Aviation Investigation Final Report

Location:	Farmington, Connecticut	**Accident Number:**	ERA21FA346
Date & Time:	September 2, 2021, 09:51 Local	**Registration:**	N560AR
Aircraft:	Cessna 560	**Aircraft Damage:**	Destroyed
Defining Event:	Collision with terr/obj (non-CFIT)	**Injuries:**	4 Fatal, 1 Serious, 3 Minor
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The flight crew was conducting a personal flight with two passengers onboard. Before departure, the cockpit voice recorder (CVR) captured the pilots verbalizing items from the before takeoff checklist, but there was no challenge response for the taxi, before takeoff, or takeoff checklists. Further, no crew briefing was performed and neither pilot mentioned releasing the parking brake.

The left seat pilot, who was the pilot flying (PF) and pilot-in-command (PIC), initiated takeoff from the slightly upsloping 3,665-ft-long asphalt runway. According to takeoff performance data that day and takeoff performance models, the airplane had adequate performance capability to take off from that runway. Flight data recorder (FDR) data indicated each thrust lever angle was set and remained at 65° while the engines were set and remained at 91% N1.

During the takeoff roll, the CVR recorded the copilot, who was the pilot monitoring (PM) and second-in-command (SIC), making callouts for “airspeed’s alive,” “eighty knots cross check,” “v one,” and “rotate.” A comparison of FDR data from the accident flight with the previous two takeoffs showed that the airplane did not become airborne at the usual location along the runway, and the longitudinal acceleration was about 33% less. At the time of the rotate callout, the airspeed was about 104 knots calibrated airspeed, and the elevator was about +9° airplane nose up (ANU). Three seconds after the rotate callout, the CVR recorded the sound of physical straining, suggesting the pilot was likely attempting to rotate the airplane by pulling the control yoke. The CVR also captured statements from both the copilot and pilot expressing surprise that the airplane was not rotating as they expected.

CVR and FDR data indicated that between the time of the rotate callout and the airplane reaching the end of the airport terrain, the airspeed increased to about 120 knots, the weight-

on-wheels (WOW) remained in an on-ground state, and the elevator position increased to a maximum value of about +16° ANU. However, the airplane's pitch attitude minimally changed.

After the airplane cleared the end of the airport terrain where the ground elevation decreased 20 to 25 ft, FDR data indicate that the WOW transitioned to air mode with near-full ANU elevator control input, and the airplane pitched up nearly 22° in less than 2 seconds. FDR data depicted forward elevator control input in response to the rapid pitch-up, and the CVR recorded a stall warning then stick shaker activation. An off airport witness reported seeing the front portion of the right engine impact a nearby pole past the departure end of the runway. The airplane then rolled right to an inverted attitude, impacted the ground, then impacted an off-airport occupied building.

There was no evidence of preimpact failure or malfunction of the flight controls or engines before impact with the pole. Postaccident examination and computed tomography of the parking brake valve revealed the parking brake was in the ON (or closed) position at the time of the accident. There was no evidence of preimpact failure or malfunction of the brakes, parking brake knob, cable, or parking brake valve. The closed position of the parking brake valve would have continued to apply pressure to both main landing gear wheel brakes during the takeoff roll,and resulted in the continuous rubber transfer from both main landing gear tires on the runway that was observed from the starting point of each to the departure end of the runway.Additionally, the smoke that witnesses observed and the surveillance video captured trailing the airplane as it traveled down the runway was likely the result of the brakes still being applied.

An NTSB performance study found that the retarding force at the wheel/runway interface that would have resulted from application of the wheel brakes during the takeoff roll created an airplane-nose-down (AND) pitching moment that opposed airplane-nose-up (ANU) rotation. When the airplane reached Vr, the pitching moment opposing the ANU rotation likely overpowered the elevator's ability to rotate the airplane nose up and prevented the airplane from taking off. When the retarding force at the wheel/runway interface was no longer present after the airplane reached the end of the airport terrain, the airplane responded aerodynamically to the near-full aft control yoke/column input and began pitching up rapidly.

Although the airplane flight manual takeoff checklist included an item for "brake release," it did not specifically indicate "parking brake release." While a specific and unambiguous checklist item that directed flight crews to verify that the parking brake had been released prior to takeoff might generally provide a mechanism for flight crews to consistently perform this pre-takeoff task, it is unlikely that a specific mention to release the parking brake in the takeoff checklist would have mitigated this accident because there were no challenge responses to checklists during the flight. The ON position of the parking brake knob and its associated valve could not be observed by the copilot (due to its obscured location on the lower left side of the left seat pilot), therefore only by completing a challenge response as part of a specified checklist could the copilot have any knowledge of the position of the parking brake. Further,

the status of the parking brake was not indicated or annunciated in the cockpit and was not part of the NO TAKEOFF configuration warning system.

