch, which was consistent with a neutral rudder trim position. The rudder trim indicator was damaged during impact.

The nose and main landing gear were found fully retracted, and the cockpit selector handle was found in the "GEAR UP" position. A measurement of the wing flap control chain corresponded with a fully-retracted flap position. The flap selector handle and indicator were damaged

during impact. An operational test of the wing spoiler actuators did not reveal any anomalies. The cockpit instrument panel sustained considerable damage during impact. The throttle quadrant was buckled and displaced to the right. Both throttles levers were found in the idle position and bent to the right. Both propeller levers were found full forward and bent to the right. Both mixture levers were found in an intermediate position and bent to the right. The cockpit altimeters had a Kollsman window setting between 29.98 and 29.99 inches of mercury. The stall warning horn and landing gear warning horn were extracted from the cockpit, and both horns produced an aural tone when electrical power was applied. Switch continuity for the wing-mounted lift sensor was confirmed. Both engine-mounted vacuum pumps exhibited impact and thermal damage. Disassembly of both vacuum pumps did not reveal any anomalies attributable to a preimpact malfunction.

Both integral wing fuel tanks were breached at their respective wingtips. Fuel was observed to drain from the left wing during wreckage recovery. Both fuel tank caps were found in the secured position. The airplane was equipped with cable-operated fuel selector valves, one for each engine, that were installed inboard of each engine nacelle. Both fuel selector valves were found in the OFF position; however, a reliable determination of the preimpact position was not possible due to impact related damage to the selector handles. The structure supporting the selector handles, located between the cockpit seats, had been displaced forward into a vertical position during impact. Both auxiliary fuel pumps exhibited thermal damage from the postimpact fire that precluded further testing.

Both engines remained partially attached to their respective nacelles and exhibited impact and postimpact fire damage. The observed thermal damage was concentrated between the airframe firewalls and the rear accessory section of each engine. Both propellers had separated from their respective engines and were found buried at a depth of about 18 inches in front of each engine. Both propellers retained their respective propeller flanges and a fractured portion of their respective engine crankshafts. Both crankshafts displayed a bend in one direction with circumferential cracks observed on the tension side of the bend, a 45° sheer lip fracture on the tension side, and an irregular/jagged fracture on the compression side. Mechanical continuity from the engine components to their respective cockpit controls could not be determined due to impact and fire damage. Internal engine and valve train continuity were confirmed when each engine was rotated through the accessory section. Compression and suction were noted on all cylinders in conjunction with crankshaft rotation. Teardown examinations of both engines and their respective turbochargers did not reveal any anomalies attributable to a preimpact malfunction. Additional documentation for each engine and turbocharger examination is included in the docket materials associated with the investigation.

Each propeller had one blade that was bent aft, one blade that appeared straight, and one blade that exhibited forward bending near the tip. Both propellers had their spinner domes formed around the propeller hub and counterweights. The spinner domes also exhibited a spiral/twisting deformation pattern. The observed blade and spinner dome damage was consistent with both propellers rotating at impact. Neither propeller was found in a feathered position. Both propellers were found on their respective start locks. According to the propeller manufacturer, for the propellers to be found on the start locks, the propeller blade angle at impact was either at or below the start lock angle when engine speed decreased below 700-900 rpm, or the blade forces during impact moved the blade angle into a start lock position after

engine speed decreased below 700-900 rpm. A teardown examination of each propeller did not reveal any anomalies that would have precluded normal operation. Additional documentation for each propeller examination is included in the docket materials associated with the investigation.

Aids To Navigation

During an ILS approach, the localizer provides lateral guidance for the final approach course, and the glideslope provides vertical guidance as the aircraft descends toward the runway. For a precision approach, such as an ILS approach, the missed approach point (MAP) is where the aircraft reaches the decision altitude while on the glideslope. If a pilot observes an invalid glideslope indication, such as an "X" displayed through the glideslope scale of an electronic horizontal situation indicator or a warning flag on an analog course deviation indicator, the pilot may continue the instrument approach using the lateral guidance of the localizer; however, without the vertical guidance of a glideslope, a higher minimum descent altitude (MDA) is stipulated for the non-precision localizer instrument approach. Further, the location of the MAP for a non-precision approach will be a specified distance from a navigational aid, a fixed distance (from the final approach fix to the MAP) with an associated elapsed time that is based on the groundspeed of the aircraft, or a specific intersection/waypoint.

