



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

November 15, 2022

Group Chairman's Factual Report

POWERPLANTS

ERA21FA346

A. ACCIDENT

Location: Farmington, Connecticut
Date: September 2, 2021
Time: 951 local time
Airplane: Cessna 560 XL XLS +, Registration: N560AR

B. POWERPLANTS GROUP

Group Chairman Harald Reichel
National Transportation Safety Board
Washington, DC

Group Member Julio Leroux
Pratt & Whitney Canada
East Hartford, Connecticut

Group Member Kevin Godbout
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C. SUMMARY

On September 2, 2021, at 0951 eastern daylight time, a Cessna Citation 560XL airplane, N560AR, was destroyed when it was involved in an accident near Farmington, Connecticut. The airplane struck an electrical pole shortly after takeoff and crashed near an industrial building. The two pilots and two passengers on board were fatally injured. The airplane was operated as a Title 14 Code of Federal Regulations part 91 personal flight.

The engines were examined on-scene by the Powerplants group on September 3-4, 2021. The field examination revealed no anomalies on either engine that would have precluded normal operation. The engines were not further examined or torn down.

A review of the flight data recorder (FDR) and global position system (GPS) data revealed that both engines were operating normally during idle, taxiing, take-off roll and takeoff up to the point where the aircraft struck the electrical pole. The left-hand (LH) and the right-hand (RH) engine data collection units (DCUs) were sent to the manufacturers, where a download and comparison of the data revealed that the DCU data agreed with the FDR data, confirming that both engines were operating

normally and providing the expected level of thrust during the takeoff up to the point where the aircraft struck the electrical pole.

D. DETAILS OF THE INVESTIGATION - FACTUAL INFORMATION

1.0 Engine Information

1.1 Engine Description

The airplane was powered by two Pratt & Whitney Canada (PWC) PW545C (Figure 1) turbofan engines. The PW545C is a two-spool medium bypass ratio turbofan engine. The fan diameter is 27.3 inches, and the engine is 75.4 inches long. According to the Federal Aviation Administration (FAA) Type Certificate Data Sheet (TCDS) No. E00059EN Revision 5, the PW545C has a rated take-off thrust of 4,119 pounds at sea level and a maximum continuous thrust (MCT) of 3,372 pounds. The PW545C certification basis was 14 CFR Section 21.29; 14 CFR Part 33, Amendments 1 through 20, effective December 13, 2000, and was certified by the FAA on May 5, 2008.

The low pressure (LP) and high pressure (HP) shafts are counter rotating, turning in counterclockwise¹ and clockwise directions, respectively. The LP spool consists of a fan and a compressor boost stage that is driven by a three-stage LP turbine. The HP compressor consists of two axial stages and one centrifugal stage driven by a single stage cooled HP turbine. The combustion chamber liner is an annular, reverse flow weldment. The fuel, mixed with air, is injected into the combustion chamber by eleven hybrid nozzles.

The intermediate case forms the main structural path to the airframe and carries the forward engine mounts. The intermediate case also contains an integral accessory gearbox and associated drive system from the HP compressor shaft. All engine driven accessories, except for the LP rotor speed (N1) sensor, are mounted on the accessory gearbox. The accessories are driven by a tower driveshaft geared to the HP rotor (N2) shaft, passing down through the intermediate case to mesh with a bevel gear in the accessory gearbox.

The engine oil tank is an integral part of the intermediate case.

The PW545C control system uses a dual channel full authority digital electronic control or engine electronic control (EEC) to control the engine's LP rotor speed and thereby the engine's thrust, in accordance with the position of the pilot operated

¹ All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF) as is the convention. All numbering in the circumferential direction starts with the No. 1 position at the 12:00 o'clock position or immediately clockwise from the 12:00 o'clock position and progresses sequentially clockwise ALF.

thrust lever angle (TLA) and the prevailing conditions. This control is accomplished in accordance with the data received by engine located sensors, with the engine trim and airframe inputs as selected via discrete signals from the cockpit. The PW545C engine control system is comprised of the following main components; EEC, fuel metering unit (FMU), bleed off valve (BOV), ignition system and engine sensors and harness.

