

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety

Washington, D.C. 20594

Airworthiness Group Chairman's Factual Report

April 2, 2019

A. ACCIDENT ERA17FA135

Location: Marietta, Georgia
Date: March 24, 2017
Time: 1922 Local Time
Aircraft: Textron Aviation Citation 500 N8DX

B. GROUP

On-Scene Activities:

Chairman: Tom Jacky
National Transportation Safety Board
Washington, D.C.

Member: Henry Soderlund
Textron Aviation
Wichita, Kansas

Member: Dave Detscher
Federal Aviation Administration
Atlanta, Georgia

Examination at Duncan Aerospace May 9-10, 2017:

Member: Henry Soderlund
Textron Aviation
Wichita, Kansas

Member: Marlyn Beisner
Federal Aviation Administration
Lincoln, Nebraska

Member: Scott Olson
Federal Aviation Administration
Lincoln, Nebraska

Member: Donald Kendall

Federal Aviation Administration
Lincoln, Nebraska

Member: Jay Eller
Honeywell
Phoenix, Arizona

Member: Jeff King
Duncan Aviation
Lincoln, Nebraska

Wreckage Examination at Griffin, Georgia, July 18, 2017:

Member: Henry Soderlund
Textron Aviation
Wichita, Kansas

Member: Dave Detscher
Federal Aviation Administration
Atlanta, Georgia

Member: Jay Eller
Honeywell Aerospace
Phoenix, Arizona

Examination of Autopilot Circuit Cards at Honeywell, August 29-30, 2017:

Member: Henry Soderlund
Textron Aviation
Wichita, Kansas

Member: Mark Pritchett
Federal Aviation Administration
Scottsdale, Arizona

Member: Jay Eller
Honeywell
Phoenix, Arizona

C. SUMMARY

On March 24, 2017, at 1924 eastern daylight time, a Cessna 500, N8DX, collided with terrain in a residential neighborhood near Marietta, Georgia. The private pilot, and sole occupant, was fatally injured. There were no ground injuries. The airplane was destroyed by the impact and post-impact fire. The airplane was registered to Shelter Charter Services Inc and operated as a 14 Code of Federal Regulations Part 91 business flight. Visual meteorological conditions existed near the accident site at

the time of the accident and the flight was operated on an instrument flight rules flight plan. The flight originated from Cincinnati Airport - Lunken Field (LUK), Cincinnati, Ohio, about 1812, and was destined for Fulton County Airport-Brown Field (FTY), Atlanta, Georgia.

The group documented the wreckage at the Marietta, Georgia accident site on March 25, 2017 and then at an aircraft salvage facility in Griffin, Georgia from March 26-27, 2017.

At the end of the on-scene phase of the investigation, the following airplane components were removed and retained by the National Transportation Safety Board for further examination:

1. Sperry Autopilot Computer
2. Elevator Auto Pilot Servo
3. Aileron Auto Pilot Servo
4. Rudder Auto Pilot Servo
5. Cockpit Voice Recorder
6. Elevator Trim Servo
7. Sperry Vertical Gyro #1
8. Sperry Vertical Gyro #2
9. Shadin Avionics Air Data Computer #1
10. Shadin Avionics Air Data Computer #2
11. Garmin 750
12. Honeywell GA-EGPWS
13. Sperry Directional Gyro #1
14. Sperry Directional Gyro #2
15. Sperry Flight Director Computer #1
16. Sperry Flight Director Computer #2
17. Wiring drawings for Garmin GTN750 #1 NAV Computer
18. Sandia Switching Unit

The group met at the Duncan Aviation facility in Lincoln, Nebraska from May 9-10, 2017 to examine the autopilot components removed from the airplane.

The group met at the Atlanta Air Salvage facility in Griffin, Georgia on July 18, 2017 to re-examine the wreckage. The purpose of the re-examination was to identify, document, and remove additional components of the airplane's autopilot system. At the end of the examination, the following airplane components were removed and retained by the National Transportation Safety Board for further examination:

1. Rotational mass from a Sperry Lateral Gyro
2. Rotational mass from a Collins Rate Gyro
3. USB drive fused to a lap belt

The group met at the Honeywell facility in Glendale, Arizona on August 29-30, 2017 to further examine the autopilot computer roll circuit card assembly (CCA).

The group used the Circuit Card Assembly Test Plan as a guide for the examinations. For these notes, some of the test plan was annotated to reflect the results. An additional transformer provided by Duncan from another Sperry SPZ-200 Autopilot Computer A2 Pitch Card (referred to as the “Red Transformer”) was examined by the group.

In addition, the NTSB conducted several CT scan examinations of the accident airplane’s Sperry SPZ-200 Autopilot Computer A1 Roll Card Transformer and the “Red Transformer”.

After each of the group activities, all pertinent documentation and photographs were provided to each of the parties.

No airworthiness failures were found by group during the investigation. For all the components, no failures were noted that could be determined as pre-impact.

D. DETAILS OF INVESTIGATION

The group met from March 25-28, 2017 to document the airplane wreckage. First, the group met at the Marietta, Georgia accident site on March 25. The wreckage was then moved to an aircraft salvage facility in Griffin, Georgia on March 25. The group then documented the wreckage at the salvage facility on March 26-28, 2017.

The airplane was identified by the manufacturer as a Citation 500:

Manufacturer Unit Number:	500-0303
Serial Number:	5000303
Year of Manufacture:	1976

The accident impact and post-crash fire damaged or consumed most of the forward portions of the airplane, including the wings, fuselage, flight deck, and nose areas. See Figure 1.



Figure 1 - Main wreckage site showing burned wreckage and residence.

The relevant aspects of the airplane’s airworthiness were documented as follows:

A. AIRPLANE SYSTEMS

For the investigation, the group identified and documented relevant systems of the airplane. Several system components were identified for further documentation and examination. The relevant airplane systems were documented according to the following categories:

1.0 Auto Flight

1.1 Description of System and On Scene Examination

The airplane was installed with a Sperry Flight Systems (now Honeywell) SPZ-500C Autopilot/Flight Director Instrument System. The system provides automatic flight control in each of the three airplane axes – pitch, roll, and yaw – with three flight maneuvering options available to the pilot – manual, automatic, and semiautomatic.

When engaged, the autopilot, with use of the integrated flight director, couples to the selected modes and flies the airplane automatically; the pilot monitors the autopilot performance on flight instruments.

A block diagram schematic of the system is shown in Figure 2.

