

Serious incident south of Örebro Airport on 11 December 2024

The Swedish Accident Investigation Authority has investigated a serious incident involving aircraft SE-LGL, a Cessna 172R, in which a loss of control occurred in connection with the use of the autopilot.

16 September 2026



About the Swedish Accident Investigation Authority

The Swedish Accident Investigation Authority (SHK) investigates accidents and incidents from a safety perspective regardless of whether they occurred on land, at sea or in the air. The authority's accident investigations are intended to disseminate knowledge and provide a basis for actions by authorities, companies, organisations, and individuals that improve safety and reduce the risk of accidents. The activities should also contribute to people feeling secure and having trust in society's institutions and the confidence in transportation systems. The mission also includes assessing the efforts made by the rescue services in connection with an accident. However, the investigations should not assign blame or liability, whether criminally, civilly, or administratively.

The investigations by SHK aim to answer three questions:

- What happened?
- Why did it happen?
- How can a similar accident/incident be avoided in the future?

Investigations of aviation accidents and incidents are primarily regulated by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and the Act (1990:712) on the investigation of accidents. The investigations are conducted in accordance with Annex 13 of the Chicago Convention.

The report is also available on the Swedish Accident Investigation Authority's website: www.shk.se.

The report is covered by the Creative Commons Attribution 2.5 Sweden (CCBY 2.5 SE) license. This means that you are allowed to copy, distribute, and modify the text as long as you attribute SHK as the copyright holder. If you use material from this report, you should cite the Swedish Accident Investigation Authority and the report number.

The illustrations in SHK's reports are protected by copyright. Unless otherwise stated in the report, SHK is the copyright holder. If someone other than SHK is the copyright holder, you need their permission to use the material.

ISSN 1400–5719

File number: L-132/24

Content

About the Swedish Accident Investigation Authority	2
Summary	6
Causes/Contributing Factors	6
Safety recommendations	7
The investigation.....	8
Investigation material	8
1. Factual information	10
1.1 History of the flight	10
1.1.1 Preconditions	10
1.1.2 Sequence of events	10
1.1.3 Other relevant information	13
1.2 Injuries to persons	13
1.3 Damage to aircraft	13
1.4 Other damage	13
1.5 Personnel information	13
1.5.1 Qualifications of the pilot	13
1.6 Aircraft information.....	14
1.6.1 The Airplane	14
1.6.2 Airworthiness standards for light aeroplanes	15
1.6.3 Control systems and flight mechanics	15
1.6.4 The autopilot system.....	19
1.6.5 Elevator servo and elevator trim servo	21
1.6.6 Data specific to the ALT-mode autopilot function.....	22
1.6.7 Actions in the event of a mistrim Alert.....	23
1.6.8 Electronic Stability and Protection.....	24
1.6.9 Emergency procedure.....	25
1.6.10 Instructions for Continued Airworthiness for the GFC 500.....	25
1.6.11 Instructions and documentation for the servo replacement	27
1.6.12 Pre-flight check of the autopilot system	28
1.6.13 The aircraft checklist.....	28
1.7 Meteorological information	29
1.8 Aids to navigation	29
1.9 Communications	29
1.10 Aerodrome information	29
1.11 Flight recorders	29
1.11.1 Flight data	29

1.11.2	Recorded video from the serious incident	30
1.11.3	Summary of flight data and information from the GoPro video	30
1.12	Site of occurrence.....	33
1.13	Medical and pathological information	33
1.14	Fire 33	
1.15	Survival aspects	33
1.15.1	Rescue operation	33
1.16	Tests and research	33
1.16.1	Technical examinations.....	33
1.16.2	System identification.....	34
1.16.3	Extract from Gain Addendum and configuration file.....	36
1.16.4	Examination of the elevator trim servo	37
1.17	Organisational and management information	38
1.17.1	The maintenance organisation exposition.....	38
1.18	Additional information	38
1.18.1	Critical maintenance tasks and requirements for error-capturing methods	38
1.18.2	Replacement of servos and software update	39
1.18.3	Differences training provided by the club for pilots.....	40
1.18.4	Upset Recovery	40
1.18.5	Surprising and Sudden Events	40
1.18.6	Actions taken.....	41
1.18.7	Similar Events	41
1.19	Special methods of investigations	42
2.	Analysis.....	42
2.1	Sequence of events up to the loss of control	42
2.1.1	Why did the pitch attitude suddenly increase?.....	43
2.1.2	Probable sequence of events leading up to the Upset.....	44
2.2	The Upset.....	44
2.2.1	Frequent intervention by the ESP system.....	45
2.2.2	Incorrect trim made it difficult to recover from the uncontrolled flight condition.....	45
2.2.3	The pilot regained control of the aircraft	46
2.3	Why did the pitch trim servo operate in the wrong direction?.....	46
2.3.1	It is unlikely that the hardware was incorrectly installed.....	46
2.3.2	It is unlikely that there was a fault in the pitch trim servo	47
2.3.3	The fault was probably related to configuration settings or to the software.....	47
2.4	Autopilot systems must be easy to understand	48
2.5	Autopilot system mistrim alert	48
2.6	Maintenance planning and execution	50
2.6.1	Garmin's Service Bulletin was unclear	50

2.6.2	The combined airworthiness organisation's work order was inadequate	50
2.6.3	Certain documentation relating to the software update was missing	51
2.6.4	Absence of an instruction for checking the pitch trim in the manual	52
2.6.5	No independent inspection of the software installation was conducted after maintenance	52
3.	Conclusions	53
3.1	Findings	53
3.2	Causes/Contributing Factors	54
4.	Safety recommendations.....	54

Summary

On 11 December 2024, a serious incident occurred involving aircraft SE-LGL, a Cessna 172R, in the airspace south of Örebro Airport. The aircraft had recently undergone maintenance during which three servos in the autopilot system were replaced and the software was updated. On the first flight following the maintenance, the pilot engaged the autopilot in altitude hold mode shortly after the climb to cruise altitude. Shortly thereafter, an amber mistrim alert was displayed on the primary flight instrument. When the autopilot was disengaged, a sudden and significant pitch-up occurred, resulting in an upset condition. During this phase, the pilot believed that the autopilot was still engaged. The autopilot's Electronic Stability and Protection (ESP) function was activated on several occasions and applied control inputs, which likely reinforced the pilot's perception that the autopilot was still acting on the system.

Recorded data shows that the autopilot commanded nose-down trim, but that the effect was the opposite, indicating that the elevator trim moved in the opposite direction to the autopilot's commands. The incorrect trim setting resulted in high control forces, particularly at high airspeed and with high power setting. Eventually, the pilot reduced engine power, pulled the circuit breaker for the autopilot, regained control and was able to land normally without injury to persons or damage to the aircraft.

The investigation has not identified any mechanical defects that could explain the significant and sudden increase in pitch attitude. The most probable cause of the incident is that the configuration settings for the autopilot system's elevator trim were incorrect.

The analysis shows that several organisational and system-related factors contributed to the fact that the erroneous behaviour of the autopilot system was not detected before the flight.

Causes/Contributing Factors

The probable cause why the upset occurred was that the configuration settings for the autopilot system's pitch trim were incorrect, causing the autopilot to command pitch trim in the opposite sense to that intended for the aircraft, i.e. nose-up instead of nose-down.

Several factors contributed to the configuration settings probably being incorrect:

- The Service Bulletin and the manuals to which it referred did not prescribe adequate functional checks following maintenance of the autopilot's pitch trim function.
- The maintenance organisation did not take sufficient measures to ensure that, after maintenance, the configuration settings were in accordance with the prescribed settings.
- The maintenance organisation did not carry out any independent inspection, nor did it apply any other method to detect errors following the software updates and configuration settings implemented during the maintenance.

A contributing factor of the upset condition was that the pilot did not notice the autopilot system's mistrim alert. This was because the alert provided by the autopilot system was not presented in a sufficiently clear manner to draw the pilot's attention to the significant control forces present in the autopilot system.

Safety recommendations

SHK submits the following recommendations:

Garmin is recommended to

- examine the possibilities for presenting mistrim alert to the pilot in a clearer manner when a pitch trim servo is installed and trimming is automatic (see Section 2.5). *(SHK 2026:17e R1)*
- ensure that Service Bulletins relating to maintenance on autopilot systems are drafted in such a way that it is clearly specified which tasks are included in the maintenance, and that they ensure adequate checks are carried out following completion of the maintenance (see Section 2.6.1). *(SHK 2026:17e R2)*
- clarify the GFC 500 Maintenance Manual so that it includes an instruction describing how the automatic electric pitch trim is to be checked after maintenance has been carried out on the trim system (see Section 2.6.4). *(SHK 2026:17e R3)*

The Combined Airworthiness Organisation is recommended to

- ensure that work orders for maintenance are clearly and correctly drafted, and that they ensure adequate checks are carried out following completion of the maintenance (see Section 2.6.2). *(SHK 2026:17e R4)*

The Maintenance Organisation is recommended to

- ensure, in connection with software maintenance on autopilot systems, that actions are documented in accordance with the instructions issued by the manufacturer of the autopilot system (see Section 2.6.3). *(SHK 2026:17e R5)*
- ensure that independent inspections are carried out, or that other methods of fault detection are applied, in connection with critical maintenance actions that include the installation and configuration of software (see Section 2.6.5). *(SHK 2026:17e R6)*

The investigation

SHK was notified on 11 December 2024 that a serious incident involving an aircraft of the type Cessna 172, registration SE-LGL, had occurred in the vicinity of Örebro Airport, Örebro County, on the same day at 15:12 hours.

The incident has been investigated by SHK represented by Kristina Börjevik Kovaniemi, Chairperson until 1 July 2025 and thereafter by Johan Albihn, Mats Trense, Investigator in Charge, Ola Olsson, Technical Investigator, Kristoffer Danèl, Technical Investigator.

As the accredited representative for the United States, Tom Jacky from the National Transportation Safety Board (NTSB) has participated.

As an adviser for the European Union Aviation Safety Agency (EASA), Matthew Hilscher has participated.

As an adviser for the Swedish Transport Agency, Magnus Axelsson has participated.

The following organisations have been notified: EASA, the EU-Commission, the Swedish Transport Agency and NTSB.

Investigation material

- Interviews with the pilot and the maintenance organisation
- Technical examinations of the aircraft
- Flight data from the aircraft's flight instruments
- Recorded video footage from the serious incident
- Flight data from reference flights
- Documentation and other information from the autopilot manufacturer Garmin
- Documentation from the aircraft manufacturer Textron Aviation

A fact-finding meeting with the parties concerned was held on 12 March 2026. A separate meeting with Garmin was held on 23 March 2026. At both meetings SHK presented the facts discovered during the investigation, available at the time.

Final report SHK 2026:17e

Data	
Aircraft	Registration: SE-LGL Model: Cessna 172R Airworthiness: Certificate of Airworthiness and Valid Airworthiness Review Certificate (ARC) ¹ Serial Number: 172-80059 Owner: Karlskogaflyg Ek Förening
Time of occurrence	11 December 2024, 15.12 hrs in daylight Note: All times are given in Swedish standard time (UTC ² + 1 hour)
Location	In the airspace of Örebro Airport, Örebro County, Position 59°11'N 14°57'E
Type of flight	Private
Weather	According to Metar: wind 210 degrees 3 knots, visibility >10 kilometres, no significant clouds, temperature/dewpoint -6/-6 °C, QNH ³ 1030 hPa
Persons on board	In total: 1
Injuries	To persons: None Damage to aircraft: None
Choose an object	Age: 57 years Licence: CPL ⁴ Total flying hours: 609 hours, of which 300 hours on type Flying hours previous 90 days: 0.5 hours, all on type Number of landings previous 90 days: 1

¹ ARC (Airworthiness Review Certificate).

² UTC (Coordinated Universal Time).

³ QNH (The atmospheric pressure adjusted to the mean sea level).

⁴ CPL (Commercial Pilot License).

1. Factual information

1.1 History of the flight

1.1.1 Preconditions

A pilot from Karlskoga Motor Flying Club planned to fly the aircraft from Örebro Airport to Karlskoga Airport.

In the days preceding the flight, the aircraft had undergone maintenance during which three servos in the autopilot system – the pitch servo, the roll servo and the pitch trim servo – were replaced. The action that was carried out was related to a Service Bulletin, i.e., a technical notice, issued by the manufacturer of the autopilot system. The maintenance included installation of the new servos, updating of the system software and the performance of post maintenance checks.

As this was the first flight after completion of the maintenance, the maintenance organisation asked the pilot to test the autopilot system during the flight to ensure that everything was functioning normally.

Pre-flight preparations were carried out in accordance with standard procedures, and no technical defects or abnormal conditions were identified.

1.1.2 Sequence of events

Short summary of the incident

The flight commenced with a southbound take-off, after which the pilot set course for Karlskoga Airport. When the aircraft reached the desired altitude, during the transition to level flight, the pilot engaged the autopilot. He also adjusted the heading to avoid a restricted area.

Shortly afterwards, the aircraft's pitch attitude increased rapidly, after which the flight became uncontrolled. The aircraft alternated several times between climbing and descending with large pitch attitude changes, and on several occasions significant bank angles occurred. During the uncontrolled flight, the aircraft temporarily entered a flight condition outside the intended operational flight envelope of the aircraft type. The pilot struggled to regain control of the aircraft.

The pilot, who believed that the autopilot was engaged, made several attempts to disconnect it. As a last resort he pulled the circuit breaker for the autopilot system and then felt that control of the aircraft was restored. The pilot declared Mayday on the radio and returned to Örebro Airport, where a normal landing was carried out.

Detailed description of the sequence of events and available data

A GoPro camera was mounted on the door side to the left of the pilot's seat. The camera captured the aircraft's instrument panel with all instruments, parts of the control yokes, as well as the surroundings and the horizon. The trim wheel and the trim position indicator for the pitch control system were, however, not visible in the recording.

In addition, detailed flight data were retrieved from the multifunction electronic flight instrument GI 275. This information made it possible to partly reconstruct how the autopilot system operated. The combined information from the video recording and the autopilot system has made it possible to obtain a relatively detailed picture of the sequence of events.

The autopilot was engaged at an altitude of 2,126 feet (QNH) during the transition to level flight while the aircraft was still climbing. The pilot selected the autopilot to control the aircraft in heading and altitude hold (ALT mode). The aircraft continued to climb slightly after the autopilot had been engaged.

According to the flight data, the autopilot adjusted the pitch attitude by controlling the elevator through the pitch servo. This was done in order to level off and then gradually descend towards the target altitude. The target altitude had been captured by the autopilot when ALT mode was selected by the pilot on the autopilot mode control panel.

Shortly thereafter, the autopilot system activated the pitch trim servo to assist the pitch servo by trimming nose-down. The pitch trim servo is activated when the force required by the pitch servo to control the elevator exceeds a certain threshold for a given period of time. The design of the autopilot system is such that by trimming the aircraft with the pitch trim servo, the load on the pitch servo is reduced.

The video recording shows that, sixteen seconds after the autopilot was engaged, an amber mistrim alert illuminated on the pilot's flight instrument. This alert indicates that the pitch servo did not have sufficient authority to provide the desired outcome of the autopilot input. At the same time, the recorded data shows that the aircraft's pitch attitude gradually increased and the aircraft began to climb slowly, while the pitch servo increased the applied torque. The pitch trim servo remained active, and the autopilot system continuously commanded nose-down trim.

Furthermore, the video recording shows that the control yoke moved rapidly forward six seconds after the mistrim alert illuminated, at the same time as the pitch servo, according to the autopilot data, reached its maximum torque in the nose-down direction. Despite this, the rate of climb continued to increase. The video also shows that, during this period, the pilot grasped the control yoke first with his right hand and then with his left hand, and that shortly thereafter, according to the data, he disconnected the autopilot system using the switch on the control yoke, see Figure 1.