The accident airplane was manufactured as an XLS+ derivative model of the Cessna 560XL, which was certified to a parking brake standard that was first issued in 1965. Cessna Aircraft Company (now Textron Aviation, Inc.), the airplane manufacturer, applied to the Federal Aviation Administration (FAA) for certification of the XLS+ as a derivative airplane in February 2006, nearly 4 years after a change to the parking brake regulation that required indication in the cockpit when the parking brake was not fully released. Because there were no substantial changes to the parking brake system of the XLS+ from the original type design, the FAA process for certification of a derivative aircraft allowed the parking brake system to be certified to the original 1965 standard without a parking brake indication.

It is likely that a cockpit indication when the parking brake was not fully released would have alerted both the pilot and copilot of the parking brake's status so that they could have immediately aborted the takeoff attempt and prevented the accident. To address this safety issue, which was also identified in NTSB case number WPR19FA230, the NTSB issued recommendations to the FAA on May 4, 2022, to require that in-service (A-22-8) and newly manufactured Cessna 560XL airplanes and future derivative models (A-22-9) meet the in-cockpit parking brake indication requirements of the updated certification standard. Based on a similar accident in 2015 involving a Cessna 550 and a serious incident in 2018 involving a Cessna 560XLS+, the Australian Transport Safety Bureau (ATSB) and Nigerian Accident Investigation Bureau (AIB), respectively, also recommended that the manufacturer include a parking brake indication.

In addition, the FAA's certification process for derivative aircraft or changed aeronautical product did not consider or require compliance with regulation changes to systems like the Cessna 560XL parking brake indication because it determined that there were no significant changes to the parking brake system. Although the FAA accurately followed the certification process for derivative aircraft, identifying and requiring the safety benefit of a parking brake indication during that process could have prevented this accident and at least one other serious incident. Therefore, the certification process for the Cessna 560XL, as a derivative aircraft, likely contributed to this accident by not evaluating the impact that the updated certification standards would have and did not identify the safety enhancing value that requiring a parking brake indication would provide.

Probable Cause and Findings

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

The pilot-in-command's failure to release the parking brake before attempting to initiate the takeoff, which produced an unexpected retarding force and airplane-nose-down pitching moment that prevented the airplane from becoming airborne within the takeoff distance available and not before the end of the airport terrain. Contributing to the accident were the airplane's lack of a warning that the parking brake was not fully released and the Federal Aviation Administration's process for certification of a derivative aircraft that did not identify the need for such an indication.

Findings

Aircraft	Brake - Incorrect use/operation
Personnel issues	Use of equip/system - Pilot
Organizational issues	Equip certification/testing - FAA/Regulator
Aircraft	(general) - Not installed/available

Factual Information

History of Flight

Takeoff	Miscellaneous/other
Takeoff	Collision with terr/obj (non-CFIT) (Defining event)
Uncontrolled descent	Collision with terr/obj (non-CFIT)
Post-impact	Fire/smoke (post-impact)

On September 2, 2021, at 0951 eastern daylight time, a Cessna 560XLS+ airplane, N560AR, was destroyed when it was involved in an accident near Farmington, Connecticut. All four airplane occupants (the pilot, copilot, and two passengers) were fatally injured. One person on the ground sustained serious injuries, and three people sustained minor injuries. The airplane was operated as a Title 14 *Code of Federal Regulations* (*CFR*) Part 91 personal flight.

According to FAA air traffic control audio recordings and CVR transcription, about 0913, the copilot contacted the Yankee Terminal Radar Approach Control Facility to obtain an instrument flight rules clearance to Dare County Regional Airport (MQI), Manteo, North Carolina. The controller provided the clearance and advised the flight to hold for release. About 0948, the copilot contacted the controller and advised that the flight was taxiing and would be ready in 1 minute, and the controller instructed the flight crew to hold for release. The flight taxied toward runway 2, and at 0948:20, the CVR recorded the controller advising the flight crew that the flight was released for departure and to enter controlled airspace on a 20° heading.

