Statens haverikommission

Serious Incident involving an aircraft of type Embraer-550 Praetor 600

The Swedish Accident Investigation Authority has investigated a serious incident at Stockholm/Bromma Airport, Stockholm County, on September 11, 2024.

11 December 2025

Final report

SHK 2025:19e

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.

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Contents

Summary

Shortly after take-off from Runway 12 at Stockholm/Bromma Airport, the pilots received a warning of a Flight Control System failure, and the aircraft experienced an increased pitch rapidly to an angle beyond what the crew expected. The pilot attempted to counteract the pitch movement using the control stick but noted that the stick had limited authority. The pilot then used the manual pitch trim to decrease the angle of the horizontal stabiliser and stop the continued climb. The crew issued a Mayday call over the radio, and the air traffic controller directed them for an approach and landing at the departure airport after the full functionality of the Flight Control System had been restored.

The aircraft's unexpected upward pitch movement was caused by a failure in both flight control computers after rotation. The Flight Control System degraded to a simpler control mode, called Direct Mode, which resulted in the stabiliser ceasing auto-trimming, leaving the aircraft at an untrimmed condition for the prevailing airspeed.

The operator, Flexjet, has been exposed to two similar events within a short timeframe. After the previous incident at Paris-Le Bourget, Flexjet implemented specific measures to mitigate the effects should a similar situation occur again.

During system testing conducted by the manufacturers, the fault was successfully recreated. The identification of the system's behaviour provided the basis for modifying the Flight Control System to reduce the risk of such failures.

SHK assesses that the measures taken by the manufacturer are sufficient to address similar incidents in the future.

During the investigation, it emerged that several similar occurrences had taken place without being reported to the Safety Investigation Authorities (SIA) in the countries where the events occurred. SHK considers this to represent a systemic issue but assesses that EASA's[1] taken and planned safety actions will effectively improve the process so that safety reports reach the appropriate SIA in a timely manner to enable an efficient investigation.

Causes of the Serious Incident

The aircraft's rapid and unexpected upward pitch movement immediately after lift-off was caused by a fault causing both Flight Control Computers to reset. This caused the system to downgrade to a simpler control mode, which also resulted in the stabiliser angle not automatically adjusting for the increasing airspeed.

The extremely out-of-trim condition required the pilot to apply almost full stick inputs to regain the commanded pitch attitude and forcing a manual re-trim of the aircraft.

Safety recommendations

None.

Given the measures already taken by EASA, Flexjet and Embraer, SHK refrains from issuing further safety recommendations.

[1] EASA – The European Union Aviation Safety Agency.

Final report SHK 2025:19e

Data	
Aircraft	Registration, type: 9H-MFX Model: Embraer-550 Praetor 600 Valid Certificate of Airworthiness and Airworthiness Review Certificate (ARC) [2] Serial number: 55020189 Operator: Flexjet Operations Malta Ltd (MT.0068)
Time of occurrence:	11 September 2024, 17:03 hrs in daylight Note: All times are given in Swedish daylight-saving time (UTC[3] + 2 hours) if not stated otherwise
Place	Stockholm/Bromma Airport, Stockholm County, (59°21'N 017°57'E, 600 feet above mean sea level)
Type of flight	Commercial Air Transport
Weather	According to SMHI's analysis: Wind south-easterly at 10 knots, with gusts up to 16 knots, visibility between 5 and 10 km, cloud base between 300 and 800 feet, temperature/dew point +15/+14°C, QNH[4] 996 hPa.
Persons on board	In total: 5 Crew members including service personnel: 3 Passengers: 2
Injuries	To persons: None Damage to aircraft: None Other damage: None
Commander:	Age: 45 years Licence: ATPL(A)[5] Total flying hours: 4,659 hours
Co-pilot	Age: 50 years Licence: ATPL(A) Total flying hours: 6,700 hours

[2] ARC – Airworthiness Review Certificate.

[3] UTC – Coordinated Universal Time.

[4] QNH – atmospheric pressure adjusted to mean sea level.

[5] ATPL(A) – Airline Transport Pilot License (Aeroplanes).

The investigation

On 12 September 2024, SHK was informed by LFV[6] of an incident involving an aircraft with the registration 9H-MFX, which occurred after take-off from Stockholm/Bromma Airport, Stockholm County, on 11 September 2024, at 17:03.

The incident has been investigated by SHK, represented by John Ahlberk as Chairman until 3 March 2025, and thereafter by Jonas Bäckstrand. The investigation team also included Gideon Singer, who acted as Investigator in Charge (IIC) and Operational Investigator, and Kristoffer Danèl, who served as Technical Investigator.

SHK was assisted by Ulf Persson, who served as an expert on Flight Control Systems.

Robert Camilleri participated as accredited representative on behalf of Malta.

Diego Bandeira da Costa participated as the accredited representative participated as accredited representative on behalf of Brazil with support from Leandro Hilário from May 19 2025. They were assisted by advisors from Embraer, including Daniel Satoshi Marimoto and Fabio Couto Bonnett.

Steve Connor participated as the accredited representative on behalf of the United Kingdom.

