

National Transportation Safety Board
Office of Aviation Safety
Washington, DC 20594



CEN21LA259

AIRCRAFT SYSTEMS

Group Chair's Factual Report
August 10, 2023

TABLE OF CONTENTS

A. ACCIDENT	3
B. AIRCRAFT SYSTEMS GROUP	3
C. SUMMARY	3
D. DETAILS OF THE INVESTIGATION	6
E. LIST OF ATTACHMENTS	20

A. ACCIDENT

Location: Aspen, Colorado
Date: June 4, 2021
Time: 0954 Local Time
Airplane: Cessna 560XL, Serial Number 560-5016, N615RG

B. AIRCRAFT SYSTEMS GROUP

Group Chair: Tom Jacky
National Transportation Safety Board
Washington, DC

Member: Andrew Hall
Textron Aviation
Wichita, Kansas

C. SUMMARY

On June 4, 2021, at 0954 mountain daylight time, a Cessna 560XL airplane, registration N615RG, was substantially damaged when it was involved in an accident at Aspen-Pitkin County Airport (ASE), Aspen, Colorado. The pilot, co-pilot, and three passengers were uninjured. The airplane was operated as a Title 14 Code of Federal Regulations Part 91 personal flight.

The airplane was originally examined on-scene by FAA and Textron representatives from June 10 – June 11, 2021. During the initial examination, the following airplane landing gear system component was removed from the airplane:

1. Landing Gear Control Handle
Textron Part Number: 9912550-1
Manufacturer Part Number: 049801-001
Serial Number: H9299

The group met at the Atlantic Aviation facility at the Aspen-Pitkin County Airport from September 14-16, 2021, to examine and test the airplane's main landing gear system.

During the group examination, the following airplane printed circuit boards (PCB) were removed for further test and examination:

2. Hydraulic Printed Circuit Board
Part Number: 6618723-1
Serial Number: 0356

3. Landing Gear Printed Circuit Board
Part Number: 6618704-6
Serial Number: 0840
4. Squat Switch Printed Circuit Board
Part Number: 6618706-1
Serial Number: 0115
5. No Takeoff Printed Circuit Board
Part Number: 6618708-1
Serial Number: 0117

The following hydraulic pressure and return filter cartridges were removed and retained for further testing:

6. Left Pressure Filter Cartridge
Purolator Part Number: 9912281-8 (Not Serialized)
Note: Fluid samples were collected from the filter bowl while removing the cartridge.
7. Right Pressure Filter Cartridge
Purolator Part Number: 9912281-8 (Not Serialized)
Note: Fluid samples were collected from the filter bowl while removing the filter cartridge.
8. Return Filter Cartridge
Purolator Part Number: 9912281-12 (Not Serialized)
Note: Fluid samples were collected from the filter bowl while removing the filter cartridge.

The following landing gear actuators and valves were removed and retained for further testing:

9. Nose Landing Gear Actuator
Part Number: 9912491-2
Serial Number: 0033
10. Left Main Landing Gear Actuator
Part Number: 9912537-1
Serial Number: 0047
11. Right Main Landing Gear Actuator
Part Number: 9912537-2

- Serial Number: 0060
12. Landing Gear Control Valve
Part Number: 71839
Serial Number: 0017
 13. Loading (Hydraulic Shutoff) Valve
Part Number: 61510-1
Serial Number: 1429A
 14. Hydraulic Relief Valve
Part Number: 4614
Serial Number: 1651A
 15. Nose Uplock Actuator
Part Number: 5527504-3
Serial Number: W425
 16. Left Main Uplock Actuator
Part Number: 5527504-3
Serial Number: W232
 17. Right Main Uplock Actuator
Part Number: 5527504-3
Serial Number: W237

The internal configuration of the airplane's landing gear control handle was documented using radiographic images that were collected from July 28 to August 16, 2021, in Chicago, Illinois. A review of the images determined that, at the time of the scans, the landing gear handle was in the extended position and there were no indications of malfunctions of the internal components of the landing gear handle.

From March 31, 2022 to April 12, 2022, examination of several of the removed components was accomplished at the Textron Aviation Facility in Wichita, Kansas. The FAA Wichita Aircraft Certification Office provided witnesses to the examination and testing. A technical specialist from Ontic, the Landing Gear Control Handle manufacturer, assisted with the examination of that component.

On August 23, 2022, the Right Landing Gear Actuator was examined at the Nabtesco Aerospace, Inc. facility in Kirkland, Washington under the witness of an investigator from the NTSB's Western Pacific Region Office.

Following each examination, all pertinent documents and photographs were provided to the parties.

D. DETAILS OF THE INVESTIGATION

1. Description of the Landing Gear System

The airplane's landing gear system is electrically controlled and hydraulically actuated. Each landing gear assembly uses a single wheel assembly and an oil over air strut.

