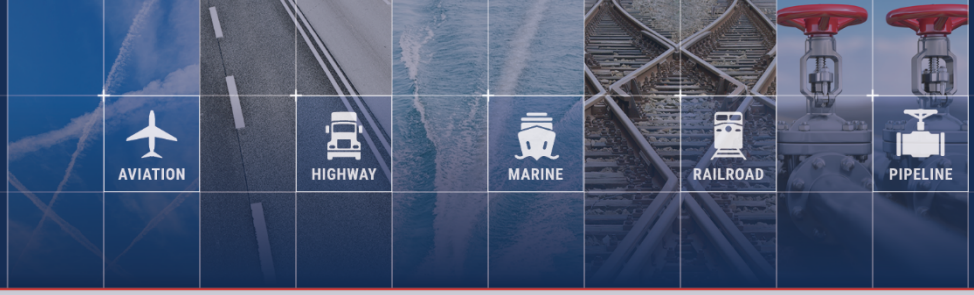

Aviation Investigation Final Report

Location:	Bellefontaine, Ohio	**Occurrence Number:**	ENG22LA004
Date & Time:	November 12, 2021, 09:02 Local	**Registration:**	N9035Q
Aircraft:	Beech F33	**Aircraft Damage:**	Minor
Defining Event:	Sys/Comp malf/fail (non-power)	**Injuries:**	1 None
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The pilot reported an uncommanded nose down pitch trim movement. The nose down pitch trim occurred immediately following the pilot's engagement of the autopilot. The uncommanded nose down trim was repeated when the pilot engaged the autopilot later in the occurrence flight as well as during postflight troubleshooting.

During the NTSB's autopilot examination on the airplane, the uncommanded nose down pitch trim movement occurred repeatedly upon autopilot engagement. When the Garmin GSA 28 pitch servo actuator was removed and replaced with another GSA 28 servo, the uncommanded nose down pitch trim movement ceased.

The pitch servo actuator examination at Garmin resulted in test element failures (related to monitoring of the pitch servo torque) that, with the servo installed as part of the airplane's autopilot, would have caused the autopilot pitch down movement, and, after several seconds, an automatic disconnect. Garmin's analysis showed that an internal failure on the pitch servo actuator circuit card could cause uncommanded autopilot pitch trim movement before the autopilot would automatically disconnect.

As a result of the investigation, the FAA issued a notice of proposed rulemaking (NPRM) for various airplanes modified with the Garmin 500 GFC Autopilot System. The proposed Airworthiness Directive (AD) would require a mandatory software upgrade to the system.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this occurrence to be:

The internal failure of the autopilot pitch servo actuator that caused the autopilot to command a nose down movement of the pitch trim.

Findings

Aircraft	Autopilot main servo - Malfunction

Factual Information

History of Flight

Enroute	Sys/Comp malf/fail (non-power) (Defining event)

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 pilot reported that he departed Mansfield (MFD) at about 0900 on a visual flight rules (VFR) trip and climbed to 4,000 feet mean sea level. Once established at a stable altitude, the pilot engaged the autopilot. The pilot reported an “immediate, pitch down attitude” from the autopilot. The pilot responded by disconnecting the autopilot via the disconnect switch on the yoke. He reported hearing an aural signal but no change in airplane attitude. He then reduced the engine power, disconnected the autopilot on the forward panel and then opened the autopilot circuit breaker. Finally, he was able to bring the airplane nose-level by use of the manual trim wheel on the forward panel.

After returning the airplane to 4,000 feet the pilot reengaged the autopilot, but the autopilot reacted in the same manner with another uncommanded nose down movement. After regaining control, the pilot did not reengage the autopilot for the remainder of the flight. The pilot assessed that the airplane could still be flown without the autopilot. After completion of the flight to Bellefontaine, the pilot returned the airplane to Mansfield and brought it to the avionics company that had originally installed the autopilot for troubleshooting.

The autopilot’s uncommanded nose down trim was repeated in several instances. In addition to the occurrence flight, the autopilot repeated the nose down trim during troubleshooting at the avionics facility that had installed the autopilot. When the NTSB conducted an autopilot examination on the airplane, the uncommanded nose down trim movement occurred repeatedly. Only after the Garmin GSA 28 autopilot servo actuator in the pitch position was replaced did the uncommanded nose down trim movement cease.

Airplane Information

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 four GSA 28 servo actuators. The G5 can function as either an attitude display indicator and/or horizontal situation indicator. 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 airplane had the four 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 trim. (The occurrence airplane also had a pitch trim wheel on the forward flight panel.)

The autopilot was installed in 2019. In August 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 replacement, the servo was removed because the “pitch trim servo was found to be inoperative.” Only the servo in the pitch trim position was replaced.

Wreckage and Impact Information

The pilot reported the following minor damage to the airplane: the left elevator trim tab was bent at the actuator arm location and the pitch trim cable was stretched.