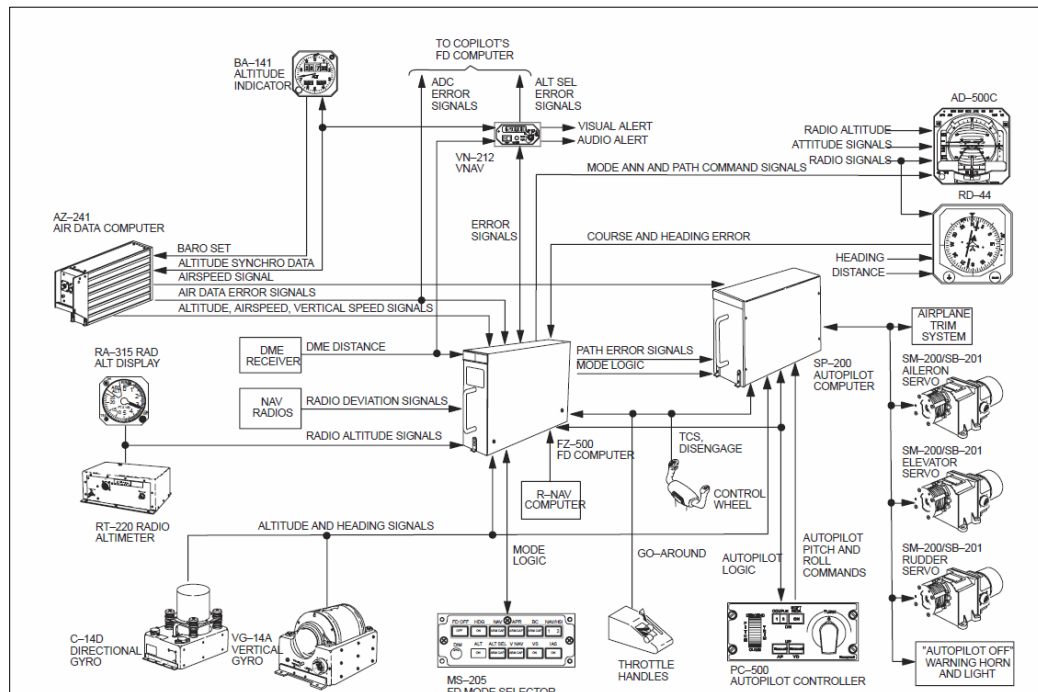


Figure 2 - Block Diagram of the SPZ-500C Autopilot System.

The following are the main components of the system:

- a. Vertical Gyros (Numbers 1 and 2) - The two Honeywell VG-14 Vertical Gyros measure and provide airplane attitude information for the system;
- b. Directional Gyros (Number 1 and 2) - The two Honeywell C-14D Direction Gyros measure and provide airplane heading information for the system;
- c. Autopilot Servos (Aileron, Elevator, Rudder, and Elevator Trim) – The Sperry Servo Drive Assemblies translated electrical inputs into a rotational, mechanical output to a drum and bracket assembly that paralleled each primary flight surface.
- d. Flight Director Computers (Number 1 and 2) – The two Sperry Z-500 Flight Director Computers receive information from the airplane sensors and output path error signals and mode logic to the autopilot computer.
- e. Autopilot Computer – The Sperry SPZ-200 Autopilot Computer, when engaged, calculates the servo drive assembly output necessary to maintain the selected mode.

The autopilot will disconnect under the following circumstances:

- A loss of the vertical or directional gyros
- A loss of valid 28-volt power to autopilot or gyros
- Autopilot torque-limiter failure
- Press of the AP TRIM DISC button
- Press of the vertical gyro FAST ERECT button
- Press of the compass LH-RH switch
- Press of the AP TEST button
- Selection of AP Go-Around mode
- Pulling the autopilot AC or DC circuit breaker
- Use of manual electric elevator trim

According to Textron Aviation and airplane operator records, the airplane had been retro-fitted with a JetTech LLC, Supplemental Type Certificate (STC) Number ST02427LA on August 28, 2013. The STC replaced and upgraded the existing flight panel instruments to a Garmin GTN 750 display on the left side and a Garmin 650 display on the right side. The STC integrated the displays with the existing Sperry SPZ-500C Autopilot/Flight Director Instrument System.

According to the STC installation documentation, the installed Garmin GTN 750 was identified as follows:

Part Number:	011-02282-00
Serial Number:	1ZA012024

The Garmin GTN 750 is a 6.9” diagonal color LCD touchscreen multi-function display. The GTN 750 supports navigation/mapping, radio tuning, weather display, and terrain/traffic awareness. a built in VHF communication feature and supports flight under instrument flight rules.

In addition to the touchscreen features, the unit has concentric knobs for data input and radio tuning.

Communication and navigation radio information are shown on the top portion of the display. For radio tuning, the unit provides electronic touchscreen “tabs” that provide recent, nearby, and saved radio frequencies. When the GTN 750 screen is touched, an audible “click” sound is annunciated. The radio frequency can also be adjusted using the large and small knobs on the lower right corner of the display.

The unit’s navigation allows for entry of waypoints to build and store flight plans for future use.

On scene, the autopilot system was examined in the airplane wreckage prior to removal of components. No evidence of an autopilot failure was noted during the on-scene examination. The components showed evidence of fire damage, sooting, and/or physical damage from impact. See Figure 3.



Figure 3 - Sperry SPZ-200 Autopilot Computer, as found.

The three primary control servos (aileron, elevator, and rudder), the elevator trim servo, the two flight director computers, the one autopilot computer, two vertical gyros, two heading gyros were removed from the wreckage for further examination.

The removed autopilot system components were shipped to the Honeywell facility in Phoenix, Arizona for further examination.

1.2.0 – Examination of Auto Pilot Components at Duncan Aviation

The group met at the Duncan Aviation facilities in Lincoln, Nebraska from May 9-10, 2017 to examine the autopilot components removed from the airplane.

Prior to the arrival of the group, Duncan Aviation checked their internal records to see if any of the components had been examined at Duncan. There was one record found, for the Z-500 Flight Director Computer Number 1 (see details in Section 1.2.2.2). Duncan keeps searchable records for 7-10 years, so any earlier history would have been deleted. Duncan Aviation noted that a component that had visited the facility would have received Duncan tags and/or warranty seals.

Honeywell shipped the components to the Duncan facility prior to the group's arrival. The components were placed into secured storage. When the group arrived, the components were removed from their individual shipping boxes and visually examined for confirmation.

The components were then examined by Duncan technicians under group instruction and witness. The following notes were compiled regarding each component examined.

1.2.1.0 Examination of Gyros

1.2.1.1 Directional Gyro Number 1

The component's data plate documented the unit as follows:

Manufacturer:	Honeywell
Model:	C-14D Directional Gyro
Part Number:	4020577-3
Serial Number:	78030670

The unit was still connected to its mounting shelf/plate. However, one of the dust covers had been dislodged by impact and was loose. The electrical connector's pins were straight, with no sooting observed. The rotor assembly was missing rotational parts. The mass rotor was missing; therefore, the group was not able to determine if the rotor was rotating at impact. The inside of the cover was damaged by impact; the group was not able to tell if the gimbal or rotor impacted the inside cover.

In addition, the following was noted:

- The main gimbal shaft could be rotated by hand.
- The B3 synchro transmitter was missing.
- Two of the synchro shafts could be rotated by hand and one could not be rotated because the shaft was bent.
- The "fuse" was shattered, but no visual indication that the fuse was activated.
- The cover/can was pulled back to view the electronic components and the bottom was removed. The transformer looked good with no visual evidence of failure.

- Components on the circuit card assembly (CCA) showed no evidence of shorts; the pins were bent due to impact damage.
- The loose rotor included with the gyro components was identified as a rotor from a Collins 345A Rate Gyro and not associated with this unit.

During the second wreckage examination on July 18, 2017, the rotational mass from a Sperry Directional gyro (heading) was identified in the wreckage. The mass and inner gimbal support frame were separated from the gyro. The group considered the rotational mass to have originated from the Directional Gyro Number 1.

The gimbal was cleaned and examined. Some rotational scoring was noted on the mass. See Figure 4.