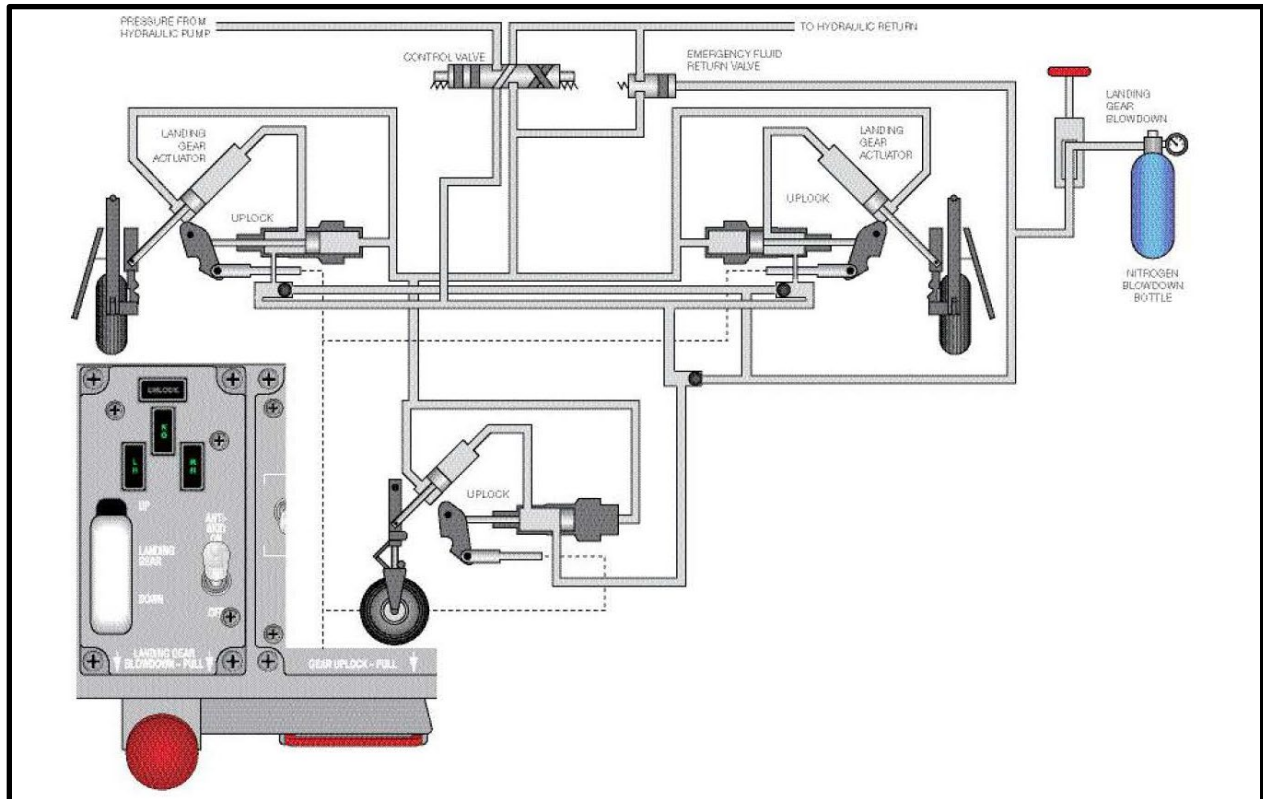


Figure 1. Schematic of the Citation Landing Gear System. [Figure from Citation XL/XLS/XLS+ Maintenance Training Manual, Volume 1]

The landing gear actuators incorporate an internal lock to hold the gear in the extended position. The actuators are held retracted by mechanical uplocks that are normally released hydraulically.

In the flight deck, the Landing Gear Control Panel contains the Landing Gear Control Handle, an audible warning system, three gear safe indicators and a red gear unlocked indicator. The Landing Gear Handle has two positions, full up and full down. The handle must be pulled out to clear a detent before it can be repositioned. Operation of the gear and gear doors will not begin until the handle has been positioned in one of the two detents. A gear handle locking solenoid activated by the

left main gear squat switch, physically prevents inadvertent movement of the gear handle while on the ground. See Figure 2.