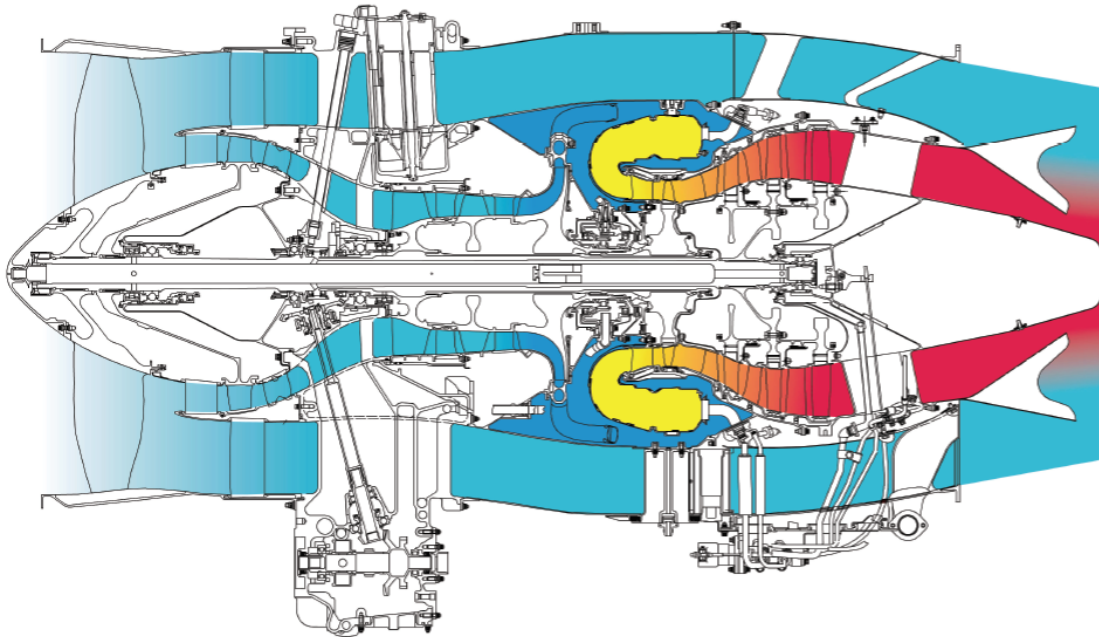


Figure 1 - Pratt & Whitney PW545 Turbofan Engine (Figure courtesy of PWC)

The engine is also equipped with a DCU which is an electronic storage device for limited or time-sensitive engine parameters used to assist maintenance staff to make decisions on service-related matters. They are not crash worthy. The EEC will write faults to the DCU when the pilot requests or when the EEC logic determines that fault criteria have been met. The data is captured as a trace recording, consisting of relevant system parameters.

1.2 Engines History

The LH engine was serial number (S/N) PCE-DF0049 while the RH engine was S/N PCE -DF0050. According to the records obtained by the FAA, the engine times on June 10, 2021, were: (See [Table 1](#)). Both engines were the original engines installed in the new airplane.

	Left Hand Engine	Right Hand Engine
Manufacturer	Pratt & Whitney Canada	Pratt & Whitney Canada
Model	PW545C	PW545C
Manufacture Date	November 2008	October 2008
Serial Number	PCE-DF0049	PCE -DF0050
Time Since Last HSI ²	27.3 hours	27.3 hours
Cycles Since Last Shop Visit	18 cycles	18 cycles
Total Time Since New (TSN)	2563.8 hours	2563.8 hours
Total Cycles Since New (CSN)	1891cycles	1891cycles

Table 1 - Engine Operational History

2.0 Details of the Field Examination

2.1 General External Condition & Observations

The empennage of the airplane was located outside of the building. Approximately the last 20 feet of the empennage was intact and inverted. The LH engine was still attached to the pylon and in position on the empennage ([Photo 1](#)). The RH engine was separated from the engine mount and found resting on the left horizontal stabilizer in a nose-down orientation ([Photo 2](#)). The airframe engine mount beam and associated structure was present however it was impact and thermally damaged. Neither engine displayed signs of uncontainment. The thrust reversers of both engines were still attached, and in their stowed position.

