

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



ENG22LA004

AIRCRAFT SYSTEMS

Group Chair's Factual Report

November 27, 2023

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A. OCCURRENCE

Location: Bellefontaine, Ohio
Date: November 12, 2021
Time: 0902 Local Time
Airplane: Beech F-33A, registration N9035Q

B. AIRCRAFT SYSTEMS GROUP

Group Chair	Tom Jacky NTSB Washington, DC
Group Member	Paul Rau Federal Aviation Administration Wichita, KS
Group Member	Tom Carr Garmin Olathe, KS

C. SUMMARY

On November 12, 2021, at 0902 eastern standard time, a Beech F-33A, registration N9035Q, reported an autopilot malfunction while enroute to Bellefontaine, Ohio. There were no injuries to the pilot, the sole occupant. The airplane was registered to Brown Vintage Airlines, LLC. and operated as a 14 Code of Federal Regulations Part 91 flight. The flight originated from Mansfield, Ohio and was destined for Bellefontaine, Ohio.

The group chair met at the Modern Avionics & Maintenance facility in Mansfield Ohio on February 16-17, 2022 to examine and test the autopilot system on the event airplane. The airplane was examined in the facility's hangar.

After the examination of the airplane's autopilot system, the following component was removed for further examination:

Garmin GSA 28 Servo Actuator (installed in the pitch servo position)
Part Number: 011-02927-11
Serial Number: 5G9001563

The group met at the Garmin facility in Olathe, Kansas on October 20, 2022 to examine and test the removed Garmin GSA 28 servo actuator.

The servo actuator failed the Garmin acceptance test procedure. During the subsequent examination of the internal components of the servo, evidence of sulphuration was noted on the servo's printed circuit board.

The servo was then submitted to the NTSB's Materials Laboratory, where the finding of sulphuration was confirmed.

Following the GSA 28 servo actuator examination, Garmin published a service bulletin for instructions on the extension of the GSA 28 service life. The bulletin detailed an exchange program for the servos in operation.

On October 3, 2023, the Federal Aviation Administration (FAA) issued a Notice of Proposed Rulemaking (NPRM) to issue an Airworthiness Directive (AD) for airplanes with a configuration of the Garmin autopilot system like the autopilot installed on the occurrence airplane.

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

D. DETAILS OF THE INVESTIGATION

1.0 Garmin Auto Flight Control System

1.1 Description of System

The airplane was fitted with a Garmin GFC 500 Autopilot System. The system included the Garmin G5 Electronic Flight Instrument, the GMC 507 Auto Pilot Mode Control Panel, and GSA 28 servo actuators, including the pitch and pitch trim positions. See Figure 1.



Figure 1. Garmin 500 Auto Flight Control System general schematic (courtesy of Garmin, taken from the G5 Electronic Flight Instrument Pilot's Guide for Certified Aircraft).

The G5 can function as either an attitude display indicator and/or horizontal situation indicator.

The airplane had GSA 28 servo actuators installed in the pitch, pitch trim, roll, and yaw positions. The pitch servo actuator was connected to the elevator surface while the pitch trim servo actuator was connected to the elevator trim surface. The servo actuators are linked via a Controller Area Network (CAN) bus. When the autopilot is engaged, the pitch trim servo will act based on information reported by the primary pitch servo received via the CAN bus.

When the autopilot is disengaged, the pitch trim servo can be commanded through a switch on the flight control yoke for manual electric pitch trim¹.

1.2 Garmin Service Bulletin Number 2063

Garmin issued Service Bulletin Number 2063, Revision B on May 6, 2020 regarding an inspection of the GSA 28 servo actuators.

¹ The occurrence airplane also had a pitch trim wheel on the forward flight panel.

The purpose of the service bulletin was to recall (identify and replace) failed GSA 28 servo actuators. The effectivity covered GSA 28 servo actuators (part number 011-0297-11) with serial numbers between 5G9000000 and 5G9002000.

For the occurrence airplane, the GSA 28 servo installed in the pitch GSA 28 position was subject to the service bulletin; the servo's serial number (5G9001563) was in the range of affected servos.

Service Bulletin 2063 is included in Attachment 1.