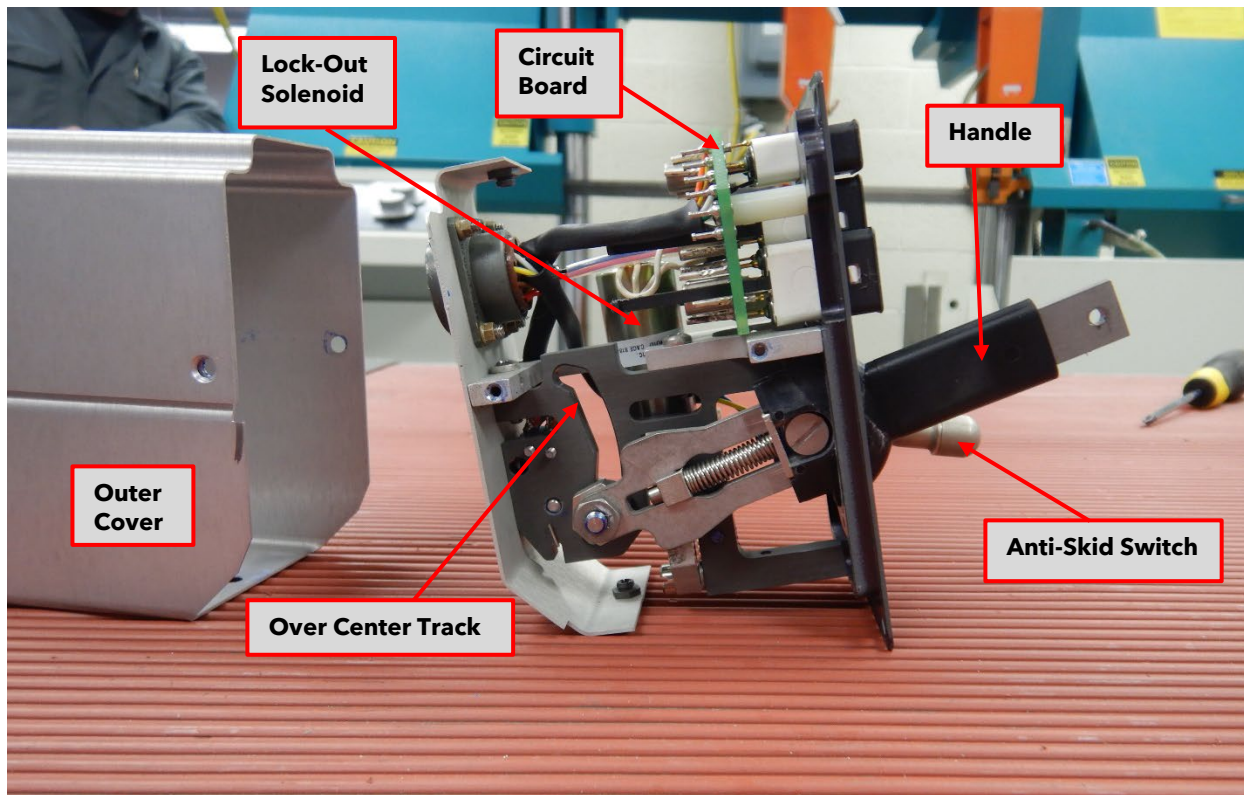


Figure 2. Landing Gear Control Handle with components annotated.

2. Initial Examination of Airplane

The initial on-scene examination was conducted at the Aspen-Pitkin County Airport by FAA and Textron representatives. Due to travel restrictions from the Covid-19 pandemic, the NTSB did not travel to the scene.

After the event the aircraft was secured by local FAA officials. During the initial examination, prior to any work being accomplished, the Textron recovery team entered the flight deck and video-recorded the flight deck area. The video shows the Landing Gear Control Handle in the landing gear retracted position.

During the examination, the Landing Gear Control Handle¹ and Cockpit Voice Recorder (CVR) were removed from the airplane and shipped to the NTSB.

3. Group Examination of Accident Airplane

¹ The Landing Gear Control Handle was replaced with a new unit.

The group met at the Atlantic Aviation facility at the Aspen-Pitkin County Airport from September 14-16, 2021, to examine and evaluate the airplane's main landing gear system. The airplane was moved into a hangar to facilitate the tests.

The examinations were conducted using the investigation plan developed by Textron and approved by the group. The examinations were conducted as follows.

3.1 Download of Recorded Engine Information

From the airplane's flight deck, a laptop computer was connected to the engine Data Collection Units (DCUs) via accessible connector ports. Using software from the engine manufacturer, the non-volatile memory files were successfully downloaded from both engine DCUs.

The downloaded data files were transferred from the Textron group representative to the NTSB IIC on September 15, 2021. The NTSB provided the data files to the engine manufacturer for conversion and assessment.

The engine manufacturer provided assessment of the DCU recorded data. For more information, please refer to the DCU Data Summary for NTSB in the public docket.

3.2 Electrical Checks of the Airplane Landing Gear System

Electrical checks of the airplane's landing gear system were conducted. In preparation for the checks, the Landing Gear Control Handle was disconnected from its electrical connector (PI009).

3.2.1 Test with Aircraft State - Power OFF, Landing Gear on Ground

The following tests were accomplished:

- Measure/Record ground between connector PI009-pin B and PI009-pin E (discrete ground used for the EXTEND/RETRACT function to Gear Logic PCB). Result: Confirmed good, ground.
- Measure/Record the resistance between PI009-pin A and PI009-pin C (discrete gear handle command to Gear Logic PCB). Result: pin A open, pin C open, and open between pins A-C. Note: all expected results.
- Measure/Record the resistance between PI009-pin H (Gear Handle Solenoid (-) input from Gear Logic PCB) and aircraft ground. Result: Open between pin H and aircraft ground. Note: expected results.

3.2.2 Test with Aircraft State - Power ON, Landing Gear on Ground

The following tests were accomplished:

- Measure/Record voltage (expected result: 28 volts) at connector PI009-pin G (Gear Handle Solenoid (+) input from Landing Gear circuit breaker (CB) from the left CB panel). Result: 27.22 volts.
- Measure/Record the resistance (expected result: open) at PI009-H (Gear Handle Solenoid (-) input from Gear Logic PCB) and aircraft ground. Result: Open between pin H and aircraft ground.

Following these checks, the aircraft was powered down.

3.3 Functional Tests of the Main Landing Gear System

For these tests, the replacement landing gear control handle was used.