Tests and Research

The NTSB conducted two examinations as part of the investigation – an examination of the airplane's autopilot, as installed, and an examination of a Garmin GSA 28 servo actuator removed from the airplane.

The examination of the airplane's Garmin 500 GFC Autopilot System was conducted in a hangar at the avionics company that had originally installed the autopilot system. For the tests, the airplane was connected to an air data test set to simulate airspeed and altitude.

With the air data test set simulating 130 knots and 4,000 feet altitude and the airplane's pitch trim in a neutral position, 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, nose down trim response. When the trim would reach the stop limit, the autopilot would disengage, with a red "X" on the flight display and an aural alert. (During the NTSB's autopilot examination in the airplane, the "Monitor Pitch Torque" message was displayed. Garmin indicated that, in flight, the autopilot's pitch torque monitor could trip after an uncommanded pitch trim movement for five seconds and disconnect the autopilot. The autopilot disconnect would be accompanied by red "AP X" text and an aural warning. However, the "Monitor Pitch Torque" message itself would not be annunciated.) 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.

During the testing, several of the autopilot system components were replaced with a new or other unit. The GMC 507 Autopilot Mode Controller and the Garmin GSA 28 servo actuator in the pitch trim position were each separately replaced. In each case, when the autopilot was engaged, a full nose down pitch trim was commanded. The GMC 507 and GSA 28 units were replaced with the original units to return the autopilot configuration to its original configuration.

When the Garmin GSA 28 servo actuator 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.

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

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

The servo was attached to a Garmin automatic test equipment (ATE) test bench and tested against the Garmin GSA 28 Minimum Performance Specification Test. The test ran normally and to completion. The results of the test indicated that the servo failed several of the test elements, including elements related to monitoring of the pitch servo torque.

Following completion of the Minimum Performance Specification Test, the unit was disassembled 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. The pitch servo was submitted to the NTSB Materials Laboratory for further documentation of the sulphuration.

Following the GSA 28 pitch servo actuator examination, Garmin indicated that a review of the resultant test 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 alert.

Garmin also noted that the condition of the tested GSA 28 servo was a unique condition that was different from the failure modes observed on other unit with sulphuration. Garmin determined that the that the servo did not fail test elements like servos that had been returned to Garmin for the sulphuration issue.

Additional Information – Garmin Release of Service Documents and FAA Notice of Proposed Rulemaking

Following the examination of the GSA 28 servo at their facility, Garmin issued the following service information:

1. Service Alert Number 22109, Date: November 21, 2022 (Revision B of the document was issued on January 11, 2023.)

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.

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 System. (The NPRM is Docket Number FAA-2023-1990, Project Identifier AD-2023-00734-A.) If adopted, the AD's list of affected airplanes would include the occurrence airplane.

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.

Pilot Information

Certificate:	Private	**Age:**	62,Male
Airplane Rating(s):	Single-engine land; Single-engine sea	**Seat Occupied:**	Front
Other Aircraft Rating(s):	Glider	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	
Medical Certification:	Class 3 Without waivers/limitations	**Last FAA Medical Exam:**	
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	January 30, 2021
Flight Time:	(Estimated) 1500 hours (Total, all aircraft), 250 hours (Total, this make and model)		

Aircraft and Owner/Operator Information

Aircraft Make:	Beech	**Registration:**	N9035Q
Model/Series:	F33 A	**Aircraft Category:**	Airplane
Year of Manufacture:	1970	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	CE-310
Landing Gear Type:	Retractable - Tricycle	**Seats:**	4
Date/Type of Last Inspection:	Unknown	**Certified Max Gross Wt.:**	3400 lbs
Time Since Last Inspection:		**Engines:**	1 Reciprocating
Airframe Total Time:	3075 Hrs as of last inspection	**Engine Manufacturer:**	Continental
ELT:	Installed	**Engine Model/Series:**	IO-520-BB
Registered Owner:	On file	**Rated Power:**	
Operator:	On file	**Operating Certificate(s) Held:**	None

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:		**Distance from Accident Site:**	
Observation Time:		**Direction from Accident Site:**	
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	/	**Turbulence Type Forecast/Actual:**	None / None
Wind Direction:		**Turbulence Severity Forecast/Actual:**	Unknown / N/A
Altimeter Setting:		**Temperature/Dew Point:**	
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Mansfield, OH (KMFD)	**Type of Flight Plan Filed:**	None
Destination:	Bellefontaine, OH (KEDJ)	**Type of Clearance:**	None
Departure Time:	09:00 Local	**Type of Airspace:**	

Wreckage and Impact Information

Crew Injuries:	1 None	**Aircraft Damage:**	Minor
Passenger Injuries:	N/A	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 None	**Latitude, Longitude:**	40.368842,-83.818066(est)

Administrative Information

Investigator In Charge (IIC):	Jacky, Thomas
Additional Participating Persons:	Paul Rau; FAA; Wichita, KS Tom Carr; Garmin; Olathe, KS
Original Publish Date:	March 8, 2024
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this occurrence.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=104339