The copilot, who was the PM and seated in the right seat as SIC, repeated the instruction. The CVR recorded the PM discussing the departure frequency and transponder code while the PF, who was seated in the left seat and was PIC, said, “kay flaps. trim three times. pitot heat on.” The copilot then said that the pitot static was coming on. Those items were part of the before takeoff checklist, but there was no challenge response for the taxi, before takeoff, or takeoff checklists, and the flight crew did not perform a crew briefing. Further, there was no mention in the CVR recording of releasing the parking brake before takeoff was initiated. FDR data did not indicate any flight control movements consistent with a check of the flight controls.

The CVR recorded the copilot make a radio call on the airport common traffic advisory frequency advising that the flight would be departing runway 2 straight out and that the final and base legs of the airport traffic pattern appeared clear. The sound of engine power advancing was heard at 0950:15. According to data from the airplane’s FDR, both thrust levers were set at about 65°, and both engines were set at and remained at 91% N1

throughout the takeoff roll. While accelerating on the runway the CVR recorded the copilot stating that “power is set…airspeed’s alive… eighty knots cross check… v one”, with the v one call occurring about 1,670 ft down the 3,665-ft-long runway. The flight continued on the runway and at 0950:44, the copilot called, “Rotate.” According to the data from the FDR, the airplane was about 2,000 ft down the runway at about 104 knots calibrated airspeed and the elevator was about +9° when the copilot made the rotate callout. Three seconds later, the CVR recorded the copilot stating, “Oht oht ‘sa matter,” followed 1.7 seconds later by a sound of heavy strain from the pilot and him stating, “it’s [not] rotating.” Then 2.4 seconds later, a sound of physical strain/grunt was recorded from the pilot.

The airplane continued along the runway centerline with left rudder input between 2° and 4,° which decreased to about 0.3° when the airplane was about 2,375 ft down the runway. The flight crew applied an increasing amount of right rudder input to a maximum of about 10°, while the right rudder input remained until the flight was about 2,500 ft down the runway, and a slight deviation to the right began. Several on- and off-airport video cameras that captured the takeoff roll and final portion of the flight showed smoke trailing the airplane, and a ground track reconstruction model determined the smoke appeared about 2,685 ft down the runway (the model is further discussed in the Additional Information section of this report). While deviating to the right, the flight crew applied left rudder input to a maximum of about 18°, and the deviation to the right ended about 0950:52 when the airplane was about 3,125 ft down the runway. The rudder values remained near neutral from the point when the right deviation stopped and the airplane track remained straight to the end of the runway, though the airplane path was offset right of the runway centerline.

When the airplane reached the end of the airport terrain, FDR data indicated the airspeed had increased to about 120 knots, the elevator deflection increased to a maximum value of about +16°, the WOW remained in an on-ground state, and the pitch of the airplane minimally changed briefly to +1° then decreased to 0°. The FDR data further indicated that past the end of the airport terrain where the ground elevation decreased 20 to 25 ft, the WOW indication changed from on-ground to air mode, the elevator position increased to a maximum recorded value of about +17° deflection (or ANU), and the airplane’s pitch increased to about +22° in less than 2 seconds. While the airplane rapidly pitched up, the elevator position rapidly decreased to about 1.0°. At 0950:54, the CVR recorded the sound of electronic stall warning followed one-tenth of a second later by stick shaker activation.

Two witnesses on the ground reported seeing a puff of blue smoke behind the airplane during the takeoff roll. One witness noted the airplane appeared to be “going slower” compared to previous flights, and because of that, he knew there was a problem. That same witness also reported that the airplane never lifted off from the runway.

A witness who was located about 280 ft north-northeast of the departure end of the runway reported seeing the airplane come off the runway in a level attitude. As the airplane continued, it pitched into a nose-up attitude but was not climbing. He noted the front portion of the right engine impact a nearby pole followed by a shower of sparks and a metallic

grinding sound.

FDR data showed that the N1 and N2 values of the No. 2 engine were 91.0% and 99.4%, respectively before the airplane impacted the pole past the departure end of the runway. After impacting the pole, the right engine N1 and N2 values immediately decreased to 80.1% and 95.1%, respectively, then both continued to decrease despite the thrust lever angle for both engines remaining at 65° for the remainder of the recording. The airplane began a roll to the right and became inverted in about 3.5 seconds. The airplane impacted the ground then an occupied building, whose sprinkler system was activated. The building and its contents sustained significant structural and fire damage.

Pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	55,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	December 7, 2020
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	March 10, 2021
Flight Time:	(Estimated) 17400 hours (Total, all aircraft)		

Co-pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	57,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	January 8, 2021
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	November 23, 2019
Flight Time:	(Estimated) 5594 hours (Total, all aircraft), 4359 hours (Pilot In Command, all aircraft), 18 hours (Last 90 days, all aircraft)		

Pilot

The pilot was a salaried pilot employed by Interstate Aviation, Inc., which was the accident operator. He received transition training in a level D simulator for the Cessna 560XL (Excel), which was the original type design of the accident airplane, at Flight Safety International (FSI) in December 2009. He subsequently obtained recurrent training at FSI in the Excel in 2017, and recurrent training in the XLS+ (a derivative model of the Cessna 560XL) in 2018, 2019, 2020, and 2021. All training was conducted in a level D simulator, and he passed all of the practical tests on the first attempt. On the paperwork for his latest training, Citation XLS+ Recurrent Pilot-In-Command Course, the instructor remarked during one flight that he observed no weaknesses, and his strengths were, "Good aircraft control, CRM [crew resource management], and procedures."

The accident operator's president, who normally flew as copilot with the accident pilot, reported that during typical takeoffs, the accident pilot would center the airplane on the runway, then when almost to a full stop, he would begin the takeoff. The accident pilot would not normally stop on the runway, apply the brakes, then advance thrust and release the brakes. When they flew together, they used the checklist and performed challenge and response. During takeoff, they would call airspeed alive, 80 knots crosscheck, takeoff-decision speed (V1), rotate. At V1, the flight crew's hands would move from the thrust levers to the control yoke, then engage the autopilot at 400 ft.

Copilot

The copilot was a contract pilot for the accident operator. A review of his available training records revealed that he completed initial training at FSI in a Cessna 525 (Citation Jet) in November 2015. He also received training in the Gulfstream G450 in 2018 and recurrent training at FSI in the Gulfstream G550 on two occasions in 2019. The latest training performed in a level D simulator between November 18, 2019, and November 23, 2019, consisted of 6 hours as the PF and 6 hours as the PM.

A review of provided logbook entries revealed no entries showing a sign off as SIC specifically for the accident make and model airplane. Entries between September 2020 and July 29, 2021, showed that he logged 11 flights as SIC in the accident airplane totaling 25 hours. The remarks section for the flights in the accident airplane did not indicate whether he had performed engine-out procedures, maneuvering with an engine out while acting as pilot-in-command, and CRM training.The attorney representing the copilot's estate cited the flights in the accident airplane but reported the copilot's family was unable to locate any records concerning simulator training and had no recollection of whether he had attended training for the Cessna 560 series.

Aircraft and Owner/Operator Information

Aircraft Make:	Cessna	**Registration:**	N560AR
Model/Series:	560 XLS+	**Aircraft Category:**	Airplane
Year of Manufacture:	2009	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	560-6026
Landing Gear Type:	Retractable - Tricycle	**Seats:**	11
Date/Type of Last Inspection:	July 2, 2021 AAIP	**Certified Max Gross Wt.:**	20200 lbs
Time Since Last Inspection:	11.3 Hrs	**Engines:**	2 Turbo fan
Airframe Total Time:	2575.1 Hrs at time of accident	**Engine Manufacturer:**	Pratt & Whitney Canada
ELT:	C126 installed, activated, did not aid in locating accident	**Engine Model/Series:**	PW545C
Registered Owner:	BROOK HAVEN PROPERTIES LLC	**Rated Power:**	4119 Lbs thrust
Operator:	BROOK HAVEN PROPERTIES LLC	**Operating Certificate(s) Held:**	None

According to the airplane's type certificate data sheet and FAA-approved airplane flight manual, the minimum flight crew for all operations were one pilot and one copilot. Inspections of the airplane and its systems as part of the manufacturer's scheduled inspection program were last performed last on July 2, 2021. At the beginning of the accident flight, the airplane had accumulated 11.3 hours since the last inspections were completed. According to the aircraft status report, the airplane's parking brake valve, which is considered an on-condition item, was original to the airplane when it was manufactured in 2009.

A pilot who had flown the airplane on August 10, 2021, and again on August 13, 2021, reported there were "zero squawks" on either flight.

The parking brake knob was located on the tilt panel forward of the left seat pilot's seat adjacent to the occupant's knee and was not visible to the right seat occupant.

