

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



ANC23FA008

SYSTEMS

Group Chair's Factual Report

September 3, 2024

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A. ACCIDENT

Location: Kaupo, HI
Date: December 15, 2022
Time: 2114 Hawaii-Aleutian standard time
0714 12/16/22 coordinated universal time (UTC)
Airplane: Raytheon Aircraft Company C90A, N13GZ, LJ-1590

B. SYSTEMS GROUP

Group Chair	John Flynn National Transportation Safety Board Washington, District of Columbia
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Group Member	Michael Koenes Global Medical Response Lewisville, Texas
Group Member	Ernest Hall Textron Aviation Wichita, KS
Group Member	Steve Wilson Collins Aerospace Cedar Rapids, IA

C. SUMMARY

On December 15, 2022, about 2114 Hawaii-Aleutian standard time, a Raytheon Aircraft Company (formerly Beech) C90A, twin-engine, turbine-powered airplane, N13GZ, sustained substantial damage when it was involved in an accident near Kaupo, Hawaii. The airline transport pilot, flight paramedic, and flight nurse were fatally injured. The airplane was operated as a Title 14 Code of Federal Regulations (CFR) Part 91 air ambulance positioning flight.

D. DETAILS OF THE INVESTIGATION

The aircraft was recovered between 7 - 12 January 2023 and the airframe and engines were examined on 13 - 14 January 2023 in a hangar at Honolulu, HI. On 02 August 2023, the systems group met at the Air Transport facility in Phoenix, Arizona to re-examine the airplane wreckage. On 07 December 2023, the systems group met at the Collins Aerospace facility in Wichita, Kansas to examine the vertical gyro. A circuit card on the vertical gyro was examined at Collins Aerospace in March 2024.

1.0 Initial Aircraft Examination

After the aircraft was recovered, the wreckage was examined.

1.1 Airframe

The main landing gear hydraulic actuators remained attached to the wing and drag brace. The actuators appeared to be retracted.

For the right wing, the inboard flap actuator remained attached to the aft wing spar but separated from the inboard flap. Inboard flap actuator extension was measured to be about 2 inches, which corresponds with flaps "UP" (fully retracted). For the right wing, the outboard flap actuator was separated from the flap and the wing, the inner housing attachment point remained attached to the wing.

For the left wing, the left inboard flap actuator remained attached to the aft spar of the wing and was found extended about 2.25 inches, which correlates to a flap position of approximately 2 degrees. The left wing outboard flap actuator remained attached to the flap and the aft spar of the wing and the extension was measured to be about 1.5 inches, which corresponds with flaps "UP".

The aileron flight control cables were continuous from the cockpit to each respective wing aileron outboard bellcrank with cables separated at each wing root. The cable separations either exhibited splayed ends and individual filaments that were consistent with signatures of tensile overload and/or the cables exhibited a straight recovery cut. The elevator flight control cables were continuous from the aft bellcrank to the cockpit. Each elevator aft bellcrank push/pull rod tubes were separated. The continuity of one rudder cable was verified from the aft rudder bellcrank to the cockpit. A section of the aft rudder bellcrank attachment remained attached to the cable end. The second rudder cable was not located.

1.2 Cockpit

The flap handle was in the UP position. The elevator trim tab control position was approximately 3° down. The aileron trim tab control was right 2°. The rudder trim control was FULL LEFT, past normal range. The landing gear handle was in the DOWN position. The instrument panel was pushed forward and down.

The left throttle was at the idle position while the right throttle was about mid-position. The left propeller lever was pulled back to idle. The right propeller lever was in feather. Mixture controls were full forward (rich).

The artificial horizon was uncaged and banked right greater than 45° and nose high. The attitude gyro was disassembled and examined on-site. Scoring was present on the inside of the gyro housing.

The left and right DC load indicators indicated off scale low. The voltage meter indicated below zero. The watts indicated was -10. The propeller ampere meter indicated zero. The propeller frequency was below zero. The generator switch indicated triple fed (TPL FED). The instrument emergency light switch was OFF. All the circuit breakers on the lower fuel panel were closed, except for the 5-amp right propeller tach circuit breaker.

On the copilot side the following items were noted. The course deviation indicator (CDI) unit was impact damaged. The CDI needle was offset to the left and the course selected was a 035 heading. The lubber line was in line with 085 degrees on the compass. The airspeed indicator V_{mo} (barber pole needle) indicated 184 knots and the white needle was at 95 knots. Altimeter was reading 21,340 feet and the Kollsman window was set to 29.95.

On the pilot side, the following items were noted. The airspeed indicator indicated 0 knots and V_{mo} needle indicated 225 knots. On the radio magnetic indicator (RMI), the automatic direction finder (ADF) needle was pointing at approximately 220° and the very high frequency omnidirectional range (VOR) needle was pointing at approximately 180°. The heading bug was at 120°. The control column was deformed down.

On the fuel panel, the following items were noted. The left and right firewall shutoff valve switches were found in the OPEN position. The left and right transfer pump override switches were in AUTO. The left and right boost pump switches were ON. The fuel quantity nacelle switch was separated. The left and right fuel gauges were below zero. The Hobbs reading was 3788.3 hours.

On the overhead light panel, the following items were noted. The overhead light panel was impact damaged. The engine instrument, avionics panel, overhead panel (OVHD PED) and subpanel knobs were set to full bright. The side panel knob was separated.

2.0 Systems Review

The Onboard Image Recorder (Appareo) - Group Chair's Factual Report documented that the autopilot and the attitude indicator failed at the same time. The only component common to both systems is the vertical gyro.

2.1 Autopilot Description

The Collins Aerospace APS-65 autopilot (AP) system is a 3-axis digital system that utilizes the outputs from various airplane sensors, and any pilot initiated commands or mode selections, to provide flight guidance commands for the attitude direction indicator (ADI) command bars and to automatically position the airplane control surfaces. The APS-65 autopilot system consists of the following: APC-65H autopilot computer, 332D-11T vertical reference gyro, ADS-65 air data sensor, YRS-65 yaw rate sensor, FCP-65 flight control panel and APP-65A autopilot controller.

The APC-65H autopilot computer is the heart of the APS-65 autopilot system. The APC-65H utilizes outputs from various airplane sensors and commands from the flight controls. This information is sent to numerous indicators and the controls. When the computer is operating it continuously performs a self-test routine. These checks include the power supplies, flight control panel (FCP) serial bus, analog/digital and digital/analog converters, address and data buses, engage/disengage circuits, and various software routines. Failure of any of these checks causes a diagnostic bit to be set. Some of these diagnostic checks will disengage the autopilot or prevent the autopilot from engaging until the diagnostic bit is cleared. Most of the diagnostic bits will clear when the fault is corrected, however, the heartbeat monitor and the pre-engage faults must be cleared by pushing the autopilot engage (AP ENG) button or by cycling power. The APC-65H is located on the left side of the middle shelf in the forward avionics compartment (see Figure 1).

The 332D-11T vertical reference gyro is a source of attitude reference information used in the integrated flight systems and the automatic flight control systems. Three-wire 400-Hz synchro outputs conforming to ARINC specifications are provided in both pitch and roll axes. The equipment features built-in starting cycle, roll cutout, and monitoring circuits. Fast erection is automatic during starting. Both manual recycling and self-testing can readily be provided by appropriate external wiring. The vertical reference gyro is located on the center of the middle shelf in the forward avionics compartment (see Figure 1). The vertical reference gyro is

electrically powered and receives 115 volts alternating current (VAC) power from the airplane inverter.

The fast erect mode is necessary for erecting and maintaining the gyro spin axis in a vertical position relative to the aircraft's position with earth. The gyro must overcome the following three separate and distinct sources of inertial error: gyro mechanical imperfections; movement of the aircraft over the earth's surface, called flight error; and rotation of the earth itself, called earth rotation error. The equipment erection circuits consist of two erection torquers and two electrolytic gravity sensors, referred to as sensor switches. The gyro spin axis is positioned by the action of the erection torquers on the gimbals that support the gyro. The sensor switches are mounted directly to the inner and outer gimbals and control the power to the erection torquers. In this manner they control the proper vertical positioning of the gyro spin axis.

The ADS-65 air data sensor contains four solid-state pressure sensors (two absolute and two differential) to provide dual pressure altitude and dual indicated airspeed signals to the autopilot computer. These signals are used for the altitude (ALT), indicated airspeed (IAS), and vertical speed (VS) hold modes as well as for gain and torque programming of the servo command signals throughout the flight regime. The air data sensor is a remote mounted unit that is connected to both the pitot and static air systems.

The YRS-65 yaw rate sensor provides a yaw rate signal to the APC-65H autopilot computer for proper operation of the rudder servo. The YRS-65 is located slightly to the left of center, on the middle shelf in the forward avionics compartment (see Figure 1). The YRS-65 receives its 26 VAC operating power from the airplane inverter.

The FCP-65 flight control panel is used to select the operating modes for the autopilot system (see Table 1). The mode select buttons are momentary-action, push-on push-off buttons. Mode selection is annunciated on the flight control panel.

Mode selection is interlocked to ensure that only compatible modes can be selected at the same time. A test button provides the operator a means to test the panel lamps and continuously monitor tests. Pushing the test button while airborne causes a momentary lamp test followed by a display that indicates if any of the continuous monitor tests have failed. Pushing the test button while on the ground selects the system diagnostic mode, consisting of a lamp test followed by a display that indicates if any of the continuous monitor tests have failed. The FCP-65 flight control panel is located in the pedestal and receives operating power from the APC-65H autopilot computer (see Figure 2).