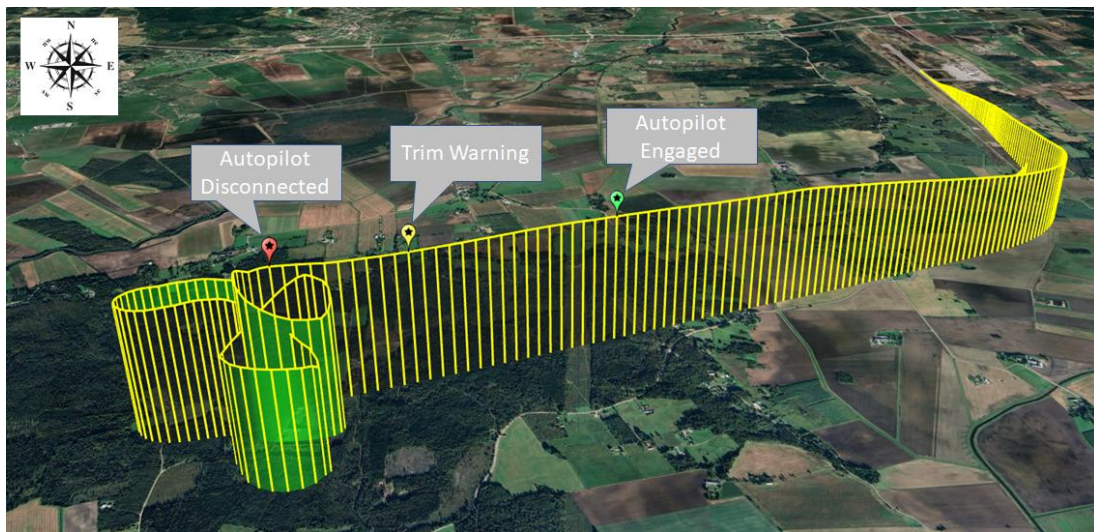


Figure 1. Flight path for the first segment of the flight. Image: Google Earth © Lantmäteriet. Markings added by the Swedish Accident Investigation Authority (SHK).

Once the autopilot system was disconnected, the pitch attitude increased rapidly at a rate of 26 degrees per second. The maximum pitch attitude reached 56 degrees and the airspeed decreased to 26 knots. The flight was then uncontrolled for 48 seconds, see Figure 2. During this period, repeated variations in pitch attitude between -51 degrees nose-down and 49 degrees nose-up occurred, as well as roll angles between -9 and -121 degrees to the left.

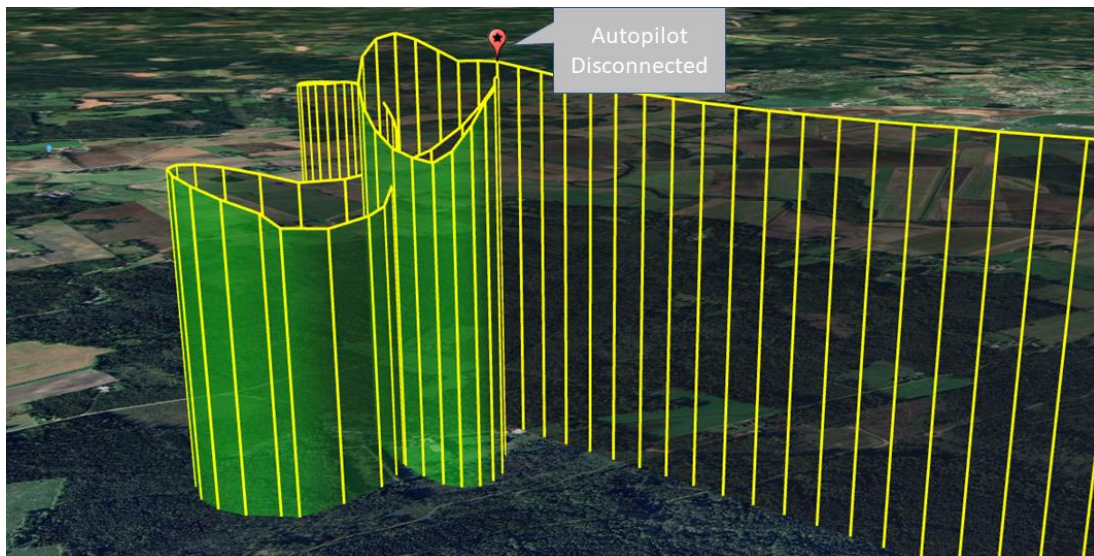


Figure 2. Flight path after the autopilot was disconnected. Image: Google Earth © Lantmäteriet. Markings added by SHK.

The pilot stated during the interviews that he believed the autopilot had remained engaged throughout the period in which the aircraft was in an uncontrolled state. The pilot felt that he had to work against the system and stated that he had to apply considerable force to make control inputs.

A large part of the pilot's attention was focused on attempting to disconnect the autopilot. Eventually, the pilot reduced the power and pulled the circuit breaker for the autopilot system, at which point he perceived that he regained control of the aircraft. Thereafter, according to the pilot, no further trimming was required for the aircraft to be flown without significant effort.

The serious incident occurred at position 59°11'N 14°57'E.

1.1.3 Other relevant information

After the incident, the aircraft was kept at a maintenance organisation for further examinations. At the end of February 2025, the aircraft returned to the flying club for operation, but with the autopilot system deactivated.

In August 2025, a new pitch trim servo was received from Garmin and installed on the aircraft by the same maintenance organisation that had carried out the original installation. The software installation was, however, carried out by another maintenance organisation that was an authorised Garmin dealer, in accordance with Garmin's instructions. Following the installation, the autopilot system was activated and operated normally.

1.2 Injuries to persons

No injuries.

1.3 Damage to aircraft

No damage.

1.4 Other damage

No damage.

1.5 Personnel information

1.5.1 Qualifications of the pilot

The pilot was 57 years old and had a valid EASA CPL license with flight operational and medical eligibility.

Flying hours - latest	24 hours	7 days	90 days	Total
All types	0	0	0.5	609
Actual type	0	0	0.5	300

Number of landings actual type previous 90 days: 1.

The class rating for single-engine aeroplanes was obtained on 13 June 2008.

Latest PC⁵ conducted on 15 April 2024 on Cessna 172.

⁵ PC (Proficiency Check).

1.6 Aircraft information

1.6.1 The Airplane

The aircraft was a Cessna 172R, a four-seat, high-wing, single-engine aeroplane, see Figure 3. It is just over 8 metres in length and has a wingspan of 11 metres. The aeroplane was equipped with a four-cylinder piston engine with a rated power of 160 horsepower.

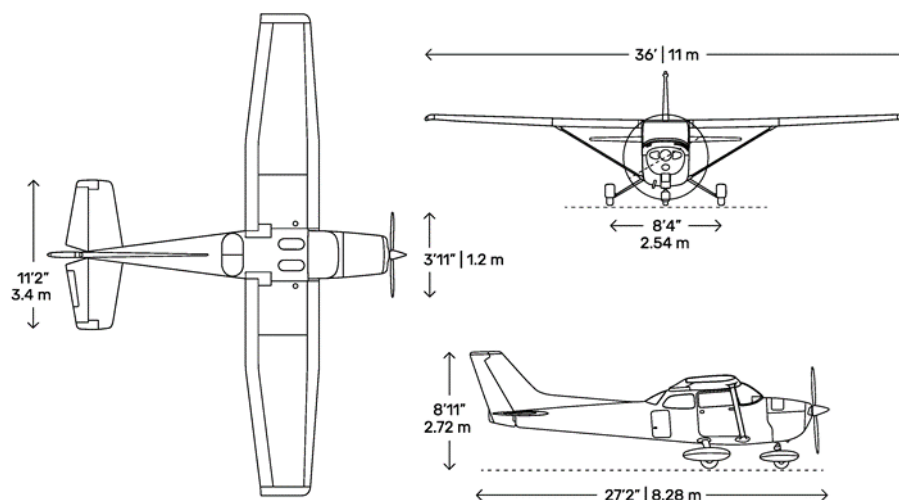


Figure 3. Three-view drawing of the Cessna 172R.

Airplane	
TC-holder	Textron Aviation Inc.
Certified in accordance with	FAR 23
Model	172R
Serial number	172-80059
Year of manufacture	1997
Gross mass, kg	Max start/landing mass suspended load 1157 current 934
Centre of gravity	Within limits (99.6 cm)
Total flying time, hours	7184
Flying time since latest inspection	0 (50-hour inspection carried out on 10 December 2024 at 7,184 hours)
Type of fuel uplifted before the occurrence	91/96 UL
Engine	Lycoming IO-360-L2A
Engine serial number	L-14635-51E
Propeller	McCauley 1A170E/JFA7658

Deferred remarks
No remarks

The aircraft had a Certificate of Airworthiness and a valid ARC.

1.6.2 Airworthiness standards for light aeroplanes

According to the airworthiness standards for light aeroplanes (CS-23/FAR 23), an aeroplane must be controllable in all phases of flight within its flight envelope. The standards specify among other things that the control forces required to control the aeroplane in pitch shall not temporarily exceed 222 N with one hand on the control yoke and 334 N with two hands on the control yoke.

1.6.3 Control systems and flight mechanics

The Cessna 172 has a conventional mechanical flight control system in which the pilot's control inputs are transmitted from the cockpit to the aircraft's control surfaces – the ailerons, elevator and rudder – through cables, pulleys and linkages. The aircraft is manoeuvred in flight using these control surfaces. The elevator is also equipped with a trim system used to reduce control forces in pitch.

Forces and moments

Deflection of the control surfaces affects the surrounding airflow, which generates forces and moments acting on the aeroplane. If these are not in balance, the aeroplane will translate or rotate about its principal axes: pitch, yaw and roll. The principal axes pass through the aeroplane's centre of mass. The main forces in the vertical plane are lift (L) and weight (W). Lift is generated by the wings as the aeroplane moves through the air and acts perpendicular to the relative airflow. Weight acts downwards, towards the centre of the Earth, and is proportional to the mass of the aeroplane. For the aeroplane to maintain altitude, the lift must be equal to the weight. In the aeroplane type, the centre of gravity is located ahead of the centre of lift and creates a nose-down pitching moment. This moment is balanced by the negative lift (F_t) generated by the horizontal tail, see Figure 4.

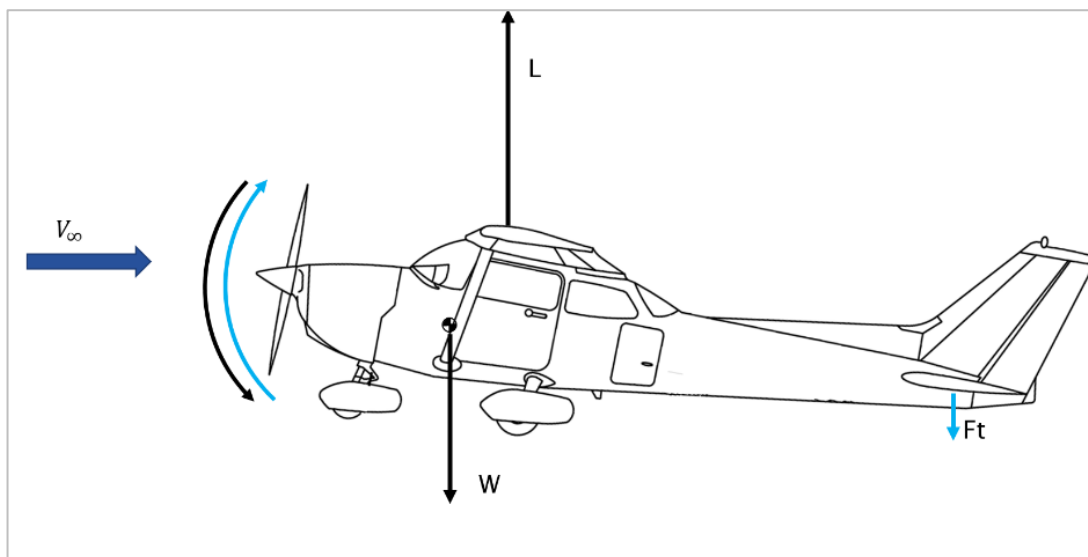


Figure 4. Forces and moments acting on an aeroplane. Image: Textron Aviation. Markings added by SHK.

Moments about the aeroplane's principal axes arise when the forces are asymmetrically distributed or when the control surfaces are deflected. Pitching moments are mainly generated by the elevator and cause the aeroplane's nose to move up or down about the lateral axis, see Figure 5.

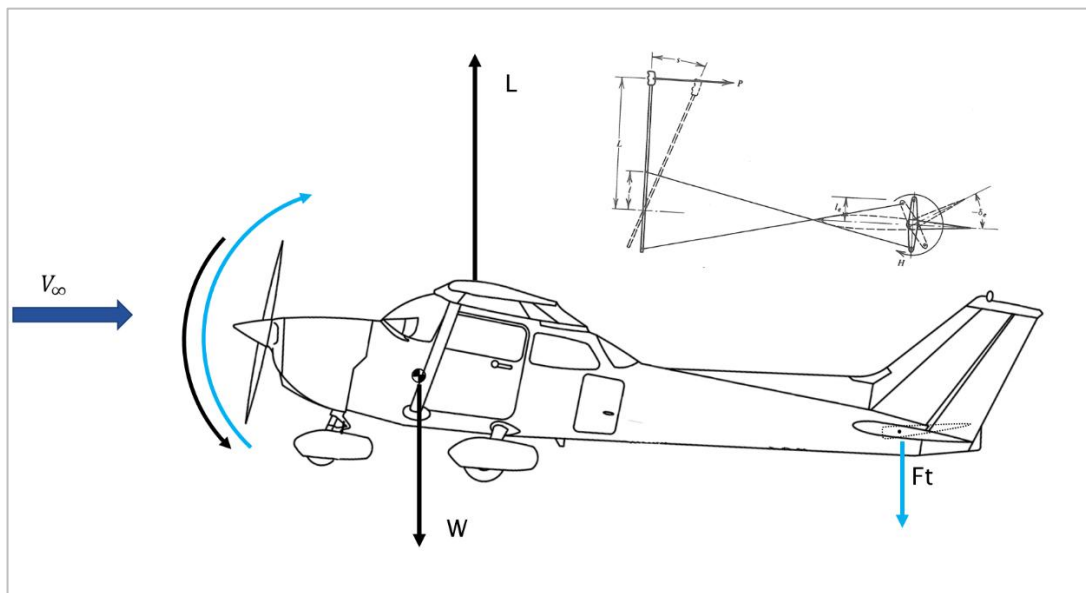


Figure 5. Forces and moments acting on an aeroplane, example illustration of elevator linkage. The black arrows represent forces and pitching moments generated by the mass and the wings. The blue arrows represent the force and pitching moment generated by the tailplane. Image: Textron Aviation. Markings added by SHK.

The pilot or the autopilot applies a force through the control system which, via the linkage, results in an elevator deflection. The magnitude of the forces arising in the linkage depends of the effective lever arms in the system. The elevator deflection generates a hinge moment (H), which must be overcome by the pilot or by the autopilot's pitch servo. The hinge moment of the control surfaces depends on the amount of deflection (angle) and on the aeroplane's attitude and speed.

The forces on the control yoke and on the pitch servo are largely directly proportional to the hinge moment. An elevator deflection affects the magnitude and direction of the lift generated by the horizontal tail (Ft) and thereby affects the pitching moment. The pitching moment varies with different flight conditions and depends, among other things, on power setting, the aeroplane's attitude and its speed.

To balance the hinge moment (H) from the elevator, the aeroplane is equipped with a so-called trim tab attached to the trailing edge of the right elevator, see Figure 6. When deflected, the trim tab produces a moment about the elevator hinge line, resulting in an elevator deflection until moment equilibrium is achieved. Note that the elevator trim tab deflects in the opposite direction to the elevator.

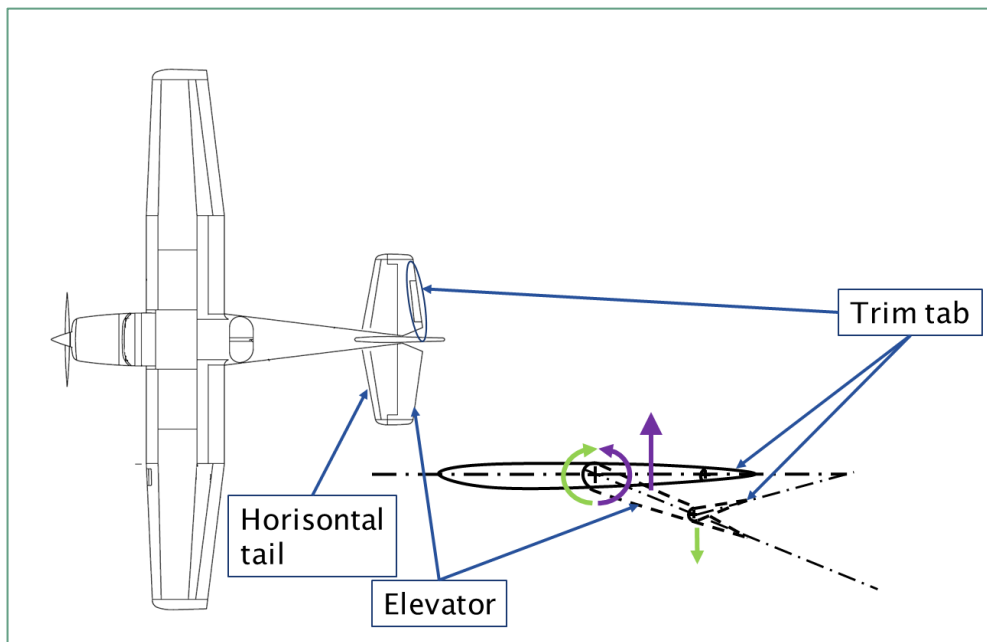


Figure 6. Trim tab on Cessna 172. Purple arrows represent the force and hinge moment generated by the elevator deflection. Green arrows represent the force and hinge moment generated by the elevator trim tab deflection. Image: Textron Aviation. Markings added by SHK.