The published inbound course for the ILS runway 20 approach at BMI was 198° magnetic, the crossing altitude for the final approach fix (EGROW) was 2,459 ft msl, and the distance between EGROW and the runway 20 threshold was 4.8 nm. The touchdown zone elevation was 871 ft msl. The decision altitude was 1,071 ft msl (200 ft agl) and required 1,800 ft RVR. The missed approach procedure was to climb on runway heading to 1,500 ft msl, then make a right turn to a 270° magnetic heading and climb to 3,000 ft msl, then join the 214° radial from the Pontiac VOR, and hold at MCLEN intersection.

In the event of a loss of vertical guidance from the glideslope during an approach, or when performing the non-precision localizer approach, the MAP was located 4.8 nm from EGROW on the localizer. The non-precision localizer approach MDA was 1,260 ft msl (389 ft agl) and required 2,400 ft RVR. The MDA for a circling approach was 1,340 ft msl (468 ft agl) and required 1 mile surface visibility.

According to air traffic control documentation, at the time of the accident, all components of the ILS were functional, with no recorded errors, and the localizer was radiating a front-course to runway 20. A postaccident flight check found no anomalies with the instrument approach.

Flight Recorders

The airplane was not equipped, nor was it required to be equipped, with a cockpit voice recorder or flight data recorder.

Medical And Pathological Information

The McLean County Coroner Office, located in Bloomington, Illinois, performed an autopsy on the pilot. The cause of death was attributed to multiple blunt-force injuries sustained during the accident. The autopsy also identified an enlarged heart with wall thickening and dilation of the chambers, 60-75% stenosis of the proximal left anterior descending artery, extensive interstitial myocardial fibrosis within the left ventricle, and severe atherosclerosis of the basal septum nodal artery. The FAA's Bioaeronautical Sciences Research Laboratory located in Oklahoma City, Oklahoma, performed toxicology tests on specimens obtained during the autopsy. The testing identified 0.010 gm/dl of ethanol in cavity blood; however, no ethanol was detected in liver or brain samples. Ethanol can be produced by microbial activity after death. Additional toxicology testing did not identify any drugs and medications in cavity blood.

The pilot's wife reported that the pilot had not experienced any major life events or stressors in the days or weeks preceding the accident. She stated that the pilot would typically sleep about 8 hours each night and that he never mentioned having any sleep-related issues. The pilot's wife stated that the pilot normally went to sleep at 10 pm and awoke at 6 am and that his sleep schedule was consistent with that routine for the 3 days preceding the accident. Additionally, she could not recall him being fatigued in the days preceding the accident. She reported that he had no serious health related issues and that he regularly exercised by running. She indicated that the pilot had recently seen a chiropractor for back pain and that he would take Aleve for pain management.

An acquaintance of the pilot reported that he and the pilot had a lengthy conversation during the hours before the accident flight as they waited for their respective passengers to return to the fixed based operator. According to the acquaintance, the pilot appeared very relaxed throughout their conversation and did not appear to be fatigued or ill.

According to FAA Advisory Circular No. 120-100, Basics of Aviation Fatigue, fatigue is a physiological state in which there is a decreased capacity to perform cognitive tasks and an increased variability in performance. Research has shown that fatigue is often attributed to extended wakefulness in which ample recovery sleep is not obtained, and that performance and alertness levels are largely influenced by the complex interaction between sleep and the 24-hour biological clock (circadian rhythm). When work is conducted during a normal sleep period, especially when it occurs after 16 hours of wakefulness, the disruption to the normal circadian rhythm can result in impaired cognitive function, performance degradation, and sleepiness. NTSB investigations have found that flightcrew on long duty days (a shift of more than 13 hours) exhibit a disproportionate amount of accidents when compared to those on short duty days (a shift of less than 13 hours). The longer the crews are awake, the more errors they tend to commit, especially cognitive errors such as decision making. Fatigue due to extended work hours, time of day, and shift work induces reductions in vigilance and reaction time and increases in risk of poor decisions, human error, incidents, and accidents.

Tests And Research

Glideslope Validity

A laboratory examination of the airplane's Garmin GNS 530W NAV/COM/GPS receiver, serial number 78410737, established that the active communication (COM) frequency was set to the BMI control tower frequency (124.6 MHz), which also served as the airport's CTAF when the control tower was closed. The standby COM frequency was set to Peoria Approach Control (128.725 MHz). The active navigation (NAV) frequency was set to the BMI ILS runway 20 instrument approach (111.9 MHz). The standby NAV frequency was set to the BMI VOR/DME frequency (108.2 MHz). The course deviation indicator (CDI) mode was selected to VOR/Localizer (VLOC). The Garmin GNS 530W did not record any historical flight parameter or navigational data.