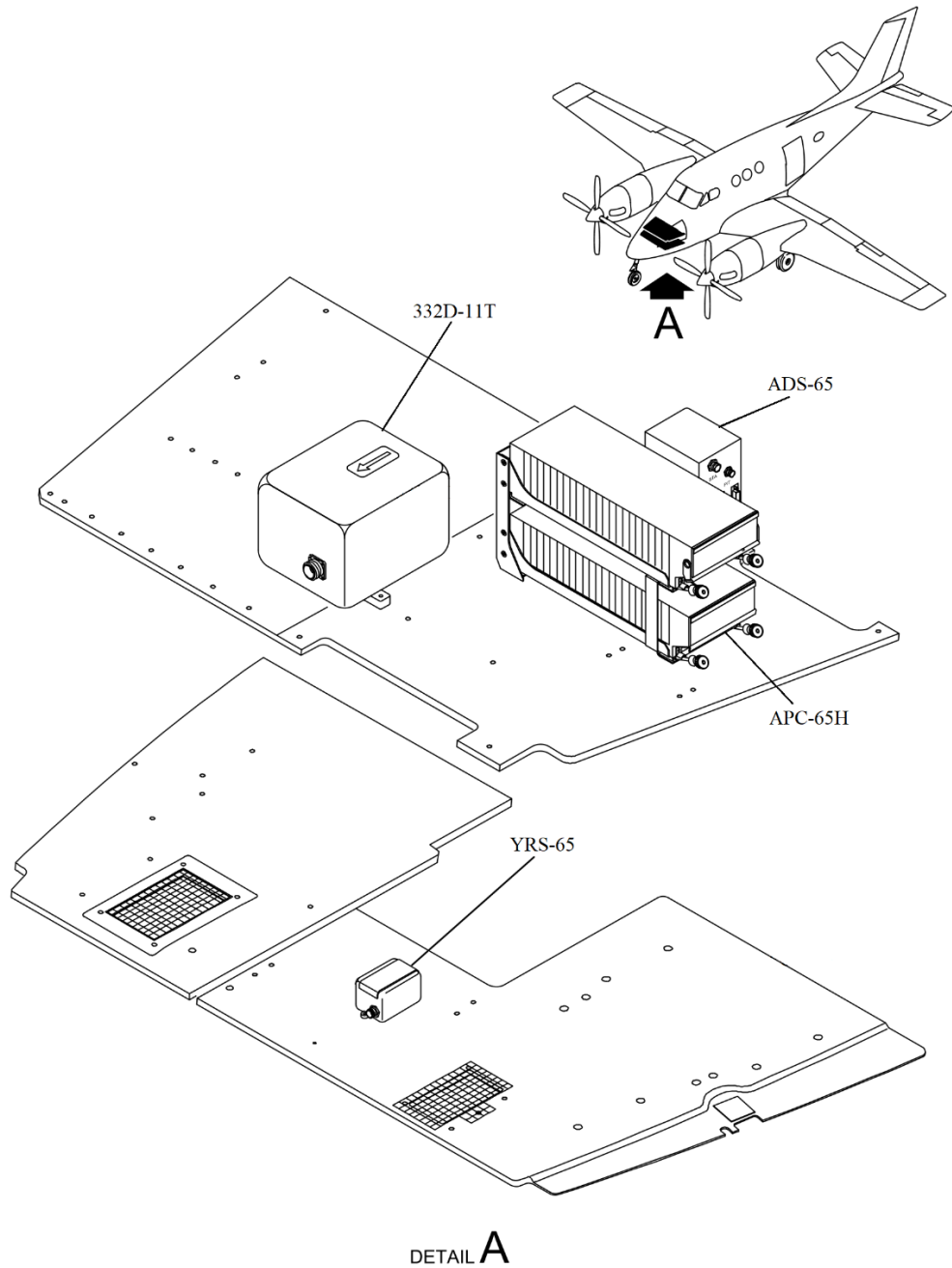


Figure 1. Location of APC-65H autopilot computer, 332D-11T vertical reference gyro, ADS-65 air data sensor, and YRS-65 yaw rate sensor. (Courtesy of Textron Aviation)

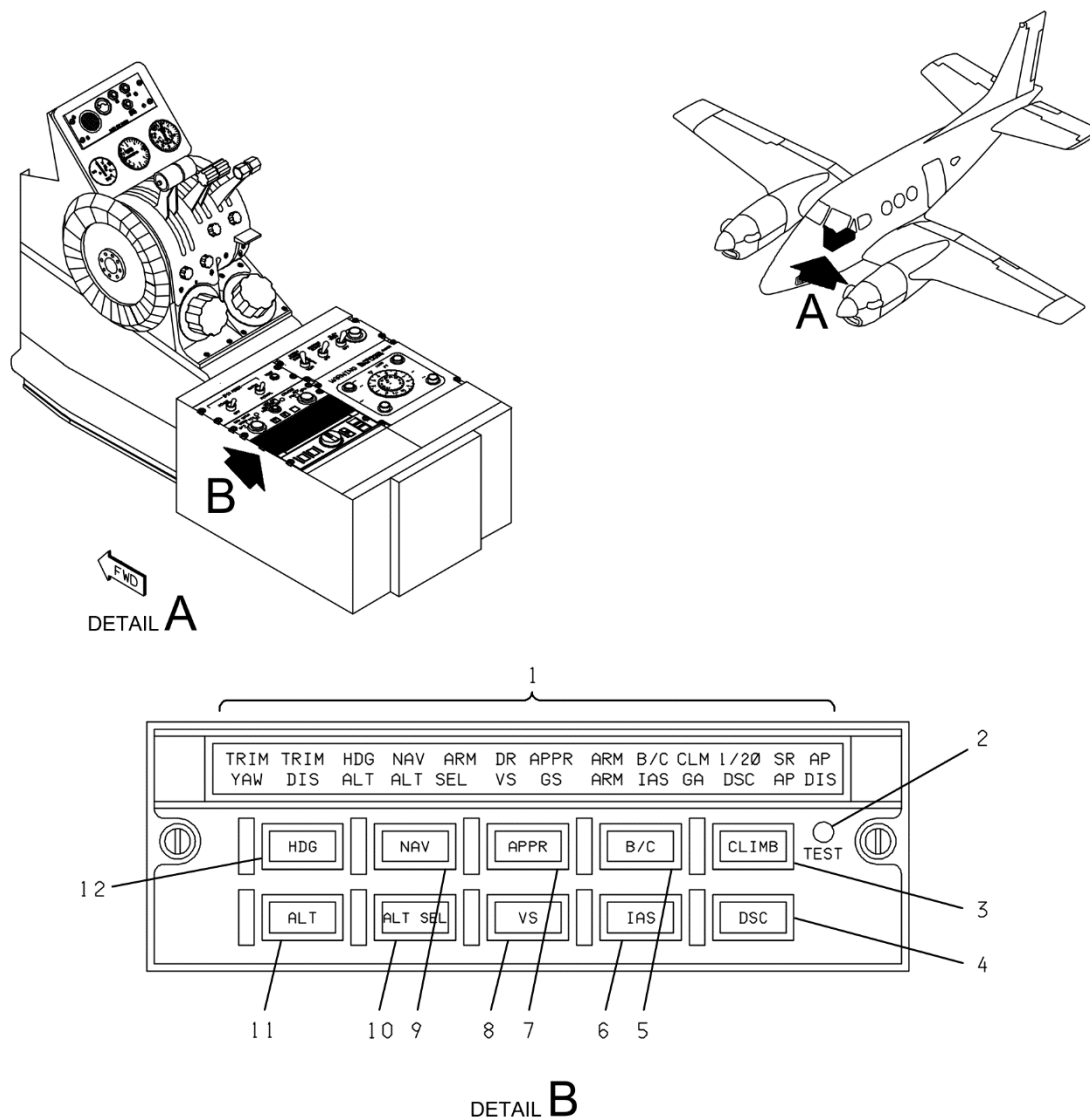


Figure 2. FCP-65 flight control panel. (Courtesy of Textron Aviation)

Table 1. FCP-65 flight control panel description.

CONTROL	FUNCTION
1. Mode annunciator	Displays modes of operation selected for the flight director or autopilot system.
2. Test switch	Selects the system diagnostic mode. This mode can be entered on the ground or in the air.
3. Climb	Selection of the climb mode automatically arms the altitude preselect mode and commands a smooth pitch change to establish the airplane on the preprogrammed vertical ascent rate.

CONTROL	FUNCTION
4. DSC (descent)	Selection of the DCS mode automatically arms the altitude preselect mode and commands a smooth pitch change to establish the airplane on the preprogrammed vertical descent rate.
5. B/C (back course)	Back course localizer approach is selected to provide commands to capture and track the localizer back course.
6. IAS	The IAS mode is a hold mode that provides commands to maintain the indicated airspeed present at the time of mode selection.
7. APPR (approach)	APPR mode is used any time an approach to a runway is desired.
8. VS	The VS mode is a hold mode that provides commands to maintain the vertical speed present at the time of mode selection. A lateral mode must be selected, or the autopilot must be engaged before the VS mode can be selected.
9. NAV (navigation)	Tuning the navigation receiver to the desired VOR or localizer frequency and selecting NAV mode puts the flight control system into the NAV arm submode.
10. ALT SEL (altitude preselect)	The ALT SEL mode works in conjunction with an altitude preselector/alerter. The desired altitude is set into the preselector, then the ALT SEL mode is selected on the FCP-65, either directly or by selecting CLIMB or DSC mode. As the altitude is approached, commands are provided to capture the altitude. After the altitude is captured, the system automatically switches to the altitude hold mode.
11. ALT	The ALT hold mode provides commands to maintain the pressure altitude existing at the time ALT mode is selected. A lateral mode must be selected, or the autopilot must be engaged before the ALT mode can be selected.
12. HDG (heading)	HDG mode brings ADI command bars into view.