In other words, the trim system is used to set a control surface position at which the aerodynamic forces on the elevator are in equilibrium. This, in turn, minimises the continuous control force required.

Elevator and elevator trim

The elevator deflection can be changed by moving the control yoke fore and aft. The deflection can also be controlled by the autopilot's pitch servo. In addition, the deflection is affected by the trim tab angle.

The trim tab deflection can be controlled in three different ways:

- by a trim wheel, which is mechanically connected to the trim tab
- via the autopilot, which activates the trim tab servo
- by a switch (Trim Switch) on the control yoke, which activates the trim tab servo.

Figure 7 shows the cockpit of SE-LGL with the control yoke, the trim wheel and the elevator trim switch on the control yoke. The trim wheel is available for manual operation and is shown in blue in the figure.

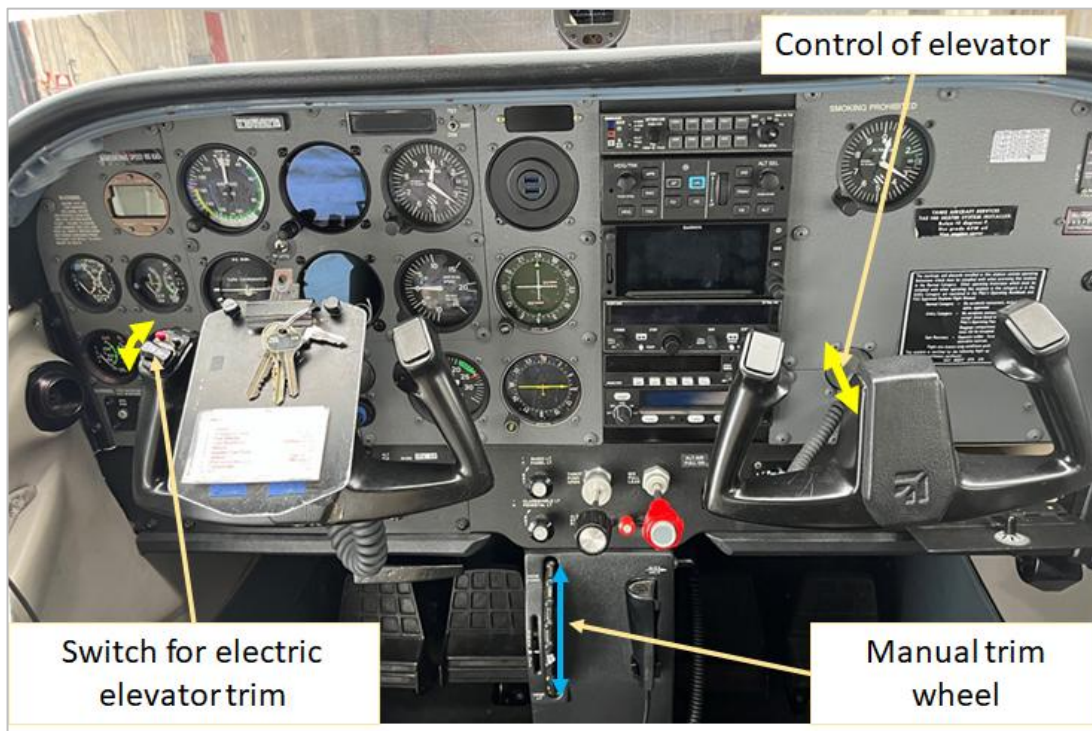


Figure 7. The cockpit of the incident aircraft with controls.

Figure 8 shows the mechanical connection between the control yokes and the elevator. The forces and motion to the elevator are transmitted via pushrods, quadrants, steel cables, pulleys and linkages.

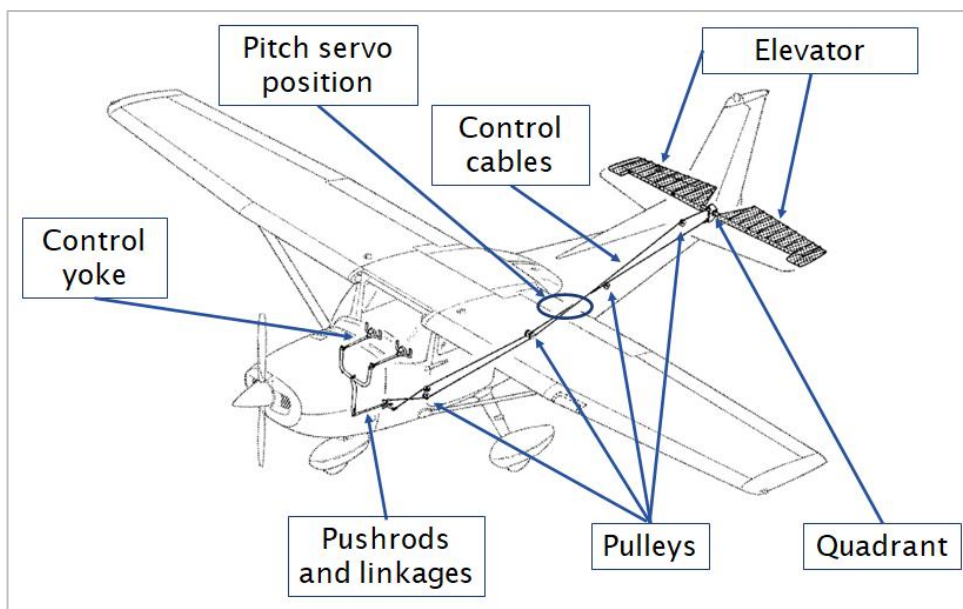


Figure 8. Mechanical linkage between controls and elevator on Cessna 172. Image: Textron Aviation. Markings added by SHK.

Figure 9 shows the mechanical connection between the trim wheel in the cockpit and the elevator trim tab. The forces and motion to the elevator trim tab are transmitted via steel cables, pulleys and a worm-gear mechanism with a pushrod. The gear ratio and design of the worm gear mean that it is self-locking and that the forces from the trim tab are not fully

transmitted further to the trim wheel or the elevator trim servo. The main forces acting on the trim wheel and the elevator trim servo are thus generated by friction within the system.

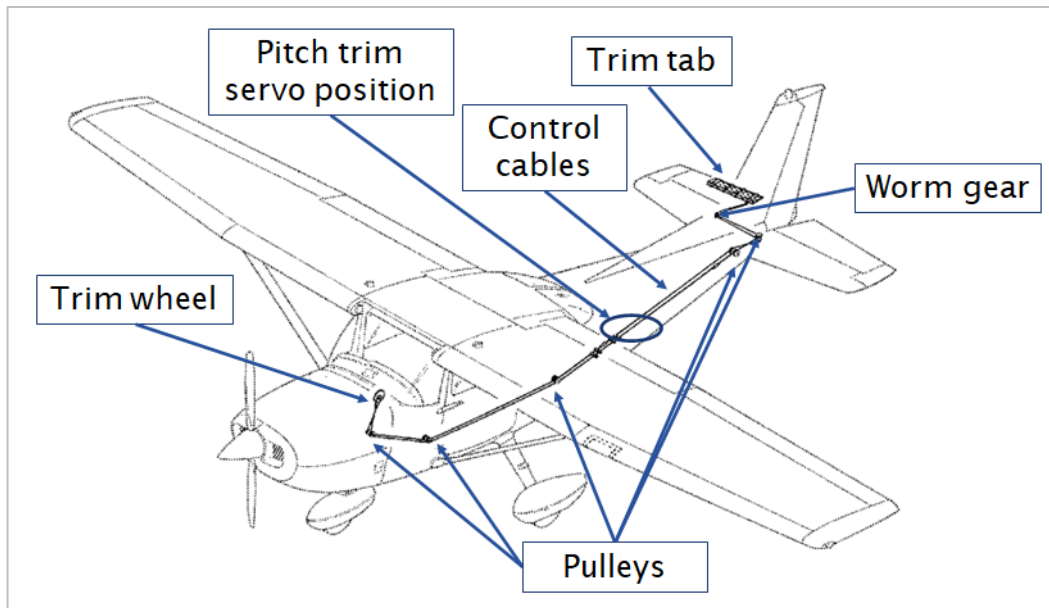


Figure 9. Mechanical linkage between controls and trim tab on Cessna 172. Image: Textron Aviation. Markings added by SHK.

1.6.4 The autopilot system

The aircraft was equipped with a Garmin GFC 500 autopilot system, which is a digital system primarily intended for general aviation aeroplanes. The autopilot system was installed in the aircraft in October 2021 in accordance with STC⁶ SA01866WI. Regarding the aircraft in question, the system was configured as a two-axis autopilot providing control in roll and pitch.

The autopilot system's certification basis includes, among other requirements, 14 CFR⁷ 23.1329, which contains U.S. certification requirements for autopilot systems in smaller aircraft.

The certification requirements entail, among other things, that an autopilot system must be designed so that it cannot cause hazardous loads on the aircraft or hazardous deviations from the flight path, either during normal operation or in the event of a malfunction, provided that the pilot intervenes within a reasonable period of time.

The system architecture is shown in Figure 10 and comprised the following main components:

- two GI 275 instruments
- one GMC 507 control panel
- three GSA 28 servos
- one switch on the left control yoke.

⁶ STC (Supplemental Type Certificate) – Approval of a modification that is not included in the aircraft's type design documentation.

⁷ CFR (U.S. Code of Federal Regulation) – Rules issued by the FAA for aircraft certification.

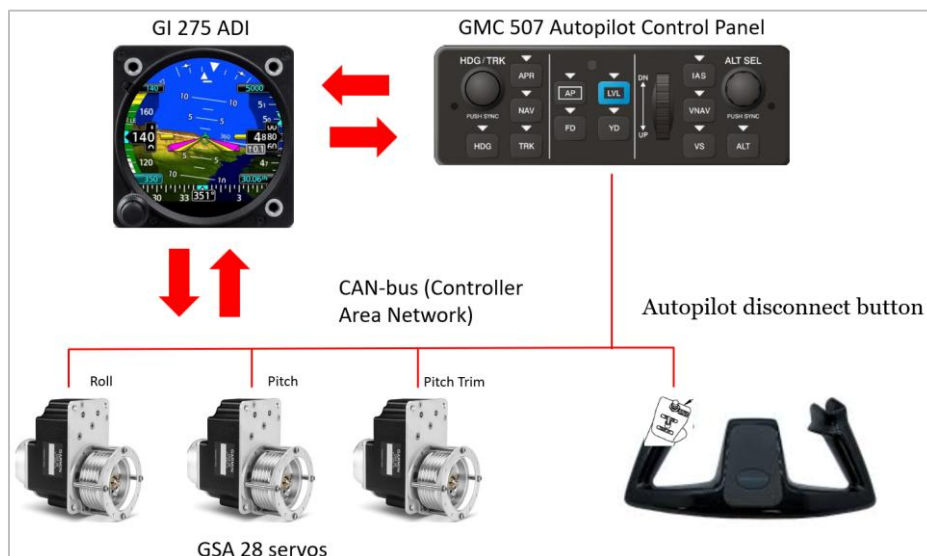


Figure 10. Main components of the autopilot system. Source: Garmin. Markings added by (SHK).

Garmin GI 275

The GI 275 is a multi-function electronic flight instrument that can be configured as a Primary Flight Display (PFD), in which case it provides an attitude indicator and primary flight data. The instrument size is 82 mm square, with a display area of 68 mm in diameter. The instrument can also be used as a Horizontal Situation Indicator (HSI) or a Multi-Function Display (MFD).

The GI 275 constitutes the interface with the autopilot and is integrated with the system to display status, mode indications such as ALT⁸ and HDG⁹, as well as warning and alert messages. It can also display a Flight Director, which helps the pilot to follow the autopilot's command signals during manual flight. The integrated electronic Air Data, Attitude and Heading Reference System (ADAHRS) supplies attitude, heading and other reference data required for the autopilot's control functions.

Garmin Mode Controller (GMC 507)

The GMC 507 is a control and mode selection panel from which the autopilot and Flight Director can be engaged. Various functions, such as heading hold, altitude hold and speed hold, can also be selected from the panel.

Garmin GSA 28

The GSA 28 is a servo that converts the autopilot's electronic control signals into mechanical movement in the aircraft's control system. Three servos were installed in the aircraft: one for the elevator control system, one for the elevator trim, and one for the aileron control system. The GSA 28 is a so-called smart servo with its own control and monitoring logic, and is capable of recording servo position, load and status, including fault monitoring. The maximum torque of the servos is 6.8 Nm.

The autopilot system can be disconnected in four ways: by pressing the autopilot disconnect button on the control yoke, activating the manual electric trim, pressing the AP button on the GMC 507, or pulling the circuit breaker for the system.

⁸ ALT (Altitude) – Altitude hold.

⁹ HDG (Heading) – Heading hold.

1.6.5 Elevator servo and elevator trim servo

The servos are mechanically integrated into the aircraft's control system and can apply torque to control the control surface deflections. Communication between the servos and the other units is transmitted via a so-called CAN bus.¹⁰

Elevator servo

The elevator servo is installed in the rear section of the fuselage and is connected to the elevator control system via a servo drum and a cable system. Through this connection, the servo can apply torque to the elevator control system and thereby affect the elevator deflection. The servo also measures the applied torque, which is used for autopilot monitoring and internal functions such as activation of the elevator trim servo.

Elevator trim servo

The elevator trim servo operates on the existing trim system via a trim drum and a cable, and can thereby change the trim setting. The elevator trim servo can be activated either electrically from the pilot's control yoke or via signals from the autopilot. The electric manual trim function is separate from the autopilot trim function and is connected directly to the elevator trim servo via discrete electrical signals (on and off). When the switch on the control yoke is actuated, the autopilot is disconnected and the elevator trim servo is then controlled by the pilot.

When the autopilot is engaged, the elevator trim servo is activated based on information from the elevator servo. Signals to activate the elevator trim are sent to the elevator trim servo when a threshold value for the elevator control torque has been exceeded for a specified period of time. In this mode, the function of the trim is to reduce the torque required from the elevator servo during more sustained control-column torque at the elevator.

Configuration of servos and system data

When the servos are delivered from Garmin, they are provided with installed default software and configuration state. When they are installed and commissioned in the aircraft, they are to be configured by means of a combination of hardware-based identification and software-based settings.

The hardware-based identification means that each servo in the system is identified through so-called strapping configuration, in which electrical connections (strapping pins) determine the function of the servo in the aircraft, for example as an elevator servo or an elevator trim servo. This configuration is specified in the wiring diagrams in the installation manual.¹¹ The strapping configuration determines the servo's role in the CAN-based network and ensures that the correct control commands are assigned to the correct unit.

¹⁰ Controller Area Network (CAN) – Is a fieldbus system developed by Bosch for communication between electronic units in vehicles.

¹¹ GFC 500 Installation Manual, 190-02291-00, Appendix A – CAN Bus / Servo Strapping.

In addition to this basic identification, the system is configured by a set of Garmin predefined parameters stored in the servos and in the GI 275 instrument. These parameters and the corresponding values/settings are defined in aircraft-specific supplementary documents, such as the C172 GFC 500 Gain Addendum (005-01470-03), and include, among other things:

- *Servo Gain*
- *Maximum Torque* (torque limits)
- *Servo Direction*
- *Trim Direction*
- Trim speeds and time limitations (e.g. *Max Run Time*)

The configuration is entered via the GI 275 configuration menus during installation or maintenance. The GI 275 therefore functions as the system's central configuration unit and distributes these parameters to the servos via the CAN bus.

The parameter *Servo Direction* reflects how the servo is physically installed in the aircraft. The setting can be either *Normal* or *Reverse* and affects the direction in which the servo is to move. The parameter *Trim Direction* determines the direction in which the servo rotates based on signals from the trim switch on the control yoke.