Aaron Sauer participated as accredited representative on behalf of the USA.

Linus Dyner followed the investigation as an advisor for the Swedish Transport Agency, and Reijo Stenman followed the investigation as an advisor for EASA.

In addition, the following organisations were notified: The International Civil Aviation Organisation (ICAO), EASA and the European Commission.

Investigation material

- Interviews were conducted with the pilots involved in the incident, the pilots from a similar incident at Paris-Le Bourget Airport on 2 August 2024, Flexjet's test pilot, and the operator's key personnel.
- An evaluation of the incidents, along with an assessment of the pilots' workload and the aircraft's flight characteristics, was carried out by SHK in an approved training simulator.
- The type documentation for the aircraft, as well as the technical documentation specific to the aircraft involved, were examined.
- Recorded data from the incident and the similar incident at Le Bourget on 2 August 2024, were analysed.
- Memory units from the aircraft's Flight Control Computers (FCCs[7]) were analysed.
- Troubleshooting results from Flight Control System tests conducted by the manufacturers were reviewed and analysed.
- Incident reports from emergency response units and air traffic control were collected and analysed.

A fact-finding meeting was held on 10 June 2025. During the meeting, SHK presented the factual material available at that time.

[6] LFV – Swedish ATC provider.

[7] FCC – Flight Control Computers.

1. Factual information

1.1 Description of the sequence of events

1.1.1 Operational conditions

At the time of the incident, two of Flexjet's customers were scheduled to be flown from Stockholm/Bromma Airport to Ostend-Bruges International Airport in Belgium. The aircraft was operating under the callsign FJO67M.

The captain was seated in the left pilot seat and was the Pilot Flying (PF[8]). The first officer was seated in the right pilot seat and acted as the Pilot Monitoring (PM[9]).

The weather in the area near the airport was cloudy with rain and moderate horizontal visibility.

The airport's air traffic control was operational and coordinating traffic with Stockholm ATCC[10]. The crew received a clearance from Bromma Tower to climb to 3,000 feet and to contact Stockholm Control after departure. During the same period, one landing and one departure were underway at the airport.

To provide a better understanding of the pilots' handling of the situation, an illustration is provided showing the pilots' primary view from their seated positions in the cockpit, as well as the positioning of the control sticks and the displays presenting flight instruments and system information (see Figure 1).

Figure 1. Design of the Cockpit. Screens display flight instruments and system information. Image: Embraer.

[8] PF – The Pilot Flying.

[9] PM – The Pilot Monitoring.

[10] ATCC – Air Traffic Control Center.

Specifically, the three cockpit functions that were important in the event are described below (see Figure 2).

Each pilot can control the aircraft using a side-stick and pedals. The side-stick provides control inputs for pitch and roll. The aircraft can be trimmed in pitch using the trim control, which adjusts the angle of the horizontal stabiliser. This is normally done automatically in flight but can be performed manually on the ground or in the air in certain failure scenarios.

The pilot can change the mode of the Flight Control System by pressing the FLIGHT CONTROLS NORMAL MODE button on the pedestal.

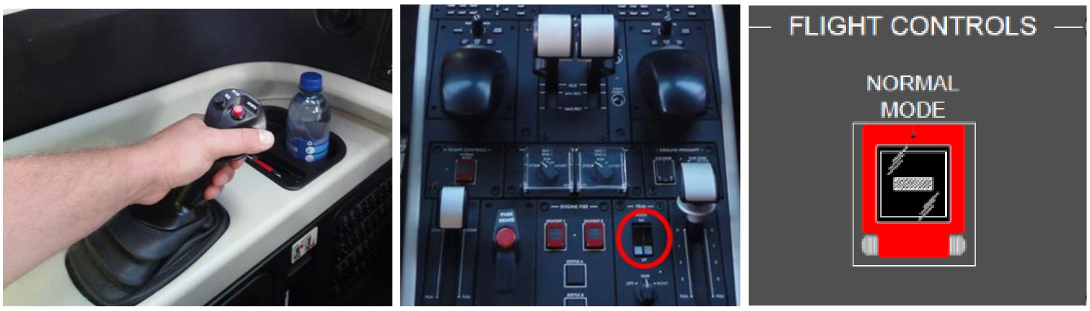


Figure 2. The left pilot's control stick for pitch and roll, the manual pitch trim control (Pitch Trim) on the central pedestal, and the Flight Controls NORMAL MODE button (a red light illuminates on the button when the system is in DIRECT MODE). Source: Embraer. A red circle indicating the pitch trim control was added by SHK.

1.1.2 Technical Preconditions

The aircraft type is equipped with a fully electronic and digital Flight Control System, a so-called full Fly-By-Wire system, which means there is no mechanical linkage between the control devices in the cockpit and the control surfaces. Sensor data and command signals are transmitted as electrical digital signals via a wiring system referred to as data buses. Moreover, the signals are modulated by computers, depending on system status, to provide different behaviors, which collectively constitute the so-called control laws (CLAWS[11]). However, these control laws are only active under certain conditions.

The cockpit is a so-called glass cockpit, where traditional flight instruments have been replaced with screens (see Figure 1). Additional data and specifications are presented in Section 1.6.1.