The APP-65A autopilot panel consists of the following; the autopilot and yaw damper engage/disengage buttons, soft-ride and half-bank mode select buttons, turn knob, vertical control, and autopilot annunciators (see Table 2). Each time the autopilot or the yaw system is engaged, the computer goes through a pre-engage test routine during which the AP and the TRIM failure annunciators are illuminated and the disengage circuits and internal monitors are checked. If the pre-engage test sequence is not completed satisfactorily, the system does not engage, and a failure annunciation is displayed on the APP- 65A and FCP-65. The computer continuously performs a self-test routine while power is applied. A disengage switch is located on each control wheel to provide a convenient means to disengage both the autopilot and the yaw damper. The APP-65A is located on the pedestal on the pilot's side (see Figure 3). Operating power for the APP-65A is supplied from the APC-65H autopilot computer.

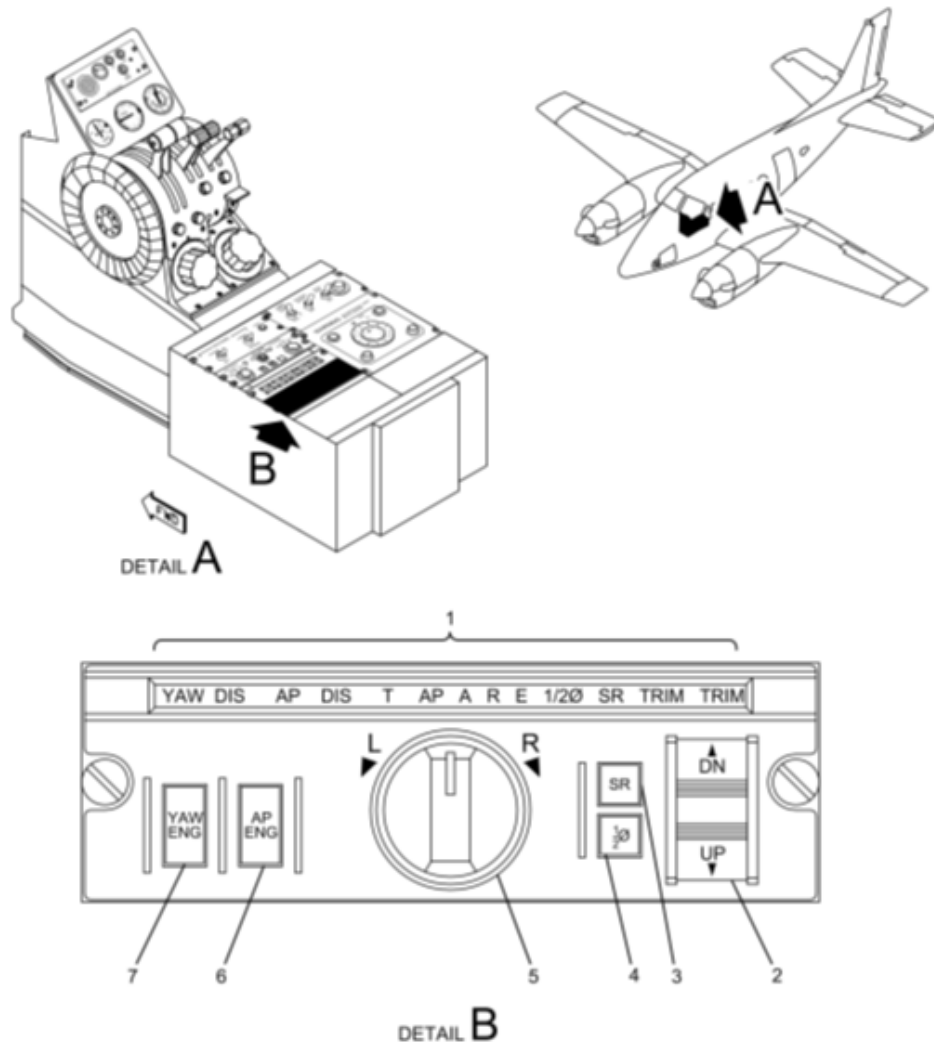


Figure 3. FCP-65 APP-65A autopilot panel. (Courtesy of Textron Aviation)

Table 2. APP-65A autopilot control panel description.

CONTROL	FUNCTION
1. Autopilot Annunciator	Displays modes of operation selected for the autopilot system.
2. Vertical Control	The UP/DN vertical control is a center-off, spring-loaded rocker switch that provides manual control of the elevator channel when the autopilot is engaged, and no vertical modes are selected.
3. SR (Soft-Ride) Mode Select Switch	The SR mode select switch is a momentary-action, push-on/push-off switch. Pushing the SR switch changes the gain of various circuits in the computer to provide increased passenger comfort during turbulent conditions.
4. ½  Mode Select Switch	The ½  (half-bank) mode select switch is a momentary-action, push-on/push-off switch. Pushing the ½  switch limits the maximum commanded bank angle to approximately 12.5 degrees.
5. Turn Knob	The turn knob is a right/left bank angle control that has a center detent position at the 0 degrees (wings level) position. The control is not spring loaded and will remain at any position between the end stops when released. The bank angle commanded by the turn knob is proportional to the displacement of the turn knob from the detent position. The turn knob becomes inactive if it is out of the detent position when the pitch synchronization (SYNC) button is pushed.
6. AP ENG (autopilot engage)	The autopilot engage switch is a momentary-action, push-on/push-off switch. Pushing the AP ENG switch once engages all autopilot servos including rudder and trim servos. Pushing the AP ENG switch a second time disengages all servos except the rudder servo, which must be disengaged by pushing the YAW ENG switch or the system disengage switch on the control wheel.

CONTROL	FUNCTION
7. YAW ENG (yaw engage)	The yaw engage switch is a momentary-action, push-on/push-off switch. Pushing the YAW ENG switch once actuates the yaw channel of the autopilot and engages the rudder servo. Pushing the YAW ENG switch a second time disengages the rudder servo.

The pitch SYNC, autopilot (AP)/yaw damper (YD) /trim disconnect (DISC) and pitch trim switches located on the pilot's and copilot's control wheel are used in conjunction with the autopilot system to provide the pilot a convenient means to change altitude, disengage autopilot, or trim the airplane (see Figure 4).

The pitch SYNC disconnect switch, located outboard of the dual-element pitch trim thumb switch on the outboard grip of each control wheel, is used to manually maneuver the airplane without completely disengaging the autopilot. Depressing the pitch SYNC button disengages the primary servos and may cancel any selected vertical modes without interrupting computer computations for the selected mode. The airplane can be maneuvered to any desired attitude while the SYNC button is depressed. When the SYNC button is released, the primary servos reengage, the autopilot computer synchronizes to the new attitude and control is returned to the previously selected modes. Return to the selected modes is restrained to prevent any rapid maneuvers when the airplane attitude varies from that commanded by the autopilot.

The AP/YD/TRIM DISC switch is a bi-level, push-button, momentary-on, disconnect switch located inboard of the dual-element pitch trim thumb switch on the outboard grip of each control wheel. Operation of the disconnect switch causes all autopilot servos to disengage and all selected vertical modes to cancel if no lateral modes are selected. The disconnect switch has two detent positions. Depressing the disconnect switch to the first of the two levels disconnects the autopilot and yaw damper system; depressing the switch to the second level disconnects the electric elevator trim system.

The dual-element pitch trim thumb switch, located on each control wheel, provides a means for the pilot to trim the airplane when the autopilot is not engaged. The dual-element trim switch is a three-position (UP/OFF/DOWN) rocker switch. Operation of the trim switch while the autopilot is engaged will cause the autopilot to disengage. Operation of the trim switch will cause the amber TRIM annunciator to illuminate on the APP-65A and FCP-65 panels. When both elements are simultaneously moved forward, a nose-down trim will be achieved. When both elements are simultaneously moved aft, a nose-up trim will be achieved. When

released they will return to the center (OFF) position. If either single element of the dual-element is pushed forward or aft, no action occurs.