3.3.1 Aircraft State: Power ON, Landing Gear on Ground

- With the gear handle in the EXTEND position, verify handle is unable to transition to RETRACT (Due to loss of solenoid ground). Result: Unable to move handle.

3.3.2 Aircraft State: Power ON, Landing Gear in Air

- Pull GEAR CTL or GEAR WRN circuit breakers on the left CB panel.
- With gear handle in EXTEND position, verify handle is unable to transition to RETRACT. (Due to loss of solenoid power) Result: When the GEAR WRN breaker is pulled, the handle was unable to transition to retract. When GEAR CTL breaker was pulled, then the handle could be transitioned to retract.
- Re-engage GEAR CTL or GEAR WRN circuit breaker on left CB panel.
- With gear handle in EXTEND position, verify handle can transition to RETRACT. (When {electrical} ground in air (GIA), the handle should be able to transition) Result: For both circuit breakers, the gear handle could be transitioned.
- With the gear handle in RETRACT position, verify that the handle can transition to EXTEND. (When GIA, handle should be able to transition) Result: For both breakers, the gear handle could be transitioned.

3.3.3 Aircraft State - Power ON, Landing Gear on Ground

- Attempt to move the gear handle to the RETRACT position. Verify that one is **unable** to return the gear handle to the RETRACT position. Result: The handle could not be transitioned to RETRACT with either breaker pulled.

3.4 Strut Travel Measurement

The airplane was lifted onto jacks. Another jack was used to raise each landing gear oleo. The strut travel necessary to achieve the squat switch change of state on the left and right main gear was measured. See Figure 3.



Figure 3. Airplane on jacks prior to Main Landing Gear strut tests.

Results:

Right Main Gear: At change of state, 7.9" of chrome showing.

Left Main Gear: At change of state, 7.95" of chrome showing.

3.5 Squat Switch Rigging Tests

Squat switch rigging tests were performed on the left and right squat switches per the Airplane Maintenance Manual (AMM) Chapter 32-61-00 as part of strut measurement tests. The airplane's squat switch continuity was confirmed, for both

switches, when the airplane was in AIR. Continuity was lost when the switches transition to GRND (expected result).

3.6 Main Landing Gear Strut Pressure Measurements

Using a calibrated digital gauge, the main landing gear strut pressures were measured per AMM Chapter 12-14-00.

Results:

Right Main Gear: 272 psi.

Left Main Gear: 290 psi.

3.7 Removal of Components from the Airplane

The components listed as items 2-17 in the Summary (Section C) were removed from the airplane during the examinations. The items were boxed and transported by Textron service vehicle from Aspen Airport to the Textron facility in Wichita, Kansas for further examination.

4. Computed Tomography Scan of the Landing Gear Control Handle

After removal from the accident airplane, the Landing Gear Control Handle was shipped to the NTSB IIC. The handle was then shipped for a computed tomography (CT) examination at the NTSB's CT contractor's facility in Chicago, Illinois.

The internal configuration of the Landing Gear Control Handle was documented using radiographic images that were collected from July 28 to August 16, 2021. A total of 4,992 computed tomography (CT) slice images were examined, processed, and analyzed by the NTSB to evaluate the components. For further information, please refer to the Computed Tomography Specialist's Factual Report, dated May 9, 2022, in the docket for this investigation.

Review of the images determined that, when the scans were conducted, the Landing Gear Control Handle was in the extended position, and there were no indications of malfunctions, broken components, disconnected wiring, or other problems with the mechanisms (including the handle spring, over center track, control switches, solenoid, and lock out lever) within the unit.

After the CT scan, the handle was sent to the Textron facility in Wichita, Kansas for further examination and functional test.

5. Landing Gear Control Handle Examination and Functional Test

The Landing Gear Control Handle was examined and tested at the Textron Aviation M&P labs and L22 labs. The testing was witnessed by personnel from the local FAA office.

5.1 Examination of the Landing Gear Control Handle

Visual inspection of the landing gear control handle was completed. No abnormal wear or damage was noted.

In addition, an X-Ray examination was accomplished by the Textron Aviation M&P labs. The X-ray examination was accomplished to view the existing internal component conditions. No abnormal conditions were noted.

The Landing Gear Control Handle's outer cover was removed. See Figure 4.