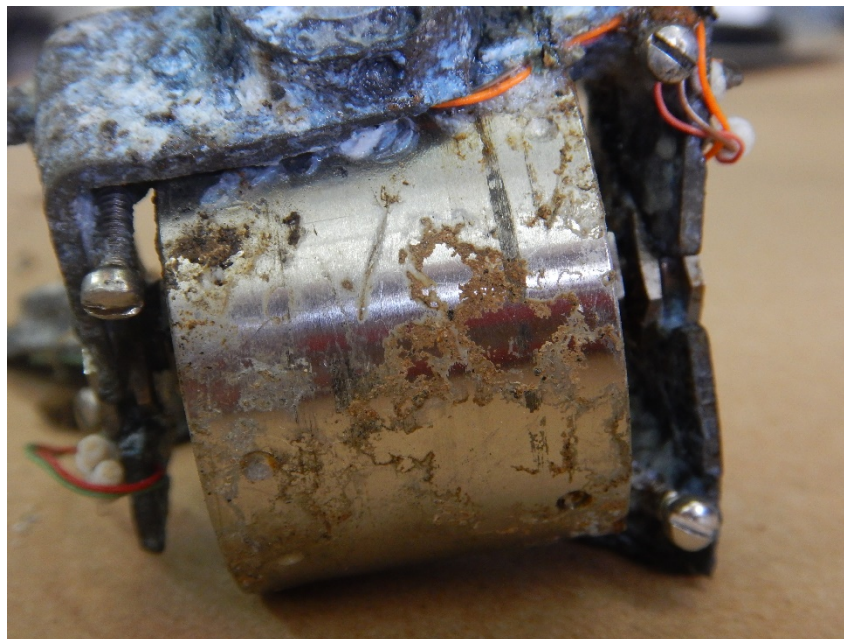


Figure 4 - Rotor identified from Directional Gyro Number 1, showing rotational scoring.

1.2.1.2 Directional Gyro Number 2

The component's data plate documented the unit as follows:

Manufacturer:	Honeywell
Model:	C-14D Directional Gyro
Part Number:	4020577-3
Serial Number:	91065006
Mod Status:	A-G marked

The following was noted:

- The cover was separated from the base. The electronic components inside the base showed no evidence of thermal failure.

- The base plate was fractured.
- The upper and lower dust covers were cut (by the group) away from the internal components.
- All three of the synchro transmitters and the motor were missing.
- The rotor and assembly were removed from the can. The rotor still rotated freely but had some roughness/pitting of internal bearings. Rust was noted on the rotor bearing surface. The rotor had scoring along the direction of rotation and some scoring along the edge; one score mark was noted 180 degrees around the rotor surface. See Figures 5a and 5b.

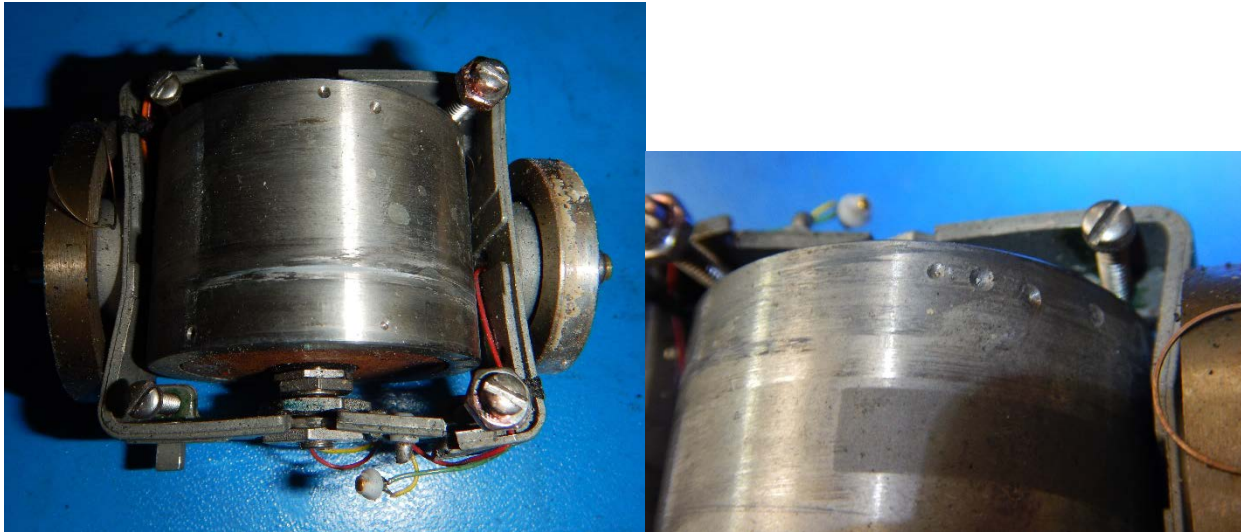


Figure 5a and 5b - Rotor from Directional Gyro Number 2, showing rotational scoring.

- When the rotor assembly was disassembled, the inner gimbal was noted fractured through the structure. Portions of the inner gimbal were smudged or had abrasions that appeared to match the rubbing on the rotor.
- No evidence of pre-existing damage to the circuit card assembly or components on the card was noted.
- The main out gimbal shaft was fractured.

1.2.1.3 Vertical Gyro Number 1

The component was identified as follows:

Manufacturer:	Honeywell:
Model:	Vertical Gyro VG-14
Part Number:	4001808-901
Serial Number:	77056726? ¹ (see below)
Mod Status:	Unknown – portion of data plate missing

¹ Throughout the report, question marks (i.e. “?”) indicate digits that were not legible.

The serial number located on the gyro's "can" was 77056726. The serial number on the gyro base was 77056708, and the serial number noted on the gyro was 770567??. Honeywell indicated that the gyro unit serial number matched the can's serial number. The airplane's maintenance records show that, during 2010, gyro unit serial number 77056726 was installed in position 1.

The following observations were noted:

- The base was crushed against the component's gyro cover. The base was cut away from the crushed component. Then the outer case was cut away. See Figure 6.



Figure 6 - General view of VG Number 1, prior to disassembly.

- The outer gimbal structure was cut away to expose the inner gimbal/rotor assembly. The inner rotor was blackened with soot.
- The deformation of the hemispheres was similar to the deformation noted on Vertical Gyro 2. The top hemisphere was crushed down onto the rotor and the bottom hemisphere was bowed "out" in some areas, crushed into the rotor in others.
- After the outer cover and outer gimbal were removed, both hemispheres were found to be broken loose from the unit's epoxy bond and crushed around the inner gimbal.
- The inner rotor/gimbal was caught in a position that indicated the unit was operating at the time of impact (note: when operating, the internal rotor shaft is in a "vertical" position).
- The top hemisphere and the outer ring were cut away and removed. The rotor surface was coated with a black material/greasy material.
- The rotor was cleaned of the black, greasy material and exposed circumferential scoring on the rotor surface. See Figure 7.



Figure 7 - Rotor removed from Vertical Gyro Number 1 (after cleaning), showing rotational scoring.

1.2.1.4 Vertical Gyro Number 2

The component was identified as follows:

Manufacturer:	Honeywell
Model:	Vertical Gyro VG-14
Part Number:	4001808-901
Serial Number:	78067318
Mod Status:	A-N marked

- The outer can was removed from the component base.
- The pitch liquid level (tilt switch) was shattered, the roll liquid level (tilt switch) was found intact.
- The inner mounting frame was fractured along 3 of the 4 longitudinal frame structures. The other structure was cut away to provide access to inner rotor assembly.
- The rotor was removed from the inner gimbal. The outer rotational gimbal was deformed/crushed around the inner rotor assembly.
- Top and bottom hemispheres were separated from the inner gimbal plate/assembly.
- The upper hemisphere appeared “concave down”, with a force towards center, and lower hemisphere appeared to have been forced away (bowed out) from the center. The force appeared to be in the same direction.
- When the inner gimbal was opened, the top rotor bearing spinning mass was found shifted down relative to normal position. The shaft was bent, and the rotor would not rotate.