The fault that triggered the sequence of events leading to the serious incident has been traced to the aircraft's Flight Control System. Parts of the system will be described in the report with varying levels of depth and detail. To understand the cause of the reported fault and the descriptions of the systems mentioned later in the report, knowledge of topics such as digital control systems in aircraft and data buses – particularly communication over TTP[12]-type data buses – is required. The following references provide an elementary description of these systems[13].

[11] CLAWS – Control Laws.

[12] TTP (Time-Triggered Protocol) – data networks and bus systems for digital communication.

[13] H. Kopetz, Real-Time Systems: Design Principles for Distributed Embedded Applications, vol. 2, Springer, 2011 and Moir, A. Seabridge and M. Jukes, Civil Avionics Systems, Wiley & Sons, 2013 and Collinson, R.P.G., Introduc-tion to Avionics Systems fourth edition, Springer Nature Switzerland AG, 2023.

The specific characteristic of the TTP bus architecture is that each bus consists of two parallel channels (A and B). Data is written synchronously to these buses by the connected nodes; however, in some cases, there may be a slight time offset between a *frame*[14] written to channel A and channel B. This offset is referred to as *skew* and is a normal characteristic of the TTP bus architecture. Another important concept to understand is *stale*, which can best be described as data transmitted over the network that has been identified as outdated or no longer reflecting the current state of the system.

1.1.3 Sequence of Events

The aircraft departed at 15:02 UTC from runway 12, and shortly after lift-off, the pilots received a CAS[15] warning indicating a Flight Control System failure, and the aircraft's pitch angle increased rapidly beyond what the crew expected for these conditions. The PF attemptted to counteract the abrupt pitch movement using almost full forward application of the side-stick but noted that the stick had limited authority in the nose-down direction. Consequently, the PF used the manual stabiliser trim control to stop the continued climb and disengaged the auto-throttle to manually control the airspeed. The aircraft exceeded the cleared altitude and climbed higher into Stockholm's airspace. After bringing the aircraft to a trimmed state, the pilot descended below the cleared altitude.

The PM communicated with air traffic control, issued a distress call "Mayday" and stated that they were unable to comply with the initial clearance.

After the PF regained full control of the flight attitude, the crew followed the checklist and pressed and released the FCS NORMAL MODE button, which restored normal functionality to the Flight Control System. After regaining normal control, the crew performed the TDODAR[16] checklist and cabin crew and passengers were briefed according to company procedures. As part of the checklist, they discussed Arlanda as a possible landing airport but decided that Bromma met the landing requirements. The subsequent approach and landing were uneventful.

During the sequence of events, the Bromma air traffic controller issued a departure clearance to another aircraft from the same runway, while an arriving aircraft was approximately 8 *NM* on final for runway 12.

Initially, the pilot's first radio transmissions were unclear to the air traffic controller. The pilot later clarified the issue as a flight control problem, followed by a "Mayday" and an intention to return for landing.

Bromma air traffic controller coordinated continuously with the Stockholm Control during the incident, taking into account the air traffic above. During the event, Stockholm Control was managing three other arrivals, which were required to enter a holding and instructed to remain in holding patterns. Two additional arrivals were also instructed to hold further south.

The incident occurred during daylight hours at position 59°21'N 017°57'E, approximately 600 feet above sea level.

[14] A *frame* is a structured unit of data that is sent over a data bus or network. It is used to ensure that data can be transferred in an organised and reliable way between different devices.

[15] CAS – Crew Alerting System.

[16] TDODAR (Time-pressure, Diagnose, Options, Decide, Act or Assign, Review) – The measures that the crew should consider before the approach, after the emergency has been resolved. Included in the operator’s procedures.

1.1.4 Previous Similar Event: Paris Le Bourget, 2 August 2024

A similar event occurred on 2 August 2024, at Paris-Le Bourget Airport involving one of Flexjet's aircraft of model EMB-550 with registration 9H-XFX. SHK has chosen to include this event in the current investigation. The failure mode, aircraft response, and impact on the crew exhibit significant similarities to the presently investigated incident at Bromma Airport. SHK has also interviewed the pilots involved in that event, analysed the aircraft data, and obtained technical information. Additionally, SHK has reviewed Flexjet's internal report on the event and retrieved data from the FCC, as referenced in Section 1.18.

The captain, who was the PF during the incident, observed a rapidly increasing pitch angle and a lack of response to forward control stick inputs. He therefore transferred control of the aircraft to the first officer, who also experienced a lack of response to forward stick inputs. Both pilots applied forward stick inputs simultaneously but without the expected response. The captain then pressed and released the FCS NORMAL MODE button, following the emergency procedure, and the fault message disappeared. The pilot regained control authority and was able to fly the aircraft normally and return to land at the departure airport.

1.2 Injuries to persons

None.

1.3 Damage to aircraft

None.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Qualifications and duty time of the pilots

Commander

The commander, 45 years old, held an ATPL(A) license for the type and a valid medical certificate. At the time of the incident, the pilot was acting as PF.