A laboratory examination of the airplane's Garmin GNS 430W NAV/COM/GPS receiver, serial number 97103703, established that the active COM frequency was set to the BMI control tower frequency (124.6 MHz). The standby COM frequency was set to the BMI automatic terminal information service (ATIS) frequency (135.35 MHz). The active NAV frequency was set to the BMI ILS runway 20 approach (111.9 MHz). The standby NAV frequency was set to the BMI VOR/DME frequency (108.2 MHz). The CDI mode was selected to VLOC. The Garmin GNS 430W did not record any historical flight parameter or navigational data.

The airplane was equipped with a Sandel Avionics SN3500 electronic horizontal situation indicator (EHSI), serial number 1058. The device performs the basic functions of a traditional horizontal situation indicator and radio magnetic indicator. Additionally, depending on installation, the device can provide RMI navigation to GPS waypoints, weather information, and traffic information. The device was configured to receive navigational data from the Garmin 530W and Garmin 430W as NAV Channels 1 and 2, respectively. The device recorded the incoming navigation data once per second to a 24-megabyte circular buffer. The intended purpose of the recorded data was for diagnostic purposes by the manufacturer. The device was sent to the manufacturer to be downloaded and decoded. The recovered dataset included, but was not limited to, the following historic flight parameters: latitude, longitude, ground speed, magnetic heading, ground track, VOR/ILS mode status, localizer and glideslope validity, and localizer and glideslope deviation. The device did not record an altitude data parameter.

A review of the data recorded by the Sandel Avionics SN3500 during the previous flight leg (BMI to IND) established that, despite being in ILS mode during the approach phase and having achieved a valid localizer state on both NAV channels, the device did not achieve a valid glideslope state until about 0.6 nm from the approach end of runway 23L at IND. A postaccident review of available weather documentation established that the airplane had landed at IND in day visual meteorological conditions that included a surface visibility of 10 miles and an overcast cloud ceiling at 2,400 ft agl (about 3,200 ft msl).

A review of the recovered data for the accident flight revealed that the Sandel Avionics SN3500 was in the ILS mode during the instrument approach phase and that it had achieved a valid localizer state on both NAV channels; however, the device never achieved a valid glideslope state on either NAV channel during the accident flight.

With the assistance of the manufacturer, the recorded data for the accident flight was replayed back through the Sandel Avionics SN3500 to document the navigational information that was

displayed by the device. The replay confirmed that the glideslope did not achieve a valid state on either NAV channel during the accident flight. The device displayed a large "X" through the glideslope scale and did not display a glideslope deviation pointer. According to the Sandel Avionics SN3500 pilot's guide, an "X" through the glideslope scale and the absence of a glideslope pointer indicated a lack of valid glideslope data. According to the manufacturer, the glideslope deviation and validity state are independently determined by the NAV/COM/GPS devices (Garmin 530W and Garmin 430W) before being transmitted, along with other navigational data, to the SN3500 device as NAV Channel 1 and NAV Channel 2 data via a standard avionics data transfer protocol.

According to the FAA Instrument Flying Handbook, a glideslope signal consists of two intersecting radio signals that are modulated at 90 Hz and 150 Hz. According to Garmin, the operating conditions that would result in an invalid glideslope state include any of the following conditions:

(a) In the absence of a glideslope radio frequency signal.
(b) In the absence of 150 Hz modulation.
(c) In the absence of 90 Hz modulation.
(d) In the absence of both 90 Hz and 150 Hz modulation.
(e) When the level of a standard deviation test signal, as generated during ground maintenance/testing, produces 50% or less of standard deflection of the deviation indicator.

Glideslope Antenna and Signal Diplexer

An additional examination of the airplane wreckage located the glideslope antenna on a small portion of radome structure. The radome had fragmented during the impact sequence. One of the solid wire antennas had separated from the antenna body and was not located during the investigation. The other solid wire antenna remained attached to the antenna body and exhibited minor damage. As found, the glideslope antenna was not connected to the coaxial cable that provided signal to the glideslope signal diplexer. Additionally, the coaxial cable was found crimped around a fuselage bulkhead stiffener. The observed crimp was consistent with damage sustained during the accident. The glideslope signal diplexer remained attached to the fuselage bulkhead, and its single coaxial input connector and two coaxial output connectors were found intact and properly secured. The remaining coaxial cable paths were continuous to the cockpit where the Garmin 530W and Garmin 430W had been previously removed during the investigation.