1.3 Installation and Previous Removal of GSA 28 Servos

According to the airplane's maintenance information, the Garmin 500 Auto Flight Control System was installed in 2019. The following GSA 28 servos were installed as part of the AFCS:

1) GSA 28 Servo, Pitch Position:
Part Number: 011-02927-11
Serial Number: 5G9001563

2) GSA 28 Servo, Yaw Position:
Part Number: 011-02927-11
Serial Number: 5G9001595

3) GSA 28 Servo, Roll Position:
Part Number: 011-02927-11
Serial Number: 5G9001594

4) GSA 28 Servo, Pitch Trim Position:
Part Number: 011-02927-11
Serial Number: 5G9001602²

On August 21, 2021, the GSA 28 servo in the pitch trim position was removed and replaced. According to the paperwork provided by the avionics facility that completed the replacement³, the servo was removed because the "pitch trim servo was found to be inoperative." The replacement GSA 28 servo and the servo removed were documented as follows:

- GSA 28 Servo OFF: Part number: 011-02927-11, Serial Number: 5G9001602

² All four of the GSA 28 servos were within the affected range of servos recalled by Garmin's Service Bulletin Number 2063.

³ The avionics facility also completed the initial installation of the Garmin 500 AFCS.

- GSA 28 Servo ON: Part number: 011-02927-11, Serial Number: 5G9018764

The paperwork indicated that the new servo was installed with no faults found during operational checks and operated normally in the autopilot system before the airplane was returned to service.

2.0 Autopilot Examination at Mansfield, Ohio

The FAA and NTSB group chair met to examine and assess the airplane's autopilot system while still installed on the airplane. The airplane was examined in the facility's hangar. See Figure 2.



Figure 2. The airplane's flight deck and autopilot installation.

For the tests, the airplane was connected to an air data test set to simulate airspeed and altitude.

Prior to and during the testing, the Garmin GSA 28 servo actuator in the pitch position was annunciating an intermittent fault. The fault annunciating was "Monitor Pitch Torque Voltage." Garmin indicated that the fault, which indicates a tripping of the pitch

torque voltage monitor within the GMC 507 Autopilot Mode Controller, would result in an automatic autopilot disconnect.

While connected to the air data test set and simulating 130 knots and 4,000 feet altitude, the autopilot was engaged. In response, the autopilot immediately commanded nose down pitch trim to the stop limits. This was repeated several times with the same, full nose down trim result.

The Garmin gain addendum software was updated for the autopilot components including the GSA28 servos and G5 instrument. The software was updated to make certain that the autopilot was using the most recent version.

The Garmin GMC 507 Autopilot Mode Controller was then swapped out for another GMC 507 unit. The autopilot was then engaged, and the autopilot again immediately commanded a full nose down pitch trim.

The Garmin GSA 28 servo actuator in the pitch trim position was then replaced with another GSA 28. The autopilot was engaged, and the autopilot again immediately commanded a full nose down pitch trim.

The GSA 28 and GMC 507 units were replaced with the original units. The airplane was then levelled and moved to an area of the hangar with GPS coverage. To level the airplane, the nose was lowered. When levelled, on the ground with no airspeed or altitude input, the autopilot did not command any pitch trim. When the airplane was re-connected to the air data test set, the autopilot commanded full nose down trim after the autopilot was engaged.

With the two GPS circuit breakers closed, the original autopilot configuration, and the airplane connected to the air data test set, the autopilot did command full nose down trim when the autopilot was engaged.

When the Garmin GSA 28 servo in the pitch position was removed and replaced with another GSA 28 servo, the autopilot did not command pitch trim when the autopilot was engaged.

When the autopilot commanded the full nose down pitch trim, the command could be stopped by grabbing the trim wheel and by disconnecting the autopilot via the control wheel switch.

At the end of the examination, the GSA 28 servo in the pitch position was retained by the NTSB for further examination.

3.0 Servo Actuator Examination at Garmin

The GSA 28 servo removed from the pitch servo position was examined at the Garmin facility in Olathe, Kansas. The unit was hand carried to the facility by the NTSB.