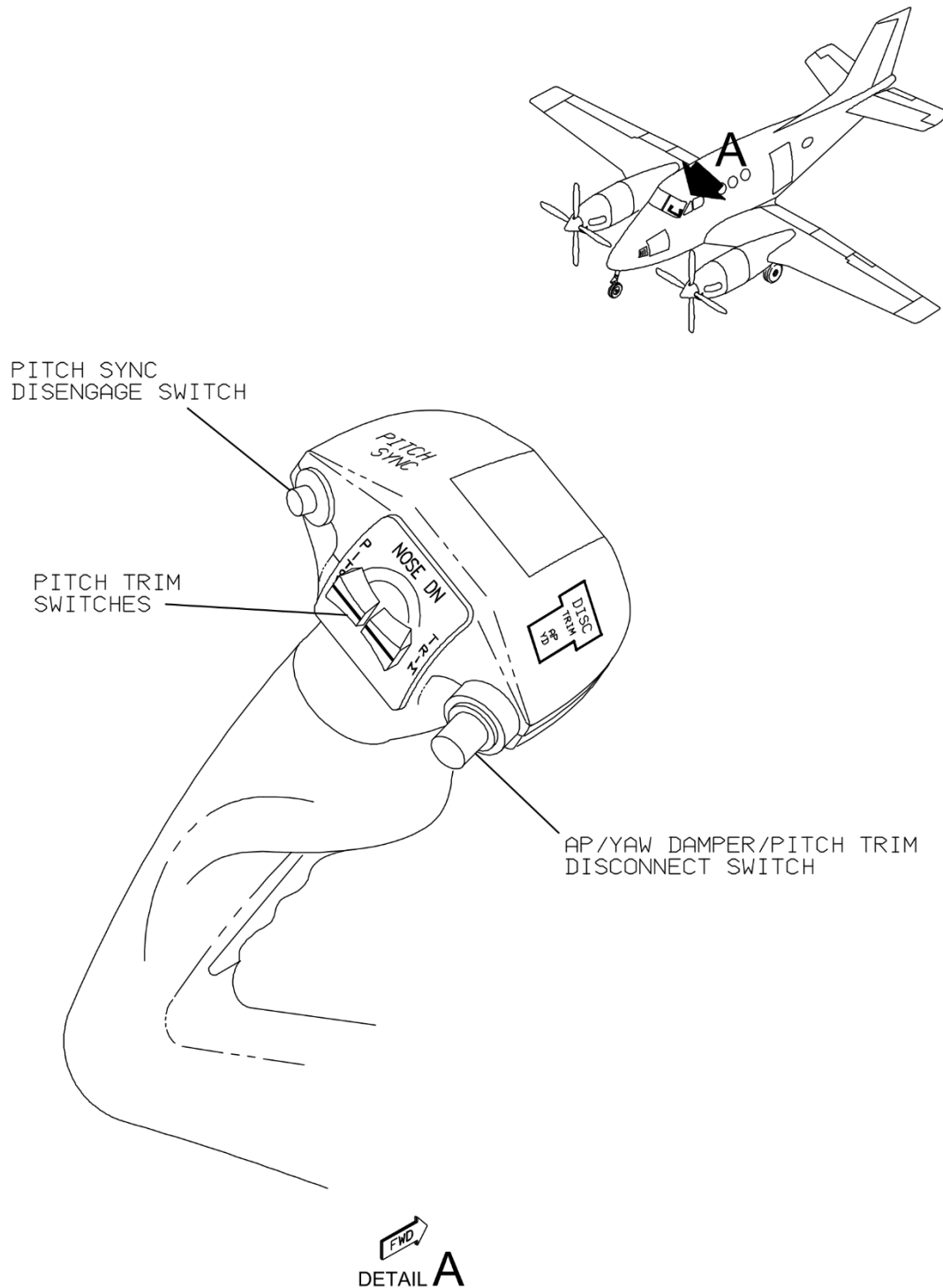


Figure 4. Autopilot control wheel switches. (Courtesy of Textron Aviation)

2.2 Cockpit Panel

The main cockpit panel is shown in Figure 5.

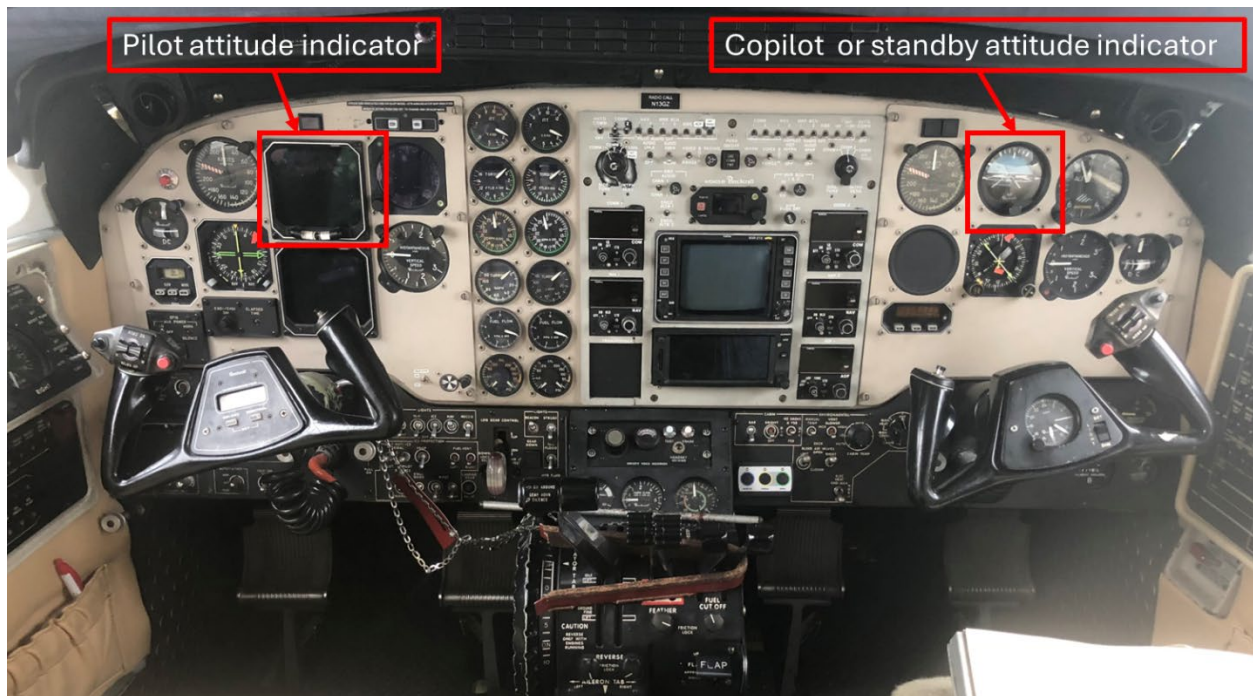


Figure 5. Photo of cockpit instrument panel. (Courtesy of Global Medical Response)

3.0 Vertical Gyro

3.1 Removal From Aircraft

The group met at the Air Transport facility in Phoenix, Arizona, on August 02, 2023, to re-examine the airplane wreckage. The vertical gyro was located in the nose of the aircraft and removed. The unit was photographed (see Figures 6 and 7) and retained for further examination. The unit had water inside it, and this was drained as much as possible before shipping the unit to Collins Aerospace.

Equipment Type:	Vertical Gyro 332D-11T
Manufacturer:	Collins Aerospace
Part Number:	622-4565-001
Serial Number:	3794
Mod Information:	SB 21, SIL 1-84, SB 22, 24, 26 and 27



Figure 6. Photo of vertical gyro after removal from wreckage.



Figure 7. Photo of vertical gyro nameplate.

3.2 Vertical Gyro History

The vertical gyro was manufactured in May 1992. Collins Aerospace researched the unit's history and the unit had been returned to the Collins Aerospace Plant 1104 (Wichita Service Center) around January 01, 2004. The record (service notification 100139816) did not provide any information on what service/repair the unit received.

The unit was overhauled by Precision Accessories and Instruments (PAI) and shipped out on August 10, 2022. The rotor and gimbal bearings, gasket, decals, and a capacitor were replaced.

The vertical gyro was installed on the aircraft on August 16, 2022.

3.3 External Inspection

The group met at the Collins Aerospace facility in Wichita, KS, on December 07, 2023, to examine the vertical gyroscope.

A detailed external inspection was completed. Photos were taken of the unit as received. The unit was crushed inward on the top and 2 sides (see Figure 8). The crushing of the case is consistent with excessive external water pressure. There were salt deposits on the electrical connector. There was a Precision Accessories Inc. (PAI) repair label on the unit. There was a Precision Heliparts warranty sticker on the part. There was no smell or odor perceived from the unit.

The airframe electrical connector was removed. The pins were straight. The sockets on the aircraft side of the connector were present and none appeared to be recessed (see Figure 9).



Figure 8. Vertical gyro at start of examination.



Figure 9. Photo of vertical gyro electrical connector and mating electrical harness connector.

3.4 Disassembly and Internal Inspection

The preservation sealing tape around the base of the unit was removed. Water was present and dripped out of the unit. The water was drained from the unit. The cover was removed. The interior of the unit was covered in marine growth and deposits (see Figure 10). The unit was washed with de-ionized water and some of the marine growth was removed (see Figure 11).

An exemplar unit was set to approximately the same position as the accident gyro. This corresponded to approximately 29 degree right roll and 3.5 degree pitch down position (see Figure 12).

The slip ring was damaged, and the damage appeared to correspond to the crushed cover (see Figure 13). Several components on the unit were observed to be crushed. An example of the crushed components is provided in Figure 14. The S1 switch was broken, and the damage appeared to correspond to the crushed cover (see Figure 15). Damage to a wire wound resistor (R61) on terminal board 7 (TB7) was observed (see Figure 16).¹ The resistance across the resistor was measured at 83.5 ohms as found. One of the wires between the resistor and the board was cut to isolate the resistor. The resistance across the resistor was re-measured at 83.4 ohms. (Note that R61 resistor has a nominal value of 82 ohms.) Terminal board 7 was removed from the unit for additional examination at Collins Aerospace.

¹ The R61 resistor was added to TB7 per 332D-11A/T/V-22-27 Service Bulletin 27. Service Bulletin 27 was added because unplugging the unit with power applied could cause a shorted or blown transistor on control board TB7. Resistor R61 was part of the short circuit protection added per the service bulletin.