² Hot Section Inspection (HSI) per PWC Maintenance Manual 30J2302 Rev. 26 was performed as well as an engine general inspection (para. 5) and a low utilization engine inspection per Section 05-20-00, Scheduled Maintenance Checks para. 5A.

RH Engine-
Detached
from Mounts



LH Engine -
Inverted

Photo 1 - RH & LH Engine - On-scene and In-Situ - View from side - Note inverted fuselage



Photo 2 - RH Engine In-Situ - View from aft. LH engine in background. Note inverted empennage

2.2 Left-hand Engine Observations

The LH engine was complete and still intact. The inlet cowl was crushed and separated and located directly in front of the engine. The cowl doors were in place and latched; however, they displayed thermal distress between the 4 and 7 o'clock location (this was the top surface as oriented in the wreckage, which is consistent with a post event fire). There was a ground fire in the vicinity of the nacelle and the distress was consistent with an external heat source. In the area of the cowl that exhibited thermal distress, the engine externals and ancillary components exhibited a black sooty deposit ([Photo 3](#)).



Photo 3 - LH Engine - Sooty deposits on external components

From 7 to 11 o'clock, the external and ancillary components were free of sooty deposits. The arc between 11 and 3 o'clock could not be observed. There were no observed fluid leaks or hot spots on the engine in the areas that were visible. The intermediate case was fractured between 6 and 10 o'clock. No in-flight soot streaking, indicative of in-flight fire was observed on the nacelle exterior surfaces. The fan case was crushed, consistent with a frontal impact on the top side of the engine. Approximately 75% of adjacent fan blades were significantly bent in the direction opposite of rotation ([Photo 4](#)), consistent with a higher power rotation during impact. Five fan blades were fractured near the root, four of which were consecutive. Most of the fan blades exhibited sharp tears on the leading edges.



Photo 4 - LH Engine - Fan blades

The 3rd stage low-pressure turbine (LPT) blades and mixer did not exhibit any damage ([Photo 5](#)).



Photo 5 - LH Engine - Low pressure turbine - No damage

The chip detector was removed and found to be chip-free and clean ([Photo 6](#)). The fuel filter was examined, revealing a clean filter element and fuel in the filter bowl ([Photo 7](#)). The oil filter was clean ([Photo 8](#)).



Photo 6 - LH Engine chip detector - Clean



Photo 7 - LH Engine fuel filter - Clean



Photo 8 - LH Engine oil filter - Clean

The LH engine DCU P/N 30J3470-01, S/N 13-014604 was separated from its mounting location; however, it was still attached to its electrical connector. It was removed and retained for download and data analysis.



Photo 9 - LH DCU

2.3 Right-hand Engine Observations

The RH engine (ref. [Photo 2](#)) cowling was not attached to the engine but was found fractured in the debris field ([Photo 10](#)).



Photo 10 – RH cowling parts retrieved from field and placed with engine

The fan disk and the fan case had separated from the engine and were found nested together in the debris field. Most of the fan blades were bent in the direction opposite of rotation, of which 4 consecutive ones were fractured near the root ([Photo 11](#)), consistent with a higher power rotation during impact. The fan case was crushed, consistent with a frontal impact on the top side of the engine.



Photo 11 - RH engine fan disk and fan case - Separated from engine

The LPC rotor and hub ([Photo 12](#)) were found intact and loose in the debris field. Approximately $\frac{3}{4}$ of the blades of the LPC rotor were bent in the direction opposite of rotation, similar to the pattern of blade bending seen on the fan disk. The LPC stator airfoils were all bent in the direction of rotation and in the approximate plane of the blades there were static impact marks consistent with airfoil shapes. The fan blade air seal track was rotationally scored, consistent with contact against the rotating fan blade tips.



Photo 12 - RH Engine LPC rotor and hub

The inner stator core ([Photo 13](#)), consisting of the LPC inlet guide vanes, their inner shroud and the inner shroud of the fan exit vanes was found in the debris field. Thirty-seven of the 60 individual fan exit vanes were found distributed along the wreckage path ([Photo 14](#)) starting near the initial ground impact point.