3.1 Visual Examination

Upon arrival, the group removed the unit from its packaging and visually examined the servo's exterior. No anomalies were noted. The servo's part and serial number were confirmed. See Figure 3.

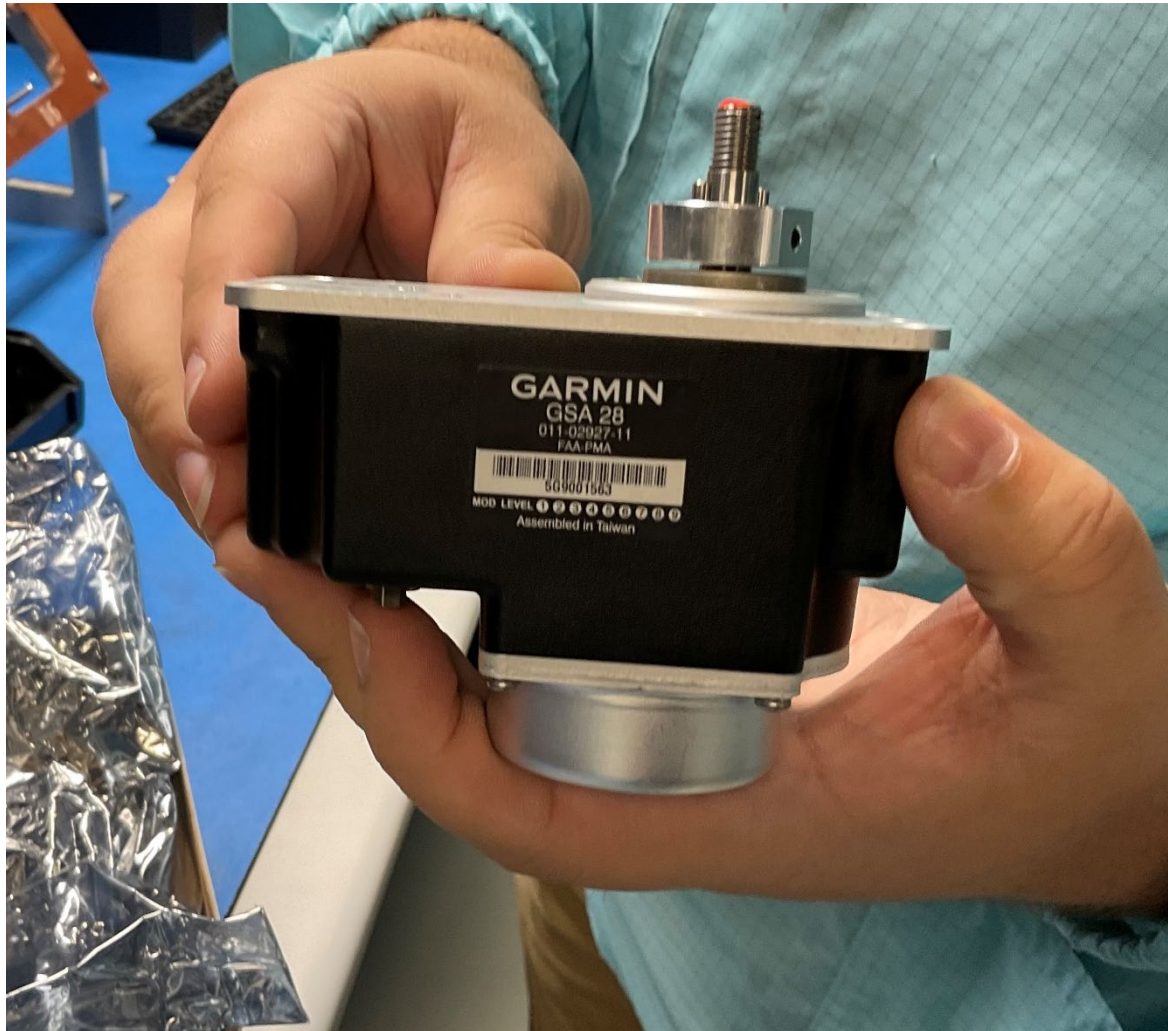


Figure 3. The GSA 28 Servo, as received at Garmin for examination.