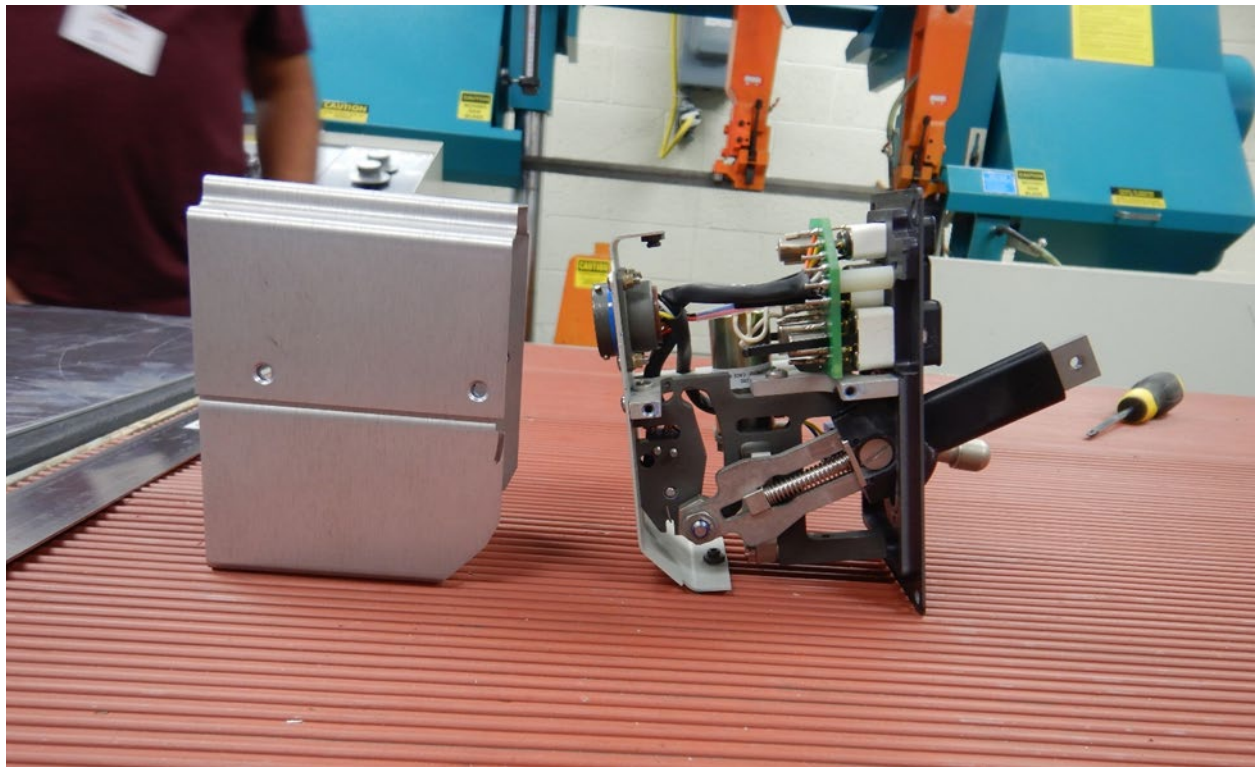


Figure 4. The Landing Gear Control Handle (right) with outer case removed.

5.2 Functional Testing of the Landing Gear Control Handle

Functional testing of the Landing Gear Control Handle was accomplished per Textron ATP-049701, Sections 5.1, 5.3 and 5.4. A representative of Ontic (the Landing Gear Control Handle manufacturer) accomplished the testing at the Textron Aviation

Lab. Ontic provided the Landing Gear Control Handle Test Boxes (Part Numbers 049901 and 049902) necessary for the ATP testing. See Figure 5.

