

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



ERA21FA346

AIRCRAFT SYSTEMS

Group Chair's Factual Report

July 18, 2023

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A. ACCIDENT

Location: Farmington, Connecticut
Date: September 2, 2021
Time: 0951 Local Time
Airplane: Cessna Citation XLS+, N560AR, line number 560XL-6026

B. AIRCRAFT SYSTEMS GROUP

Chair: Tom Jacky
National Transportation Safety Board
Washington, DC

Member: Andrew Hall
Textron Aviation
Wichita, Kansas

Member: Kevin Godbout
Federal Aviation Administration
Enfield, Connecticut

Member: Tracey Canterbury
Collins Aerospace
Troy, Ohio

C. SUMMARY

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. The two pilots 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 Part 91 personal flight.

During the initial on-scene investigation, the Investigator In Charge removed the parking brake valve from the accident airplane and sent it to the aircraft systems group chair in Washington, DC. The parking brake valve was described as follows:

Manufacturer:	GarKenyon Aerospace & Defense
Part Number:	98433-2
Cessna Part Number:	9912388-11
Serial Number:	0289

The group met at the aircraft wreckage storage facility in Clayton, Delaware on February 10-11, 2022 to examine airplane components related to the brake and parking brake systems. The following components were removed for further examination:

- 1) Flight deck parking brake knob and attached portion of the tilt (instrument) panel.
- 2) Three segments of the parking brake actuating cable.
- 3) The two (left and right) main landing gear wheel, tire, and brake assemblies.

The parking brake knob, attached flight deck tilt panel, and parking cable segments were submitted to the NTSB Materials Laboratory.

The group met at the Collins Aerospace facility in Troy, Ohio on May 4-5, 2022, to examine the left and right brake assemblies.

The group met at the GarKenyon Aerospace & Defense facility in Meriden, Connecticut on May 17, 2022 to examine and disassemble the parking brake valve. The examination confirmed that the valve was in the parking brake applied (ON) position. No faults were noted during the examination of the valve.

D. DETAILS OF THE INVESTIGATION

Due to the circumstances of the accident, the group's investigation focused on the airplane's brake and parking brake systems.

1. Description of Airplane Systems

1.1 Parking Brake System and Parking Brake Valve

The aircraft was equipped with a parking brake. The brake is set "On" and released "Off" by use of the parking brake knob (handle) in the flight deck. The parking brake is operated manually, by the person sitting in the pilot (left) seat.

The parking brake knob is located on the pilot (left) side of the flight deck, on a tilt panel at the base of the instrument panel. See Figure 1. The parking brake knob, when "On," is pulled out and extends aft, approximately 4 inches from the "Off" position. When in the "Off" position, the knob is pushed in, and the knob is close to the instrument panel.

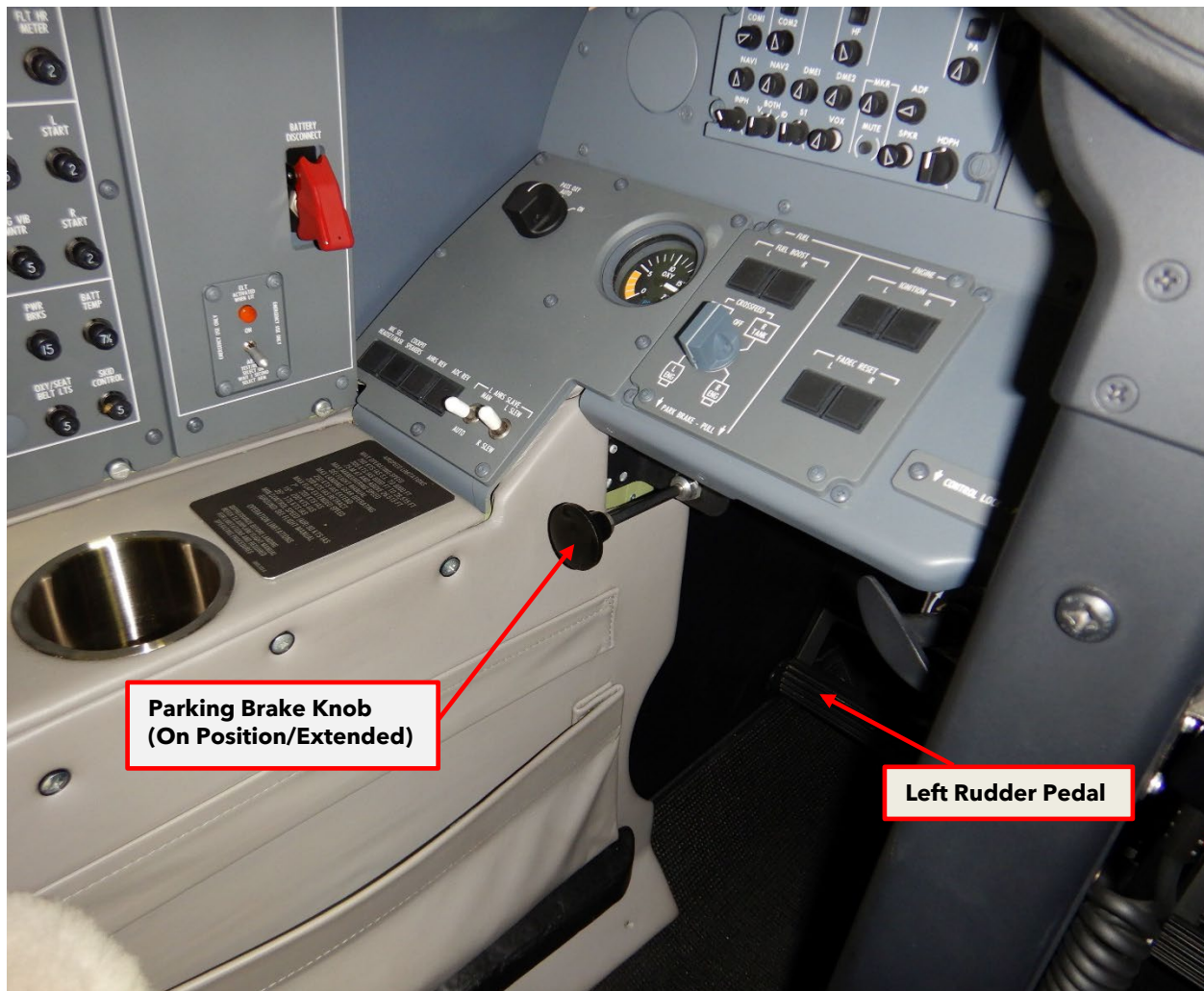


Figure 1. The parking brake knob and surrounding area in an exemplar Cessna Citation 560XL.