3.2 Servo Gain Determination and Automatic Test

The unit was attached to a Garmin automatic test equipment (ATE) test bench. First, the servo's initial configuration was queried and recorded.

The unit was then tested against the Garmin GSA 28 Minimum Performance

Specification Test, Drawing Number 004-00381-00, Revision V. The test ran normally and to completion. The preliminary results of the ATE indicated that the servo failed the test, due to failures of several of the test elements. The specification steps and results were recorded by the ATE. The results of the ATE test are included in Attachment 2.

The servo gain configuration and ATE results were provided to the parties electronically.

3.3 Disassembly of Servo and Examination of Circuit Board

Following completion of the ATE Minimum Performance Specification Test, the unit was dis-assembled to access the servo's circuit board. The purpose of the visual examination was to look for evidence of sulphuration on the circuit board. Garmin indicated that sulphuration of components on the circuit board was the root cause of the failed servos identified in Service Bulletin 2063.

The circuit board was removed from the servo and the padding protecting the reverse/bottom side of the board was removed. The components on the board were examined under magnification. Garmin identified that at least two resistors (R540 and R536, parts of the torque monitoring circuitry) exhibited damage or evidence of sulphuration. See Figure 4.

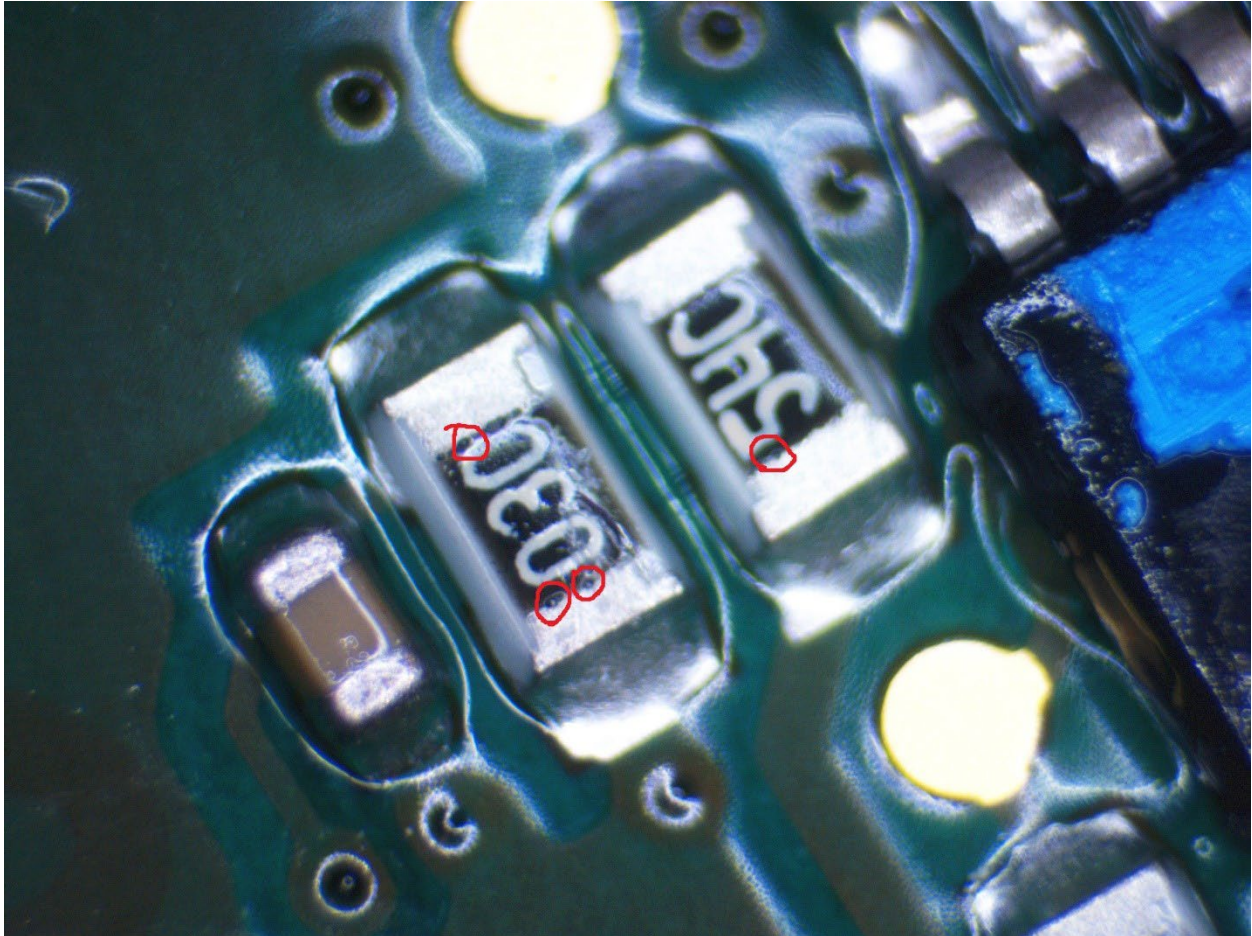


Figure 4. Servo circuit board viewed under magnification with areas of sulphuration circled in red. Photo courtesy of Garmin.

At the end of the examination, the NTSB retained possession of the GSA 28 servo from the pitch servo position.

4.0 Examination of PCB Board by NTSB Materials Laboratory

The GSA 28 pitch servo actuator was submitted to the NTSB Materials Laboratory for further examination and documentation of the sulphuration on the servo's PCB board.

For further information, please refer to the Materials Laboratory Factual Report 23-047, dated May 25, 2023 in the docket for this investigation.

5.0 Garmin's Post-Examination Actions

Following the GSA 28 pitch servo actuator examination, Garmin indicated that a review of the resultant ATE data lead to the determination that an internal failure within the pitch servo can cause the pitch trim servo to run for five seconds before a monitor