Photo 13 - RH engine inner stator core



Photo 14 - RH engine fan exit guide vanes - Collected from debris field

The rest of the RH engine was complete from the intermediate case through the thrust reverser. There were no indications of under-cowl fire on the engine cases.

The 3rd stage LPT blades and mixer did not exhibit any damage ([Photo 15](#)).



Photo 15 - RH engine last stage LPT blades and mixer

The chip detector was removed and found to be chip-free and clean ([Photo 16](#)). The fuel filter was removed, revealing a clean filter element and fuel in the filter bowl ([Photo 17](#)). The oil filter was clean ([Photo 18](#)).



Photo 16 - RH engine chip detector - Clean



Photo 17 - RH engine fuel filter - Clean



Photo 18 - RH Engine oil filter - Clean

The electrical connector of the RH engine DCU, P/N 30J3419-01, S/N DP09-1046 (**Photo 19**) was separated, exposing the internal components and wires. It was removed for download and data analysis.



Photo 19 - RH Engine DCU

3.0 Flight Data Recorder (FDR), GPS and DCU Review

3.1 FDR Review

The data from the FDR plotted on [Figure 2](#) displays the engine parameters. Reference to the FDR Specialist's Factual Report in this docket for further details.

The engine parameters³ shown on the plot are:

Eng 1 TLA Cha B (degrees)
Eng 1 Thrust Target (%N1 RPM)
Eng 1 N1 (%RPM)
Eng 1 N2 (%RPM)
Eng 1 ITT (degrees C)
Eng 1 Fuel Flow (PPH)

Eng 2 TLA Cha B (degrees)
Eng 2 Thrust Target (%N1 RPM)
Eng 2 N1 (%RPM)
Eng 2 N2 (%RPM)
Eng 2 ITT (degrees C)
Eng 2 Fuel Flow (PPH)