The aircraft operating manual (AOM) provides the following description of the parking brake:

"The parking brake is a part of the normal brake system and employs controllable check valves that can prevent the return of fluid after the brakes have been set. Parking brakes are set by depressing the toe brakes and pulling out the black parking brake knob (handle) located under the lower left side of the instrument panel. The parking brake should not be set if the brakes are very hot. This increases brake cool-down time due to decreased airflow and may result in sufficient heat transfer from the brakes to cause the parking brake thermal relief valves to open or to melt the thermal relief plugs in the wheel, causing deflation of the tire."

The parking brake cable assembly extends from behind the flight deck panel and parking brake knob, across the left side of the flight deck to the right, then back along the right side of the lower fuselage to about the area of the wing root, and then

turns and crosses to about the middle of the fuselage, ending at the parking brake valve. According to Textron, the entire length of the parking brake cable assembly in the airplane is 263 inches.

Movement of the parking brake knob results in movement of the parking brake valve's lever. When the flight deck parking brake knob is "OFF" or, pushed in, the parking brake valve is in the "OFF" (open) position, see Figure 2.

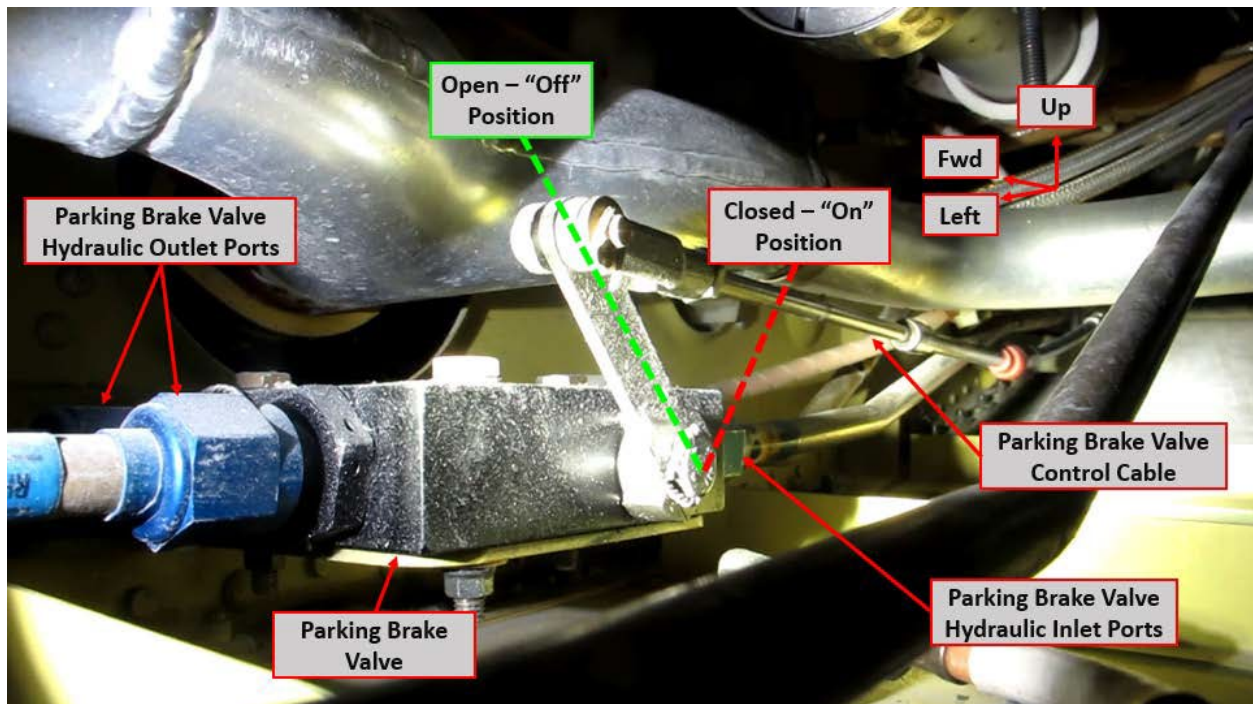


Figure 2. The parking brake valve, with the valve in the "OFF" position, on an exemplar airplane.

When the parking brake knob is pulled out, the parking brake valve is moved into the ON (closed) position, see Figure 3.