- The bearings were hammered out with the shaft. When the bottom hemisphere was removed, along with the inner bearings, the outer surface of the rotor showed some evidence of scoring along the edges of the rotor. There was also scoring along the equator or middle of the rotor – the rotor appeared to contact the inner gimbal. The scoring along the edge would be consistent with the hemisphere contact.

1.2.2.0 Sperry Flight Computers

1.2.2.1 SPZ-200 Autopilot Computer

The component was identified as follows:

Manufacturer	Sperry
Model:	SPZ-200 Autopilot Computer
Part Number:	4008519-911
Serial Number:	5090297
Mod Status:	A, D, AC marked

- The unit's chassis was crushed and deformed. See Figure 8. The cover sleeve was peeled back and removed. The circuit card assemblies (CCA) were inspected and retaining screws removed. Each CCA appeared deformed from impact damage.



Figure 8 - The side of the Autopilot Computer, showing dust cover and chassis deformation.

- The Roll CCA was removed and examined. The card was bent and cracked in areas. Some integrated circuit components exhibited damage such as top cover missing, was bent, etc. See Figure 9.

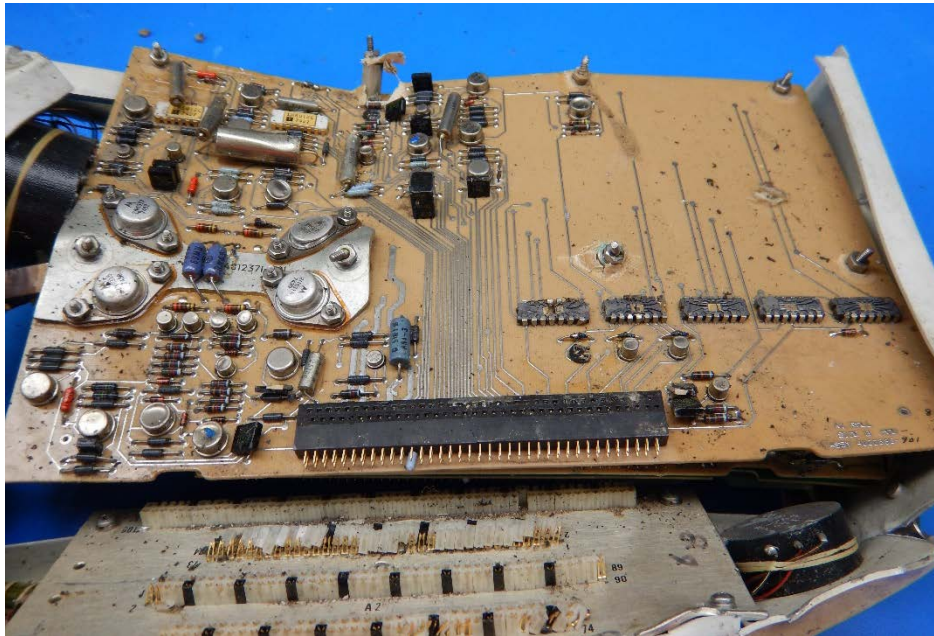


Figure 9 - Autopilot Computer Roll Circuit Card Assembly.

- The pitch CCA was then removed, then yaw CCA. Finally, the adaptor card was removed.
- All cards were examined for faults, hot spots, etc. Several areas of blackened material were noted on CCAs but could be attributed to contact with the adjacent card, impact damage. Physical damage was noted on each card to the components, damage, along with damage to the CCA itself.
- Areas of blackened material were attributed to contact from adjacent card, puncture damage through the outer dust cover.
- None of the damage could be attributed to pre-impact damage.
- The unit and CCAs were too damaged for acceptance test protocol (ATP) testing.

1.2.2.2 Z-500 Flight Director Computer Number 1

The component was identified as follows:

Manufacturer:	Sperry
Model:	Z-500 Flight Director Computer
Part Number:	406369-901
Serial Number:	78050687
Mod Status:	A, B, and D marked

- Note: the component serial number was the same as the serial number that maintenance records show as the captain's side. The records show the component was installed in 2014 as the Number 1 flight director.

- Duncan records indicated that the unit was received in 2014. It was sent it with the discrepancy "Heading Course error off 60 degrees." Duncan did not find any problems with the Flight Director Computer and it was tagged and returned as "Tested."
- The unit was crushed and deformed, including the dust cover was crushed around the internal components and chassis. The dust cover was removed. The bottom, forward chassis and segments of the circuit cards exhibited heat/fire damage. The outer card was sooted.
- All cards were examined for faults, hot spots, etc. Several areas of blackened material were noted on CCAs but could be attributed to contact with the adjacent card, impact damage. Physical damage was noted on each card to the components, along with damage to the CCA itself.

1.2.2.3 Z-500 Flight Director Computer Number 2

The component was identified as follows:

Manufacturer:	Sperry
Model:	Z-500 Flight Director Computer
Part Number:	406369-901
Serial Number:	7? (rest of number missing)
Mod Status:	A, B, and D marked

A visual examination the component noted the following:

- Portions of the data plate were missing. The maintenance records showed the Flight Director had same part number as the other unit, part number -901.
- No apparent fire damage but substantial physical impact damage was noted. The damage indicated evidence of contact between cards.
- The unit was still attached to its avionics rack (noted as #2) and pried off before opening the computer.
- All cards were examined for faults, hot spots, etc. Several areas of blackened material were noted on CCAs but could be attributed to contact with the adjacent card, impact damage. Physical damage was noted on each card to the components, along with damage to the CCA itself.

1.2.3.0 Examination of Autopilot Servos

1.2.3.1 Elevator Autopilot Servo

The component was identified as follows:

Manufacturer:	Sperry
Model:	Servo Drive Assembly
Part Number:	4006719-904
Serial Number:	090839

Mod Status: No mod status indicated

The visual examination of the component noted the following:

- The cable drum could be rotated by hand, with some resistance.
- The output drive shaft could be rotated freely.
- The clutch was found disengaged.
- The outer dust cover was covered in soot; the wiring into unit burnt.
- The internal components do not show visual evidence of heat/fire damage.
- The synchro was separated from its mount.
- The internal gear train moves freely by hand.
- Clutch engages on bench test, electric circuit test using servo connector.
- The synchro was operational during a bench check, but the group was unable to check validity of the output.
- The Component Maintenance Manual (CMM) functional test, Section 22-11-50, Test Requirements was conducted on the unit. The test results were hand-written on a copy of the Test Specification Sheet and included in this report in Attachment 1.

1.2.3.2 Rudder Autopilot Servo

The component was identified as follows:

Manufacturer: Sperry
Model: Servo Drive Assembly
Part Number: 4006719-906
Serial Number: 090845

- The cable drum could be rotated, but barely.
- The drive shaft could be rotated freely by hand.
- The clutch was found disengaged.
- The outer dust cover was covered with soot and the wiring into the connector was burnt.
- The synchro was noted as mounted in place.
- The internal gearing train moved freely by hand. No visual evidence of faults was noted.
- The clutch was engaged and disengaged electrically.
- The Component Maintenance Manual (CMM) functional test, Section 22-11-50, Test Requirements was conducted on the unit. The test results were hand-written on a copy of the Test Specification Sheet and included in Attachment 1.