in the GMC 507 Autopilot Mode Controller detects the failure and disconnects the autopilot. If this occurred, the message shown to the pilot would be a red "AP" annunciation against a black background, indicating an "autopilot abnormal disconnect" accompanied by an aural alert⁴.

Garmin also noted that the condition of the tested GSA 28 servo was a unique condition that had not been documented on other customer-returned hardware⁵.

Based on this information, Garmin released the following documents:

1. Service Alert Number 22109, Date: November 21, 2022⁶

Subject: Automatic Pitch Trim

Products Affected: Garmin GFC 500 Autopilots with GSA 28 pitch trim servo

Action: Before further flight either disable the GFC 500 by pulling the AUTOPILOT circuit breaker and placard "Inoperative" or contact a Garmin dealer to disable the pitch trim.

2. Aviation Service Document Notification, Date: November 21, 2022

Subject: Disabling Electric Pitch Trim

Products Affected: Garmin 500 Autopilot Systems using STC SA01866WI

Purpose: The notification provided an alert to the Service Alert Bulletin 22109

3. Service Bulletin 22123, Date January 3, 2023

Subject: Automatic Pitch Trim Enable

To: GFC 5009 Autopilot System Owner and Operators

Action: The service bulletin authorized a software update that would allow pitch trim to be enabled for the affected autopilot systems.

6.0 Post-Examination Actions by the Federal Aviation Administration

On October 3, 2023, the Federal Aviation Administration issued a Notice of Proposed Rulemaking (NPRM) to issue an Airworthiness Directive (AD) for airplanes modified with a configuration of the Garmin GFC 500 Autopilot System⁷. If adopted, the AD's list of affected airplanes would include the occurrence airplane.

⁴ If the tripped monitor was the Pitch Torque Voltage Monitor, the words "Monitor Pitch Torque Voltage" would not have been displayed to the pilot.

⁵ For hardware returned per Garmin Service Bulletin 2063.

⁶ Revision B of the document was issued on January 11, 2023.

⁷ The NPRM is Docket Number FAA-2023-1990, Project Identifier AD-2023-00734-A.

The AD would require updating the applicable Garmin GFC 500 Autopilot System software and prohibit installing earlier versions of the software.

The software update would be required within 12 months of the effective date of the AD.

Tom Jacky
Aircraft Systems Investigator

Attachments

1. Garmin Service Bulletin 2063
2. Results of Garmin ATE for GSA28 Servo