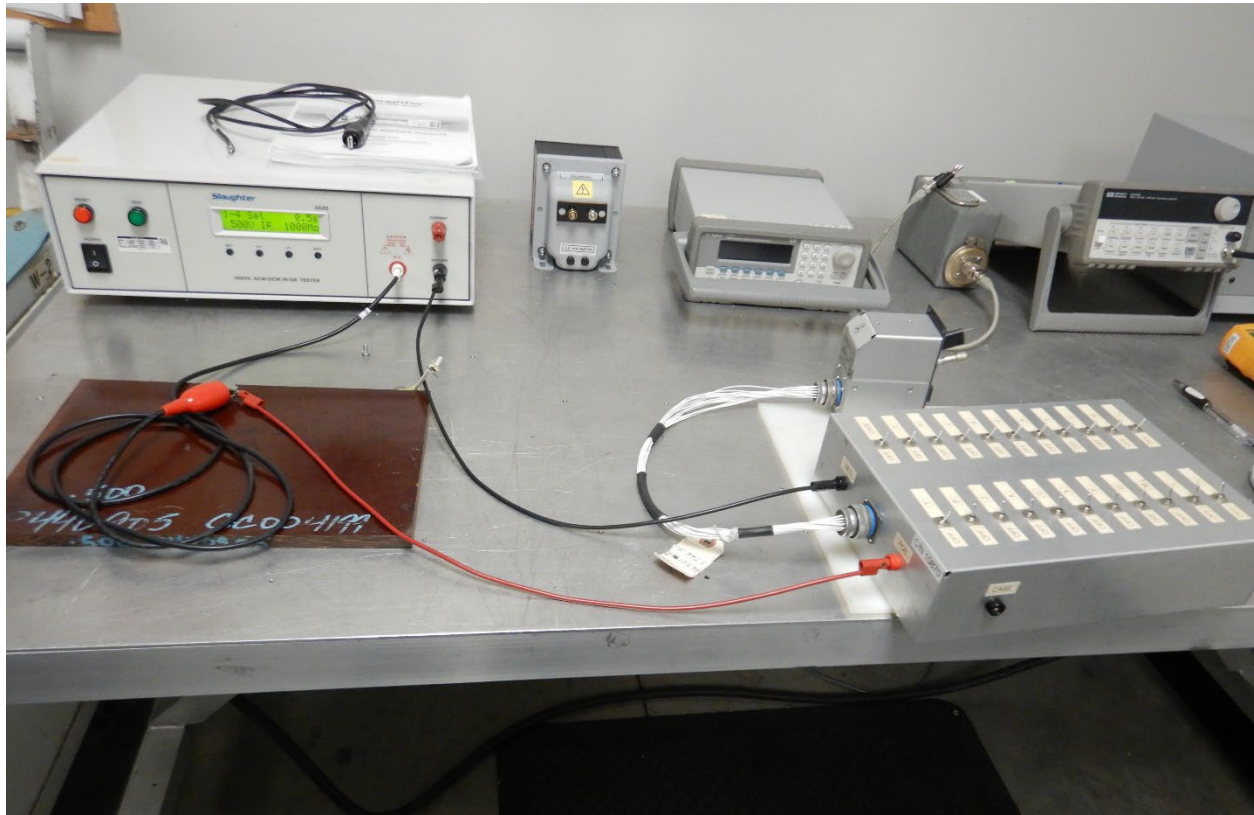


Figure 5. The Textron Landing Gear Control Handle Test Stand.

For ATP Section 5.1, Functional Test, the test elements were completed, with the unit passing all requirements except paragraph 5.1.1.5. ATP paragraph 5.1.1.5 requires that the landing gear handle returns to either the "UP" or "DOWN" position when released from any position. During the testing, the handle exhibited a tendency to stick in place when released. This tendency was repeated multiple times, with the handle released anywhere between mid-travel and within approximately 0.25 inch of the "RETRACT" detent. The handle remained in the position it was released in, on the retract half of the travel. When the handle was released on the "extend" side of travel, it would snap completely to the "extend" detent. When stuck in a position outside of the extend or retract detents, it would only transition further if vibration was applied to the case or the handle was manually transitioned.

It was noted that an "extend command" was provided as an output from the handle after moving less than 0.25" out of the "retract" position and the "extend command" was sustained throughout the remaining travel between the extend and retract detents. This allowed the handle to provide an "extend command" while the handle was stuck in a mid-travel position and with some vibration on the case, it

would slowly transition towards the retract position and would eventually move into the retract detent position and provide a "retract command." See Figure 6.