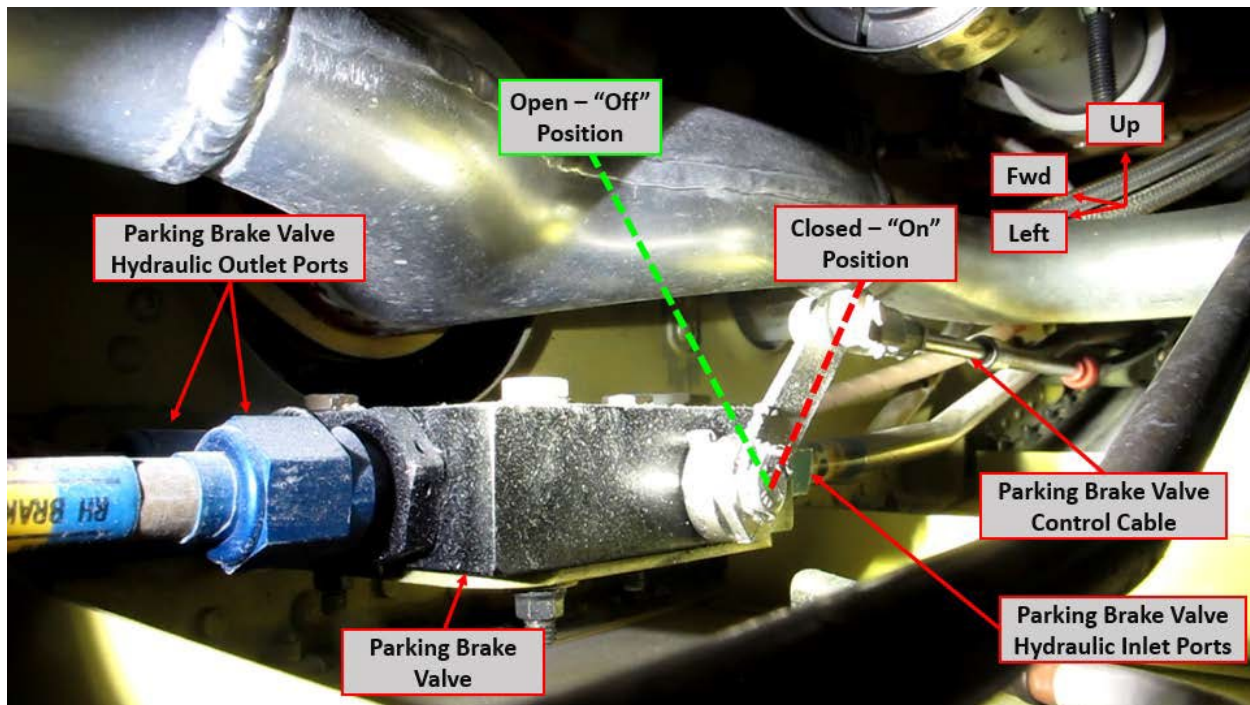


Figure 3. The parking brake valve, with the valve in the "ON" position, on an exemplar airplane.

Some Citation Excel aircraft certified¹ for operations in some foreign countries (i.e., Denmark, Ireland, and United Kingdom) are delivered with a proximity switch installed by the parking brake valve. The proximity switch is used in the aircraft "NO TAKEOFF" annunciator logic for the flight deck. For more information, see Section 8 of this report.

1.2 Wheels and Brakes

The airplane is equipped with two main landing gears, located on the underside of each wing, each with one wheel and brake assembly. See Figure 4.

¹ For more information regarding the certification information for the Textron 560XL airplane brake and parking brake systems, please refer to the [Systems Group Chairman's Factual Report](#), for the August 21, 2019 Citation Accident at Oroville, California (NTSB Investigation WPR19FA230) Section 4.4, "Aircraft Certification Information".

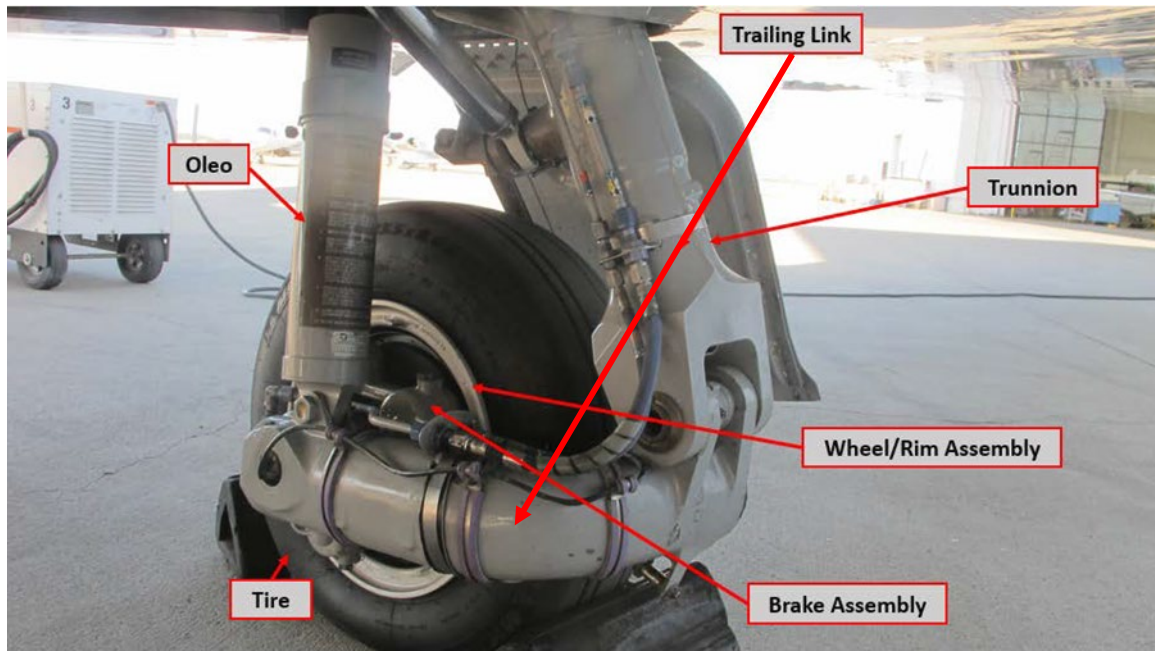


Figure 4. Main landing gear, tire, and brake assembly, from an exemplar airplane.

For each brake assembly, there is a multiple disc Carbon brake at each main landing gear wheel. The brakes are operated by a power brake valve, which is controlled by master cylinders that connect to the lower part of the flight deck rudder pedals.