Flying hours - latest	24 hours	7 days	90 days	Total
All types	4	9	151	4,659
Actual type	4	9	151	1,088

Number of landings actual type previous 90 days: 47.

Type rating concluded on 13 February 2022.

Latest PC [17] conducted on 12 March 2024 on the type.

[17] PC – Proficiency check.

The co-pilot

The pilot, 50 years old, held an ATPL(A) license for the type and a valid medical certificate. At the time of the incident, the pilot was acting as PM.

Flying hours - latest	24 hours	7 days	90 days	Total
All types	4	14	92	6,700
Actual type	4	14	92	275

Number of landings actual type previous 90 days: 17.

Type rating concluded on 24 October 2023.

The pilots' duty times, in terms of the number of days on duty and accumulated flight hours, were within the prescribed limits. Both pilots had a continuous rest period of more than 13 hours prior to the day in question.

1.5.2 Cabin crew

A service crew member from Flexjet was onboard. This individual was seated in the rear of the cabin and did not have any cabin safety responsibilities.

1.6 Aircraft information

The aircraft, an Embraer-550 Praetor 600, is a twin-engine business jet with a range of 7,441 km. It can carry up to 12 passengers. An image of the aircraft is shown in Figure 3.

Figure 3. Embraer-550 Praetor 600. Photo: Flexjet.

1.6.1 The aircraft

The aircraft	
TC-holder	Embraer
Model	EMB-550 Preator 600
Serial number	20189
Year of manufacture	2023

The aircraft	
Gross mass, kg	Max start/landing mass suspended load 19 440 kg, current 16 049 kg
Centre of gravity	Within limits for take-off 27% MAC (FWD 19% MAC AFT 37% MAC)
Total flying time, hours	985
Flying time since latest inspection	37
Number of cycles	32
Type of fuel uplifted before the occurrence	Jet-A1

Engine	
TC-holder	Honeywell
Type	AS907-3-1E
Number of engines	2
Engine no 1	
Serial number	P131685
Total operating time, hours	985
Operating time since overhaul, hours	44
Engine no 2	
Serial number	P131683
Total operating time, hours	985
Operating time since overhaul, hours	44

Deferred remarks
No relevant remarks

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

The EMB-550 Praetor 600 was certified in 2019 by the Brazilian Airworthiness Authority and by EASA.

1.6.2 The Flight Control System

Control Surfaces of the Flight Control System

An aircraft has a number of control surfaces that, when deflected, generate aerodynamic forces that influence and thereby control the aircraft's movements. On the aircraft type in question, all control surfaces are governed by the Fly-By-Wire system. These include the elevators and the horizontal stabiliser. A movable stabilizer and a two-part elevator control the aircraft's pitch attitude and angle of attack. Control inputs are generated from the sidesticks in the cockpit, the autopilot system, and internally within the FCS.

The horizontal stabiliser stabilises the aircraft in the pitch axis, and its angle is adjustable to trim the aircraft in pitch. Trim settings are controlled by the Autotrim System in Normal Mode (NM[18]) and manually via trim switches in Direct Mode (DM[19]). Figure 4 shows the location of the control surfaces on the aircraft.