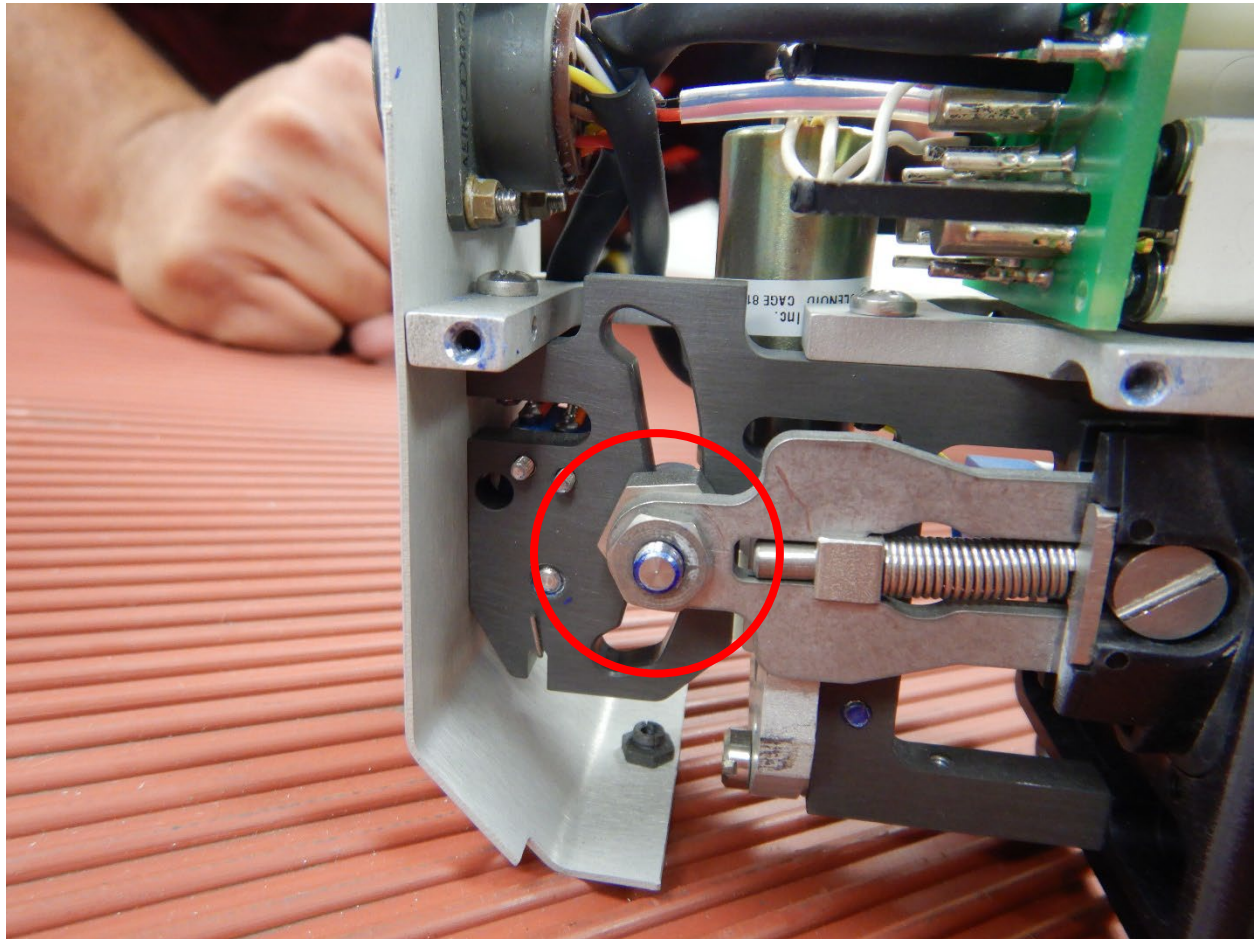


Figure 6. The landing gear handle in a "mid" position, circled in red.

For ATP Section 5.3, Insulation Resistance, the test elements were completed, with the unit passing all requirements.

For ATP Section 5.4, Dielectric Withstanding Voltage, the test elements were completed, with the unit passing all requirements.

Following the ATP tests, additional X-Rays of the Landing Gear Control Handle were taken to examine the internal component conditions, in the landing gear extend and retract position. No visible damage or abnormal conditions were noted.

The outer (dust cover) case of the Landing Gear Control Handle was removed to inspect the internal components of the unit. The inspection of the Landing Gear Control Handle's internal components did not reveal any component damage or abnormalities.

While inspecting the internal components for a cause of the handle sticking, a small amount of white residue was noted near the pivot point of the handle. A sample of the white residue was taken and analyzed by the Textron Aviation M&P Laboratory.

Using Fourier Transform Infrared Spectroscopy analysis (FTIR), the white residue material was identified as a polymer matching the plastic of the handle in that area. The polymer also matched with Polyether Ether Ketone (PEEK)² from polymer data found in the Textron Aviation M&P laboratory's material library. The black plastic part of the handle is grooved in the area where the white powder was found. The white powder consists of fine particles of the PEEK-constructed part.

6. Testing of Removed Components

Textron conducted testing of the remainder of the components removed from the accident airplane at the Textron Aviation Facility in Wichita, Kansas from March 31, 2022 through April 12, 2022. The test elements that require hydraulic pressure were conducted at Textron's Wichita Citation Service Center hydraulics component shop. The Wichita FAA office provided witness to the examinations.

A summary of the component examinations is as follows:

6.1 Left Main Landing Gear Uplock Actuator

A visual inspection of the Left Main Landing Gear Uplock Actuator was completed. No abnormal appearances were noted.

Functional testing was accomplished per the actuator's Component Maintenance Manual (CMM) Chapter 32-30-05, Sections A (1), A (2), and A (3). Sections A (1) and A (2) required the actuator piston rod to be restrained using a one-inch spacer and applying 1,500 pounds per square inch (psi) pressure to the actuator's inlet valve for one minute. The actuator leaked 31 drops of hydraulic fluid, which exceeds the maximum of 5 drops per minute allowed. According to Textron, the amount of leakage observed during this test would not prevent the actuator from performing as intended in service but is beyond allowable limits for a new or overhauled uplock actuator.

No teardown or further examination was conducted, since testing indicated normal function with minor leakage observed, consistent with in-service wear.

6.2 Nose Landing Gear Uplock Actuator

² PEEK is a thermoplastic noted for its toughness.

A visual inspection of the Nose Landing Gear (NLG) Uplock Actuator was completed. No abnormal appearances were noted.

Like the Left MLG Uplock Actuator, functional testing of the NLG Uplock Actuator was accomplished per CMM 32-30-05, sections A (3), followed by sections A (1) and A (2). No drops of hydraulic fluid were seen which meets the requirements of this test. The actuator passed the tests with normal function.

No teardown or further examination was conducted.

6.3 Right Main Landing Gear Uplock Actuator

A visual inspection of the Right Main Landing Gear Uplock Actuator was completed. No abnormal appearances were noted.

Like the Left MLG Uplock Actuator, functional testing of the Right MLG Uplock Actuator was accomplished per CMM 32-30-05, sections A (3), followed by sections A (1) and A (2). During the tests, the actuator leaked 38 drops of hydraulic fluid, which exceeds the maximum of 5 drops per minute allowed. According to Textron, the amount of leakage observed during this test would not prevent the actuator from performing as intended in service but is beyond allowable limits for a new or overhauled uplock actuator.

No teardown or further examination was conducted, since testing indicated normal function with minor leakage observed, consistent with in-service wear.

6.4 Nose Landing Gear Actuator

A visual inspection of the Nose Landing Gear Actuator was completed. No abnormal appearances were noted.

The actuator position switch was connected to a test box, which indicated that the actuator was in the down and locked configuration. The test box indications matched the visual indications.

Functional testing was accomplished per Textron Acceptance Test Procedure ATP) WP00248 sections 4.3, 4.4, 4.5, 4.6 and 4.7, with the test conditions defined in section 4.1. The actuator passed all ATP tests.