Each main gear wheel is a tubeless lock-ring assembly constructed of aluminum. The tire inflation valve is in the wheelbase outer assembly. See Figure 5. Each wheelbase has heat shields installed to prevent heat, generated by the brake assembly, from damaging the wheels and tires. In addition, each wheel has an overinflation plug, installed 180 degrees from the inflation valve on the wheelbase assembly. Finally, three thermal fuse plugs are installed in the wheelbase assembly. The plugs melt at a predetermined temperature to prevent tire over-inflation caused by a brake heat or overtemperature condition.



Figure 5. Main landing gear tire and wheel assembly, from an exemplar airplane.

2. Parking Brake System, On-scene Inspection

The flight deck parking brake knob was identified during the on-scene portion of the investigation. Based on a visual inspection by the airplane manufacturer group representative and the NTSB Investigator in Charge (IIC), the knob was in the extended, or parking brake “ON” position.

The parking brake valve was identified during the on-scene portion of the investigation. The valve was damaged by fire. The cable was removed from the valve without disturbing the as-found valve lever position. Based on a visual inspection of the lever position by the airplane manufacturer group representative and the NTSB IIC, the brake valve was in the “ON” position. No part identification or data plate could be found on the component.

After the on-scene investigation was complete, the parking brake valve was sent to NTSB headquarters for further examination. As part of the examination, the valve was subjected to computed tomography (CT) scanning to document the internal condition of the components. The results from the CT scanning are documented in the “Computed Tomography Specialist’s Factual Report,” dated December 17, 2021, found in the docket to this investigation.

3. Examination of Airplane at Wreckage Storage Facility

The airplane wreckage was moved to a storage facility in Clayton, Delaware following the on-scene portion of the investigation. The group met at the storage facility to identify and remove additional airplane components, including the parking brake knob, parking brake cable, and the airplane's wheel and brake assemblies.

3.1 Parking Brake Flight Deck Knob

The airplane's flight deck parking brake knob was identified in the wreckage. The knob was still attached to the tilt panel. The knob was jammed and extended approximately 2.5 inches from the base of the tilt panel. The knob exhibited fire damage and was slightly bent. See Figure 6.



Figure 6. The flight deck parking brake knob, as identified in the airplane wreckage.

A portion of the threaded shroud was noted at the end of the knob handle, on the back of the tilt panel flange, measured at approximately $1\frac{7}{8}$ inches.

3.2 Parking Brake Cable

An approximate 102-inch section of the parking brake cable was identified in the wreckage. The part number 67-2531-2019 was marked on the cable. One end of

the cable had a portion of bent shroud on it. The shroud length was approximately 4 inches. The length of the threaded portion on the fractured end of the shroud was approximately $\frac{1}{8}$ inch. See Figure 7.



Figure 7. Portions of the parking brake cable (and parking brake knob), as found.

Another 38-inch segment of parking brake cable was identified in the wreckage. One end of the cable segment was wrapped in green electrical tape to indicate that the cable was purposely cut at that area during the on-scene portion of the investigation.

An additional portion of parking brake cable was noted in a UPS box. The additional segment measured approximately 18 inches.

The combined length of parking brake cable identified in the wreckage was 159 inches.

The parking brake knob and cable were hand-carried to NTSB headquarters by the group chair and submitted to the NTSB Materials Laboratory for evaluation. For further information, please refer to Materials Laboratory Factual Report Number 22-060, dated August 19, 2022, found in the docket for this investigation.

3.3 Left Wheel and Brake Assembly

According to CESSCOM maintenance records, the left main landing gear brake assembly was installed on the airplane on October 24, 2020.

The left wheel and brake assembly was examined. To examine the brake components, the wheel and heat shield were removed from the assembly. The left wheel and brake assembly remained attached to the left main landing gear trailing link. See Figure 8.



Figure 8. The left main landing gear wheel assembly and trailing link. The overinflation plug is circled in red.

The extension on the five hydraulic brake pistons was negligible. The left main brake housing exhibited extreme post-impact thermal damage. The three rotor assemblies were free to move on the brake stack. The brake stack was not disassembled so a detailed brake stack examination was not accomplished. The left main brake stators remained attached to the brake housing. The left main gear assembly hub cap was missing, and the retainer screws were noted in place. The left brake stack was secured with a piece of wood and the wheel retaining nut for storage. See Figure 9.



Figure 9. The left wheel and brake assembly.

One of the two wear pins was bent and not measured; the extension on the other wear pin was measured as 1.05 inches. The measurement was taken without hydraulic pressure applied to the brake stack.

The height of the brake stack was 5.4 inches.

The thickness of the two center stators was 0.73 inches. The thickness of the three center rotors was 0.85 inches.

Three fuse plug holes were noted on the outside of the wheel hub. One of the three holes was open and clear; the other two were plugged. See Figure 10.



Figure 10. An opened fuse plug hole on the left wheel.

The inflation valve and overinflation valve were noted on the left wheel. Both valves were observed with post-impact thermal damage.

The wheel speed transducer was free to rotate, however, there was some drag during rotation.

No evidence of brake seizing was noted.

The left wheel assembly exhibited extreme post-impact thermal damage. A portion of the wheel was melted and resolidified. The left main inboard wheel half flange was not observed and missing. The left main wheel side rim and lock ring assembly were also missing. The left main outboard wheel half flange also exhibited extreme post-impact thermal damage.

3.4 Right Wheel and Brake Assembly

According to CESSCOM maintenance records, the right main brake assembly was installed on the airplane on September 26, 2014.

A portion (bead wiring) of the right tire material was still attached to the wheel. The right wheel and brake assemblies remained attached to the right main landing gear trailing link and trunnion. See Figure 11.



Figure 11. The right landing gear, tire remnants, and wheel assembly.

The right tire remnants and wheel hub were removed from the assembly to examine the brakes.

The inflation valve was missing and appeared to be broken off at the base of the valve stem. The tire overinflation plug was noted and was observed with post-impact thermal damage.