Per the airplane operating manual, the parking brake is set by depressing the toe brakes in the normal manner, then pulling out the parking brake pull knob on the left lower side of the tilt panel. That action mechanically actuates the parking brake valve, trapping fluid in the brakes. The parking brake is released by pushing in the parking brake pull knob.

Figure 1. Pictures from an exemplar 560 XLS+ showing the parking brake off (left) and set (right).

The airplane was equipped with a crew alerting system (CAS) that did not incorporate parking brake valve position as part of its activation logic, nor was there an indication or annunciation in the cockpit when the parking brake was not fully released. A red NO TAKEOFF warning CAS message would display a NO TAKEOFF aural warning for some conditions that would impede a safe takeoff, such as if the throttles were advanced beyond the climb setting or the flaps were not configured for takeoff.

Certification

The parking brake standard outlined in 14 *CFR* 25.735, Brakes and Braking Systems, was first issued in 1965 and remained the standard until May 2002. To meet the original requirements of 14 *CFR* 25.735 in force between 1965 and 2002, the parking brake must prevent the airplane from rolling on a paved, level runway when set by the pilot and with takeoff power on the critical engine. In May 2002, the regulation was changed to Amendment 25-107, which incorporated, in part, indication in the cockpit when the parking brake was not fully released.

The FAA's aircraft certification process in 14 *CFR* 21.101, Certification Procedures for Products and Parts - Changes to Type Certificates, allowed an aircraft manufacturer to introduce a derivative model (or "changed aeronautical product") as a design update on a previously certificated aircraft and to add the changed product to an existing type certificate. The FAA approved changes for derivative models if it found that (1) if the change was not significant, (2) for those areas or components not affected by the change, (3) if such compliance would not contribute materially to the level of safety, and (4) if such compliance would be impractical. That process enabled a manufacturer to introduce design updates without resubmitting the entire aircraft design for certification review.

When the accident aircraft manufacturer applied to the FAA for certification of the XLS+ on February 17, 2006, 14 *CFR* 21.101 Amendment 21-77 was effective and stated that an applicant must show that the changed product complies with the airworthiness regulations in effect on the date of the application. However, the applicant may show compliance with an earlier amendment of a regulation for a change the FAA finds not to be significant. Although

the location and movement of the parking brake knob in the cockpit for the XLS+ changed from the previous design, there was no change to the parking brake architecture or operation. Because there were no significant changes to the parking brake system, the FAA did not require recertification of the parking brake system on the XLS+. Thus, the XLS+ was certificated on May 30, 2008, to the 1965 parking brake standard.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KBDL,175 ft msl	**Distance from Accident Site:**	17 Nautical Miles
Observation Time:	09:51 Local	**Direction from Accident Site:**	29°
Lowest Cloud Condition:	Scattered / 2700 ft AGL	**Visibility**	10 miles
Lowest Ceiling:		**Visibility (RVR):**	
Wind Speed/Gusts:	12 knots /	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	350°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.77 inches Hg	**Temperature/Dew Point:**	19°C / 13°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Farmington, CT	**Type of Flight Plan Filed:**	IFR
Destination:	Manteo, NC (MQI)	**Type of Clearance:**	IFR
Departure Time:		**Type of Airspace:**	

Airport Information

Airport:	ROBERTSON FLD 4B8	**Runway Surface Type:**	Asphalt
Airport Elevation:	201 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	02/20	**IFR Approach:**	None
Runway Length/Width:	3665 ft / 75 ft	**VFR Approach/Landing:**	None

The elevation at the approach and departure ends of runway 02 were reported to be 188.6 ft and 201.6 ft, respectively. An approximate 20 ft width of grass was noted beyond the departure end of runway 02, followed by an approximate 20 to 25 ft elevation decrease past the airport boundary terrain.

Examination of the taxiway leading onto the approach end of runway 2, and entire length of runway 2 included three-dimensional laser scanning of the entire length of the runway, the area immediately past the departure end of the runway, and the area of the impacted pole. No tire remnants were found on or near the runway. There were no discernable tire marks associated with the accident airplane near the approach end of runway 2. The first discernable mark

associated with the right main landing gear tire was located about 9 ft right of runway centerline and about 2,361 ft from the approach end of the runway. The first discernable mark from the left main landing gear tire was located about 6 ft left of runway centerline and 2,482 ft from the approach end of the runway. The marks from both main landing gear tires continued past the end of the runway.