No teardown or further examination was conducted.

6.5 Right Main Landing Gear Actuator

A visual inspection of the Right Main Landing Gear Actuator was completed. No anomalies were noted.

Functional testing of the Right Main Landing Gear Actuator was accomplished per Textron ATP WP00258, Sections 4.3, 4.4, 4.6, 4.7 and 4.8, with the test conditions defined in section 4.1.

The test results are summarized as follows:

1. The Proof Pressure and Leakage Tests were accomplished with no substantial leakage noted.
2. The Actuator Locking and Unlocking Tests were conducted with the actuator transitioning within requirements.
3. The actuator Retract Test was accomplished three times and, each time, the actuator took slightly longer than the maximum allowed test requirement to retract. The group noted that the exceedance in retract time may have been attributed to error in manual operation of a stopwatch.

The actuator was submitted to the component supplier for additional testing, teardown, and dimensional verification of key components required.

6.6 Left Main Landing Gear Actuator

A visual inspection of the Left Main Landing Gear Actuator was completed. No anomalies were noted.

Functional testing of the Left Main Landing Gear Actuator was accomplished per Textron ATP WP00258, Sections 4.3, 4.4, 4.6, 4.7 and 4.8, with the test conditions defined in section 4.1.

The test results are summarized as follows:

1. For the Proof Pressure and Leakage Tests, no substantial leakage was noted.
2. The Actuator Locking and Unlocking Tests were conducted with the actuator transitioning within requirements.
3. The Actuator Retract Tests were conducted with no failures noted.

No teardown or further examination was conducted.

6.7 Squat Switch PCB

A visual inspection of the Squat Switch PCB was completed. No anomalies were noted.

A functional test of the Squat Switch PCB was accomplished. The test was conducted per CES-FT-XL-0056, starting with section 6.1.3 and then proceeding with 6.2.1, 6.2.2, 6.2.3 and 6.2.4. The PCB passed all requirements of the test.

No further examination or teardown was conducted on the PCB.

6.8 No Takeoff PCB

A visual inspection of the No Takeoff PCB was completed. No anomalies were noted.

A functional test of the No Takeoff PCB was accomplished. The test was conducted per CES-FT-XL-0058, sections 6.2.1, 6.2.2, 6.2.3 and 6.2.4. The PCB passed all requirements of the test.

No further examination or teardown was conducted on the PCB.

6.9 Landing Gear PCB

A visual inspection of the Landing Gear PCB was completed. No anomalies were noted.

A functional test of the Landing Gear PCB was accomplished. The test was conducted per CES-FT-XL-0054, sections 6.2.1, 6.2.2, 6.2.3 and 6.2.4. The PCB passed all requirements of the test.

No further examination or teardown was conducted on the PCB.

6.10 Hydraulic PCB

A visual inspection of the Hydraulic PCB was completed. No anomalies were noted.

A functional test of the Hydraulic PCB was accomplished. The test was conducted per CES-FT-XL-0105, sections 6.2.1 and 6.2.2. The PCB passed all requirements of the test.

No further examination or teardown was conducted on the PCB.

6.11 Filter Elements and Fluid Samples

An examination of the fluid samples and filters was conducted by the Textron Aviation M&P Laboratory.

The filters were processed so that trapped particles were loosened and then collected. The fluid was then filtered. The filters of debris from the filters, along with the collected fluid samples were magnified 100X and then photographed.

Textron laboratory personnel examined the magnified images. According to the resultant Textron report document there was "very little" debris in the filters and no abnormal contents were found.

The samples were discarded.

A document from Textron with the investigation details was included in Attachment 1.

7. Examination of Right Main Landing Gear Actuator at Nabtesco Aerospace

The Right Main Landing Gear Actuator was shipped from the Textron facility in Wichita, Kansas to the Nabtesco Aerospace facility in Kirkland, Washington for further test and examination.

The actuator was tested and examined at the Nabtesco Aerospace facility on August 23, 2022 under witness by an investigator from the NTSB's Western Pacific Region Office.

The actuator was examined in the following manner:

- Receiving Visual Inspection
- Functional Test per Component Maintenance Manual
- Textron Requested Tests
- Actuator Disassembly and Visual Inspection
- Dimensional Checks and Inspection
- Verification Test of Switch Operation

In summary, the examination results indicated that the actuator functioned normally and passed all functional tests as well as the additional tests requested by Textron Aviation. In addition, all actuator components were within their dimensional requirements.

Two minor anomalies were noted:

- 1) The actuator's position indication switch was not adjusted to the original factory specification. However, this did not affect the switch indication of the locked and unlocked position during the testing. A separate bench test

of the Down-Lock Switch confirmed that the switch operation was within required limits.

- 2) The actuator's snubber tube exhibited some mechanical wear on one end. However, the actuator operated within requirements.

For more information, please refer to the NTSB Examination Summary - Right Landing Gear Actuator report in the NTSB public docket for this investigation.

E. LIST OF ATTACHMENTS

1. Textron Examination Notes for Removed Components

Submitted by:

Tom Jacky
Systems Group Chair