At delivery the servos are set by Garmin to a default configuration, and the configuration parameter *Servo Direction* is set to *Normal*. The servos also have a database consisting of a set of system data, which includes:

- Software (firmware) for each unit
- Configuration parameters
- System identification and version information
- Internal calibration data and diagnostic functions

The software for the GSA 28 (as well as the GI 275 and GFC 500) is updated by loading so-called software loaders, normally via memory media or service tools.

In connection with an update, verification of the installed software version and system configuration is to be carried out in accordance with the procedures in the maintenance manual.

When the system is started, an automatic check of the configuration of the various units is performed. If deviations are detected, for example in a servo setting, a warning message will be generated and the system will not be operable. The servo software settings are cross-checked against the configuration entered in the GI 275.

1.6.6 Data specific to the ALT-mode autopilot function

In ALT mode, the function of the autopilot is to maintain a preselected altitude. This is achieved through interaction between the elevator servo and the elevator trim servo.

When the autopilot is engaged, the elevator servo applies a torque to counteract deviations from the selected altitude. The torque generated is monitored internally within the system and is used for control and monitoring of the function.

In the case of small and short-term deviations, the elevator servo generates the necessary control torque. In the case of sustained control deflections (sustained pitch servo torque), for example due to a changed trim condition, the elevator trim servo is activated in order to reduce the force that the elevator servo needs to apply.

Control principle for the autopilot's ALT mode

The log data from the GI 275 (see Section 1.11) contain the parameters ApAltCmd (altitude command) and ApVsCmd (vertical speed command). In ALT mode, the altitude command is used to maintain the selected altitude. If the aircraft deviates from this altitude, a vertical speed command is instead generated in order to return the aircraft to the target altitude.

Aircraft-specific parameters such as speed thresholds, gains, limit values and others are specified in the configuration data, but how these parameters affect the internal control logic of the autopilot is not evident from the documentation available. SHK has requested this information but not received a complete and comprehensive description.

1.6.7 Actions in the event of a mistrim Alert

A mistrim alert is illuminated on the primary flight instrument when the autopilot detects a sustained applied pitch servo torque above a threshold value with a pitch trim servo installed. The preconditions for activation of the alert are that the elevator trim servo has been active for 10 seconds while the torque of the elevator servo exceeds 50 per cent of the configured maximum value, see Figure 11. The message ceases to be displayed when these conditions are no longer fulfilled.

Alert Condition	Annunciation	Description
Up-elevator Trim Required	TRIM UP	The autopilot does not have the required elevator authority to reach the desired flight condition.
Down-elevator Trim Required	TRIM DOWN	
Status Alerts		

Figure 11. Description of mistrim alert. Source: GI 275 Pilot's Guide 190-02246-01 Rev. P.

The mistrim alert Trim Down is presented on the instrument as TRIM DN, even though the Pilot's Guide uses the wording Trim Down. Garmin's documentation does not state where on the Primary Flight Display (PFD) the alert is presented.

The Aircraft Flight Manual Supplement for the GFC 500 autopilot specifies the actions to be taken by the pilot in the event of a mistrim alert when an elevator trim servo is installed, see Figure 12.

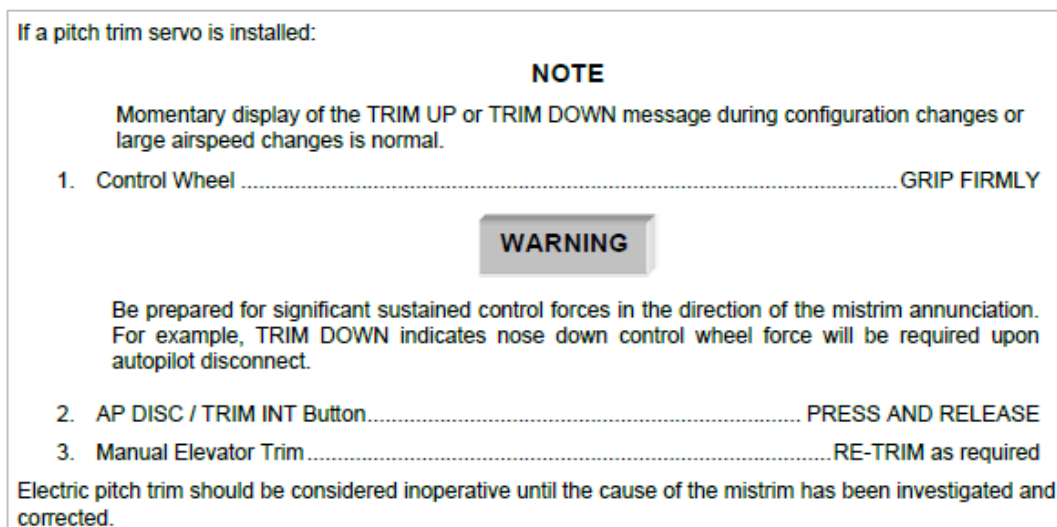


Figure 12. Procedure in the event of a mistrim alert in accordance with the aircraft's supplement for the GFC 500 autopilot with ESP installed. Image: Garmin FAA Approved Airplane Flight Manual Supplement, GFC 500 Autopilot with ESP installed.

1.6.8 Electronic Stability and Protection

Electronic Stability and Protection (ESP) is a stability and safety function within the autopilot system that monitors the aircraft's flight attitudes. The function is active when the autopilot is disengaged and is intended to support the pilot in preventing undesired flight attitudes during manual flight. Threshold values for ESP are configured in the GI 275.¹²

If the limits for pitch and bank angles and airspeeds are exceeded, the system automatically provides control commands to the roll and elevator servos in order to limit the deviations.

On the aircraft in question, ESP was set to activate at a bank angle of 45 degrees. When ESP is active, the torque applied to the servo is highest when the bank angle is 15 degrees above the configured bank angle limit (i.e. at 60 degrees) and decreases gradually to a minimal torque when the bank angle is 15 degrees below the configured bank angle limit (i.e. 30 degrees).

The pitch angle limits were set to 20 degrees nose up and 15 degrees nose down. When ESP is active, the applied torque is greatest when the pitch angles are 5 degrees beyond the configured limits for nose-up and nose-down, respectively, and decreases gradually to a minimal torque when the pitch angle is 5 degrees below the pitch angle limit, see Figure 13.

However, ESP operates only within a limited envelope and is deactivated if the bank angle exceeds 75 degrees or if the pitch angle exceeds 50 degrees.

ESP can be temporarily disengaged by pressing and holding the autopilot disconnect button on the yoke. If the button is held for more than five seconds when the aircraft is in flight, the ESP system is fully deactivated of the remaining flight.

¹² <https://www.garmin.com/en-US/blog/aviation/understanding-garmin-electronic-stability-protection-esp/>

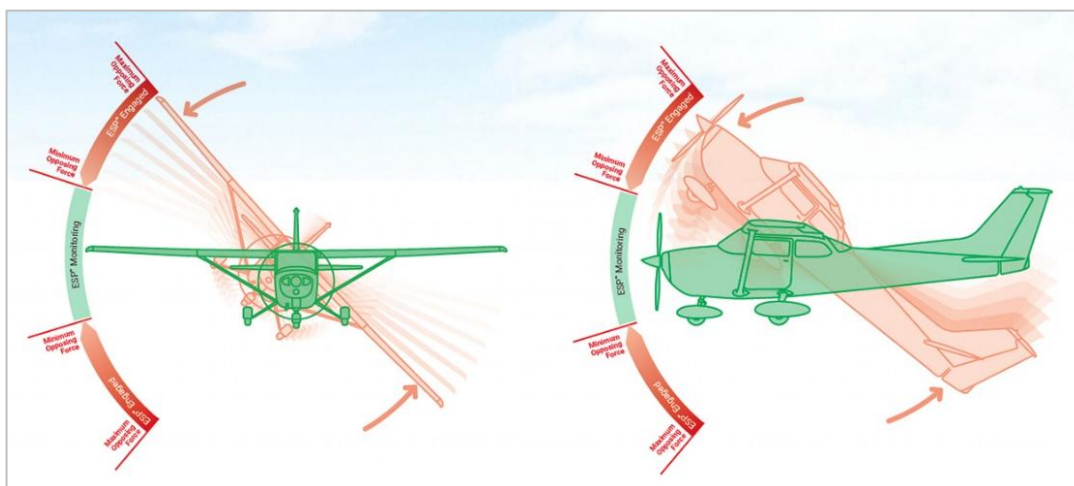


Figure 13. Activation principle for ESP. Image: Garmin.

1.6.9 Emergency procedure

The Aircraft Flight Manual Supplement for the GFC 500 autopilot specifies the actions to be taken by the pilot in the event of *Autopilot Malfunction/Trim Runaway*, see Figure 14.

AUTOPILOT MALFUNCTION / PITCH TRIM RUNAWAY

If the airplane deviates unexpectedly from the planned flight path:

1. Control Wheel GRIP FIRMLY
2. AP DISC / TRIM INT Button PRESS AND HOLD

CAUTION

Be prepared for high elevator control forces.

3. Aircraft Attitude MAINTAIN / REGAIN AIRCRAFT CONTROL
4. Elevator Trim RE-TRIM if necessary using Elevator Trim Control Wheel
5. AUTOPILOT Circuit Breaker PULL

NOTE

Do not release the AP DISC / TRIM INT Button until after pulling the AUTOPILOT Circuit Breaker.

Pulling the AUTOPILOT circuit breaker will render the autopilot and ESP inoperative.

6. AP DISC / TRIM INT Button RELEASE

Figure 14. Procedure in the event of autopilot malfunction pitch trim runaway. Image: Garmin FAA Approved Airplane Flight Manual Supplement, GFC 500 Autopilot.

1.6.10 Instructions for Continued Airworthiness for the GFC 500

The GFC 500 system has been subject to Service Bulletins¹³ and Service Alerts¹⁴ as well as an Airworthiness Directive.

Garmin issued in November 2022 Service Alert 22109 Rev A addressing a risk of uncommanded automatic pitch-trim operation when engaging GFC 500 autopilots equipped with a GSA 28 pitch-trim servo. This could lead to an uncommanded deviation from the intended flight path. As an interim measure, the service alert specified that, before further flight, the autopilot system must be disabled. An alternative compliance was to disable only the electrical pitch trim. This Service Alert had not been complied with for the aircraft in question prior to the maintenance event in December 2024. The autopilot system and the electric elevator trim therefore remained enabled until the maintenance action to replace the servos in 2024.

¹³ Service Bulletin (SB) – Document containing instructions for maintenance and continuing airworthiness.

¹⁴ Service Alert – Urgent safety notice specifying immediate actions.

In August 2024, the Federal Aviation Administration (FAA¹⁵) issued an Airworthiness Directive (AD 2024 14 03) applicable to aeroplanes equipped with a specific configuration of the Garmin GFC 500 autopilot system, including a GSA 28 elevator trim servo, installed in accordance with Supplemental Type Certificate (STC) No. SA01866WI. The aircraft SE-LGL was subject to the directive.

The Airworthiness Directive was prompted by a report of an uncommanded automatic pitch trim runaway when the autopilot was first engaged. The directive required that the software in the Garmin GFC 500 autopilot system be updated within 12 months to an approved version and prohibited installation of software version 2.59 or earlier for the GI 275.

Once the software version in the GFC 500 autopilot system had been updated in accordance with the Airworthiness Directive and Garmin's software service bulletin, the operator was permitted to reactivate the autopilot system and the electric elevator trim.

As part of the Service Life Extension Program for the GSA 28 servo, Garmin issued Service Bulletin No. 23024 Rev. A. The bulletin described design and manufacturing improvements to increase the reliability of the GSA 28 servos and offered replacement of the servos under warranty. The planned maintenance action for the aircraft in question was therefore to replace all GSA 28 servos in accordance with Garmin's service bulletin and to update the software version in accordance with the Airworthiness Directive.

The bulletin specifies that the GSA 28 servos are to be removed and installed in accordance with the instructions in the relevant document listed in the References section, see Table 1.

Table 1. Refererade dokument från Service Bulletin 23024 REV A.

Document Number	Revision (or later)	Description
190-02291-01	9	GFC 500 Autopilot with Electronic Stability and Protection Part 23 AML STC Maintenance Manual with Instructions for Continued Airworthiness
190-02291-00	24	GFC 500 Autopilot with ESP™ Part 23 AML STC Installation Manual
190-01112-10	30	G5 STC Installation Manual
190-02246-10	15	GI 275 AML STC Installation Manual
190-02472-01	12	G3X Touch™ STC Installation Manual

It is further specified that the necessary checks are to be carried out after the installation.

There is also a note referring to the GFC 500 installation manual (Section 5.5.1) for instructions on how to enter the GFC 500 gains on a GI 275.

When the installation and the required post-installation checks have been completed, a log-book entry is to be made indicating that Garmin Service Bulletin 23024 has been complied with.

¹⁵ Federal Aviation Administration (FAA) – The national aviation authority of the United States.

1.6.11 Instructions and documentation for the servo replacement

Replacing a servo is a maintenance action for which the maintenance manual is normally to be followed. The procedure includes:

- removal and installation of the servo
- software update
- configuration of system parameters
- verification by means of post-installation checks and return-to-service procedures.

Figure 15 shows the overall procedural flow, as interpreted by SHK, which is described in more detail in the relevant parts later in this section.

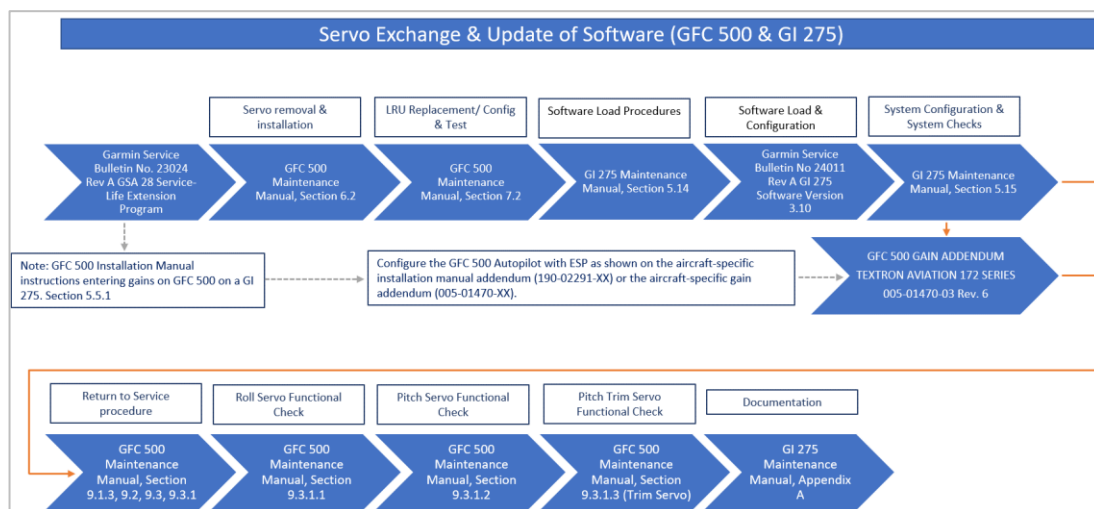


Figure 15. The overall procedural flow for a servo replacement and software installation. Flowchart compiled by SHK.

The procedural flow starts with Garmin's Service Bulletin relating to the Service Life Extension Programme for servo replacement, as described in Section 1.6.9.

The GFC 500 Maintenance Manual¹⁶ specifies that the GSA 28 servos are to be removed and installed in accordance with the instructions in the applicable model-specific installation addendum.

After the servos have been replaced and installed, the software is to be installed. When the system is powered up, the software versions for the GMC 507 and GSA 28 are verified. If there is any discrepancy in the software versions, a system message is generated and the Pre-Flight Test (PFT) fails.

For software updates, reference is made to the GI 275 Part 23 AML STC Maintenance Manual.¹⁷ Section 5 states, among other things, that it is recommended to save the system configuration to a USB memory stick and to print the configuration log before units in the autopilot system are replaced. The update is to begin with loading the software to the GI 275, after which all connected units are updated. When the software version is updated, the relevant Garmin Service Bulletin for the software concerned is to be used. This includes,

¹⁶ Document number 190-02291-01.

¹⁷ P/N 190-02246-11.

among other things, modification instructions. Regarding the maintenance action in question, Garmin Service Bulletin No. 24011 Rev. A for version 3.10 was applicable.