The motor/spinning mass casing was observed to be normal in color. If the motor seizes, the motor/spinning mass casing becomes discolored due to overheating (see Figure 17).

3.4.1 Continuity Checks

Continuity checks were performed on the electrical connector of the unit. The results are documented in the Table 1. Operation of the unit was not possible due to deposits on the unit and the out of limits continuity checks.

Table 1. Data from continuity checks.

Point 1	Point 2	Value	Specified limit
A	B	11.7 Ohm	B to C value +/- 2 Ohm
B	C	680 kOhm	9.5 – 14.5 Ohms
D	E	11.3 Ohm	E to F value +/- 2 Ohm
E	F	11.3 Ohm	9.5 – 14.5 Ohms
G	H	14.2 Ohm	8-12 Ohm
H	Case	0.7 Ohm	Not to Exceed 2 Ohms
M	R	680 kOhm	270 – 330 Ohm
W	X	0.4 Ohm	270 – 330 Ohm

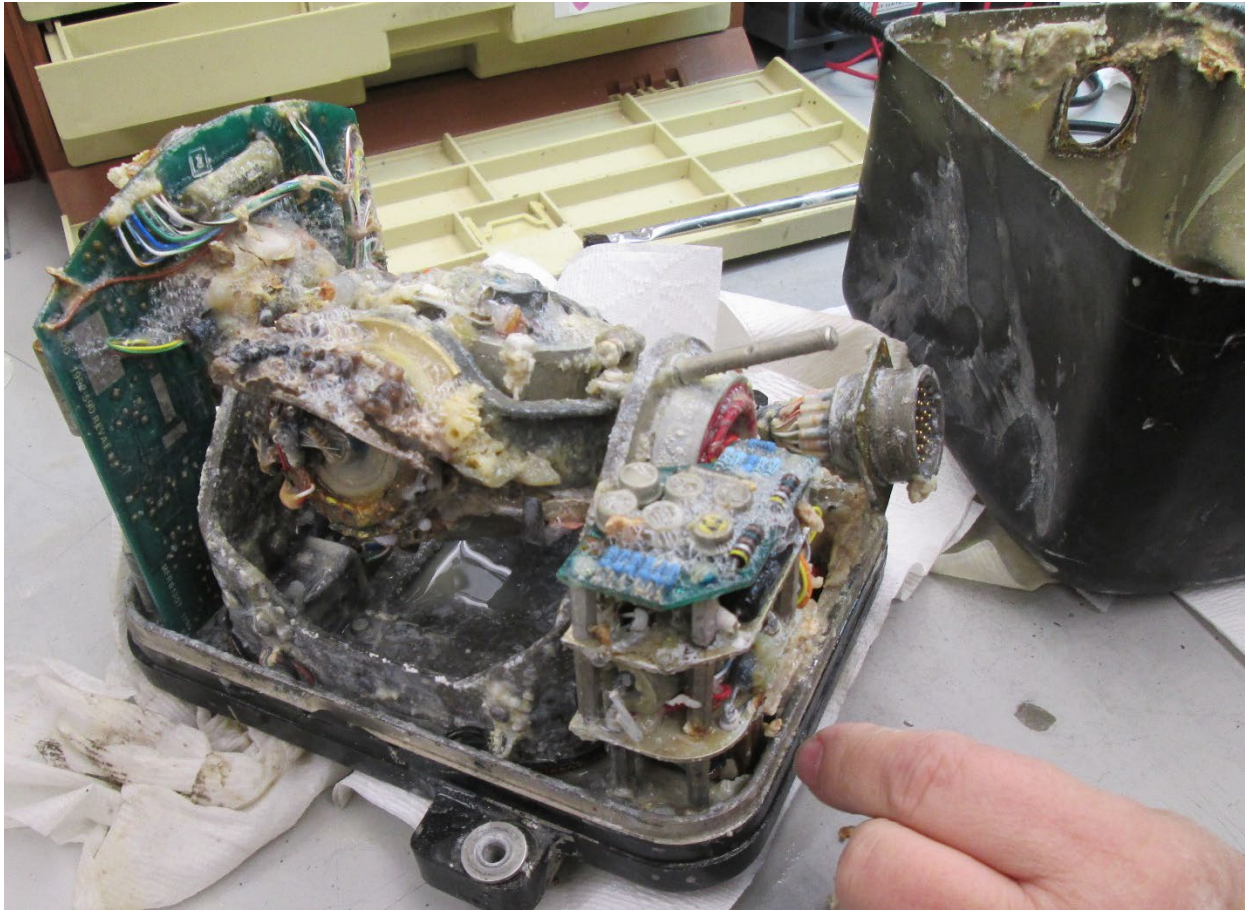


Figure 10. Photo of interior of the vertical gyro showing marine growth and deposits.

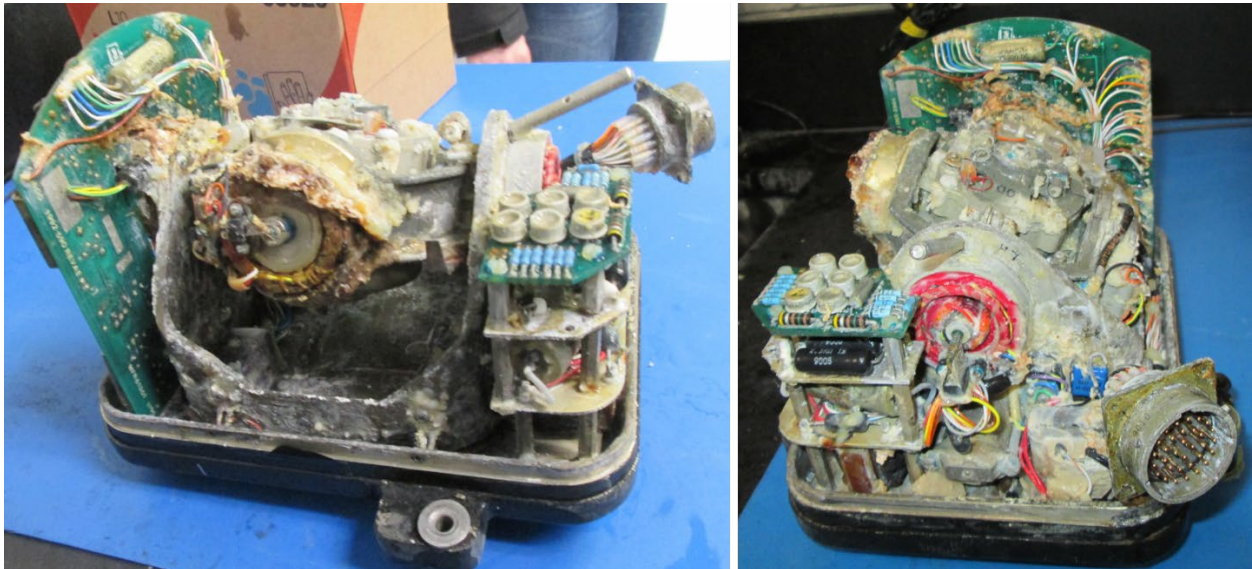


Figure 11. Photos of the vertical gyro after rinsing with de-ionized water.

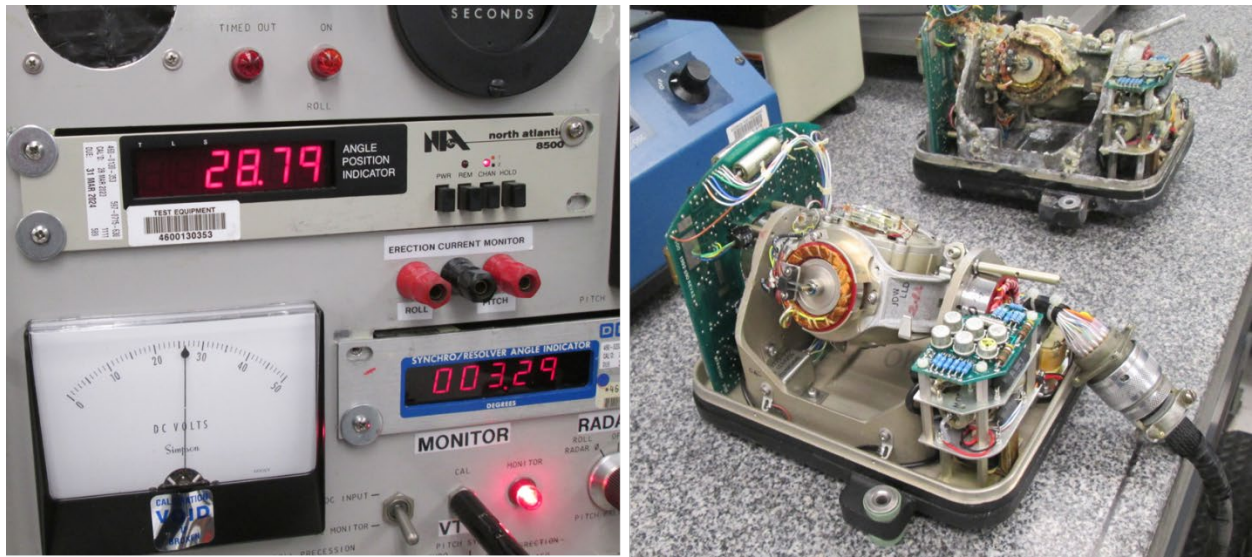


Figure 12. Photos of exemplar vertical gyro set to the same position as the accident unit.