The five brake pistons were all extended to approximately 0.7 inches. The right main brake housing exhibited post-impact thermal damage. The three rotor assemblies were free to move on the brake stack. The brake stack was not disassembled, so a detailed brake stack examination was not accomplished. The right main brake stators remained attached to the brake housing. The right main gear assembly hub cap was observed in place and the retainer screws were also noted in

place. The right brake stack was secured with a piece of wood and the wheel retaining nut for storage.

The wheel speed transducer was free to rotate.

Three fuse plug holes were noted on the outside of the wheel hub. Two of the three holes were open and clear; the other hole was plugged. See Figure 12.



Figure 12. An opened fuse plug hole on the right wheel.

The wheel speed transducer sensor wire was noted on the wheel assembly and ran into the landing gear structure.

The right wheel assembly exhibited post-impact thermal damage. The right main inboard wheel half flange was observed with impact and post-impact thermal damage. The right lock ring assembly was noted in place, but the right main wheel side rim was observed with post-impact thermal damage; some of the rim was missing. The right main outboard wheel half flange was observed with heat damage with significant darkening of the wheel around the axle.

The wheel and brake assemblies were shipped to the manufacturer's facility in Troy, Ohio for further examination.

3.5 Other Miscellaneous Identified Components

The landing gear handle panel was found in the wreckage. The panel exhibited heat and impact damage. The landing gear handle appeared to be in the down position. The anti-skid switch was in the up (on) position.

The brake control cables from the flight deck area were identified.

4. Examination of the Airplane Brake Assemblies

The group met at the Collins Aerospace Landing Systems facility in Troy, Ohio to examine the airplane brake assemblies, as follows:

4.1 Examination of the Right Brake Assembly

The right brake assembly was documented as follows:

Part Number: 2-1601-1
Serial Number: 1700
Manufacture Date: 05-08

Note: Collins Aerospace had no record of this brake assembly being overhauled at a Collins facility.

There was no evidence of fluid leaks on the brake assembly. The assembly remained attached to the right main landing gear trunnion/axle during shipment. The brake assembly was removed from the axle. The brakes could not be pressurized because the shuttle valve and adjuster assemblies were compromised (by impact and thermal damage) and would leak. See Figure 13.

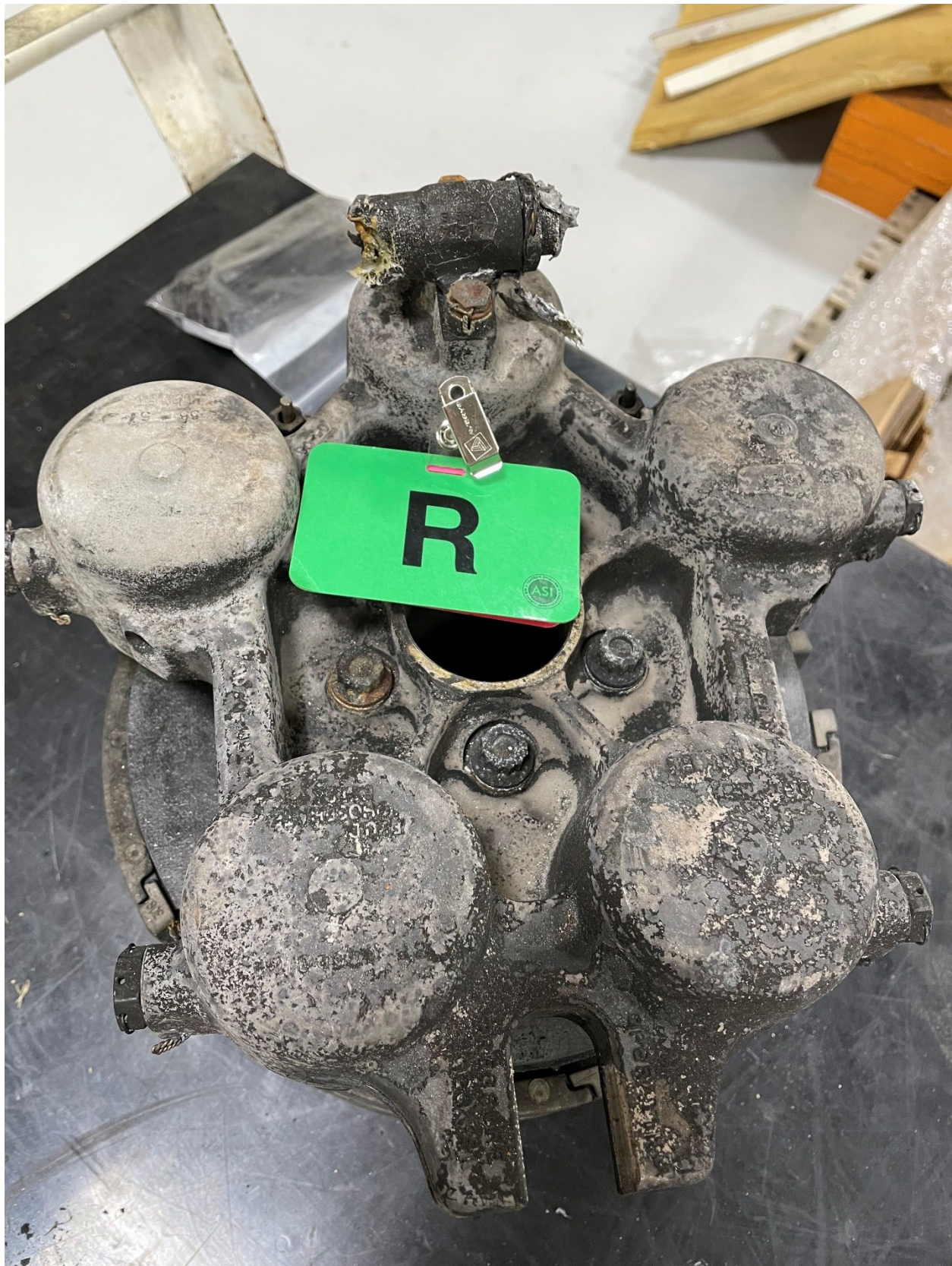


Figure 13. Right brake assembly.