After the software update, the GI 275 Maintenance Manual contains a section dealing with system configuration and system checks. This states that the configuration settings are to be configured in accordance with the previously printed configuration log. There are no references to this section elsewhere in the manual set.

Instructions for entering servo gains on the GFC 500 are referred, by means of a note in Garmin's service bulletin via the GFC 500 Installation Manual, to the aircraft-specific supplementary document GFC 500 Gain Addendum Textron Aviation 172 Series.

The GFC 500 Maintenance Manual then refers to the Return to Service Procedures section, which describes functional tests, calibration and configuration of the autopilot system, including the Pre-Flight Test. It is also specified that a check is to be carried out regarding the duration of the elevator trim servo to travel fully between its end positions, using the manual electric elevator trim function.

The Maintenance Manual does not contain any description of, or reference to, a check that verifies the function and direction of the automatic electric trim.

Finally, Appendix A of the GI 275 Maintenance Manual states that the maintenance action is to be documented. The configuration log is to be saved to a USB memory stick and printed, and then attached to the maintenance documentation.

1.6.12 Pre-flight check of the autopilot system

The Aircraft Flight Manual Supplement for the GFC 500 states that an automatic system test (pre-flight test) is performed when the GFC 500 autopilot is started. During this test, the text PFT (Pre-Flight Test) is shown in the autopilot status field on the GI 275 display. Once the system test has been successfully completed, PFT disappears from the status field, indicating that the autopilot is ready for use.

The GI 275 supplement does not specify any additional pre-flight checks if the autopilot system is manufactured by Garmin. The GI 275 Pilot's Guide states that the autopilot is to be engaged before take-off and then disengaged, in order to verify that an aural alert is heard and that the aircraft's controls are free to move. The supplement states that the pilot guide be readily accessible to the pilot.

The information contained in the supplements complements or replaces the information provided in, among other documents, the Pilot's Operating Handbook (POH) and other documentation, such as maintenance and installation manuals.

1.6.13 The aircraft checklist

The aircraft was equipped with a checklist covering the different phases of a flight. In the section on actions before take-off, it is specified that the pilot is to ensure that the autopilot is disengaged before take-off.

1.7 Meteorological information

According to Metar: Wind 210 degrees 3 knots, no significant clouds, temperature/dewpoint -6/-6 °C, QNH 1030 hPa.

The incident occurred in daylight.

1.8 Aids to navigation

The aircraft was equipped with a Garmin GTN 650 navigation unit.

1.9 Communications

Once the control of the aircraft was regained, a Mayday message was transmitted to the Air Traffic Control.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

No permanently installed flight data recorder or cockpit voice recorder was installed in the aircraft, nor was such equipment required for this type of aeroplane.

The Swedish Accident Investigation Authority (SHK) has obtained and downloaded recorded data from other sources and units, as presented below.

1.11.1 Flight data

The multifunction electronic flight instrument GI 275 automatically stores essential flight data. Data are recorded once per second while the system is powered. All flight data logged on a specific date are stored in a file with a filename format that includes the date, time and the identifier of the nearest aerodrome.

The parameters that were relevant to the incident are presented in Table 2.

Table 2. Relevant parameters. Source: GI 275 Part 23 AML STC Installation Manual, Table 7-1 Flight Data Log Descriptions.

Parameter	Logged Name	Units	Definition
Indicated Barometric Altitude	AltB	ft	Displayed value
Indicated Airspeed	IAS	kts	Selected ADC
Vertical Speed	VSpd	ft/min	Selected ADC
Attitude Pitch Angle	Pitch	DEG	Selected AHRS
Autopilot is engaged?	AfcsOn	Boolean	0: Autopilot not engaged 1: Autopilot engaged
Autopilot Pitch Mode	PitchM	enum	Abbreviated text of autopilot pitch mode
Pressure Altitude	AltPress	ft	Selected ADC
Autopilot State	ApState	enum	AP_off: Autopilot is off AP_eng: Autopilot is engaged AP_fail: Autopilot is failed AP_inv: Autopilot is unknown state
Flight Director Target Altitude	FdTrgtAlt	ft	
Autopilot Vertical Speed Command	ApVsCmd	ft/min	
Autopilot Pitch Torque (servo)	ApPitTrq	%	Autopilot Pitch Torque where 100% is 60 in-lb for a GFC 500 system
Autopilot Pitch Trim Torque (trim servo)	ApPitTrimTrq	%	Autopilot Pitch Torque where 100% is 60 in-lb for a GFC 500 system
Autopilot Disengage Cause	ApDisCause	enum	Various
Autopilot Altitude Command	ApAltCmd	ft	Internal Garmin use
Envelope Protection Status	EpStatus	enum	Roll, Pitch, IAS, Mach

1.11.2 Recorded video from the serious incident

The GoPro camera installed in the cockpit recorded the sequence of events at a frame rate of 50 frames per second.

1.11.3 Summary of flight data and information from the GoPro video

To provide a better understanding of the sequence of events, the flight data and actions visible on the GoPro video have been compiled into two timelines. The data sources have been timed aligned by using flight data time reference and recorded events with same events observed on video. The first timeline relates to the period from when the autopilot was engaged until it was deactivated according to the flight data. The second timeline shows the final eight seconds leading up to the upset, see Figure 16 and Figure 17.

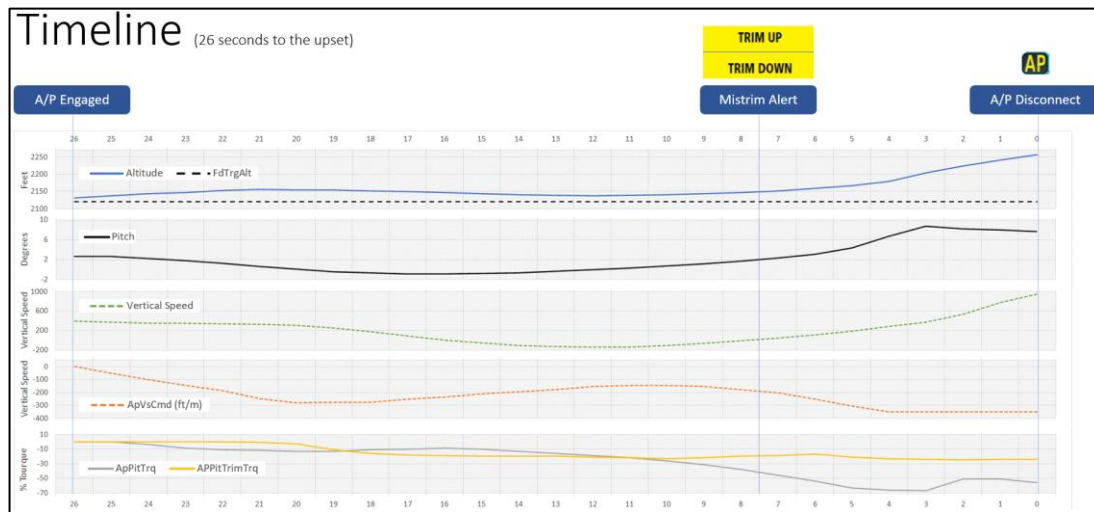


Figure 16. Summary of flight data and GoPro video from when the autopilot was engaged until it was deactivated, 26 seconds later.

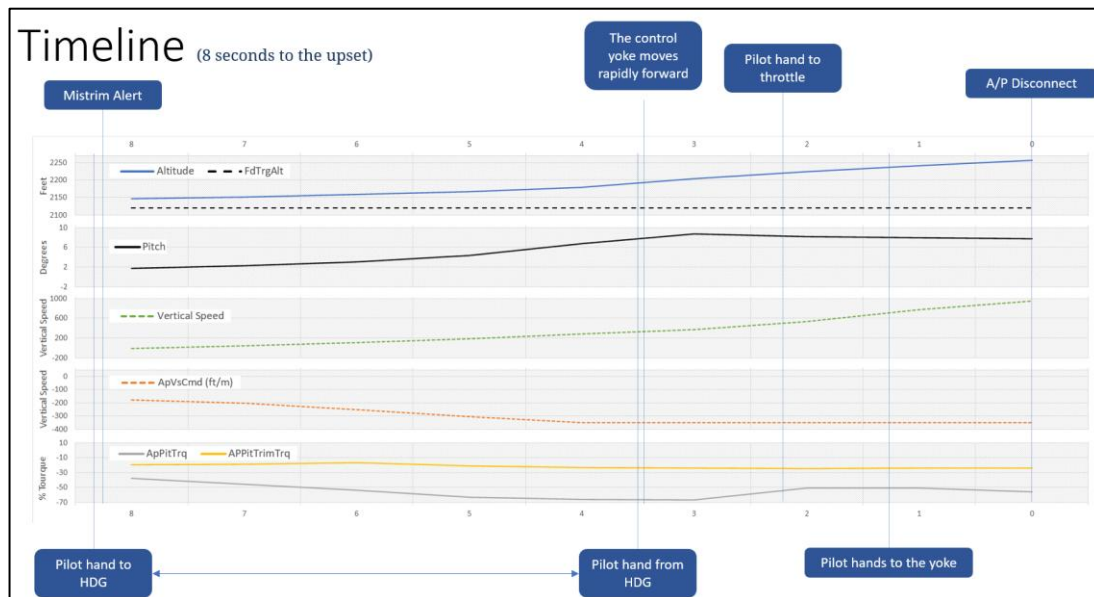


Figure 17. Summary of flight data and GoPro video during the final 8 seconds leading up to the upset.

The timeline in Figure 18 covers the period during which the aircraft was uncontrolled, from the moment the autopilot was disengaged until the pilot regained control of the aircraft. The graph showing engine power (RPM) is based on the audio recording from the GoPro video, where the propeller speed has been calculated from the frequency of the propeller noise. The graph of the control wheel position shows the estimated control wheel position derived from the GoPro video. Negative values represent control wheel deflection to the left and positive values represent control wheel deflection to the right.

In addition, information that can be interpreted from the video is presented, including the points in time when the pilot is holding the control wheel with one or both hands, when the pilot attempts to disengage the autopilot, changes in engine power setting, and the period during which it was possible to retrim the aircraft manually with the right hand.

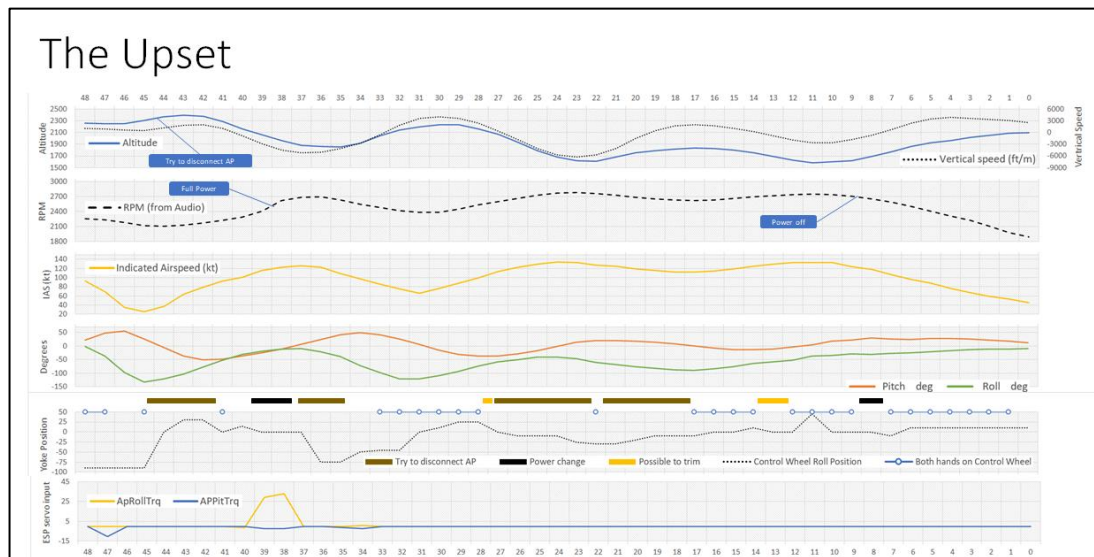


Figure 18. Summary of flight data and information from the GoPro video during upset.

Data specific to the autopilot function

Figure 19 presents data for a 30-second sequence, starting 26 seconds before the upset. Four graphs are shown in the figure. The upper graph shows pitch angle (Pitch) and vertical speed (VSpd). The next graph illustrates the autopilot vertical speed command (ApVSpdCmd), the autopilot pitch command for the Flight Director (FDPitchC), the autopilot target altitude (FdTrgtAlt), and the aircraft barometric altitude (AltB). The third graph presents the elevator servo torque (ApPitTrq) and the elevator trim servo torque (ApPitTrimTrq). The bottom graph shows pitch rate and pitch acceleration.

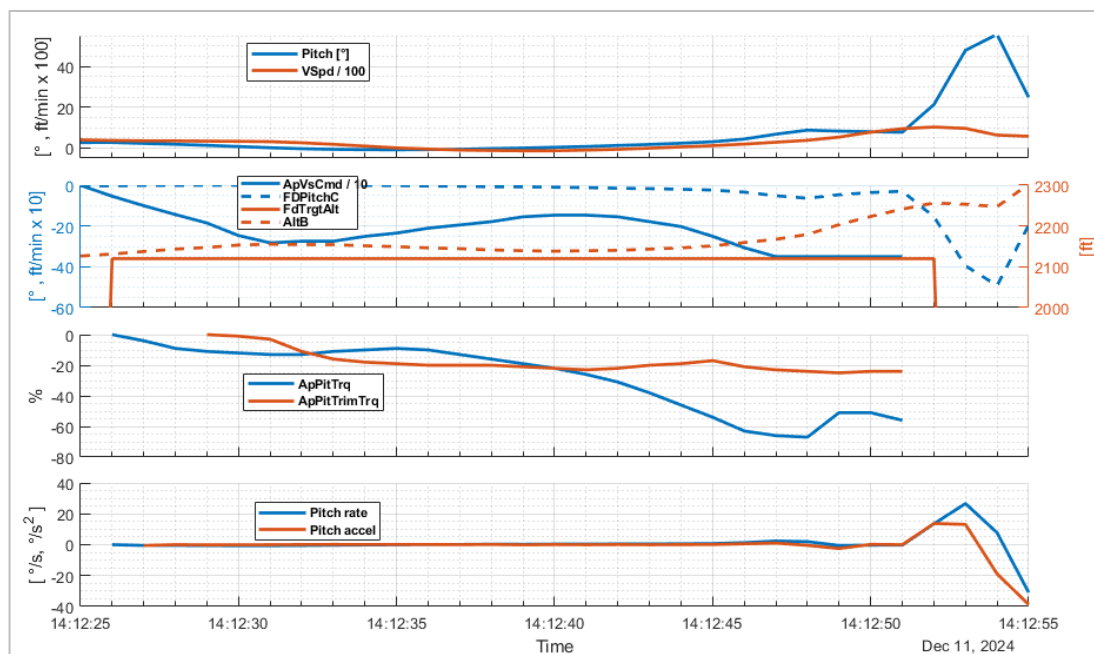


Figure 19. Data for a 30-second sequence, starting 26 seconds before the rapid change in pitch angle, while the autopilot was engaged.

The data in Figure 19 represent a number of characteristic variables relating to the altitude-hold function of the autopilot. The variables in the bottom graph are derived values based on pitch-angle data. The autopilot was engaged to maintain an altitude of 2,100 feet at 14:12:26, at which time the aircraft was above 2,120 feet and climbing. Almost immediately, the elevator servo began to apply a nose-down elevator torque and the autopilot integrated the vertical speed in order to reduce the altitude. Four seconds later, the elevator trim servo was activated to offload the elevator servo (negative values). At around 14:12:32, the altitude began to decrease, before increasing again eight seconds later. The elevator servo continuously applied a nose-down torque which, from 14:12:40, became more negative and reached the maximum negative torque (-67 % of -70 % possible). The elevator servo torque was then reduced to -51 % and finally -56 % at 14:12:51. At 14:12:48, the pitch rate can be seen to decrease slightly.

1.12 Site of occurrence

In the airspace south-west of Örebro Airport.

1.13 Medical and pathological information

Nothing has emerged to indicate that the pilot's mental or physical condition was impaired before or during the flight.

1.14 Fire

No fire occurred.

1.15 Survival aspects

1.15.1 Rescue operation

The pilot declared an emergency after he had regained control of the aircraft. A normal landing was carried out and no rescue operation was initiated.