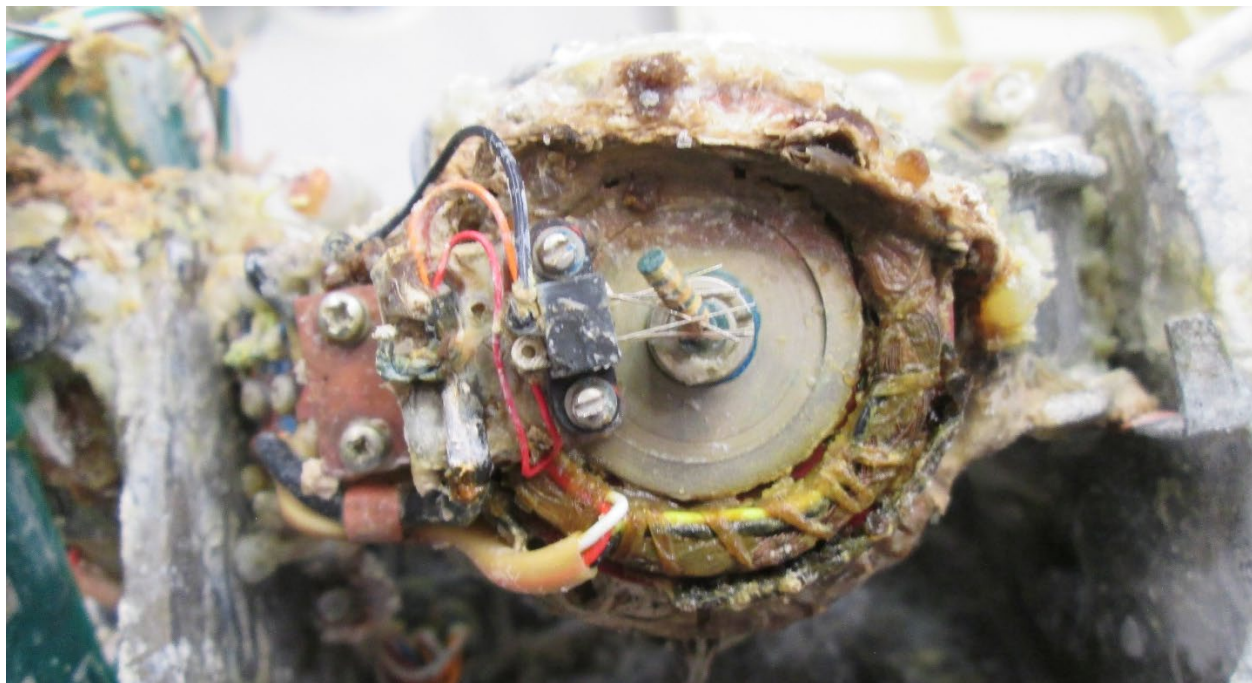


Figure 13. Photo of the vertical gyro showing damaged slip ring.

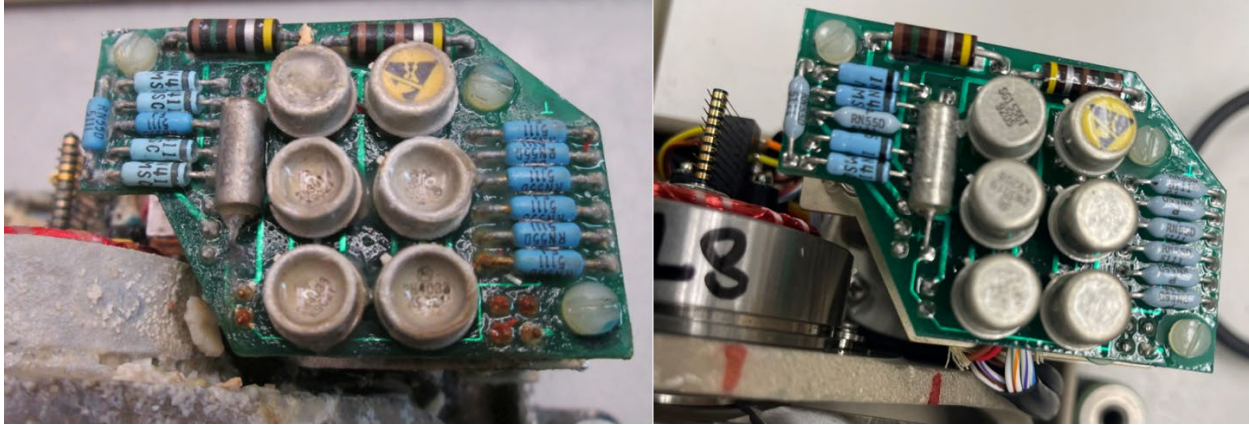


Figure 14. Photo of crushed components in the vertical gyro (left) and exemplar unit (right).

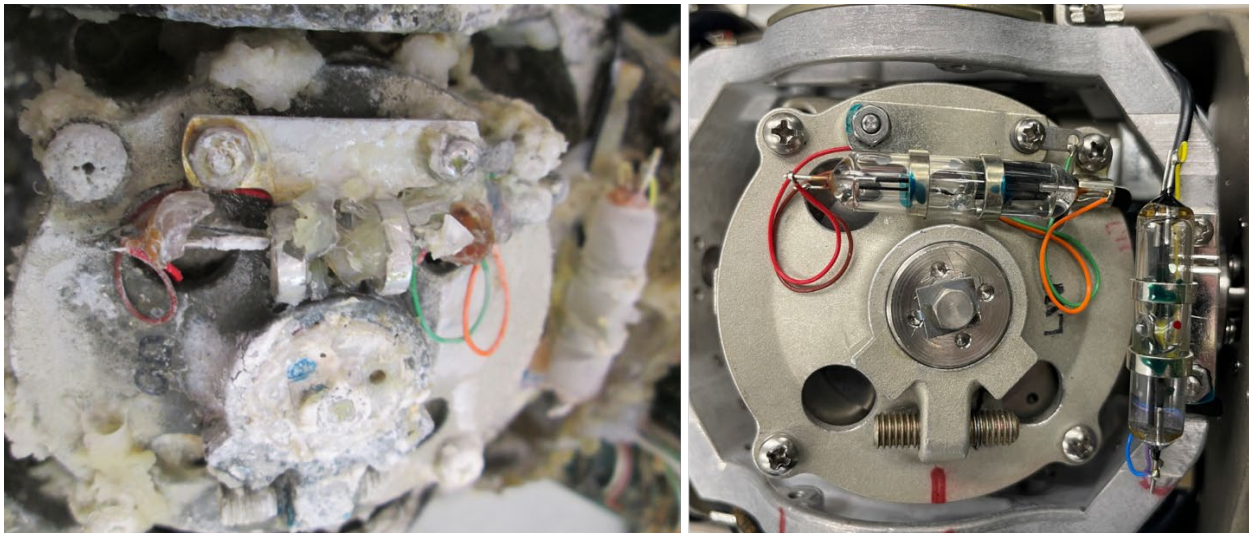


Figure 15. Photo of the vertical gyro showing damaged S1 switch (left) and an exemplar unit S1 switch (right).

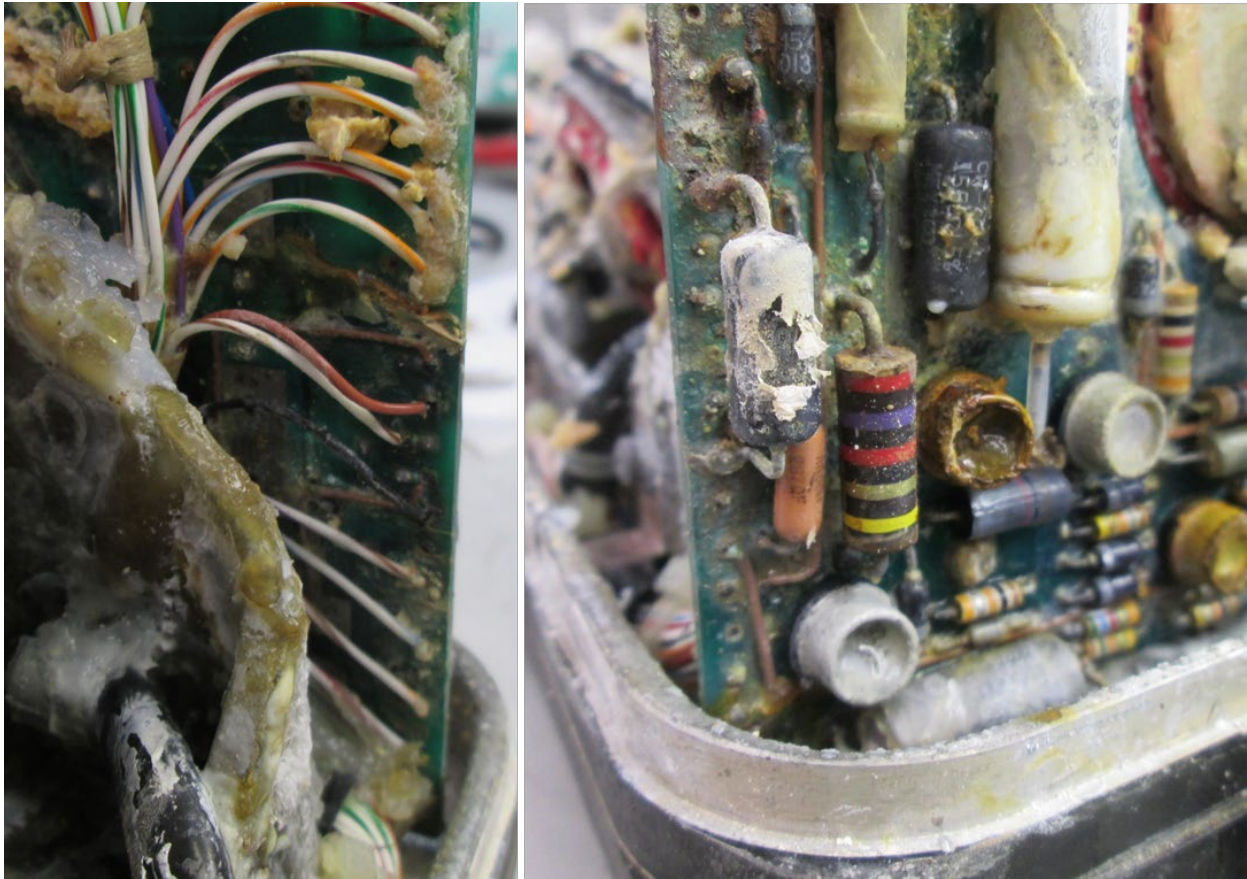


Figure 16. Photos of damage to TB7 resistor R61.