1.2.3.3 Aileron Autopilot Servo

The component was identified as follows:

Manufacturer: Sperry
Model: Servo Drive Assembly
Part Number: 4006719-904
Serial Number: 090695

- The cable drum could be rotated by hand with some resistance.
- The dust cover was covered with soot, heat damage evident. The wiring into the connector was burnt, the connector material was melted.
- The cover was removed, and the output shaft rotated freely. The internal wiring near the connector backside was melted, heat damaged.
- The gear train could be rotated by hand but not as freely as the other servos.
- The clutch was found disengaged.
- When bench tested, the clutch engaged at ~10 volts dc, disengaged at ~2-4 volts dc.
- The motor input shaft could not be rotated by hand.
- The motor compartment was opened for visual inspection. Once open, the motor compartment showed the internal components were melted, heat damage. The motor could not be tested.
- The keyway on the main gear appeared intact.
- Then clutch was opened. The gearing moved freely, the springs were functional and could disengage freely, no evidence of failure or fault.

1.2.3.4 Elevator Trim Servo

The component was identified as follows:

Manufacturer: Textron Aviation
Model: Elevator Electric Trim Actuator
Part Number: 5115231-19

- The unit showed visual evidence of heat exposure. The unit was covered with soot, and the wiring into the unit was burnt.
- The side panels were removed, and the clutch assembly could be rotated by pulling on the attached cables.
- The motor was seized.
- When 28 volts dc was applied to the clutch to check functionality, the clutch did engage. When power was removed, the clutch did not appear to disengage. However, the clutch would disengage when the attached cable was pulled back and forth.

1.3.0 Further Examination of Autopilot Computer Circuit Cards

1.3.1 Discussion of and Ancillary Autopilot Transformer

Based on group discussions during the autopilot component examinations at Duncan Aviation, the group determined to further examine the autopilot computer's roll servo circuit card assembly (CCA # A1). The determination was based on a previous event involving a Cessna 500 roll excursion² and subsequent examination of the airplane's SPZ-200 Autopilot Computer.

During the previous investigation, Duncan attempted to replicate an intermittent failure of an isolation transformer (component A1T1) on the roll CCA A1, from the removed SPZ-200 Autopilot Computer. Based on the previous investigation, the group determined to further examine the roll circuit on the roll CCA and specifically at the A1T1 isolation transformer. See Figure 10.

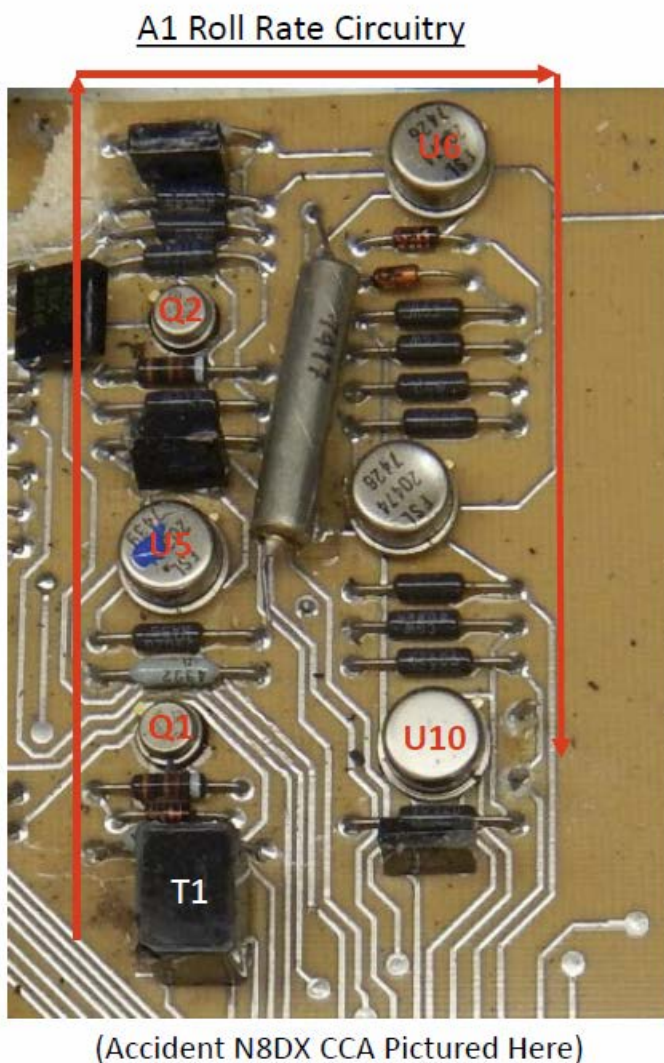


Figure 10 - Roll Rate Circuit Components, as located on the accident airplane's Autopilot Computer A1 Circuit Card Assembly. Component labelled T1 is the transformer.

The A1 transformer is an audio transformer with 6 legs that are soldered into the roll CCA.

² NTSB investigation CEN13FA101

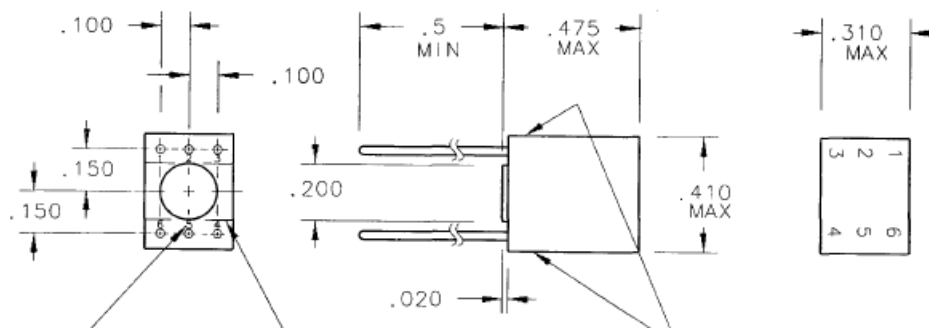


Figure 11 - Drawing of the transformer.

The transformer is part of the roll CCA feedback loop circuit. Honeywell indicated that a failure of the A1T1 isolation transformer could cause the autopilot to roll the aircraft if the autopilot was still engaged and the commanded heading was different than the current heading. As the A1T1 is a component in the circuitry that determines roll rate feedback for the autopilot computations, if the A1T1 transformer fails (assumed to go to no output, voltage = 0), then the calculated roll rate would be zero and thus the autopilot would continue to command an increase in roll angle in order to try to get the heading rate to increase in order to turn to the desired heading.

The roll rate is calculated from the roll attitude input from a vertical gyro within the autopilot computer. The feedback to the autopilot for the roll attitude is from the airplane's vertical gyro. A failure of the vertical gyro where it does not move correctly with aircraft attitude changes will also result in the auto pilot commanding a roll which may not be expected. The rate of the uncommanded roll would not be able to be determined because it would vary depending on how it failed, the current heading, and the commanded heading.