1.16 Tests and research

1.16.1 Technical examinations

Following the serious incident, SHK carried out a number of technical examinations and functional checks of the aircraft and its autopilot system. The examinations were conducted with support from Garmin and with the involvement of an independent, certified maintenance organisation. Garmin has declined to answer certain questions that the SHK has put forward regarding the system logic. Therefore, the SHK has carried out technical system tests and system identification in order to better understand the system.

The mechanical installation of the autopilot system hardware, including installation of the servos and routing of the control and trim cables, was inspected and found to have been correctly carried out in accordance with the applicable installation manuals and documentation. The functioning of the system was also verified.

The configuration settings of the autopilot system were reviewed and found to be consistent with the documentation in the GFC 500 Gain Addendum for the 172 series, see Section 1.16.3.

Other checks were carried out in accordance with Garmin's maintenance and installation manuals for the GFC 500 and included, among other things, Servo Functional Check, GI 275 Trim Direction Checks, Autopilot Switch Checks and Interface Checks. In addition, a check of the autopilot's automatic elevator trim function was performed.

No remarks or discrepancies were identified during the examinations.

1.16.2 System identification

Reference flights

To evaluate the function of the autopilot system, identify system functions and verify the recorded data, SHK carried out three reference flights. Two with the aircraft in question and one with another aircraft of the same type. Each flight was recorded using GoPro cameras installed in the cockpit. Using this documentation, together with flight data from the GI 275, it was possible to analyse each reference flight.

The flights were conducted at altitudes and speeds corresponding to those at the time of the serious incident.

The overall result showed that the system functioned as intended by design, with good handling qualities and smooth control inputs according to the reference flight pilots. The data collected were consistent with the manoeuvres performed.

In accordance with the design, the servos could be overridden by the pilot, which required a moderate effort. The Electronic Stability and Protection (ESP) function was clearly noticeable in roll. This was experienced as somewhat surprising, as one does not normally expect any force input from the system when the autopilot is disengaged, unless one has previously flown with ESP. The ESP system function in pitch was not examined.

During flight with the autopilot disengaged, different elevator trim positions were used to obtain different pitch rates. The aircraft was flown in level flight at an altitude and speed representative of the incident. Control forces on the control yoke were measured while the elevator trim tab deflection was changed until the load had reached a predetermined value. The control yoke was then released and the aircraft was allowed to change pitch attitude by a number of degrees before control was regained.

Different elevator trim tab deflections were applied and the forces on the control yoke were measured, after which the trim tab angle was fixed by holding the trim wheel and then engaging the autopilot in altitude-hold mode during level flight. In this way, the relationship between the elevator servo torque and the forces on the control yoke could be determined. The exercise was completed by disengaging the autopilot in order to document the pitch attitude change for each measured force.

When the autopilot was engaged in ALT mode and the elevator trim deflection was controlled automatically (auto trim), it was noted that the trim wheel speed varied. This variation was later identified to be related to the servo torque, with low torque resulting in low speed and high torque in higher speed.

Finally, different degrees of pilot input into the autopilot system were evaluated in order to investigate possible effects when the autopilot is engaged. Apart from the warning stated in the aircraft supplement – that by applying force to the control yoke, the pilot can cause the

elevator trim to move in the opposite direction to the applied force – no other effects could be observed.

Elevator trim tab angular rate from reference flight data

By observing the trim wheel speed in different flight conditions and comparing it with different elevator servo torque values, the change in elevator trim tab position, expressed in degrees per second, could be calculated. A polynomial was then derived which links the elevator servo torque to the trim wheel speed. This polynomial was subsequently used to calculate the trim tab speed at the time of the incident. In this way, the elevator trim tab deflection immediately before the upset could be calculated to be approximately 18 degrees.

Measurement of the elevator and elevator trim systems

Measurement of the elevator movement showed a maximum deflection of 30 degrees upwards and 22 degrees downwards. According to the type certificate holder, the maximum elevator movement is to be within the range 28 to 29 degrees upwards and 23 to 24 degrees downwards.

Measurement of the trim tab movement showed a maximum deflection of 22 degrees upwards and 19 degrees downwards. According to the type certificate holder, the maximum trim tab movement is to be within the range 22 to 23 degrees upwards and 19 to 20 degrees downwards.

To move the trim tab between its end positions, the trim wheel had to be rotated 4.5 turns. This corresponds to an elevator change of 9.3 degrees per turn. Four full hand-grips were required to rotate the trim wheel one full turn.

Ground tests for system identification

As the logic of the autopilot system is described only very briefly and in general terms in the manuals, SHK needed to carry out ground tests in order to identify various system functions. An external air pressure system was connected to the aircraft air data system to enable simulation of different altitudes and speeds.

The mass of the elevators was balanced using external weights (tared). To simulate aerodynamic loads on the control surfaces, a system of weights connected to the control surfaces was used.

In addition, system tests of the autopilot and trim system were carried out in accordance with the Garmin manuals. The results showed that the system operated in accordance with the system description and that the data collected were consistent with the observed outcome.

To investigate any change of sign (positive or negative) in the recorded data for the elevator trim servo, the parameter Servo Direction was set to *Normal* while the other parameters were left unchanged. This combination showed that the direction of movement of the trim tab changed, while the sign of the torque direction remained unchanged.

The *Servo Direction* and *Trim Direction* settings govern the direction of movement of the trim servo. In order to examine the function of the electric automatic pitch trim and the electric manual trim under different combinations of these settings, tests have been conducted. The results showed that, for nose-up respective nose-down trim commands, it is

possible for the electric automatic pitch trim to move in the opposite direction to the electric manual trim, which is controlled via the switch on the control wheel, see Table 3.

Table 3. Tested configuration settings for *Servo Direction* and *Trim Direction*. Green colour indicates when the configuration for the individual parameter is set in accordance with the aircraft-specific addendum.

Test #	Setting Servo Direction	Setting Trim Direction	Commanding source	Effect in flight
1	Reverse	Normal	Autopilot	Pitch down when trimming down
			Manual electric trim	Pitch down when trimming down
2	Reverse	Reverse	Autopilot	Pitch down when trimming down
			Manual electric trim	Pitch up when trimming down
3	Normal	Reverse	Autopilot	Pitch up when trimming down
			Manual electric trim	Pitch down when trimming down
4	Normal	Normal	Autopilot	Pitch up when trimming down
			Manual electric trim	Pitch up when trimming down

Forces and torques

Based on the investigations described above, the data and forces have been analysed and the servo torque has been correlated with the corresponding control column forces. The force on the control yoke immediately before the autopilot (and the elevator servo) was disengaged is estimated to have been approximately 180 N.

The ground tests and flight tests carried out showed that the actual maximum elevator servo-torque is reached at 67–68 per cent, even though the maximum torque has been limited in the configuration file to 70 per cent of the nominal maximum.

1.16.3 Extract from Gain Addendum and configuration file

From the GI 275, a summary of the configuration settings (a configuration log) can be generated and saved to an external USB drive. Such a configuration file was created two days after the serious incident. The configuration settings corresponded to the configuration specified in the Gain Addendum. Extract of some of the settings after the incident and the corresponding settings in the Gain Addendum can be found in Table 4 and 5. Table 3 shows the configuration settings for the elevator servo and Table 4 for the elevator trim servo.

Table 4. Configuration of elevator servo and values from the Gain Addendum.

Parameter	Config 24-12-12	Addendum
Maximum Torque	70%	70%
Servo Direction	Reverse	Reverse
Clutch Monitor	Enabled	Enabled

Table 5. Configuration of elevator trim servo and values from the Gain Addendum.

Parameter	Config 24-12-12	Addendum
Trim Control	Garmin Servo	Garmin Servo
Maximum Torque	60%	60%
Servo Direction	Reverse	Reverse
Trim Direction	Normal	Normal
Auto Trim	Enabled	Enabled
Fastest Speed	30%	30%
Slowest Speed	20%	20%
Auto Trim Min Speed	3%	3%

1.16.4 Examination of the elevator trim servo

On 16 September 2025, SHK handed over the elevator trim servo to Garmin in Dallas Fort Worth, USA, in order for further technical examinations to be carried out. This is standard procedure, as the manufacturer of the component under examination possesses the specialised knowledge and equipment required to perform in-depth analyses. In such examinations, the investigation authority normally participates. If the manufacturer is located in another country, the investigating authority participates together with, or by agreement with, the investigation authority in that other country, in this case the NTSB.

In the case in question, Garmin declined the participation of SHK and the NTSB in the examinations. The examinations were postponed several times because Garmin did not wish to allow the authorities to attend. To enable progress in the investigation, SHK eventually decided that Garmin could continue the examinations without the authorities being present.

On 5 November, SHK received the results of the examination from Garmin, transmitted via the NTSB. The results showed the following:

- The manufacturer confirmed that the configuration stored in the unit matched the configuration expected for the aircraft.
- The servo calibration data corresponded to the calibration with which the servo had originally been delivered from the factory.
- An auto-trim direction test was carried out, in which the servo was placed on a bench and its rotational direction observed during a simulated auto-trim. The servo shaft responded by rotating in the correct direction and passed the test.
- An ATE¹⁸ Final Inspection Test was performed without remarks. Three test runs were conducted: at room temperature, at high temperature and at low temperature.
- The examination showed that the servo had different software from that installed at delivery from the factory. This was expected and is not considered to have been a factor in the incident, as the servo had been updated to the correct, STC-approved version for the application concerned.

Garmin finally stated that there were no further tests to be carried out.

¹⁸ ATE (Automatic Test Equipment).

1.17 Organisational and management information

The organisation that carried out the actions involving the replacement of the servos in question in accordance with Service Bulletin No. 23024, as well as the initial installation of the autopilot system in October 2021, is, inter alia, approved by the Swedish Transport Agency as a maintenance organisation (Part-145¹⁹) and as a Combined Airworthiness Organisation (Part-CAO²⁰) in accordance with Regulation (EU) 2018/1139.²¹

The organisation held the ratings required to perform the actions concerned.

1.17.1 The maintenance organisation exposition

The maintenance organisation exposition (MOE) specifies that an independent inspection (see Section 1.18), or another suitable error-capturing method, has to be carried out before a certificate of release to service is issued for critical maintenance tasks.

Critical maintenance tasks are stated to include, among other things, the installation and adjustment of flight control systems and other systems that affect the stability of the aircraft, such as autopilot systems.

The independent inspection is to be performed by a person other than the one who has carried out the maintenance work concerned.

The inspection is to verify, among other things, that the system as a whole operates in the correct sense of operation and that any software is of the correct version and compatible with the aircraft's current configuration.

1.18 Additional information

1.18.1 Critical maintenance tasks and requirements for error-capturing methods

Commission Regulation (EU) No 1321/2014²² stipulates in Annex II (Part-145) that a maintenance organisation is to ensure that an error-capturing method is applied after each critical maintenance task. Critical maintenance tasks include, among other things, work that may affect the control and stability of the aircraft, including work on flight control and autopilot systems.

Error-capturing methods are intended to detect maintenance errors and mistakes that occur during the performance of maintenance. In some cases, a combination of several actions, such as visual inspection, functional testing and rigging checks, may be necessary.

¹⁹ Part-145 – Annex II to Commission Regulation (EU) No 1321/2014, which sets out how maintenance organisations are to operate in order to maintain aviation safety within civil aviation in Europe.

²⁰ CAO – An organisation that is permitted to perform both maintenance activities and continuing airworthiness management ("combined airworthiness organisation"), typically for smaller/non-complex aircraft.

²¹ REGULATION (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91.

²² COMMISSION REGULATION (EU) No 1321/2014 of 26 November 2014 on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks.

One error-capturing method is an independent inspection, which is a verification carried out by a qualified person who has not been involved in the maintenance work concerned. The inspection is to ensure that the work has been performed in accordance with the applicable requirements and that no errors or mistakes have been made. The purpose is to minimise the risk of errors with a potential impact on flight safety.

If work has been carried out on the flight control system, the independent qualified person is to observe its overall function independently in order to ensure that the control system operates in the correct sense of operation and that any software forming part of the critical maintenance task is checked, for example for compatibility with the aircraft configuration.

1.18.2 Replacement of servos and software update

In connection with maintenance of the aircraft on 5 December 2024, all three GSA 28 autopilot servos (aileron, elevator and elevator trim) were replaced in accordance with the work order and under warranty, in compliance with Service Bulletin 23024 Rev. A. The new servos had part number 011-02927-21.

Following the replacement of the servos, tests of the autopilot system were carried out on 6 December. During these tests, fault messages occurred, including autopilot and communication faults (AP_fail and Communication fault). This was due to the software in the new servos not being compatible with the version installed in the autopilot system.

On 9 December, the servo-software was updated via the GI 275 instrument from version 2.41 to version 3.10. The first attempt at updating was not accepted by the system and the action had to be repeated. However, fault messages recurred during a number of subsequent tests, including AP fail, Communication fault and Preflight test failed, before a successful test was finally completed, see Figure 20.

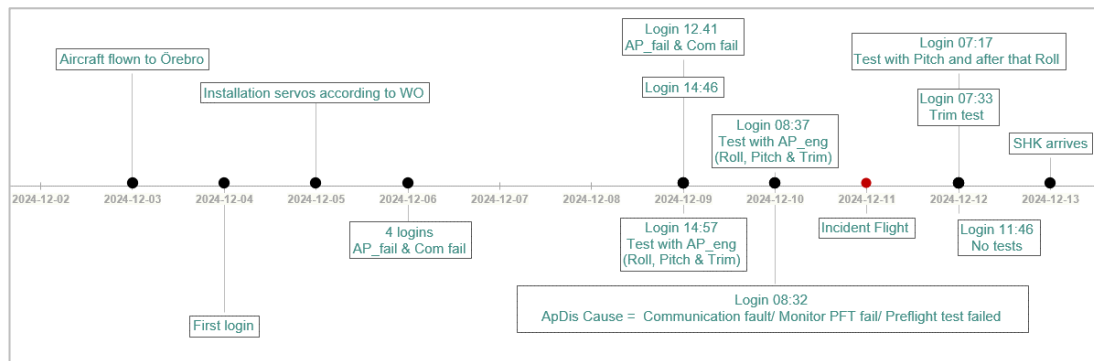


Figure 20. The timeline shows the period from when the aircraft arrived at Örebro for maintenance until SHK was able to examine it. Logins indicate that the maintenance organisation started the GI 275 flight instrument, which then stored data.

SHK has not been able to identify the particular actions that led to the successful completion of the installation.

Work order

A work order is a document issued by a continuing airworthiness organisation describing for the maintenance organisation which tasks are to be carried out and which maintenance data are to be used. Once the work has been completed, the individual items are to be signed off by a licensed maintenance engineer.

For the work order concerned, the maintenance data referred partly to Service Bulletin 23024 and partly to maintenance data for the Cessna 172 series with the Garmin GFC 700 autopilot system and G1000 installation, i.e. a different system installation from the one actually installed.

The work order shows that the maintenance organisation had signed the independent inspections relating to the mechanical replacement of the servos. However, it does not show that the maintenance organisation carried out any independent inspection or used any other error-capturing method in connection with the software update and configuration settings of the autopilot system. According to the maintenance organisation, no such actions were carried out.

The maintenance organisation did not perform any test of the automatic elevator trim function, and the GFC 500 Maintenance Manual does not contain any requirement for such a test to be carried out.

No configuration log of the configuration settings entered was saved by the maintenance organisation after the software update.

The certificate of release to service after completion of the work was issued in accordance with Part-145.

1.18.3 Differences training provided by the club for pilots

There are no training requirements for pilots in relation to the autopilot system, and it is the pilots' own responsibility to familiarise themselves with the system.

In connection with the installation of the autopilot and navigation system, a difference training course and a checklist were developed to ensure that the club's members learned how to use the systems. The training included basic knowledge of the autopilot and how the lower installed GI 275 unit could be activated as a primary flight instrument. No training was provided on how to handle abnormal, autopilot-related failures.

1.18.4 Upset Recovery

There are a variety of factors that can lead to an aircraft upset when the aircraft exceeds normal operational limits. Some of the factors may be weather, system or pilot induced. This can cause the pilot to lose control of the aircraft.

To regain control in a high pitch attitude and low speed situation, there are various techniques. One technique is to bank the aircraft to lower the pitch attitude and avoid stall.