The shuttle valve assembly (part number 211-114, serial number 1810) was examined. The port with lock wire was melted, so a functional test could not be completed.

One wear pin (right of shuttle valve) extension was 0.285 inches² and the second wear pin (left of shuttle valve) extension was 0.300 inches. The brake stack was too damaged to hold hydraulic pressure, so the measurements were taken without hydraulic pressure applied to the brake stack³.

The piston housing assembly exhibited post-impact thermal damage. The main three rotor assemblies were free to move on the brake stack. The running clearance between the piston insulators and the brake stack was at least 0.020 inches⁴. The brake stack was removed. The five adjuster assemblies in the piston housing assembly were all safety wired. The adjuster assemblies were arbitrarily numbered 1-5 with a grease pencil. The safety wire was removed, and the adjuster assemblies were removed from the piston housing. For all adjuster assemblies, visual inspection of the components indicated that the O-ring and back-up ring were installed but had extreme thermal damage. The adjuster spring was intact. The piston housing assembly fluid passages were clear.

The brake stack was disassembled. The pressure plate showed normal wear. See Figure 14. The stators and rotors were examined. The wear was considered normal. The stators and rotors did not exhibit any sign of oxidation or deterioration. One of the drive grooves on stator 2 exhibited minor mechanical damage to the carbon.

² Collins Aerospace caliper V0429 was used for the wear pin measurements.

³ Collins Aerospace measured wear pin length on exemplar brake assemblies of the same part number with and without hydraulic pressure being applied. The wear pin was extended approximately 0.040 - 0.045 inches more without hydraulic pressure.

⁴ Collins Aerospace feeler gauge 09204 was used for the measurement.



Figure 14. The right brake assembly pressure plate, top side, after disassembly.

4.2 Examination of Left Brake Assembly

The left brake assembly was documented as follows:

Part Number: 2-1601-1
Serial Number: 0424
Manufacture Date: 12-00

Note: According to Collins Aerospace records, Collins overhauled this brake assembly in June 2020.

The left brake assembly was examined. There was no evidence of fluid leaks. The left brake assembly remained attached to the left main landing gear trunnion/axle during shipment. The brake assembly could not easily be removed from the axle. To gain access to the brake stack, the back side of the torque plate was cutoff using a plasma torch. The brakes could not be pressurized because the shuttle valve was missing and extreme thermal damage to the brake housing exposed the piston cavities. The shuttle valve bolts and their lockwire remained. See Figure 15.



Figure 15. Left brake assembly and damage to the brake piston housings.

The wear pin (right of shuttle valve) was bent and could not be measured. The wear pin (left of shuttle valve) was measured at 0.941 inches. (Caliper V0429 was used for the measurement.) The measurement was taken without hydraulic pressure applied to the brake stack. The pistons appeared to be fully retracted. See Figure 16.