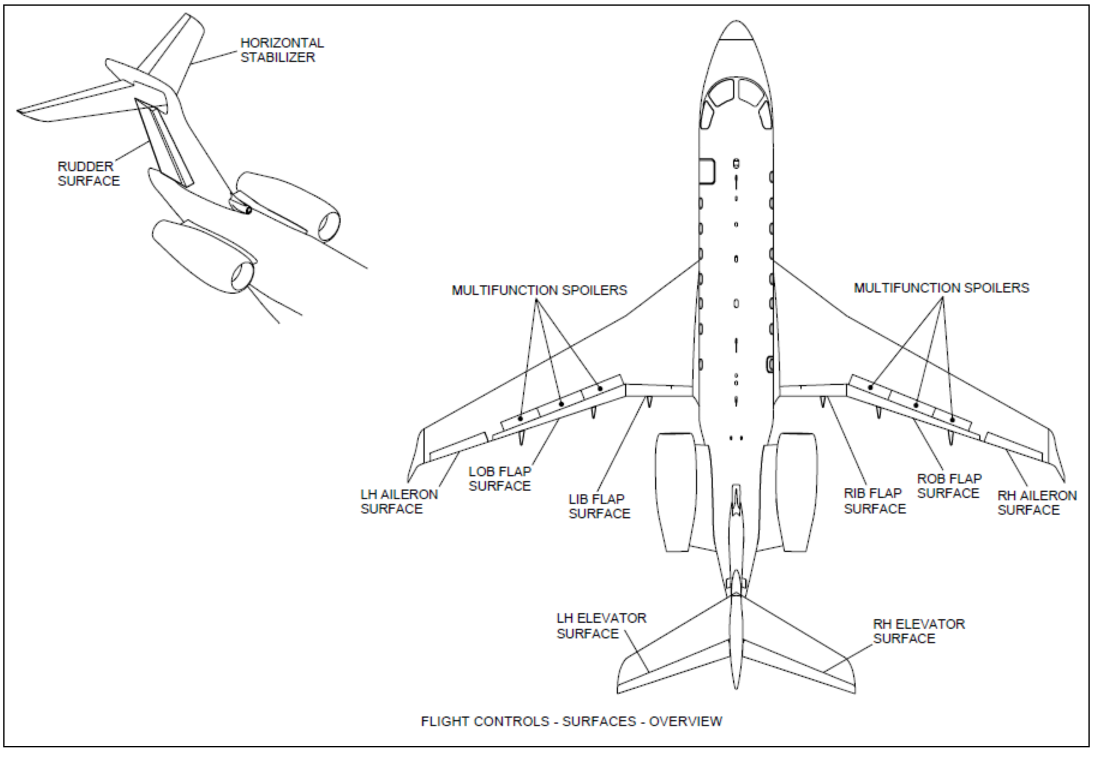


Figure 4. Excerpt from a schematic image of all control surfaces. Source: Embraer AMM.

Overview of the Flight Control System components and modes

The FCS in the aircraft type in question consists of several integrated components working together. This section provides an overview of the system, focusing on the components directly relevant to the incident.

The FCS consists of, among other components:

- Four Inceptor Interface Modules (IIM[20])
- Eight Remote Electronic Units (REU[21])
- Two FCCs
- Two Motor Control Electronics (MCE[22])

Data is communicated through a TTP bus system comprising four parallel TTP data buses.

The systems and components listed above ensure that pilot commands from cockpit controls, autopilot commands, and internal FCS commands are translated into control surface deflections, engine thrust setting, flap positions, etc., to control the aircraft's movements.

[18] NM – Normal Mode.

[19] DM – Direct Mode.

[20] IIM – Inceptor Interface Module.

[21] REU – Remote Electronic Unit.

[22] MCE – Motor Control Electronics.

Communication within the FCS and its components occurs via three different types of data buses, each dedicated to specific communication needs: TTP, A429, and CCDL[23].

When the aircraft is airborne, the FCS operates in two primary modes:

- *Normal Mode*: Used during normal flight and includes functions such as autotrim, angle-of-attack protection, and overspeed protection. All data buses are utilised in this mode.
- *Direct Mode*: Activated during system failures, this mode provides the pilot with direct control over the control surfaces without protection functions. Signal transmission is then carried out via A429, TTP and CCDL buses.

Normal Mode, as the name suggests, is used during regular flight operations. NM aims to reduce pilot workload through functionalities such as autotrim, flight path stabilisation, angle-of-attack limits, overspeed protection, and load factor protection.

In Normal Mode, various control laws are applied, meaning that the primary flight computers modulate/enhance the pilot's control inputs before they are sent to the control surfaces.

Direct Mode is activated when the flight computers are unable to maintain NM and provides the pilot with control logic similar to that of a conventional aircraft. The pilot must then manually trim the aircraft, and protection functions are disabled. In DM, signals from pilot inputs can either pass through the REUs via an A429 or through the FCC and TTP bus.

Reasons why neither FCC1 nor FCC2 can maintain NM may include invalid signals from essential sensors for normal mode (e.g., AHRS[24], ADS[25], or flap indication), mismatch detected by CIM[26], a primary control surface incapable of normal operation, node synchronisation failure, or the pressing of the FCS button in the cockpit (see Figure 2).

The FCC will revert to NM if the FCCs are capable of NM and the aircraft is on the ground and stationary, or if the FCC is capable of NM, the aircraft is airborne, and the FCS button in the cockpit is pressed.

CONTROL LAWS

As previously mentioned, the FCS operates in two modes, referred to as Normal Mode and Direct Mode. The control laws are active only in NM and vary depending on the flight phase the aircraft is in.

Longitudinal Control and Pitch Control

Pitch control in Normal Mode varies depending on the flight phase. On the ground and below 65 knots, the system operates with a fixed stick-to-surface gain, meaning no modulation other than amplification (gain) of the command signals occurs. When the speed exceeds 65 knots, stick commands generate a pitch rate command. Three seconds after lift-off, the

[23] CCDL – Cross Channel Data Link.

[24] AHRS (Attitude and Heading Reference System) – Unit that provides information about air data systems. This unit s is used to measure, calculate and provide information about various aircraft-related parameters that affect the performance and safety of the flight.

[25] ADS (Air Data System) – A system for measuring, calculating and providing information on various air-related parameters that affect the performance and safety of the flight.

[26] CIM – Command Integrity Monitor.

control law transitions to the pitch attitude damping control law, which is active during the rotation phase. Five seconds after lift-off, the control law transitions to flight path angle rate mode (gamma dot[27]), and the autotrim function is activated (see Figure 5).

The control law used during flight is the Longitudinal Control Law. This law ensures that the aircraft remains on its flight path, and control inputs are modulated to adapt to changes in the flight path. When no control inputs are given (sidestick in neutral), the control law ensures that the aircraft maintains the correct flight path angle (gamma) relative to the flight path. The aircraft thus becomes "path-stable", though the speed may vary, i.e., it is not speed-stable. The control law ensures the aircraft is trimmed at different speeds and compensates for any speed variations that may occur.