1.18.5 Surprising and Sudden Events

There are obvious difficulties in predicting how an individual will act in a sudden and unexpected situation. From a theoretical perspective, the term 'Startle Effect' can be used. This phenomenon has been defined as a combination of a cognitive and an emotional response to a sudden stimulus, i.e. both as an autonomous reaction (not directly voluntary) and an emotional reaction (e.g. fear). The difference between, for example, beginners and experts can generally be described as the extent of their experience and practice. Situations that have been rehearsed, or that the individual has tangible experience of, can more frequently be said to have prepared them for such sudden and surprising occurrences. However, even experienced pilots may act in an unexpected way precisely because the response to

a sudden and surprising stimulus is not directly voluntary and has an emotional component. What often characterises this sort of response is that the action is immediate and aims to resolve the present emergency situation rather than the situation as a whole. In hindsight, such actions may be perceived as irrational and it may be difficult to find a clear logic behind the decision-making.

There is no universal approach that can prepare an individual for all possible eventualities. Nonetheless, the basic premise should be to prepare and train for identifiable and uncommon situations so that a practised pattern of behaviour can replace the basic autonomous reactions to the greatest possible extent. However, this provides no guarantee that such a pattern of behaviour will actually be used.

1.18.6 Actions taken

Karlskoga Motor Flying Club

Karlskoga Motor Flying Club has marked the circuit breaker for the autopilot in the aircraft in question in order to facilitate its identification.

1.18.7 Similar Events

Serious incident at Bellefontaine, USA, involving aircraft N9035Q

On 12 November 2021, an autopilot malfunction was reported on a Beech F-33A equipped with a Garmin GFC 500 autopilot system. The pilot reported an uncommanded nose-down trim movement of the elevator. The nose-down trim occurred immediately after the pilot had engaged the autopilot. The uncommanded nose-down trim was repeated when the pilot later during the flight engaged the autopilot again, as well as during post-flight troubleshooting.

A system test showed that the pitch servo (GSA 28) could command full nose-down trim for several seconds before the autopilot disconnected, and a laboratory examination showed sulphide corrosion on the servo's circuit board. The investigation resulted in the issuance of an Airworthiness Directive.

Accident near Astatula, USA, involving aircraft N580JA

On 17 September 2025, a Piper PA-28-181 sustained extensive structural damage during an emergency landing near Astatula, Florida. During the approach to the runway, the pilot discontinued the landing due to traffic on the runway and carried out a go-around. During the subsequent climb, the autopilot was engaged. Shortly thereafter, the pilot noticed that the engine rpm increased and that the aircraft was descending. The pilot therefore disengaged the autopilot and stopped the descent. Shortly afterwards, the pitch attitude changed downwards and the aircraft again began to descend. The pilot applied force to the control wheel to arrest the descent, but the aircraft nevertheless continued to descend. When the pilot realised that it was not possible to stop the descent, he elected to carry out an emergency landing on a gravel road.

After the accident, it was established that the elevator trim was in the full nose-down position, and that the control surface position corresponded with the trim indicator in the cockpit. The elevator trim had not, according to the pilot, been operated during the sequence of events. The occurrence is under investigation.

1.19 Special methods of investigations

None.

2. Analysis

In the days preceding the flight, the aircraft had undergone maintenance during which three servos in the autopilot system were replaced. The serious incident occurred during the first flight following the maintenance actions and shortly after the autopilot had been engaged. A central question in the analysis is therefore whether, and to what extent, the maintenance actions and the autopilot system influenced the sequence of events.

To facilitate understanding of the sequence of events, the analysis is conducted in two stages:

1. the period up to the point at which the pilot lost control of the aircraft
2. the period from the loss of control until the pilot regained control.

The analysis also addresses issues relating to control measures following maintenance work involving autopilot systems, and how the configuration settings of autopilot systems are adapted to the aircraft type. Finally, the design of the service bulletin, the manuals and the maintenance organisation's work order are analysed.

2.1 Sequence of events up to the loss of control

It was the first flight after the maintenance, and the maintenance organisation asked the pilot to test the autopilot system during the flight. During the pre-flight inspection, the pilot noted no discrepancies. After engine start, the pilot taxied for departure and followed the instructions in the aircraft checklist.

The take-off and climb to cruise altitude were normal and conducted with the autopilot disengaged. When the cruise altitude was reached, the pilot reduced the rate of climb. The autopilot was then engaged during the climb, which resulted in the aircraft ending up above the autopilot's target altitude. The pilot did not experience anything abnormal when the autopilot was engaged.

When the pilot needed to adjust the heading in order to avoid a restricted area, his attention was directed outside the aircraft. The pilot therefore did not notice that a mistrim alert was displayed.

Shortly before the abrupt change in pitch attitude, flight data from the autopilot system shows that the autopilot issued a nose-down command to the elevator servo, which in turn commanded nose-down trim from the elevator trim servo. Despite this, the aircraft started to climb shortly thereafter.

When the pilot again focused inside the cockpit, just over three seconds remained until control of the aircraft was lost. The pilot has not been able to give a detailed account of that part of the sequence of events. It is likely that, for some reason, he perceived the situation as abnormal, as he grasped the control wheel with both hands. This was not something he normally did when the autopilot was engaged. Just over one second after the pilot grasped the control wheel, the aircraft's pitch attitude increased rapidly. In connection with this, the flight data show that the pilot manually disengaged the autopilot using the switch on the control wheel.

2.1.1 Why did the pitch attitude suddenly increase?

The investigation has not identified any mechanical defects in the aircraft that could explain the increase in pitch attitude. Nor is there anything to indicate that the pilot influenced the sequence of events in that phase.

Data retrieved from the autopilot system show that, during the period immediately preceding the rapid pitch attitude change, the autopilot had commanded both the elevator servo and the pitch trim servo to drive nose-down. Despite this, the outcome was a substantial increase in pitch attitude. This raises the question of whether the elevator servo and/or the pitch trim servo actually operated in the correct direction in relation to the autopilot command.

The SHK assesses that it can be ruled out that the elevator servo was operating in the wrong direction. Had that been the case, it would, within a considerably shorter time after autopilot engagement, have led to a much greater effect on the flight path. This, in turn, means that there are grounds to examine more closely whether the pitch trim servo and thereby the trim tab moved in the wrong direction.

The trim tab is used to reduce the control force required for a given elevator deflection, that is, the magnitude of the elevator hinge moment. If the trim tab was, for any reason, to move in the wrong direction, the elevator hinge moment would instead increase.

The autopilot system recorded the torque values generated by the elevator servo and the trim servo in order to drive the elevator and the trim tab respectively. The torque values for the trim servo show that the trim tab moved and that its deflection increased, see Section 1.11.3, Figure 19. Had the trim tab deflected in the direction commanded by the autopilot, the torque value for the elevator servo ought to have decreased. Despite this, the system recorded that the magnitude of the torque increased to nearly the elevator servo's maximum value. It can therefore be established that the effect of the trim tab deflection was opposite to that intended.

SHK assesses that the only reasonable explanation for this is that the pitch trim servo, and thereby the trim tab, moved in the wrong direction.

When the autopilot was disengaged, the control signal to the elevator servo ceased and thereby the torque applied by the servo to the elevator was removed. At the same time, the trim tab remained in the position it had immediately before autopilot disengagement. This led to the elevator rapidly changing its deflection in order to reach an aerodynamic equilibrium corresponding to the trim tab deflection. This, in turn, resulted in the sudden change in pitch attitude.

The question of the reason why the trim system moved in the wrong direction is addressed in Section 2.2.

2.1.2 Probable sequence of events leading up to the Upset

The most probable sequence of events is as follows. When the autopilot was engaged, the aircraft was in a climb. The autopilot then began to correct the flight path using the elevator servo, which in turn led to the aircraft commencing a slow descent towards the selected altitude. As the torque on the elevator servo increased, the pitch trim servo began to assist. SHK has observed that the trim moves slowly at low torque. However, when the need for trim assistance increases, the pitch trim servo speed also increases, and consequently the angular rate of the trim tab.

Due to the incorrect trim direction, the pitch trim tab acted against the autopilot command. When the elevator servo had demanded trim assistance for ten seconds and the torque exceeded 50 per cent of its maximum value, an alert was activated and displayed on the upper GI 275 instrument. The cockpit video shows that an alert was triggered, but it is not possible to determine whether it related to trim down or trim up. The alert probably concerned trim down (Trim DN).

The pitch trim tab continued to act against the autopilot pitch command. The system did not detect that the pitch trim tab was moving in the wrong direction, which it is not designed to do. As a result, the desired flight attitude could not be achieved, and the elevator servo torque was increasing which in turn increased the pitch trim speed. When the elevator servo was no longer able to counteract the forces, the aircraft started to climb. The more the autopilot trimmed, the more the pitch attitude increased. Initially, the development was slow and then escalated into a rapid and uncontrolled change of flight attitude.

The pilot probably reacted to the abnormal change in pitch attitude in the final stage of the sequence and disengaged the autopilot. When the autopilot was disengaged, the pitch trim servo torque was 24 per cent of the maximum possible 60 per cent. This meant that the pitch trim was not at its travel limit, since in that case the torque would have been close to 60 per cent. SHK has calculated that the pitch trim tab deflection was approximately 18 degrees, which is close to the maximum deflection of 22 degrees. The deflection of the pitch trim tab at that time in turn generated significant control column forces when the autopilot was disengaged. The control column force corresponding to this deflection has been calculated as 180 N.

The pilot was not prepared for the force that occurred, which led to him being startled by the situation (Startle Effect, see Section 1.18.5). The pilot has stated that he reacted to the rapid increase in pitch attitude, but the change was so abrupt and substantial that there was probably insufficient time to apply enough nose-down control column input before the situation further developed into an uncontrolled flight condition.

2.2 The Upset

The pilot was probably affected by the startle effect during most of the uncontrolled flight condition. When the pitch attitude increased rapidly, the pilot believed that the autopilot was still engaged and causing the control forces, which meant that a significant proportion of his cognitive capacity was devoted to trying to understand and manage the situation. Although he was not trained to handle abnormal attitudes, he reacted instinctively, possibly because the high pitch attitude restricted his forward visibility, and applied full left aileron. This

manoeuvre reduced the pitch attitude and thereby decreased the risk of the situation deteriorating further. The manoeuvre was repeated later during subsequent instances of high pitch attitude.

2.2.1 Frequent intervention by the ESP system

The autopilot's ESP system (see Section 1.6.8) is designed to intervene within certain limits in abnormal attitudes when the autopilot is disengaged. Flight data from the autopilot system show that the ESP system was activated during the uncontrolled flight condition. The roll and pitch servos commanded control inputs to help the pilot return to a normal attitude, which probably reinforced his perception that the autopilot was still engaged.

The ESP system assists the pilot if the pitch attitude exceeds either 20 degrees nose-up or 15 degrees nose-down, or if the bank angle exceeds 45 degrees. The system is deactivated if the pitch attitude exceeds 50 degrees or the bank angle exceeds 75 degrees. During the uncontrolled flight condition, there were repeated variations in pitch attitude between 51 degrees nose-down and 49 degrees nose-up, and in bank angles between 9 and 121 degrees to the left. As a result of the system logic, the ESP system was therefore deactivated and reactivated frequently. In the most critical attitudes, the system was inactive. When the aircraft again reached bank angles of less than 75 degrees and pitch attitudes of less than 50 degrees, the system was, however, reactivated and applied control inputs. This was probably perceived as abnormal, as control inputs from the system occurred when the aircraft was moving towards more normal attitudes, and is likely to have further reinforced the pilot's impression that the autopilot was engaged.

There is an emergency procedure for autopilot malfunction and pitch trim runaway. In accordance with the checklist, the autopilot disconnect button should be pressed and held. While the button is held, the ESP system is deactivated and will therefore not intervene during an upset. Had the pilot kept the button continuously depressed in accordance with the checklist, the ESP system would not have intervened during the uncontrolled flight condition. This might, in turn, have increased his situational awareness and freed up capacity to manoeuvre the aeroplane out of the upset.

2.2.2 Incorrect trim made it difficult to recover from the uncontrolled flight condition

When the uncontrolled flight condition was triggered, the pitch trim tab deflection was approximately 18 degrees nose-up (out of a maximum of 22 degrees). During those parts of the sequence when the pitch attitude decreased, the aircraft speed increased. This in turn increased the authority of the trim tab, which affected control surface and control column forces. This made it more difficult for the pilot to counteract the resulting forces, as aerodynamic loads increase with the square of the airspeed. In addition, the pilot increased engine power, which further contributed to higher control column forces.

The aircraft is designed so that it should be possible for the pilot to manoeuvre it even when it is mistrimmed, and maximum control column forces are specified for both one-handed and two-handed grip. The pilot devoted a considerable proportion of the time to attempting to disengage the autopilot, even though it was already disengaged. As a result, for part of the time he was holding the control wheel with only one hand whilst trying to disconnect the autopilot with the other. This reduced his ability to counteract the forces, which at certain points were probably above the certification limit for a one-handed grip (222 N), but still

below the limit for a two-handed grip (334 N). When the flight attitude became more abnormal, however, the pilot gripped the control wheel with both hands, which improved his ability to control the aircraft.

It is possible that the pilot trimmed the aircraft during this period, even though he does not recall doing so. On two occasions in the video, his right hand is outside the frame and, as the trim wheel is not visible in the recording, it cannot be determined with certainty whether manual trimming was carried out. A reduced climb amplitude during the sequence, in combination with the fact that the speed does not decrease, indicates that the trim setting changed.

2.2.3 The pilot regained control of the aircraft

The pilot has stated that he saw no other solution than to pull the autopilot circuit breaker in order to remove the force he perceived as being applied by the autopilot. At the moment when the circuit breaker was pulled, he felt that he regained control of the aircraft. However, there is nothing in the flight data to indicate that the autopilot was engaged or that the servos were active and applied forces into the system when the circuit breaker was pulled.

The factors that contributed to the pilot being able to regain control were instead probably the reduced control column forces resulting from the decrease in airspeed and reduced power setting. In addition, when the opportunity arose, it is likely that the pilot trimmed the aircraft manually, without being aware of it. The trimming likely occurred both during the upset condition and when control was being regained. The video recording shows that, even after control had been regained, the control column was used in a manner indicating that the aircraft was still not fully in trim.

2.3 Why did the pitch trim servo operate in the wrong direction?

There may be several reasons why the pitch trim operates in the wrong direction. The most likely are:

- the hardware, i.e. the pitch trim servo, was installed incorrectly during the maintenance work
- a fault in the servo function
- the software was installed or configured incorrectly during the maintenance work.

2.3.1 It is unlikely that the hardware was incorrectly installed

Two days after the serious incident, SHK examined the system and established that the hardware had been correctly installed. This was also confirmed by an independent maintenance organisation, which was likewise an authorised Garmin dealer. It is therefore unlikely that the hardware was incorrectly installed at the time of the serious incident.

However, the aircraft was not under SHK's control during the period between the serious incident and SHK's initial examinations. It is therefore not possible to rule out that changes to the hardware may have been made during that time.

2.3.2 It is unlikely that there was a fault in the pitch trim servo

Garmin has carried out examinations of the pitch trim servo. These examinations did not identify any faults that may have contributed to the serious incident.

Garmin declined the participation of NTSB and SHK in the conduct of these tests (see Section 1.16.4). The normal procedure is for the investigation authorities to be take part during the tests and inspections. The investigation authorities are responsible for ensuring that examinations conducted as part of an investigation are carried out in an objective and impartial manner. If the investigation authorities are denied insight into the examinations, their ability to assess the reliability of those examinations is reduced.

The fact that the investigation authorities were not able to be present during the examinations in question means that it is not possible for SHK to rule out the existence of a fault in the pitch trim servo, even though, in view of the results of Garmin's own examinations, this is unlikely.

2.3.3 The fault was probably related to configuration settings or to the software

SHK has carried out tests to determine whether incorrect configuration settings of the pitch trim servo could cause the pitch trim to move in the wrong direction. One of the parameters that can be configured during installation is the trim *Servo Direction*, i.e. the signal that determines in which direction the hardware should operate for a given command from the autopilot. This parameter can be set either to *Normal* or to *Reverse*. On the aircraft concerned, the correct configuration was *Reverse*.

In its testing, SHK examined the effect of setting this parameter incorrectly to *Normal* in both the GI 275 instrument and in the servo. The test showed that this results in the trim servo moving in the opposite direction to that commanded by the autopilot. At the same time, the system records data indicating that the trim servo has moved in the commanded direction. An incorrect configuration of this kind thus produces an erroneous outcome that is consistent with how the fault manifested itself during the serious incident.

During the examinations carried out two days after the serious incident, the *Servo Direction* setting was found to be set correctly to *Reverse*.

The maintenance organisation that carried out the installation has stated that it initially had difficulty getting the system to accept the new software, but that the update was eventually completed. The organisation has further stated that no changes to the configuration settings were made either during the maintenance action or after the serious incident.