Wreckage and Impact Information

Crew Injuries:	2 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:	2 Fatal	**Aircraft Fire:**	Both in-flight and on-ground
Ground Injuries:	1 Serious, 3 Minor	**Aircraft Explosion:**	On-ground
Total Injuries:	4 Fatal, 1 Serious, 3 Minor	**Latitude, Longitude:**	41.69761,-72.86326

Examination of the accident site area revealed a broken telephone/electrical pole about 011° and 361 ft past the departure end of the runway, about 27 ft above ground level and about 1.8 ft lower than the departure end of the runway. An approximate 3-ft-long section of the outboard end of the airplane's right inboard flap was located in wetlands east of the impacted pole. Additional airplane wreckage was located close to the impacted pole.

Examination of the area north of the impacted pole revealed ground scars on grass about 850 ft from the damaged pole on a magnetic heading of 036° about 245 ft from the impacted building. The aft empennage came to rest inverted on a magnetic heading of 130° outside of the building, while the heat-damaged cockpit and cabin were just inside the impacted building. The wing, which exhibited extensive impact and fire damage, was both inside and immediately outside the building.

Wreckage including upper cabin material, were found along the ground impact energy path consistent with the airplane being inverted at impact. Flight control surfaces, and engine components were also noted along the energy path between the ground scar and the resting position of the airplane.

Examination of the wreckage revealed the wings, cockpit, and cabin were damaged and/or consumed by a post-crash fire. All primary and secondary flight control surfaces or the remains of them, both wingtips, the top of the vertical stabilizer and rudder, ends of both horizontal stabilizers and elevators were accounted for at the accident site.

Examination of the flight controls for roll, pitch, and yaw revealed no evidence of preimpact

failure or malfunction. Both speed brakes were retracted. Although the positions of the flaps based on the flap actuators could not be determined, the FDR data reflected they were set to and remained at 15° throughout the recorded data. The two-position horizontal stabilizer was positioned to takeoff/land, and according to FDR data, it remained at that position throughout the recorded data. According to the FDR data during takeoff, the aileron trim was between 10° and 11° tab trailing edge down or left wing down, while the elevator trim was 18.02° ANU, which was beyond the maximum limit and did not change throughout the recorded data. The rudder trim actuator measured 1.9 inches, which equated to neutral. The elevator and aileron trim values recorded by the FDR during the accident flight were consistent with the same values for the entirety of data for each recorded by the FDR.

Examination of the parking brake handle revealed it remained partially attached to the tilt panel. The handle was extended about 2.5 inches and its sleeve was bent and fractured. Examination of the parking brake push/pull rod and knob with section of panel mount, deformed and fractured sleeve, and sections of control cable revealed that the fractured or cut surfaces of the sleeve, Bowden cable, and inner actuated cable were consistent, respectively, with overstress fractures or being cut in the field for recovery.

The field examination of both engines revealed no anomalies on either engine that would have precluded normal operation. FDR data further showed there were no fault codes for either engine recorded on its respective data collection unit, and both engines were operating normally until just past the impact with the pole.

Parking Brake Valve, Landing Gear, and Brake System Components

Examination of the parking brake valve revealed it was separated from the structure and thermally damaged. The cable remained attached to the lever, which was bent aft and positioned against the parking brake full-on stop toward the single structural attach bolt.

X-ray radiograph and computed tomography scanning of the parking brake valve revealed that the shaft flat was adjacent to the mechanisms (consistent with the valve being in the closed or brake set position), and the lever-to-shaft interface did not show any indications of cracks, missing material, or other abnormalities. Further, there were indications of high-density particles and possible debris consistent with burned material from outside the valve or from heated material within the valve. Comparison between the accident valve and an exemplar valve revealed that the accident valve was in a closed position when exposed to elevated temperatures, which was confirmed when disassembled. The parking brake valve position and normal wheel or parking brake application were not recorded by the FDR. Other than its closed position during operation, examination of the parking brake valve did not reveal any anomalies that would have precluded normal operation.

Examination of the left and right main landing gear revealed postimpact thermal damage and no anomalies that would have precluded normal operation.

Examination of the left brake revealed it could not be pressurized. The wear pin right of shuttle valve was bent and could not be measured, and without hydraulic pressure applied to the brake stack, the other wear pin left of shuttle valve was measured at 0.941 inch. The pistons appeared to be fully retracted. Disassembly of the brake stack revealed normal wear of the pressure plate, and the stators and rotors exhibited normal wear. No anomalies were noted with the left brake that would have precluded normal operation.