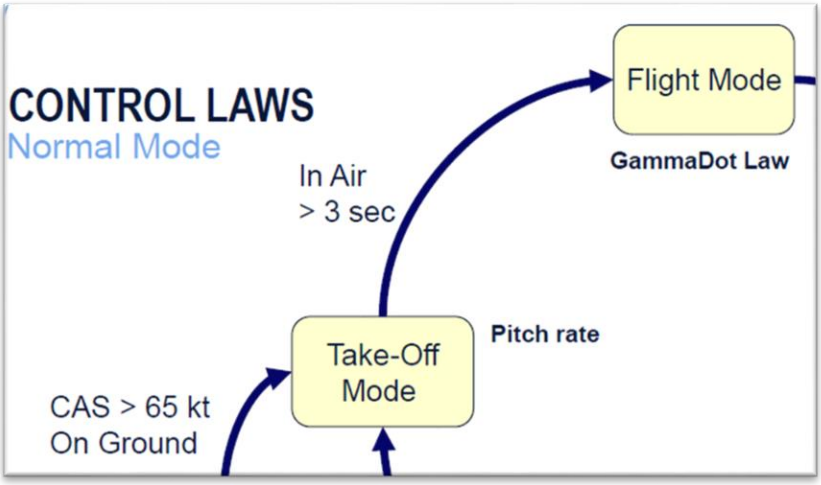


Figure 5. Schematics describing how the control laws change between different flight phases after take-off. Source: Embraer.

Pitch Trim Logic

In Normal Mode and in flight, there is no option to manually trim the horizontal stabiliser. Trimming is performed exclusively automatically by the Flight Control System. On the ground, in NM, manual trimming of the horizontal stabiliser is possible and required prior to take-off.

In Direct Mode, the manual trimming function via the trim switch is available. When the flight control system enters DM, the CAS warning message "FLTCTRL N-MODE FAIL" is triggered.

Flight Control System Data Communication

The Flight Control System includes communication buses of three different types: TTP buses, A429 buses, and CCDL. TTP buses are used in NM, A429 buses are used in both NM and DM, and CCDL buses are used for communication between the REUs in all modes.

[27] Gamma refers to the flight path angle relative to the horizontal plane and gammadot refers to its time derivative, which means the rate of change of the flight path angle per unit of time. In the control law gammadot, the aircraft's control system regulates the rate of change of the flight path angle.

In Normal Mode, data communication is carried out via TTP buses. There are four parallel TTP buses. Four IIMs transmit the data necessary for calculating control commands to FCC1 and FCC2. The FCCs compute the control commands and then send them back to the respective IIM, which in turn forward them to an REU. The REU controls the actuators, which move the control surface to the commanded position.

In Direct Mode, the information required for controlling the aircraft is sent from the IIMs to the REUs via A429 buses. The REUs then calculate the control commands based on the information transmitted over the A429 buses.

Communication between REUs is handled by CCDL, which are Ethernet-type links.

Figure 6 shows a schematic diagram of the flight control system and its communication.

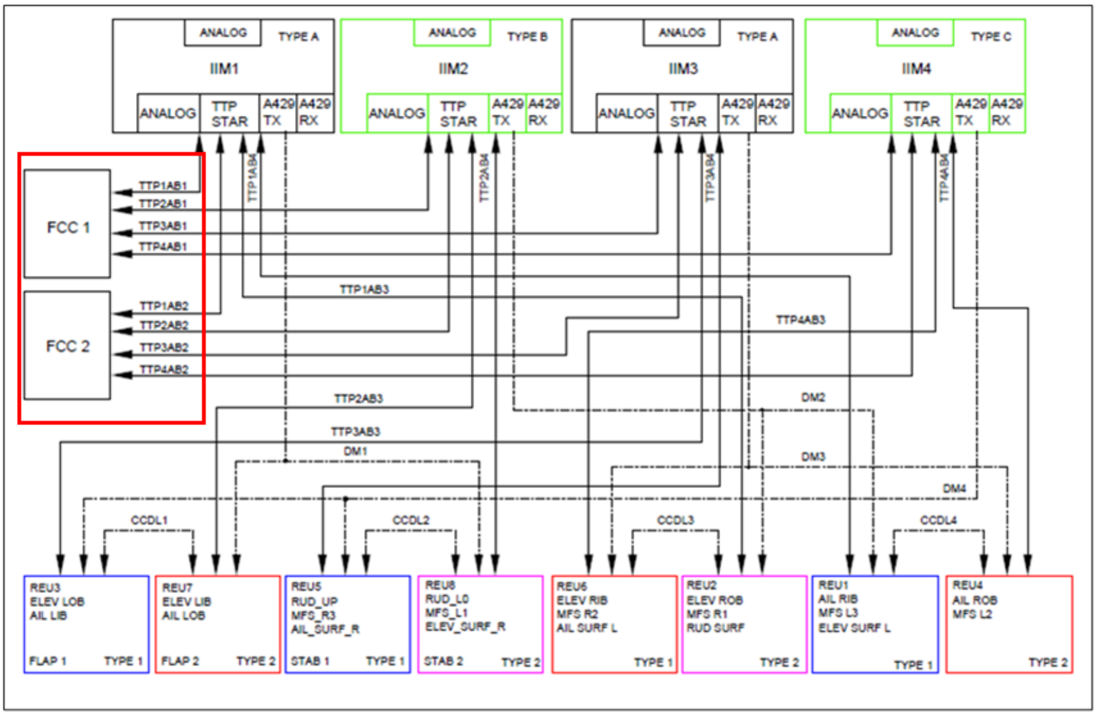


Figure 6. TPP and CCDL communication scheme. TPP inputs to FCC1 and 2 marked in red by SHK.
Source: Embraer. Excerpt from Embraer AMM.