A plausible explanation for the pitch trim servo moving in the wrong direction is that the trim *Servo Direction* parameter was, for some reason, set to *Normal* at the time of the serious incident. The servos were delivered with this default setting, which means that only the corresponding parameter in the GI 275 instrument needed to be set to *Normal* for the system to pass the self-test.

However, the investigation cannot establish with certainty that this was the case. Nor is it possible to determine whether such a fault would in turn be due to a design error or other shortcomings in the software, resulting in certain configuration actions not being imple-

mented correctly, or whether it would be due to incorrect configuration during the maintenance work.

The fact that the investigation has not been able fully to clarify the reason why the pitch trim servo moved in the wrong direction is due to several factors. It is attributable to two main circumstances: partly that the maintenance organisation did not document the maintenance work to the extent required, and partly that the manufacturer of the autopilot system has not, to a sufficient degree, provided the information needed for SHK to be able fully to understand the system logic.

2.4 Autopilot systems must be easy to understand

Technological developments have led to the introduction of new, advanced autopilot systems. These systems offer a range of complex functions and user options that contribute to increased safety and efficiency in flight. At the same time, they are becoming increasingly sophisticated and extensive, which can make it challenging for pilots to fully understand all functions and to use them correctly. There are no formal training requirements for pilots in general aviation in respect of autopilot systems, which means that it is up to the pilots themselves to learn the system. Although the club's pilots flew with an instructor, the instruction provided was general in nature and focused on basic use of the autopilot.

Manufacturers provide pilot guides and instructional videos, but it is nonetheless not always possible for users to assimilate all the information. This is particularly true for pilots with limited experience of, and training on, advanced autopilot systems. Even in airline operations, where pilots undergo training and simulator checks, similar challenges exist. Under time pressure or in other stressful situations, the risk of certain functions being misunderstood increases, which affects system handling and may constitute a safety risk.

During most of the upset condition, the pilot believed that the autopilot was engaged (see Section 2.2). It cannot be ruled out that a higher level of system understanding would have led the pilot to interpret the situation differently, which in turn might have enabled him to devote a greater share of his cognitive capacity to flying the aircraft, rather than attempting to disconnect the autopilot.

The incident in question, together with SHK's examinations of the autopilot system, indicates that manufacturers of autopilot systems overestimate the ability of pilots with limited experience to fully understand and manage system functions. The ability to quickly absorb and interpret a large amount of information may also be overestimated, particularly when this is presented on the Primary Flight Display (PFD), which is small in relation to the volume of information shown.

It is therefore crucial that manufacturers aim to design systems that are logically structured and intuitive to use. Warnings and alert must be clear and comprehensible and must be designed in such a way that they genuinely help pilots to quickly identify and understand when action is required.

2.5 Autopilot system mistrim alert

Shortly before the upset condition, the GI 275 instrument displayed a mistrim alert. This alert constitutes critical information and indicates that the pilot might need to take action in order to maintain the continued safe operation of the flight. In the serious incident, the

mistrim alert was not noticed by the pilot, which contributed to the subsequent loss of control. There is therefore reason to examine whether the mistrim alert in the system clearly draws the pilot's attention, enabling the pilot to recognise that control forces are present in the system.

The mistrim alert is indicated on the GI 275 instrument by TRIM UP or TRIM DN. It shares a limited display area with a considerable amount of other information. One challenge for the pilot is that Garmin's manuals do not provide an overview of where on the display the mistrim alert is presented. This makes it more difficult for the pilot to prepare and, ultimately, to notice and interpret the alert from the system. The mistrim alert is presented only visually and as a static indication on the instrument. There is no associated aural alert, which further increases the risk of it being overlooked. This is particularly the case when the pilot is operating under VFR²³ and is not continuously monitoring the flight instruments, see Figure 21.



Figure 21. Amber mistrim alert on the PFD indicated by a white arrow. Source: Supercub.org. Annotation and mistrim alert (TRIM DN) added by SHK.

From a system perspective, it may be understandable that aural alerts are not used, since the GI 275 can be installed both with and without a pitch trim servo. In an installation without a trim servo, an aural alert could be distracting and create unnecessary alert overload, as all trimming is carried out manually. In systems with a pitch trim servo, by contrast, trimming takes place automatically, which ought to result in fewer alerts.

If the system were equipped with a more sophisticated logic that adapted the alert presentation to the type of installation, it could provide clearer warnings in those cases where they are genuinely needed, without overloading the pilot with unnecessary alerts. Had the pilot received a clear alert relating to the trim state, he could have intervened earlier, which would probably have allowed the situation to be managed with significantly lower control column forces. This, in turn, would have enabled greater focus to be placed on flying the aircraft and regaining control, rather than attempting to disengage the autopilot.

²³ VFR (Visual Flight Rules).

It is also a certification requirement which states that protection must be provided against hazardous autopilot commands or autopilot malfunctions. It is worth noting that certain critical warnings, such as the overspeed warning, are already accompanied by aural alerts.

An aural alert, in addition to the visual mistrim alert, would provide the pilot with better opportunities to detect and manage a developing situation in time, before it leads to a loss of control of the aircraft. Garmin is therefore recommended to examine the possibilities for presenting mistrim alert in a clearer manner.

2.6 Maintenance planning and execution

2.6.1 Garmin's Service Bulletin was unclear

Garmin Service Bulletin 23024 stipulates that the replacement of the servos is to be carried out in accordance with the instructions in the relevant documentation listed under the References section (see Section 1.6.9, Table 1), and that the necessary checks are to be performed after installation.

Apart from a reference in the Service Bulletin to the GFC 500 Installation Manual, which in turn refers to the aircraft type-specific installation addendum, there is no description of how the work sequence is to be structured. Instead, a number of reference documents are listed which contain extensive information for the complete Garmin system.

The GFC 500 Maintenance Manual initially describes the tasks to be carried out when replacing a servo. This manual then refers to the GI 275 Maintenance Manual for procedures relating to software updating. However, the latter manual is not included among the documents referenced in the Service Bulletin.

The prescribed work sequence appears fragmented. SHK assesses that the instructions in the Service Bulletin are not sufficiently clear regarding which tasks are to be carried out when replacing the affected servos, including software, and which checks are to be conducted after the replacement. This results in an increased risk of errors occurring during the maintenance task, particularly if the maintenance organisation is not a Garmin dealer, as access to training, guidance materials, up-to-date manuals, and support may be limited.

Garmin is therefore recommended to ensure that Service Bulletins relating to maintenance on autopilot systems are drafted in such a way that it is clearly evident which tasks are included in the maintenance, and that adequate checks are specified and carried out following completion of the maintenance.

2.6.2 The combined airworthiness organisation's work order was inadequate

Prior to the maintenance action, the combined airworthiness organisation issued a work order referring both to Garmin Service Bulletin 23024 Rev A and to the maintenance manual for the Cessna 172 series with Garmin GFC 700 autopilot and G1000 installation. However, the reference to the maintenance manual related to a different autopilot and instrumentation system from that installed in the aircraft, which meant that the documentation was not applicable. This may have created uncertainties regarding which actions and checks were to be carried out.

The work order did not include the individual steps in the maintenance process or clear references to the maintenance data. As a consequence, there are no entries (*Sign-offs*) for individual steps in the maintenance process relating to the software update and checks. This lack of traceability in the documentation makes it difficult, in retrospect, to establish exactly which maintenance data actually formed the basis for the work carried out.

SHK's overall assessment is that the work order was inadequate regarding the instructions on how the work was to be performed and the applicable maintenance data.

The combined airworthiness organisation is therefore recommended to ensure that work orders for maintenance are clearly and correctly drafted, and that they ensure adequate checks are carried out following completion of the maintenance.

2.6.3 Certain documentation relating to the software update was missing

With regard to the software update of the autopilot system, the GFC 500 Maintenance Manual refers to the software update procedure in the GI 275 Maintenance Manual, Section 5.14. The introductory information in Chapter 5 states that the system configuration is to be saved and that the configuration log is to be printed before any units are replaced. The purpose of the export is to ensure that, following the software update, the settings can be configured in the same way and verified. Such an export was carried out by the maintenance organisation on the day the aircraft arrived in Örebro.

Section 5.15, System Checks, in the GI 275 Maintenance Manual describes how to proceed in order to ensure that all units are correctly configured. It states that the system is to be configured using the previously printed configuration log. The maintenance organisation has stated that this action was carried out.

Furthermore, the introductory information in Chapter 5 specifies that, after maintenance, the maintenance organisation is to save the configuration log to a USB memory device and print it out for inclusion in the maintenance documentation. The maintenance organisation has not been able to demonstrate that any such export was carried out after the software update.

Exporting and documenting the configuration log after the software update would have facilitated the maintenance organisation's verification that the settings in the autopilot system corresponded either to the previously exported configuration log or to the model-specific installation addendum. Had an independent inspection been carried out (see Section 2.6.5), such a document could also have been used to document the verification of the configuration settings during the inspection.

The absence of this documentation also meant that it was not possible for SHK subsequently to verify that the settings in the autopilot system corresponded either to the configuration log documented before the maintenance or to the model-specific installation addendum.

The maintenance organisation is therefore recommended, in connection with software maintenance on autopilot systems, to ensure that actions are documented in accordance with the instructions issued by the manufacturer of the autopilot system.

2.6.4 Absence of an instruction for checking the pitch trim in the manual

The GFC 500 Maintenance Manual stipulates that checks are to be carried out on equipment that has been replaced and configured. One of these checks concerns the time taken by the pitch trim servo to move the pitch trim tab through its full range of travel when the manual electric pitch trim is used. The GI 275 flight data log in question contains no data indicating that such a check was performed after the replacement. Had the check been carried out, it would have been visible in the instrument's recorded data.

However, the maintenance organisation did perform a functional check of the pitch trim, activating it via the switch on the control yoke. According to the maintenance organisation, this functional check showed that the trim tab moved correctly. That check does not, however, ensure that the trim tab moves in the correct direction when the autopilot activates the automatic electric pitch trim function. This is because the *Trim Direction* parameter only affects the trim direction for the electric manual trim, in contrast to *Servo Direction*, which affects both the automatic pitch trim and the electric manual trim.

One possible scenario is that the settings for the *Servo Direction* and *Trim Direction* parameters were inadvertently mixed up. Regarding the aircraft in question, the correct parameter setting for *Servo Direction* was *Reverse* and for the parameter *Trim Direction* *Normal*. If these settings had been set the other way round – *Servo Direction* to *Normal* and *Trim Direction* to *Reverse* – the aircraft's behaviour would have been consistent with the behaviour observed during the serious incident (as described in Section 2.2.3). The functional test carried out by the maintenance organisation using only the electric manual trim would then have shown a correct trim direction (see Section 1.16.4, Table 3, test #3). This would also explain why the maintenance organisation did not detect that the electric automatic pitch trim was operating in the opposite direction. A functional test using only the electric manual pitch trim does not capture all combinations of settings and outcomes for the trim servo.

The GFC 500 Maintenance Manual does not contain any instruction on how the automatic electric pitch trim function is to be checked after a maintenance action. By contrast, the GI 275 Installation Manual, which relates to new installations, contains a section describing how the automatic trim function of the autopilot system is to be functionally tested. There was no direct cross-reference in the Service Bulletin or the Maintenance Manual to this section, which meant that the maintenance organisation was not explicitly directed to carry out such a functional test. A functional check of this kind would have resulted in the incorrect direction of trim tab movement being detected, regardless of the underlying cause of the fault.

Garmin is therefore recommended to clarify the GFC 500 Maintenance Manual so that it includes an instruction describing how the automatic electric pitch trim is to be checked following maintenance.

2.6.5 No independent inspection of the software installation was conducted after maintenance

When critical maintenance has been performed, the maintenance organisation shall conduct independent inspections (see Section 1.18.1). In this case, the maintenance organisation performed such an inspection of the mechanical installation of the servos. However, no independent inspection of the software update or the associated configuration settings was

performed. No other method of fault identification was applied either. This meant that no comprehensive functional check to verify that the autopilot system trim function was operating in the correct direction was performed. Thus, the final safety barrier to detect and reduce the risk of maintenance errors that could affect flight safety after a critical maintenance action was not maintained.

The maintenance organisation is therefore recommended to ensure that independent inspections are carried out, or that other methods of fault detection are applied, in connection with critical maintenance actions that include the installation and configuration of software.

3. Conclusions

3.1 Findings

- a) The aircraft had undergone maintenance during which parts of the autopilot system had been replaced.
- b) The pilot did not detect anything abnormal during the daily inspection.
- c) Shortly after the autopilot was engaged, the pitch attitude began to increase, and shortly thereafter the autopilot was disengaged.
- d) Immediately after the autopilot had been disengaged, the flight became uncontrolled.
- e) There is no indication that the pilot influenced the sequence of events up to the onset of the uncontrolled flight condition.
- f) The pilot was not prepared for the control forces that arose on the control wheel when the autopilot was disengaged, which led to him being startled by the situation.
- g) During the uncontrolled flight condition, the pilot believed that the autopilot was engaged and was adversely affecting the flight. He therefore made numerous attempts to disengage it, which increased his workload.
- h) The investigation has not identified any mechanical defects in the aircraft that could explain the increase in pitch attitude that initiated the uncontrolled flight.
- i) The increase in pitch attitude was due to the autopilot system's pitch trim servo moving in the wrong direction during the serious incident.
- j) During SHK's examinations of the aircraft, the servo operated in the correct direction.
- k) The most probable reason why the servo operated in the wrong direction is an error in the software configuration carried out during the maintenance. However, it cannot be ruled out that there was a fault in the software.
- l) The Service Bulletin that gave rise to the maintenance was unclearly drafted.
- m) The work order issued by the combined airworthiness organisation was inadequately drafted.
- n) Certain maintenance tasks, concerning the software update, had not been documented.
- o) The maintenance manual for the autopilot system contained no description of functional checks of the automatic pitch trim system.
- p) The functional checks carried out after the maintenance were inadequate.
- q) No independent inspection was performed to ensure that the software update and configuration settings were correct following the maintenance.

3.2 Causes/Contributing Factors

The probable cause why the upset occurred was that the configuration settings for the autopilot system's pitch trim were incorrect, causing the autopilot to command pitch trim in the opposite sense to that intended for the aircraft, i.e. nose-up instead of nose-down.

Several factors contributed to the configuration settings probably being incorrect:

- The Service Bulletin and the manuals to which it referred did not prescribe adequate functional checks following maintenance of the autopilot's pitch trim function.
- The maintenance organisation did not take sufficient measures to ensure that, after maintenance, the configuration settings were in accordance with the prescribed settings.
- The maintenance organisation did not carry out any independent inspection, nor did it apply any other method to detect errors following the software updates and configuration settings implemented during the maintenance.

A contributing factor of the upset condition was that the pilot did not notice the autopilot system's mistrim alert. This was because the alert provided by the autopilot system was not presented in a sufficiently clear manner to draw the pilot's attention to the significant control forces present in the autopilot system.

4. Safety recommendations

Garmin is recommended to

- examine the possibilities for presenting mistrim alert to the pilot in a clearer manner when a pitch trim servo is installed and trimming is automatic (see Section 2.5). *(SHK 2026:17e R1)*
- ensure that Service Bulletins relating to maintenance on autopilot systems are drafted in such a way that it is clearly specified which tasks are included in the maintenance, and that they ensure adequate checks are carried out following completion of the maintenance (see Section 2.6.1). *(SHK 2026:17e R2)*
- clarify the GFC 500 Maintenance Manual so that it includes an instruction describing how the automatic electric pitch trim is to be checked after maintenance has been carried out on the trim system (see Section 2.6.4). *(SHK 2026:17e R3)*

The Combined Airworthiness Organisation is recommended to

- ensure that work orders for maintenance are clearly and correctly drafted, and that they ensure adequate checks are carried out following completion of the maintenance (see Section 2.6.2). *(SHK 2026:17e R4)*

The Maintenance Organisation is recommended to

- ensure, in connection with software maintenance on autopilot systems, that actions are documented in accordance with the instructions issued by the manufacturer of the autopilot system (see Section 2.6.3). *(SHK 2026:17e R5)*
- ensure that independent inspections are carried out, or that other methods of fault detection are applied, in connection with critical maintenance actions that include the installation and configuration of software (see Section 2.6.5). *(SHK 2026:17e R6)*

The Swedish Accident Investigation Authority respectfully requests to receive, **by 16 December 2026 at the latest**, information regarding measures taken in response to the safety recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Johan Albihn

Mats Trense