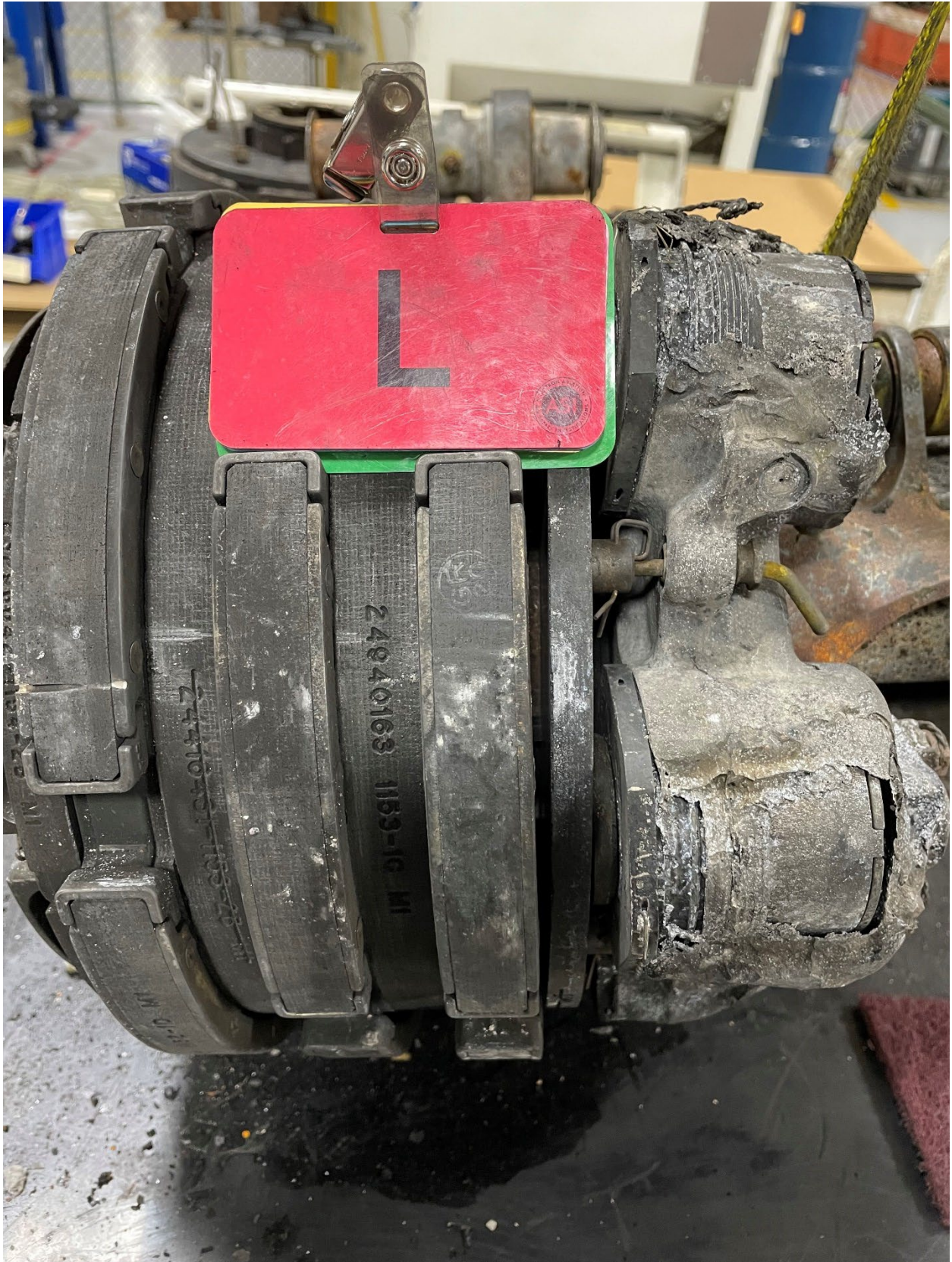


Figure 16. Left brake assembly, stators, and rotors.

The piston housing assembly exhibited severe post-impact thermal damage. The left main landing gear's three rotor assemblies were free to move on the brake stack. The five adjuster assemblies in the piston housing assembly were all safety wired.

Due to thermal damage to the piston housing, only one adjuster assembly was removed - the one assembly that still had an intact, enclosed cavity. The group declined to remove the other adjuster assemblies, since they were already damaged, and an attempted removal would cause further damage to the piston housing assembly. The safety wire was removed. The flats of the adjuster assembly were ground down to allow enough clearance to rotate the adjuster assembly. The adjuster assembly was removed from the piston housing. A visual inspection of the components indicated that the O-ring and back-up ring were installed but had extreme thermal damage.

The adjuster assembly was disassembled. During disassembly, the adjuster nut fell on the floor and could not be found after an extensive search. Visual inspection of the components indicated that the seals were installed but had extreme thermal damage. The adjuster spring was intact.

The brake stack was disassembled. The pressure plate showed normal wear. See Figure 17. The stators and rotors were examined. The observed wear was considered normal. The stators and rotors did not exhibit any sign of oxidation or deterioration.



Figure 17. The left brake assembly pressure plate, top side.

5. Examination of Parking Brake Valve at Manufacturer's Facility

Following the computed tomography (CT) and radiographic imaging examination, the parking brake valve was shipped to the GarKenyon facility, prior to the arrival of the group.

Upon arrival of the group, the valve was removed from storage, the shipping box opened, and the valve examined. The valve was damaged by post-crash fire; it was covered with smoke and fire residue.

A visual examination of the valve determined the valve lever was in the closed position. When the plastic restraint holding the valve handle was removed, the valve lever could not be moved by hand. See Figure 18.

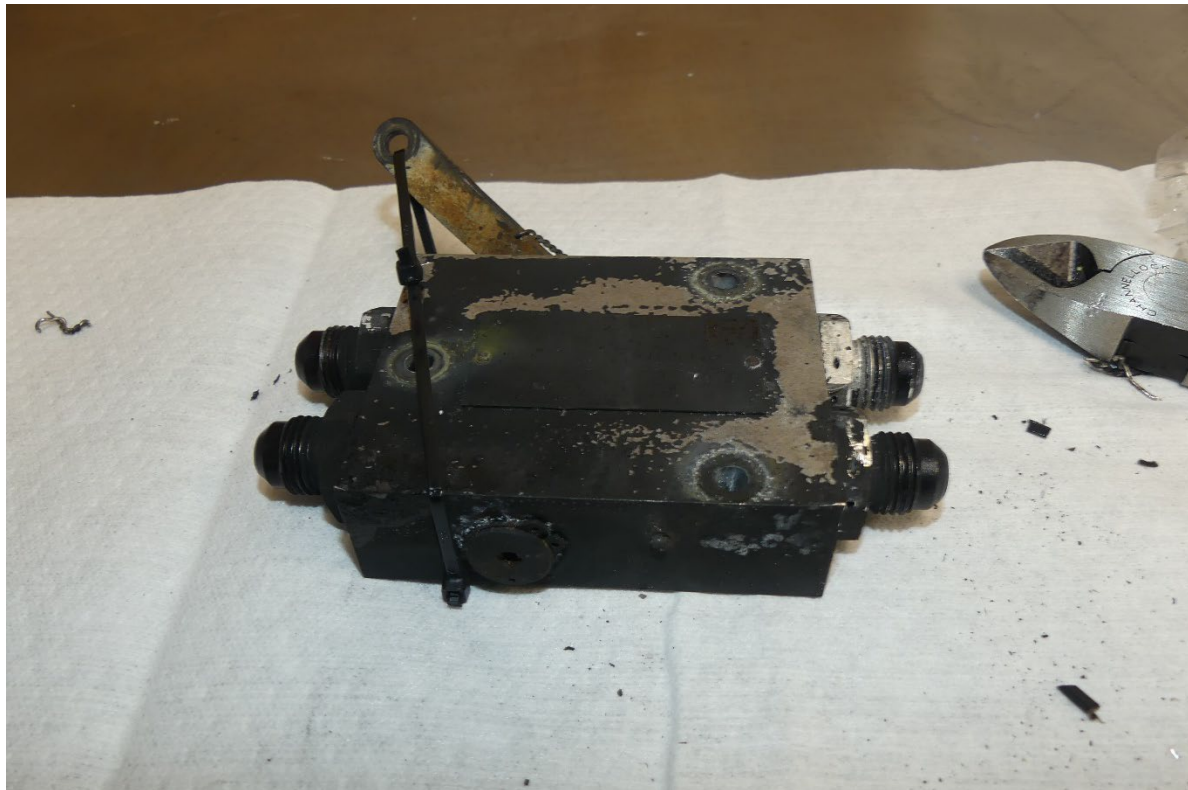


Figure 18. The parking brake valve, as received, prior to disassembly, with plastic restraint on valve handle.