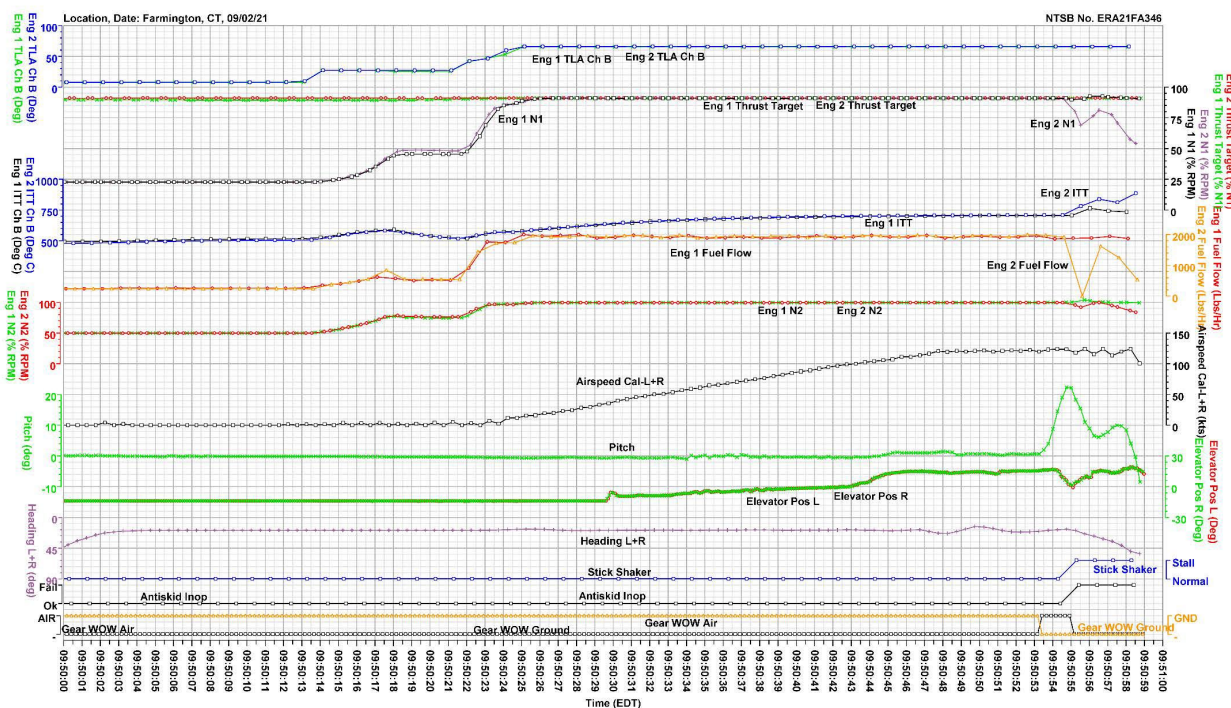


Figure 2 - FDR Plot of takeoff and engine parameters

³ Thrust Lever Angle (TLA), Channel B (Cha B), Revolutions per Minute (RPM), Pounds per hour (PPH)

During the takeoff roll at about 9:50:14, the engine TLAs advanced from an idle power setting of 7 degrees to 27 degrees and the engines accelerated and stabilized at 45% N1 with the aircraft still stationary on the runway. At 9:50:22 the engine TLAs increased again, and the aircraft started its takeoff roll. During the two power increase commands via the TLA, both engines accelerated smoothly and in unison, consistent with normal operation.

During the takeoff, both engines reached their target take-off engine speeds with 90.9% N1, 99.3% N2, interstage turbine temperature (ITT) of 710 degrees C and fuel flow approximately 1850 pounds per hour (pph). According to PWC, these values were normal for the specific ambient conditions. Additionally, a review of the two previous take-offs revealed that the parameters were similar to the values observed during this takeoff.

According to the FDR Specialist's Factual Report, after leaving the runway and at approximately 9:50:55, the gear position and weight on wheels signals became invalid, consistent with damage to the landing gear. Changes in aircraft accelerations at this time were consistent with the aircraft striking the electrical pole and the aircraft began a roll to the right, becoming inverted after about 3.5 seconds.

At approximately 9:50:55.5, the RH engine N1 began a significant, immediate, and uncommanded decrease, while the ITT increased, and fuel flow decreased, consistent with sudden damage to the engine. The RH engine N2 core speed also moderately decreased to about 92%. This suggests that the N1 spool, of which the fan and LPC are parts, was damaged, consistent with impact damage from an external source, rather than an internal engine failure.

3.2 GPS Review

A review of the GPS data is shown on [Figure 3](#). This map depicts the parameters of the RH engine overlaid onto the GPS location when it occurred. The engine data is highlighted and expanded on the figure for clarity. The flight's ground path is shown as a purple line. The flight direction is highlighted in yellow. The data shows the RH engine operating normally before striking the electrical pole (Eng 2 N2: 99.4%, Eng 2 N1: 91.0%, Eng 2 Fuel Fl: 1918.5 pph) and then in a degraded manner immediately after the electrical pole (Eng 2 N2: 95.1%, Eng 2 N1: 80.1%). The next location after the impact shows an even more degraded engine condition of (Eng 2 N2: 91.7%, Eng 2 N1: 68.9%).

The data shows that both engines were operating normally during idle, take-off roll and takeoff up to the point where the aircraft struck the electrical pole. Only the RH engine was affected, which is consistent with the findings in the debris field.