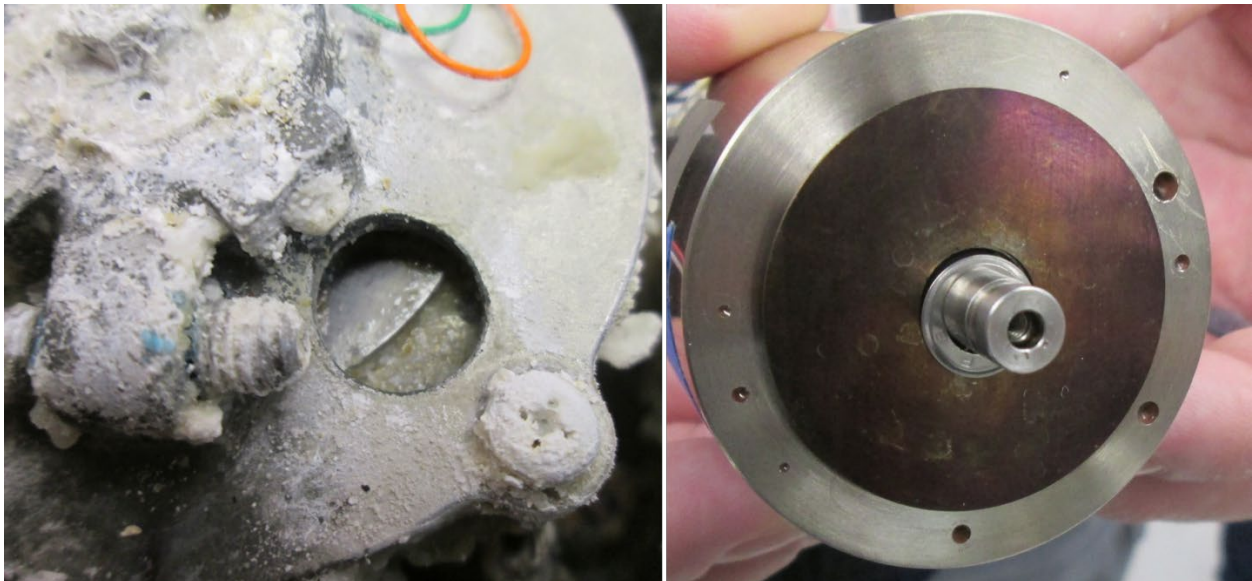


Figure 17. Photo of the vertical gyro motor/spinning mass casing inside hole (left) and exemplar overheated unit (right).

3.5 Examination of Terminal Board 7

Terminal board 7 was examined at the Collins Aerospace facility on 04 March 2024. The R61 resistor was separated from the terminal board as received (see Figures 18 and 19). The terminal board was cleaned with an alkaline soap and water mixture and a nylon brush. The board was examined after the cleaning (see Figures 20 and 21). The area where the R61 resistor was located showed some corrosion deposits but no thermal damage.

Collins Aerospace also completed a computed tomography (CT) scan on the terminal board and R61 resistor. The CT scan showed indications of a break in a connection between 2 components (see Figure 22). The terminal board was cleaned again in this area, and it was confirmed that the connection was present (see Figure 23).

No other anomalies were observed during the examination.

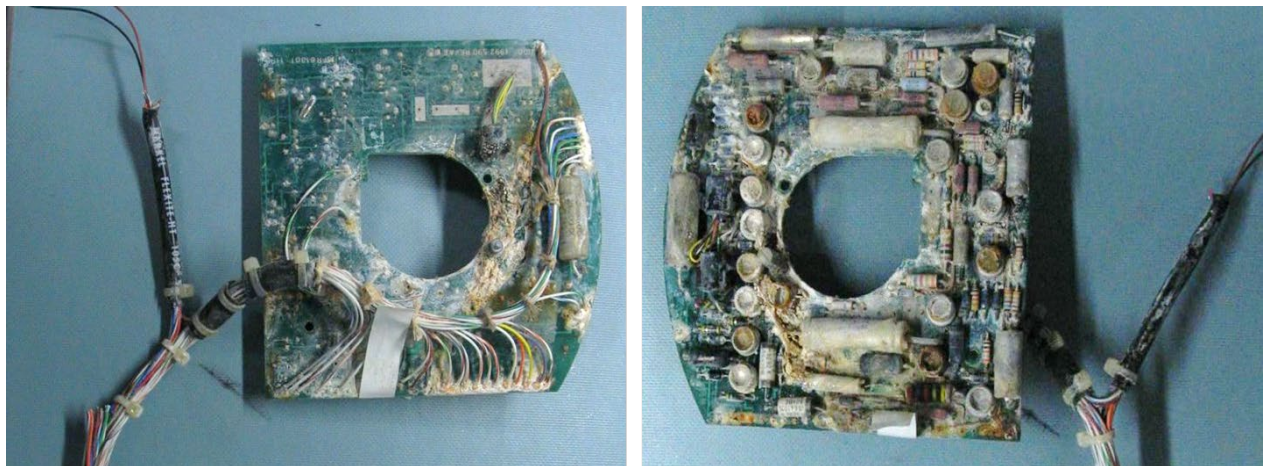


Figure 18. Photos of TB7 as received at Collins Aerospace.

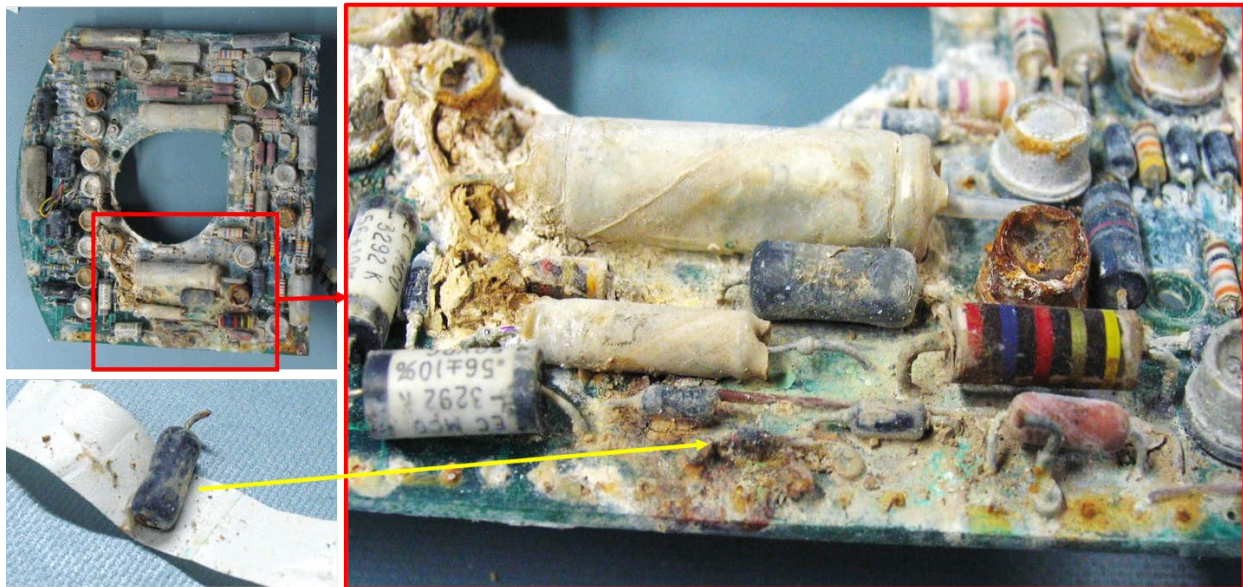


Figure 19. Photos of TB7 and R61 resistor as received at Collins Aerospace.