Examination of the right brake revealed it could not be pressurized. Without hydraulic pressure applied to the brake stack, one wear pin (right of shuttle valve) extension was 0.285 inch and the other wear pin (left of shuttle valve) extension was 0.300 inch. Disassembly of the brake stack revealed normal wear of the pressure plate, and the stators and rotors exhibited normal wear. No anomalies were noted with the right brake that would have precluded normal operation.

Flight recorders

The airplane was equipped with a CVR andFDR.

The CVR did not show obvious signs of deformation damage but did show some evidence of heat damage. The recorder's crash survivable memory unit and the internal non-volatile memory chip stack appeared undamaged. The chip stack and associated ribbon cable were in good condition and were read out normally using an L3 FA-2100 surrogate. The data downloaded normally from the CVR and produced files consistent with the logic of a 2-hour CVR. The audio quality for all channels was characterized as "good."

The FDR was covered with dirt and carbon soot and combustion particles. The memory module ribbon cable, and connector showed no signs of heat stress. The temperature dot indicated the memory module was not compromised by heat exposure. The memory module was downloaded and contained approximately 197 hours of data. The event flight was the last flight of the recording, and its duration was approximately 6 minutes.

Medical and Pathological Information

Postmortem examinations of the flight crew were performed by the Office of the Chief Medical Examiner, Farmington, Connecticut. The cause of death for the pilot was blunt injuries of head, torso, and extremities, and the cause of death for the copilot was blunt injuries of head, neck, torso, and extremities. The autopsy report for the copilot also cited moderate coronary artery atherosclerosis.

Toxicology testing performed by the FAA Forensic Sciences Laboratory on the pilot's specimens detected 51 mg/dL glucose, along with unquantified amounts of atenolol (which is used to treat high blood pressure), acetaminophen (sometimes marketed as Tylenol), and salicylic acid (Aspirin), which are not generally considered impairing.

Toxicology testing performed by the FAA's Forensic Sciences Laboratory on the copilot's urine and vitreus detected 14 mg/dL and 48 mg/dL glucose, respectively, along with unquantified amounts of amlodipine, which the copilot had reported using to treat high blood pressure; these are not generally considered impairing. Toxicology testing also detected desmethylsildenafil (Viagra), which is not generally considered impairing, but the FAA states that pilots should wait 8 hours before flying to monitor for side effects such as symptomatic low blood pressure.

Additional Information

PerformanceStudy

An NTSB performance study with representatives of the airplane manufacturer and the FAA used data from the FDR, CVR, video footage, tire skid marks on the runway, witness information, environmental conditions, engine performance, weight and balance calculations, aerodynamics and engine data generated during flight test, and airplane flight manual data. The study found that for the accident flight conditions that day at 15° flap setting, the calculated values in terms of knots calibrated airspeed (KCAS) for target V1, rotational speed (Vr), and angle-of-climb speed (V2) speeds were 106, 111, and 120, respectively.

During the four preceding takeoffs, the calculated airplane braking coefficient values (the friction between the tires and the runway) during the takeoff ground roll were between about 0.02 to 0.03. During the accident takeoff ground roll, the calculated airplane braking coefficient values ranged from about 0.09 to 0.11 for groundspeeds below 100 knots and from 0.11 to 0.35 between 100 and 118 knots. Peak longitudinal acceleration was about 0.27 g during the accident flight and about 0.4 g during the previous 2 takeoffs. In both previous

takeoffs, the elevator began deflecting at similar speeds to the accident takeoff attempt and the airplane rotated to about 10° over about 4 seconds, lifting off from the runway in both cases as it rotated. The FDR data showed that the recorded aileron and elevator trim readings during the accident flight takeoff were consistent with the previous four takeoff settings.

During the accident flight takeoff roll, FDR data showed that the crew began ANU elevator deflection near V1 and reached full ANU elevator deflection at Vr. The airplane accelerated while on the runway to an airspeed above 115 knots, but the airplane pitch attitude did not increase above 1° before the airplane's departure from the improved pavement surface.

The study indicated that the Vr value correlated to about 105 knots ground speed. Using the vertical center of gravity value of 5.4 ft, at the Vr groundspeed, the calculated equivalent AND pitching moment due to adverse retarding force was about 12,420 ft pounds which was 77% greater than the nominal elevator/horizontal tail ANU pitching moment capability which was at least 7,000 ft pounds. Between 105 and 110 knots groundspeed, the equivalent AND pitching moment decreased to about 9,180 ft pounds but was still about 31% greater than the nominal elevator/horizontal tail ANU pitching moment capability. Beginning at 110 knots groundspeed, the equivalent AND pitching moment due to the adverse retarding force significantly increased from about 9,180 ft pounds and reached an equivalent AND pitching moment of 32,940 ft pounds at 118 knots.