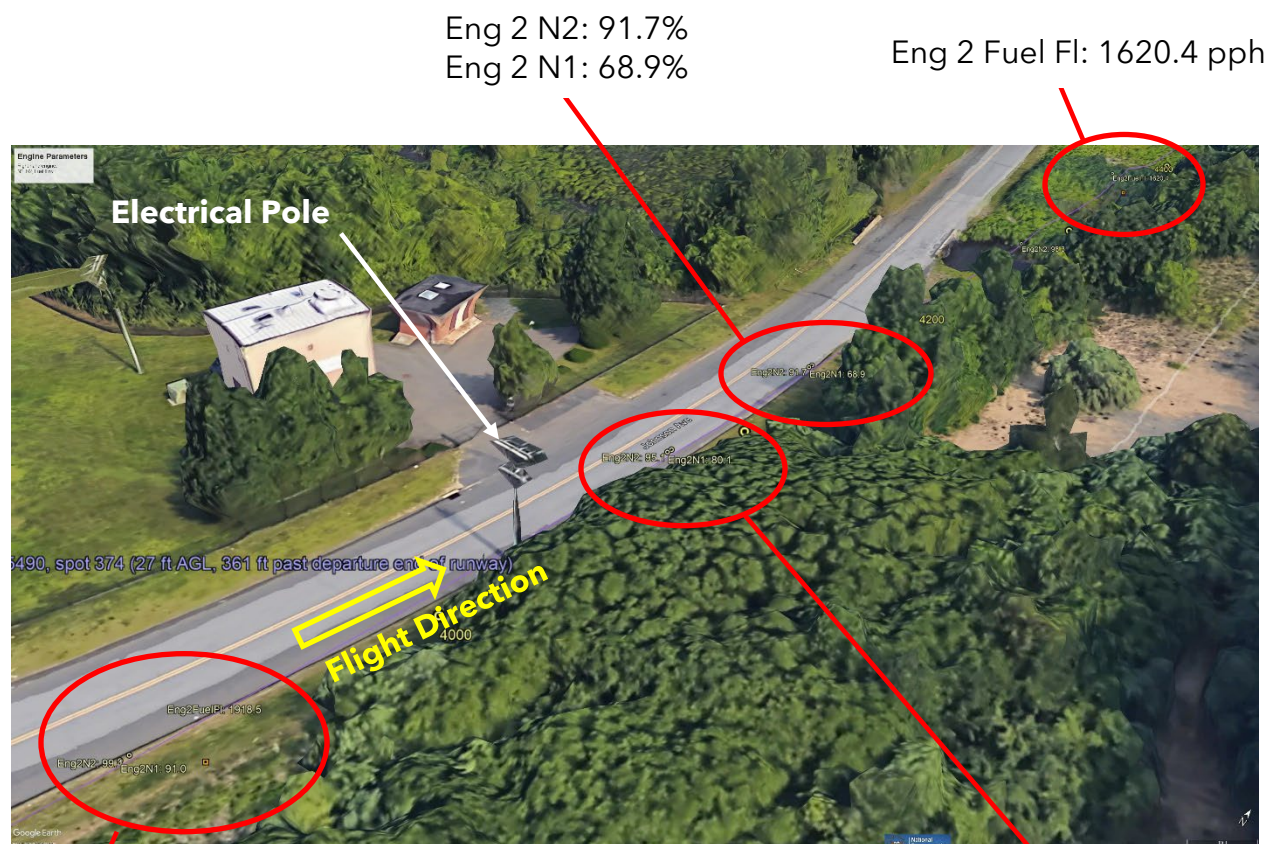


Figure 3 - GPS image of area near electrical pole

Eng 2 N2: 99.4%
Eng 2 N1: 91.0%
Eng 2 Fuel FI: 1918.5 pph

Eng 2 N2: 95.1%
Eng 2 N1: 80.1%

3.3 DCU Review

The DCUs from each engine were forwarded to the P&WC Service Investigation Facilities in Bridgeport, West Virginia for download and analysis. According to PWC the findings from the DCU data were:

The DCU was correlated to the FDR data. Each engine contained a "short" trace recording at time 9:50:53 for DF0049 (LH engine) and 9:50:51 for DF0050 (RH engine) approximately 25 seconds into the take-off roll and ending approximately 1

to 2 seconds prior to the aircraft becoming airborne. The DCU data concurred with the FDR data, confirming that both engines were operating normally and providing the expected level of thrust during the takeoff.

The DCU findings were:

- The N1 speeds were maintaining the target N1 reference speed of 90.9% N1, as expected for the take-off setting at the given ambient conditions
- The N2 speeds were maintaining approximately 99.2%N2, considered a normal/typical
- Speed for the conditions are indicative of healthy engines
- The TLA setting was steady at 65 degrees (take-off setting). Both engine's TLAs remained in the take-off position up to the point of impact into the commercial building.
- The ITT was slowly rising through 705 - 710 degrees C, which is normal for the conditions and indicative of healthy engines.
- The oil pressures and temperatures were in the normal range
- There were no active fault codes for either engine

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