The glideslope antenna design incorporated a quarter-turn twist-lock BNC-type connector with the female portion of the connector installed on the glideslope antenna body. The male portion of the connector was attached to the coaxial cable that connected to the glideslope signal diplexer. A laboratory examination of the female portion of the connector revealed that it was intact with some minor deformation and light debris found on the interior and exterior surfaces. The locking pins of the female connector were intact, and no corrosion was observed. The male portion of the connector was intact and undamaged except for one of the six shielding/ground fingers. The damaged finger was folded and bent into the connector. The central conductor pin was undamaged, and no corrosion was apparent. Although initially found disconnected from the glideslope antenna, the coaxial cable could be reconnected and twist locked with minimal difficulty.

The electrical properties of the glideslope signal diplexer were subsequently evaluated at an avionics repair station. No repairs were made to the crimped portion of the coaxial cable that normally connected the glideslope antenna to the glideslope signal diplexer. A glideslope source signal of 92 decibels (dBm) was transmitted by the test bench through the coaxial cable that was connected to the diplexer. The signal level was measured after it passed through the diplexer at the two output connectors. During the bench test, the diplexer split the original source signal into two signal paths which measured 89.8 dBm and 88.8 dBm for glideslope 1 and 2, respectively. According to the bench technician, the observed differences between the source and output signals was normal and would not have affected glideslope signal transmission to the Garmin 530W and Garmin 430W that were located downstream of the diplexer. The operational bench test revealed no anomalies with the glideslope signal diplexer and, although damaged during impact, the coaxial cable demonstrated the ability to transmit an adequate glideslope signal to the diplexer.

Aircraft Performance Simulation Study

A postaccident simulation study was completed by the National Transportation Safety Board's Vehicle Performance Division. The simulation study indicated that airplane's lateral flight path did not track the localizer centerline; the flight path was one or more dots to the right of the localizer centerline while inbound from the final approach fix. The airplane also flew one or more dots below the target glideslope until it leveled briefly near the minimum descent altitude for a localizer-only instrument approach. The simulation study indicated that the airplane did not intercept and track the glideslope at any time during the instrument approach. About 1.7 nm from the runway 20 threshold the airplane climbed through the glideslope guidance. About 1 nm from the runway 20 threshold, the airplane crossed through the localizer guidance width, from right to left, during a 90° left turn to an east course. The airplane made a series of pitch excursions as it flew away from the localizer.

The simulation study also indicated that the airplane was at 150 knots calibrated airspeed (KCAS) at the final approach fix, and it subsequently slowed below 80 KCAS on multiple occasions as it proceeded toward the runway and during the course deviation to the east. Based on the calculated angle of attack and lift coefficient data, the observed 90° left turn to the east was not associated with an aerodynamic stall; however, the simulation results indicated that the airplane likely encountered at least one aerodynamic stall during its course deviation to the east.

The simulation study also determined that the minimum engine power required to adequately match the recorded flight trajectory exceeded the maximum horsepower that could be generated by a single engine. Specifically, the simulation results indicated that 75% to 90% of time-varying dual engine power was required to achieve acceptable and simultaneous parameter match to the recorded altitude, latitude/longitude position, and ground speed data.

Administrative Information

Investigator In Charge (IIC):	Andrew T Fox	**Adopted Date:**	08/29/2017
Additional Participating Persons:	Stanley Swank; Federal Aviation Administration - Springfield FSDO; Springfield, IL Ernest Hall; Textron Aviation; Wichita, KS Christopher Lang; Continental Motors; Mobile, AL Les A Doud; Hartzell Propeller; Piqua, OH Rick Roper; RAM Aircraft; Waco, TX Tom Carr; Garmin; Olathe, KS Ken Kochi; Sandel Avionics; Vista, CA Jeff Shapiro; Spoilers, Inc.; Gig Harbor, WA		
Publish Date:	08/29/2017		
Note:	The NTSB traveled to the scene of this accident.		
Investigation Docket:	http://dms.ntsb.gov/pubdms/search/dockList.cfm?mKey=90991		