For speeds at and beyond Vr, a successful takeoff with such an unexpected, adverse retarding force at the wheel/runway interface would have required an ANU pitching moment capability that exceeded the accident airplane's certified envelope, as measured by the forward center of gravity limit of the weight and balance envelope.

Takeoff Checklists

A review of the FAA-approved airplane flight manual revealed that its checklists for preliminary cockpit inspection, before starting engines, and shutdown each include setting the parking brake. The static takeoff and rolling takeoff checklists both cite "Brakes…Release" with no specific mention of the wheel brakes or parking brake.

Airplane Location Correlated with Smoke

To determine the airplane's location when smoke appeared, NTSB created a ground track reconstruction model overlaid onto aerial imagery, which included video surveillance frames, longitudinal acceleration from FDR data, and the measured runway tire marks. According to the model, the video frame time 0952:33 aligned with FDR time 5048.8. After this video frame time, the FDR showed a decrease in the longitudinal acceleration data – a decrease of 0.10/0.15 g to 0.1 g and lower. According to the time alignment with the model, the white smoke on the video aligned with where the runway marks associated with the right main landing gear darkened, 2,685 ft past the approach end of runway 2.

Previous Related Recommendations and Similar Accidents

During its investigation of this accident and another Cessna 560XL accident (NTSB case number WPR19FA230), the NTSB determined that without a parking brake indication, some Cessna 560XL pilots may not recognize that the parking brake is not fully released and attempt to take off, which could result in a runway overrun. Because Cessna 560XL airplanes continue to operate in the United States without a parking brake indication and the manufacturer continues to manufacture and deliver airplanes in the United States without such an alert, the NTSB issued the following safety recommendations:

Safety Recommendation A-22-8 to the FAA: Issue an airworthiness directive for in-service Cessna 560XL airplanes to require that they meet the parking brake indication requirements of Amendment 25-107 of 14 *CFR* 25.735.

Safety Recommendation A-22-9 to the FAA: Revise the type certification basis for Cessna 560XL airplanes and future derivative models to require that newly manufactured airplanes meet the parking brake indication requirements of Amendment 25-107 of 14 *CFR* 25.735. (NTSB Aviation Investigation Report NTSB/AIR-22-06, "Require Safeguards to Prevent Cessna 560XL Takeoff with Parking Brake Engaged.")

In September 2015, the Australian Transport Safety Bureau (ATSB) investigated a similar accident near Lismore, New South Wales, Australia, involving a Cessna 550 that did not have cockpit annunciation to alert the pilots that the parking brake was set. The pilot did not release the parking brake before attempting to takeoff, which led to a rejected takeoff and runway overrun. The ATSB made recommendations for all Cessna Citation airplanes (including the Cessna 560XL) to include a parking brake annunciation. In an October 2017 response, the manufacturer stated that the recommended actions were not needed because it was "simple airmanship" to remember to release the parking brake before the takeoff run. (ATSB Transport Safety Report AO-2015-114, "Runway excursion involving Cessna 550, VH-FGK, Lismore Airport, New South Wales, 25 December 2015.")

On October 3, 2018, a Cessna 560XL, 5N-HAR, was involved in a serious incident in Bauchi State, Nigeria. The XLS+ derivative model airplane, which was not equipped with parking brake annunciation, would not rotate during takeoff at Vr and the takeoff was aborted, which resulted in a wheel fire and no injuries. The Nigerian Accident Investigation Bureau (AIB) recommended the airplane manufacturer redesign the parking brake system to incorporate takeoff protection visual and aural warnings, and to make the position of the parking brake control visible to both flight crew members. The manufacturer stated that, as of the publication of this report, it was reviewing the recommendations but had not yet responded to AIB. (AIB Aircraft Accident Report NPF/2018/10/03/F, "Final Report on serious incident involving Cessna Citation 560 XLS+ aircraft with nationality and registration marks 5N-HAR operated by the Nigeria Police

Airwing which occurred at Sir Abubakar Tafawa Balewa Airport Bauchi, Nigeria on 3rd October, 2018.")

Administrative Information

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