Main Components of the Flight Control

Inceptor Interface Module

The Flight Control System includes four IIMs of two different types (top four boxes in Figure 6). The basic function of the IIM is to perform data acquisition, in-line monitoring of respective sensor inputs, analogue-to-digital conversion, and to transmit digital data to devices via TTP and A429 buses. The IIM provides communication to and from the aircraft's Avionics System through A429. The IIMs receive A429 signals from the Air Data Smart Probes (ADSP[28]), as well as an analogue interface from the left and right sidesticks and pedals. These signals are transmitted via A429 buses and TTP to the REUs and are used exclusively in Direct Mode. It is the IIM that converts, for example, sidestick deflections into a digital signal that is forwarded to the FCS.

[28] ADSP – Air Data Smart Probes.

Flight Control Computer
The Fly-By-Wire (FBW) electronic flight control system includes two main flight control computers, known as FCCs (Flight Control Computers). In Figure 6, they are marked with a red box. One FCC is located beneath the cockpit, and the other one is located in the rear of the cabin.

Communication between the IIMs, FCCs and REUs is carried out via TTP buses, as described in the section *Flight Control System Data Communication*. Additionally, both FCCs communicate with sensors via the A429 data bus.

The design and functionality of the FCCs were implemented by BAe Systems as defined by Parker and Embraer.

In Normal Mode, the FCC manages the control laws using a closed-loop system, meaning there is feedback based on observations and measurements of the system's state.

Both FCCs operate simultaneously and process data in parallel, but only one FCC is responsible for issuing flight control commands at any given time. This arrangement is designed to ensure redundancy and fault tolerance while maintaining efficient and reliable system operation. If, for any reason, one FCC is unable to perform its tasks, the other FCC takes over, provided it has sufficient capability. Both FCCs actively monitor and process system inputs and outputs, such as pilot commands, sensor data, and actuator statuses. The data processing performed by both FCCs is reported to be identical. The FCCs continuously calculate control surface commands (positions) and monitor each other's performance and decisions.

Although both computers are active, only one FCC acts as the "commanding FCC" (responsible), while the other operates as the "standby FCC". The determination of which FCC is the commanding one is governed by a priority logic.

Startup and Priority Logic

After system startup on the ground, the FCCs perform a power-up test, and the FCC that was previously commanding will now become the standby FCC. During operation, a priority mechanism, based on the aforementioned priority logic, determines which FCC has control and is the commanding FCC. The priority mechanism produces a priority index ranging from 0 to 6 (see Table 1). The FCC with the most available resources and the highest operational capability (e.g., in terms of communication buses, autopilot functionality, and sensor integrity) assumes the role of the commanding FCC. The priority logic is based on the availability of various subsystems, one of which is the number of valid TTP buses.

Table 1. FCC Priority Index

FCC Priority Index	FCC Operability	Operating Permit
6-3	NM	Normality
2-1	DM	FCC Direct Mode
0	Not operable/available	REU direct

FCC In Command

Under normal operating conditions, the commanding FCC (FCC In Command) retains control during a flight. Before the next flight, the commanding FCC will switch to the other FCC.

If the commanding FCC experiences a fault or degraded performance (e.g., loss of critical inputs or resources), the system will switch to the standby FCC, which will seamlessly take over control and decision-making functions. The standby FCC acts as a backup and monitors the commanding FCC. Internally, within each FCC, between the FCCs, and among the REUs, a voting logic is used to select the most reliable commands and data, ensuring a smooth and error-free transition.

Ensuring System Integrity
Within the FCS as a whole, and for each individual FCC, internal functions are designed to ensure system integrity by processing received sensor data, state activation, and fault management. This is achieved through two distinct but parallel processes. Each process has its own communication path: the *Monitor (Mon) Lane* and the *Command (Com) Lane*, which form the basis of internal monitoring. These two processes are handled by integrated components in the FCC system architecture and consist of two mirrored modules, providing a redundant and fault-tolerant design for the FCS. This internal data verification process is referred to as the Command Integrity Monitor (CIM).

Via the Command Lane, control commands are sent to the IIMs and then forwarded to the REUs and actuators, which, in turn, manoeuvre the control surfaces. The Command Lane serves as the primary communication path for executing control functions and driving actuators during normal operation.

The Monitor Lane operates in parallel with the Command Lane as a safety check. Its primary role is to supervise the primary communication path's decisions, actions, and outputs to ensure accuracy and integrity. It operates with its own hardware and independent software logic to prevent errors from propagating from the Command Lane. It continuously compares the results of calculations with those from the Command Lane to detect discrepancies, including deviations from established thresholds calculated values and time intervals. If an error is identified, it is stored in the FCC's internal memory (NVM[29]). The process and communication paths are schematically illustrated in Figure 7.