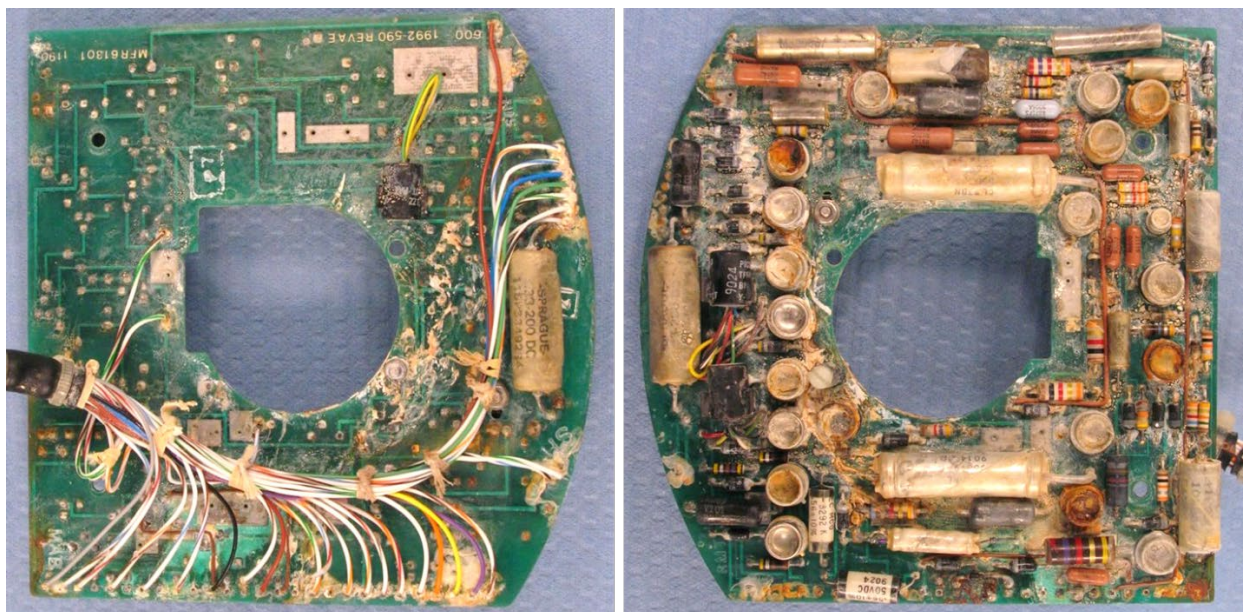


Figure 20. Photos of TB7 after being cleaned with an alkaline soap and water mixture and nylon brush.

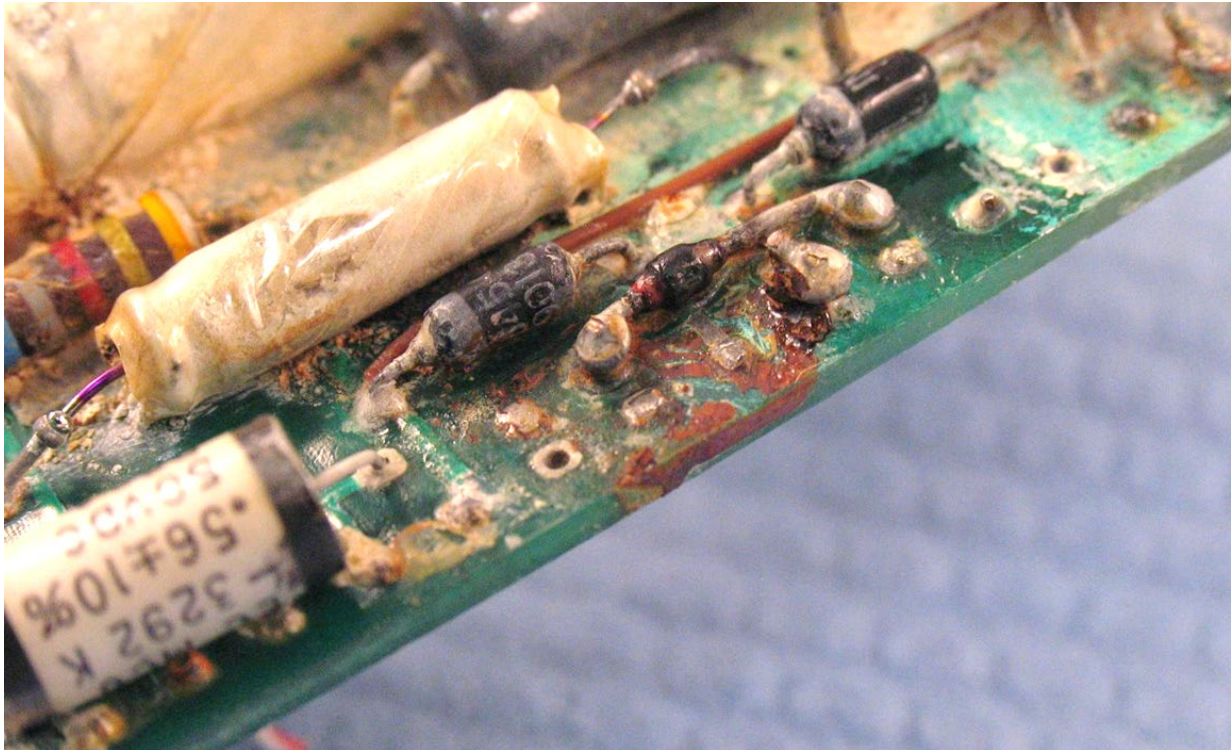


Figure 21. Photo of TB7 where the R61 resistor was located.

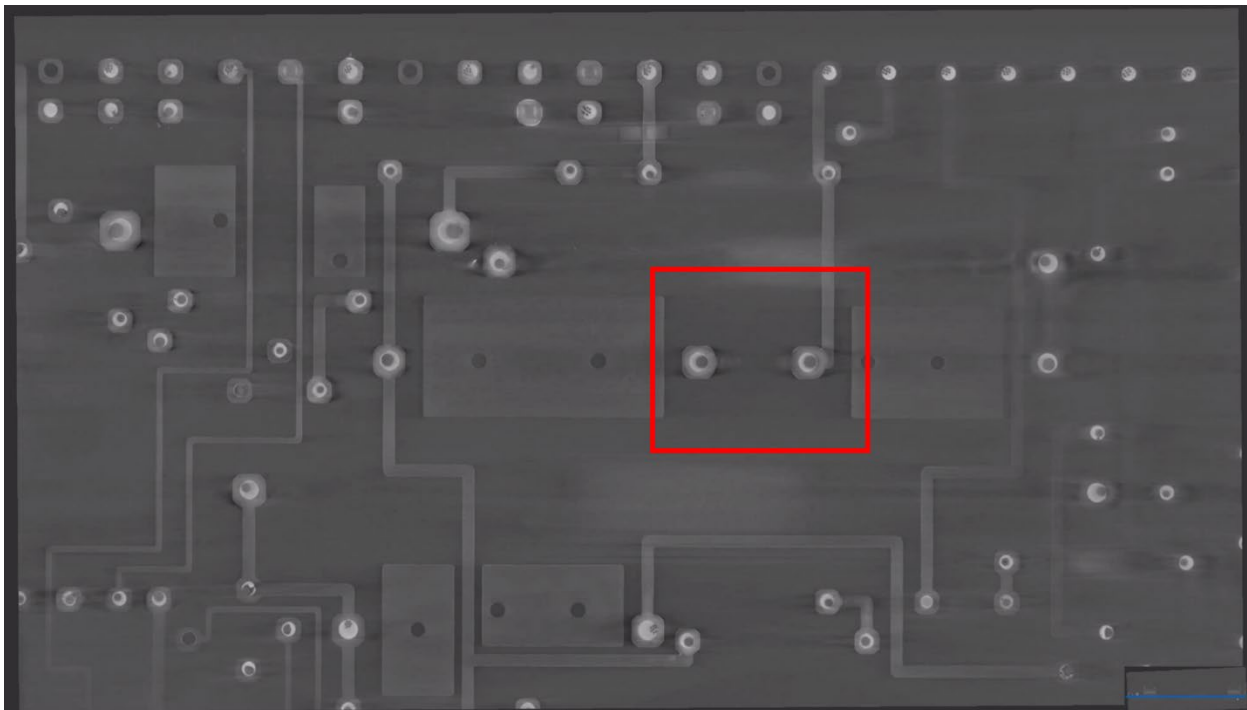


Figure 22. CT image of TB7 where indication of a break in a connection was located.

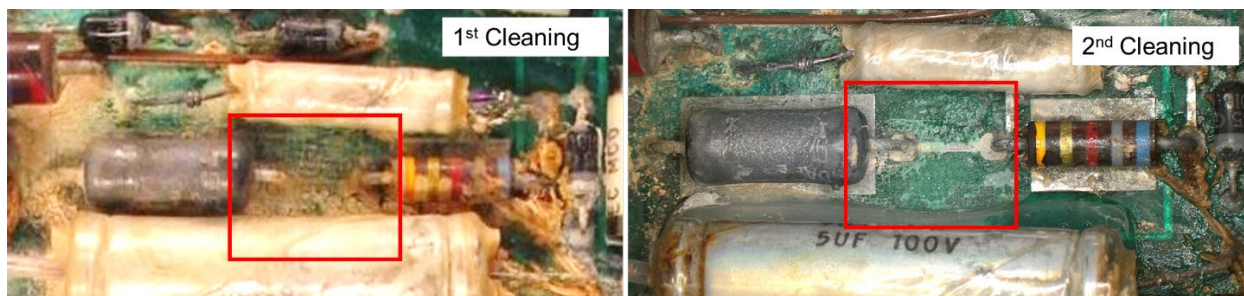


Figure 23. Photos of TB7 where the CT scan showed an indication of a break in a connection.

Submitted by:

John Flynn
Aircraft Systems Investigator