Examination of the transformer (See Figures 12a and 12b) identified the component as follows:

Manufacturer: Triad-Utrad
Model: TF5SX13ZZ

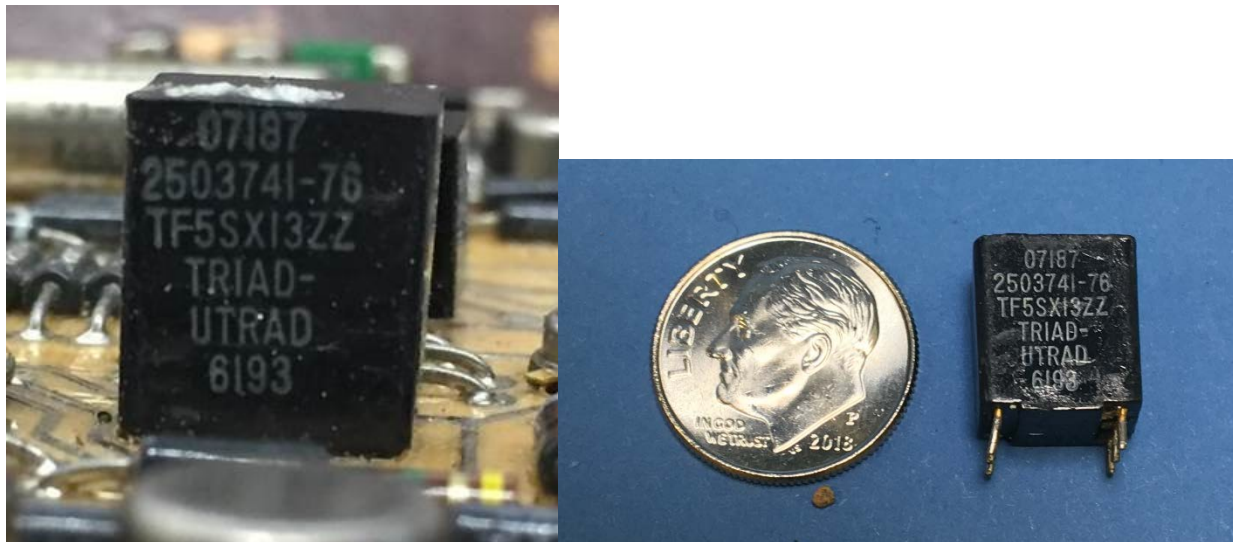


Figure 12a and 12b - The A1T1 Transformer as located on the circuit card and removed.

Honeywell indicated that the transformer was supplied by different manufacturers during the time of manufacture and repair of the SPZ-200. Honeywell provided exemplars of the current transformers used for the repair of the autopilot computer. The current supplier of the A1T1 and A2T1³ transformers is a different manufacturer than Triad.

Following the identification of the A1T1 for further examination, a request was made to Duncan Aviation to identify and provide any additional failed transformers from SPZ-200 Autopilot computers submitted to Duncan for repair. In July 2017 Duncan notified the group of a failed transformer from an ancillary Sperry SPZ-200 computer. The failed component was removed from the Pitch CCA and provided to the group for examination. This additional A2T1 transformer, red in color, was identified as follows (see Figures 13a and 13b):

Manufacturer: Triad Magnetics
 Model: SP-66 (TF5S21ZZ)
 Date Code: 8126

³ The SPZ-200 pitch circuit card has a similar circuitry and transformer.



Figures 13a and 13b – Views of the "Red Transformer" prior to removal from an ancillary Pitch CCA by Duncan Aviation.

The “Red Transformer” was used as a reference during the further examinations by the group.

In response to a group chairman request, Honeywell provided a list of Sperry SPZ-200 Autopilot Computers (i.e. Part Number 4008519 and associated dash number) certificated for other airplane types. These SPZ-200 versions would also be fitted with a roll (and pitch) CCA feedback loop circuit, like the accident version. The table of associated autopilot computers is included in Attachment 2.

1.3.2 Computed Tomography Scans Prior to Examination

Prior to the examinations at Honeywell, the accident airplane’s A1 Roll Circuit Card and A2 Pitch Circuit Card were subjected to computed tomography (CT) scanning at Varex Imaging Corporation, a contracted facility in Lincolnshire, Illinois. The scans concentrated on the A1T1 transformer but included the surrounding components in the roll computation circuitry.

For more information, please refer to the [CT Scan Factual Report of Investigation](#).

1.3.3.0 Further Examination of Circuit Cards at Honeywell

1.3.3.1 Details and Definition of Problem

The group met at the Failure Analysis Laboratory at Honeywell’s Glendale, Arizona facility on August 29-30, 2017 to conduct additional examinations of the Sperry SPZ-200 Autopilot Computer circuit card assemblies (CCA). In addition, the “Red Transformer”, provided by Duncan Aviation from another Sperry SPZ-200 Autopilot Computer A2 Pitch Card, was examined by the group.

Prior to the examinations, the NTSB shipped the Autopilot Computer A1 Roll CCA to Honeywell Accident Investigation group and was placed in storage. The shipping package was removed from storage upon arrival of the group.

The purpose of the tests was to further examine the T1 transformer on the Autopilot Computer's A1 Roll Card. To facilitate the tests, the group developed a Circuit Card Assembly Test Plan as a guide. During the examinations, the test plan was annotated to reflect the results.

None of the tests conducted on the accident A1T1 transformer resulted in a failure or loss of function.

1.3.3.2 Document of Accident A1T1 Transformer Using Photography and Real-Time X-ray

Once removed from storage and the shipping package, the A1 roll circuit card was photo documented using Honeywell's laboratory cameras. The documentation focused on the T1 transformer but also included the components of the roll rate computation circuit. The documentation included photographs under magnification.

Using Honeywell's real-time x-ray, an examination of the A1 roll card was accomplished. The electrical components included in the roll rate calculations - T1, Q1, U5, Q2, U6, U10, and associated resistors were examined. This x-ray was also used to examine the traces between components associated on the circuit card to look for pre-impact damage, gaps in traces, connections, etc.

The real-time x-rays were accomplished with no significant findings.

1.3.3.3 Check of A1 Roll Circuit Integrity

The electrical continuity of the components associated with the A1 Roll CCA, especially the components used in the roll rate circuit, were examined. The testing of roll CCA was accomplished with the T1 transformer still attached to the CCA.

The CCA was examined as follows:

DC Resistance Test

Using a multimeter, the DC resistance of the transformer was measured as follows:

- Pins 1 to 3 (primary) = 914 Ohms
- Pins 4 to 6 (secondary) = 1211 Ohms

Nominal Inductance Test

The transformer's inductance was measured as follows:

- Test is performed with 5V rms at 1kHz
- Pins 1 to 3 (primary) = 6.83 HY
- Pins 4 to 6 (secondary) = 7.05 HY

Turn Ratio Test

Using a signal generator, a 200 mV (peak to peak), 800 Hz signal was input on the primary “side” (pins 1 and 3). At the same time, an oscilloscope was used to monitor the input to primary side (pins 1 and 3) and the secondary side (pins 4 and 6). The two wave forms were plotted on the oscilloscope at the same time to verify that the amplitude and phase were matching.

The test was conducted by inserting the 200mv (peak to peak) signal on pins 31 and 32 of the main connector of the CCA. The output was checked at pins 4 and 6 of the transformer on the backside of the CCA at the solder joint to those pins.

In addition:

- The test was conducted at room temperature (25°C).
- A 1-to-1 signal in both amplitude and phase were indicated on the oscilloscope.
- The test set up was verified on a known, serviceable exemplar A1 transformer prior to the test of the accident CCA.

Cold temperature testing of the accident roll CCA

A Honeywell Environmental Chamber was used to conduct temperature tests; the chamber had the ability to control the temperature, both hot and cold. For the test, the roll card was placed into the chamber with electrical jumpers connected to the CCA. The wires were passed through the chamber door and connected to an oscilloscope. Using a signal generator, a 200 mV (peak to peak), 800 Hz signal was input on the primary “side” (pins 1 and 3). At the same time, an oscilloscope was used to monitor the input to primary side (pins 1 and 3) and the secondary side (pins 4 and 6). The two wave forms were plotted on the oscilloscope at the same time to verify that the amplitude and phase were matching.

The temperature of the chamber was then decreased. Once the chamber reached the test point value, the CCA was held at the temperature for ten minutes. During all points of the test, the oscilloscope was monitored for any signal disturbances.