The valve's data plate was consumed by heat and fire damage. The valve's part and serial number were determined by airplane and valve manufacturer records.

Lockwires were noted on the valve handle and the GarKenyon fitting. The lockwires were removed.

On the upstream side of the valve, the Cessna fittings were removed from the valve.

The GarKenyon fittings were removed from the valve. The fittings were noted on the downstream side (towards the airplane wheels) of the valve.

After the GarKenyon fittings were removed, the internal springs and poppet valves were removed. The springs were noted as twisted from their normal state, considered by the group to be because of exposure to heat.

The seals on the poppet tip were missing. The seals were assumed to be melted from the heat damage to the valve.

Once the remainder of the internal components were removed from the valve, the cam was examined internally. The valve lever could not be moved by hand or by using a wrench, so the cam was pushed out from the valve housing by use of a hydraulic press. When the cam was partially pushed out, examination of the cam and valve indicated that the found position of the valve was in the closed position and the cam flat spots were oriented towards the poppet valves.

Circular witness marks were noted on the flat portion of the cam. GarKenyon personnel indicated that, based on the position of the valve, the marks may have been made by heat damage from the poppet valve touching the flat spots of the cam during the post-crash fire. See Figure 19.



Figure 19. The parking brake valve cam, with witness marks on the flat spots.

The cam (and attached lever) from the accident valve was compared to a newly manufactured cam. See Figure 20.



Figure 20. Side by side comparison of the accident parking brake valve's cam and lever (left) against a new cam (right).

At the conclusion of the examination, the valve was repackaged, and hand carried from the facility by the NTSB.

6. Examination of Runway Marks

During the on-scene portion of the investigation, the takeoff runway (runway 2) at Robertson Field Airport was examined for tire marks. The taxiway leading onto the runway was also examined for tire marks. The examination was conducted by the NTSB, FAA, Textron Aviation, and personnel from West Hartford Police Department.

Additional runway tire track measurements were taken by the West Hartford Police Department, including three-dimensional scans and geo-positioning of known, marked locations.

There were no identifiable tire marks associated with the accident airplane in the approach end of runway 2. The first identified mark, associated with the accident airplane's right main landing gear tire, was located about 9 feet right of runway 2 centerline and about 2,360.9 feet from the approach end of the runway⁵. The first identified mark from the left main landing gear tire was located about 6 feet left of the runway centerline and 2,482 ft from the approach end of the runway. The distance between the center of the marks were about 15 feet, consistent with the published width between the left and right main landing gear tires.

Although the marks from both main landing gear tires remained on the runway until the departure end of the runway, both marks continued to the right of the runway centerline, with the mark from the left tire crossing the runway centerline about 2,720⁶ feet from the approach end of the runway. The mark from the right main landing gear tire became darker at 2,685 feet from the approach end of the runway and about 12 ft right of runway centerline. At about 2,744 feet from the approach end of runway 2, alternating light and dark marks from the left and right main landing gear tires were spaced 6 feet 6 inches apart.

The marks from both main landing gears continue to the end of the runway and onto the adjacent grass. The marks stop at the end of the grass. A review of the departure end of runway 2 revealed a small width of grass, followed by an approximate 20-foot elevation decrease past the departure end of the runway.

Further inspection of the tire marks at the end of the runway revealed the mark from the left main was lighter in color than the mark from the right main landing gear tire. Additionally, the left main still depicted grooves consistent with an inflated tire, while the mark from the right main landing gear tire was solid black.

No tire remnants from the accident airplane were found on the runway.

7. Takeoff Roll Video and Google Earth Depiction of Aircraft Data

The security camera videos of the airplane's accident takeoff roll were reviewed for relevant information. The videos were divided into files of still frames for the review, for each of the cameras that recorded the aircraft movement.

The following observations were made from the videos (Note: The times listed below are taken from the time embedded in the "Airport" camera frames, and have not been altered or aligned with FDR or CVR data⁷):

⁵ All measurement values, unless stated otherwise, are relative to the approach end of runway 2 and the runway centerline, looking towards the departure end of runway 2.

⁶ This distance was determined from GPS readings taken by the Textron group member when placed into the Google Earth model.

⁷ For more information regarding Local Time alignment, please refer to the Aircraft Performance

- At time 9:52:32, white smoke was noted around the inboard right wing of the airplane.
- At time 9:52:37 more white smoke or dust on the right side of airplane.

In addition, the aircraft performance group's NTSB Google Earth ground track reconstruction model was examined to assess the position of the airplane on the runway when the first instance of white smoke was noted. The Google Earth model included representation of several aircraft datasets, including the video surveillance frames, the integration of the longitudinal acceleration FDR data, and the measured runway tire marks⁸.

According to the reconstruction model, the video frame at (video) time 09:52:33 aligns with FDR time 50:48.8. After this time (video frame), the FDR shows 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 Google Earth reconstruction model, the white smoke video aligns with where the runway marks identified with the right main landing gear (R MLG) darkens, 2,685 ft past the approach end of runway 2.

8. Textron Service Bulletin to install Flight Deck Parking Brake Indication

Cessna (Textron) issued Service Bulletin SB560XL-03-01, "Certification Requirements - UK Certification Requirements", Revision 1, on September 25, 2002 to provide the means to install a flight deck parking brake annunciation on the Citation 560XLS models. The service bulletin provided the method, parts, and instructions to configure the effected airplane to comply with certification requirements that require the installation of a flight deck parking brake annunciation.

This modification was not available for the Citation 560XLS+ models, including the accident airplane.

Submitted by:

Tom Jacky
Aircraft Systems Investigator

Group Study in the docket for this investigation.

⁸ For more information regarding the NTSB Google Earth ground track reconstruction model, please refer to the Aircraft Performance Group Study in the docket for this investigation. For more information regarding the flight data recorder information, please refer to the Flight Data Recorder Specialist's Factual Report in the docket for this investigation.