For the test, the following test points and results were achieved:

Temperature (°C)	Dwell Time at Temp (minutes)	Result
25	10	Pass
15	10	Pass
5	10	Pass
-5	10	Pass
-15	10	Pass
-25	10	Pass
-35	10	Pass

While the unit was at -35C, the chamber was opened and the T1 was pressed/wiggled by hand. No change in the output signal was observed while trying to manually manipulate the part.

High Temperature Testing of the Accident Roll CCA

Using the same setup as described for the Cold Temperature Test, the temperature of the chamber was then increased to a maximum of 85 degrees C.

For the test, the following test points and results were achieved:

Temperature (°C)	Dwell Time at Temp (minutes)	Result
25	10	Pass
35	10	Pass
45	10	Pass
55	10	Pass
65	10	Pass
75	10	Pass
85	10	Pass

Following completion of the test, the chamber door was removed and the chamber (with the CCA still inside) temperature allowed to decrease to room temperature, all while monitoring the oscilloscope. During this time period (about 10-15 minutes), the oscilloscope signals did not change.

1.3.3.4 Component Level Testing of the T1 Transformer

Since the T1 Transformer was operational, the component was considered testable. With group concurrence, the T1 Transformer was removed from the A1 Roll CCA by de-soldering the device's legs.

The following tests were conducted on the transformer:

DC Resistance test of the transformer after removal from the roll CCA

The tests were conducted in the same manner as when the transformer was still attached to the CCA, with the following results:

- Pins 1 to 3 (primary) = 924 Ohms
- Pins 4 to 6 (secondary) = 1227 Ohms

Nominal inductance test of the transformer after removal from the roll CCA

The tests were conducted in the same manner as when the transformer was still attached to the CCA, with the following results:

- Test was performed with 5V rms at 1kHz

- Pins 1 to 3 (primary) = 6.86 HY
- Pins 4 to 6 (secondary) = 6.86 HY

Step 10: Turns Ratio Test of the transformer after removal from the roll CCA

The tests were conducted in the same manner as when the transformer was still attached to the CCA. Using a signal generator, a 200 mV (peak to peak), 800 Hz signal was input on the primary “side” (pins 1 and 3). At the same time, an oscilloscope was used to monitor the input to primary side (pins 1 and 3) and the secondary side (pins 4 and 6). The two wave forms were plotted on the oscilloscope at the same time to verify that the amplitude and phase were matching. The test was conducted at room temperature (25°C).

The test results were as follows:

- A 1 to 1 signal in both amplitude and phase were indicated on the oscilloscope.
- A manual push of each pin was performed, by hand. No change in input or output signal was noted while attempting to push on each pin.
- While still attached to the test instrumentation, the transformer was lightly tapped repeatedly on the hard table. No change in input or output signal was noted while performing this action.

1.3.3.5 Examination of the A2T1 Transformer Removed by Duncan (“Red Transformer”)

The additional A2T1 transformer, provided by Duncan from another Sperry SPZ-200 Autopilot Computer (“Red Transformer”), was examined by the group.

Using a signal generator, a 200 mV (peak to peak), 800 Hz signal was input on the primary “side” (pins 1 and 3). At the same time, an oscilloscope was used to monitor the input to primary side (pins 1 and 3) and the secondary side (pins 4 and 6). The two wave forms were plotted on the oscilloscope at the same time to verify that the amplitude and phase matched.

Initially the oscilloscope indicated the part was outputting correctly. However, when pressure was applied by hand to pin 6, the output was shown to drop out (go open). This result could be repeated by removing and applying pressure to pin 6.

The red transformer was also examined under the Honeywell real-time X-ray equipment. Using the X-rays no damaged areas were noted on the transformer.

At the end of the examinations, all the components were repackaged and placed into secured storage.

1.3.4 Further CT Scans of A1T1 Roll Transformer

Following the Honeywell examinations, and after the A1T1 Roll transformer was removed from its CCA, additional CT scans were conducted.

First, the A1T1 Roll Transformer was sent to the Varex facility for additional scanning. In addition, the “Red Transformer”, provided by Duncan Aviation from the ancillary Sperry SPZ-200 Autopilot Computer A2 Pitch Card, was also scanned by Varex.

The A1T1 Roll transformer was sent to the Lawrence Livermore Laboratory in Livermore, California for additional CT scans. The Lawrence Livermore Laboratory was selected for use because of the laboratory’s nano-scale CT scan capability.

For more information regarding these scans, please refer to the Computed Tomography Specialist’s Factual Report.

2.0 Communications

Two Collins radio receivers were noted in the tail section of the airplane.

The airplane’s Garmin 750 unit was removed from the airplane. However, due to the severe heat and fire damage to the unit, no further examination of the Garmin 750 was accomplished. See Figure 14.



Figure 14 - Garmin GTN 750 Display, as found.

3.0 Equipment & Furnishings

The flight deck area of the airplane was damaged by impact and post-impact fire. Due to the damage, the flight deck seat belt usage was undetermined.

During the second wreckage examination in July 2017 a partially melted USB stick was found fused to a segment of seat belt. The USB drive was submitted to the NTSB Electronics Laboratory for examination of the contents. No items of interest were found on the drive.

4.0 Flight Controls

Primary Flight Control Systems

Control cable continuity was confirmed for each primary flight control system. The control cables were traced from the flight control surface (aileron, rudder, elevator) through the fuselage, and forward to the flight deck. For each control surface, the cable runs were continuous except in areas of structure break or severe fire damage. All control surfaces were found attached with at least 1 hinge connected. For the check in the fuselage and flight deck area, the control cables were covered by flooring and debris and had to be cleared before the check.

The group searched the wreckage for the left (pilot) side control wheel but did not identify it.

4.1 Pitch Control System

In general, the pitch control system cables, from the flight deck to empennage area, were accounted for. All breaks in the elevator cables were consistent with breaks in the fuselage and elevator structure.

Elevator flight deck continuity was checked to the balls at the bottom of the control rod quadrant. The cables were connected at the cockpit and the aft bellcrank. The cables were separated in the area of the tail cone access hole.

The elevator push/pull tubes from the elevator to the elevator aft bellcrank were found fractured.

The elevator trim was separated in the area of the tail cone access hole. The chain was noted around the trim actuator.

The elevator trim actuator was measured to be 2.1 inches from the sleeve to the center of the rod connection. Textron Aviation indicated that the measurement translated to a 10 degrees tab up position.

The flight deck trim indicator was noted between neutral and nose down.

4.2 Roll Control System

The roll control cable continuity was confirmed. The cable continuity was confirmed from the ailerons to the aileron sector and from the sector to the control wheels. All the breaks in the aileron cables were consistent with breaks in the wing structure.

The left aileron upper bellcrank cable was separated near the bellcrank. The left aileron lower bellcrank cable was separated near main landing gear. The left, right, forward, and autopilot servo cables connected to aileron sector. The right aileron cables separated in area of main landing gear. One aileron cable "ear" separated from control yoke and the aileron control yoke interconnect cable separated in the middle (under pedestal).

The aileron trim cables were found intact from the wing to flight deck. The left aileron trim tab actuation was measured as 1.6 inches from the sleeve to the center of the rod connection. The chain was found in approximately even lengths from either side of the cockpit control sprocket, with the chain around the sprocket.

4.3 Yaw Control System

The yaw control cable continuity, from the flight deck to the empennage, was confirmed. The rudder cables were found intact from the rudder pedals to the rudder bellcrank. The left side of rudder bellcrank was found fractured.

The rudder trim actuation was measured as 1.7 inches from the sleeve to the center of the rod connection. According to Textron Aviation, the actuation equated to a trim position of 5 degrees tab trailing edge right. The rudder trim chain was also found approximately equal distance on either side of the sprocket, with the chain around the trim actuator sprocket and chain around the cockpit control sprocket. The cockpit trim control wheel was fractured.

Secondary Flight Control Systems

4.4 Trailing Edge Flaps

The airplane was fitted with two trailing edge flaps, one on each wing. The flap chains were found connected to the motor. The position of the left outboard flap track indicated that the left flap was in an intermediate position. The found flap chain position with chain links on either side of the flap drive assembly; Textron Aviation indicated that this position would coincide with an intermediate flap position.

The flap handle was found in the second (take off and approach), position.

4.5 Speed Brakes

The airplane was fitted with two speed brakes, one on each wing. The speed brake on the left wing was consumed by fire; the speed brake on the right wing was noted in a down, faired position with the wing.

5.0 Fuel

The airplane's fuel tanks, one in each wing, can hold a quantity of 287 gallons and 5 gallons of unusable fuel.

Two fuel cross feed valves were noted in the wreckage. Both valves were noted to be in the open position.

6.0 Indicating and Recording Systems

The flight deck instrument panels were damaged by fire and impact; no indication assessment was possible. See Figure 15.



Figure 15 - The Left Main Flight Instrument Panel, as found. The Garmin GTN 750 is to the right of the panel.

The center throttle pedestal was pushed over to left.

The cockpit voice recorder was removed from the aft section of the wreckage. The CVR was documented as follows (see Figure 16):

Manufacturer:	Fairchild Weston Systems
Model:	GA100
Part Number:	GA100-0000
Serial Number:	00894
Date:	1790



Figure 16 - The front face and data plate of the Cockpit Voice Recorder.

The CVR was shipped to the NTSB Flight Recorder Laboratory in Washington, DC for readout. For more information regarding readout and transcription of the CVR, please refer to the Specialists Factual Report – CVR.

7.0 Landing Gear

The airplane was fitted with a nose and main landing gear systems. All three landing gears, and associated tires, were located at the accident site.

Based on the on-scene examination, all three gears were considered down at impact.

NOSE LANDING GEAR

The nose landing gear structure was located underneath the forward portion of the fuselage. The landing gear leg was folded aft and under the fuselage.

LEFT MAIN LANDING GEAR

The left main landing gear was found under portions of the left wing. The gear leg was folded underneath the wing.

RIGHT MAIN LANDING GEAR

The right main landing gear was found under portions of the right wing. The gear leg was folded underneath the wing.

8.0 Navigation

The airplane was equipped with a Terrain Awareness and Warning System (TAWS) unit. The unit was located and removed from the wreckage. See Figure 17.



Figure 17 - The airplane's TAWS unit, prior to removal from the wreckage.

The unit was identified as follows:

Manufacturer:	Bendix/King (now Honeywell)
Model:	KGP 560 GA-EGPWS
Model Number:	965-1104-?
Serial Number:	442455?
Mod Status:	1-3 marked

The EGPWS was shipped to the NTSB Vehicle Recorder Laboratory for examination and readout. The non-volatile memory devices U8 and U24 were identified and removed from their associated circuit card assemblies by de-soldering. The memory devices were then placed into the laboratory's automated chip reader and the contents of the memory downloaded.

Once downloaded, the memory files (u8.bin and u24.bin) were provided to Honeywell in Redmond, Washington. Honeywell converted the information into engineering units. Honeywell then provided the converted engineering units file to the NTSB.

The following was noted in the converted data:

- The status history file showed that terrain database 466N (Americas Region, appropriate for operating in USA) was loaded. The latest terrain database available at the time of the accident was 483N.
- The counts data file showed that the unite was configured for Category 10 = 0 (no roll input), so the Roll Angle parametric data shown in the warning history data file were derived by the EGPWS and may not be accurate in a loss of control scenario.
- Leg 544 was the last flight leg in the status history records. The leg shows a takeoff record from KLUK⁴ at operating time 1217:07:36, a little more than an hour before the warning data picks up at 1218:19:57. The last recorded time stamp in the warning history is at 1218:20:27.
- The warning history data file showed that two warnings were annunciated. Originally, at an altitude of 4,000 feet and on a 160° track, the airplane rolled to the left and descended. The airplane's descent rate increased from approximately zero feet per minute (fpm) to approximately 8,500 fpm. Then the first warning, a Mode 1 Sinkrate alert was annunciated (at operating time 1218:20:17). The descent rate increased, and a Mode 1 Pull Up Warning was annunciated at an altitude of 2,900 feet (at operating time 1218:20:21).
- The EGPWS data ends approximately 7 seconds later with a descent rate of almost 12,000 feet per minute.
- There were no internal faults recorded during the accident flight leg.

Selected warning history data was included in Attachment 3.

B. AIRPLANE STRUCTURE

The aircraft wreckage was found on the front yards and street of a residential neighborhood. The aircraft impacted the ground in an approximate nose level/wings level attitude with little to no forward momentum. An indentation in the ground of approximately same size and shape as left wing was noted in the front yard of the house. The wires and trees close to house and driveway did not appear to have been struck by the airplane. Based on the initial impact indentation of the left wing, the airplane bounced aft approximately 3 feet.

The group examined the airplane structure on-site. The group determined that the entire airplane structure was at the accident site; no evidence was noted that the airplane structure had separated from the airplane prior to ground impact.

⁴ KLUK is the ICAO letter designator for Cincinnati Municipal Airport – Lunken Field



Figure 18 - Airplane wreckage as found at arrival. Note intact overhead house wires.



Figure 19 - Airplane orientation at accident site. Note intact overhead wires to the house.

1. Doors

A portion of the main cabin door was found on-scene. An emergency exit door was also noted.

2. Fuselage

The bottom of the fuselage was crushed from impact. The top portions of the fuselage, from the rear pressure bulkhead forward to the nose of the airplane, was consumed by fire.

3. Nacelles and Pylons

The left (number 1) engine pylon was separated from the aft fuselage. The pylon and engine were folded on top of the right (number 2) engine. See Figure 20.



Figure 20 - The airplane engines, with Engine 1 found on top of Engine 2.

4. Stabilizers

The horizontal and vertical stabilizers remained attached to each other but separated from the fuselage. The stabilizers were in the front yard of the house across the street from the main wreckage site. See Figures 21a and 21b.



Figures 21a and 21b - Found Location of Vertical and Horizontal Stabilizers; Note Main Wreckage in Background.

The empennage separated from the airplane at the aft pressure bulkhead.

The horizontal stabilizer and segments of the left and right elevators were laid out at the accident site for documentation. See Figures 22a and 22b.



Figure 22a and 22b - The left and right elevator laid out near horizontal stabilizer.

5. Windows

The forward flight deck windscreen was burned and melted almost completely.

6. Wings

The left wing was almost completely consumed by the post-impact fire.



Figure 23 - Left wing, looking inboard.

The right wing was noted with some fire damage inboard, with impact damage the outboard portion. The spar was broken on the outboard section of the wing.



Figure 24 - Right wing, looking outboard, and noting fire at the inboard forward section.

C. AIRPLANE POWERPLANTS

The airplane was fitted with 2 powerplants, mounted on each side of the aft fuselage. The powerplants were noted as follows:

Manufacturer: Pratt & Whitney

Model: JT15-1A

Engine Number 1 (left) Serial Number: 76777

Engine Number 2 (right) Serial Number: 76667

The bottom of both engine cowlings was noted pushed up. The left engine (Engine 1) was rotated over the empennage and came to rest on top of the right engine (Engine 2).

Engine controls: the left throttle arm was noted out of the pedestal; the right throttle arm was noted at idle.

Tom Jacky
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