In essence, the CIM verifies the consistency between the Command Lane and the Monitor Lane. If a discrepancy is detected, the system can initiate a fallback or switch to a safe mode (e.g., Direct Mode or a downgrade to minimal functionality).

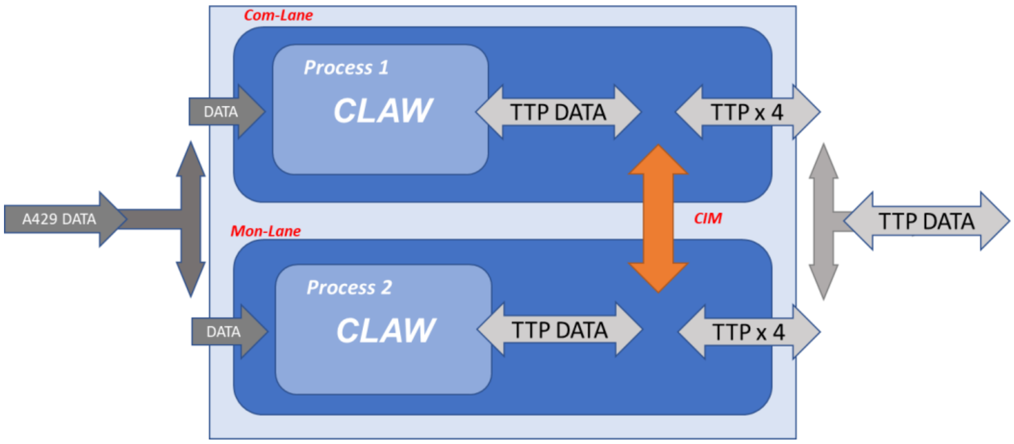
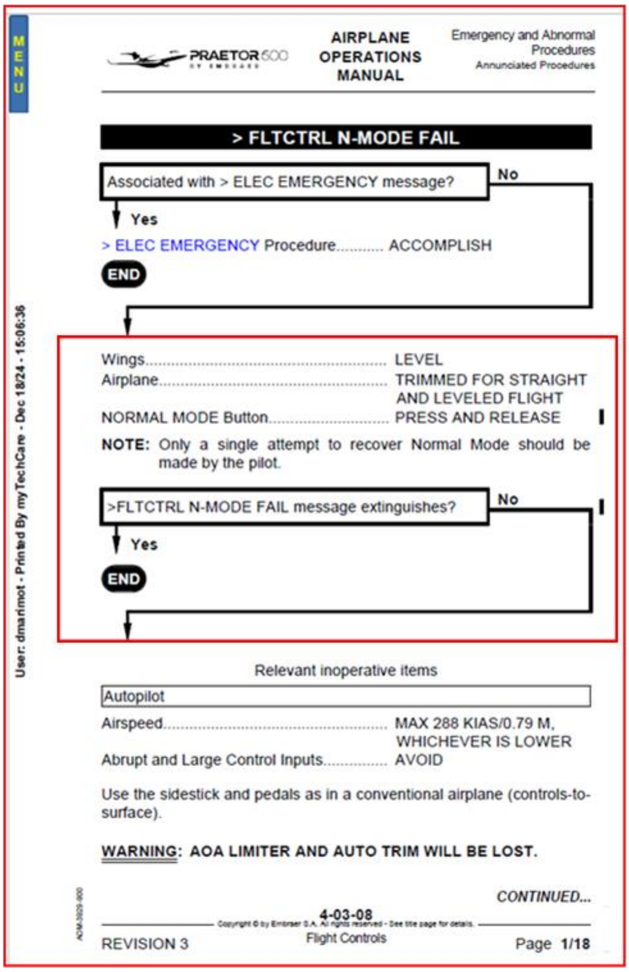


Figure 7. Schematic representation of processes and communication paths at the control computer (FCC).

[29] NVM – Non-Volatile Memory.

1.6.3 AOM Emergency Procedure for the Warning Message "FLTCTRL N-MODE FAIL"

In the event of the CAS warning message presented during the incident, the pilots are provided with an electronic emergency checklist, shown in Figure 8.



MENU

PRAETOR 600 BY EMBRAER — AIRPLANE OPERATIONS MANUAL — Emergency and Abnormal Procedures, Annunciated Procedures

> FLTCTRL N-MODE FAIL

Associated with > ELEC EMERGENCY message? — No / Yes

> ELEC EMERGENCY Procedure.......... ACCOMPLISH

END

Wings.......... LEVEL
Airplane.......... TRIMMED FOR STRAIGHT AND LEVELED FLIGHT
NORMAL MODE Button.......... PRESS AND RELEASE

NOTE: Only a single attempt to recover Normal Mode should be made by the pilot.

>FLTCTRL N-MODE FAIL message extinguishes? — No / Yes

END

Relevant inoperative items

Autopilot

Airspeed.......... MAX 288 KIAS/0.79 M, WHICHEVER IS LOWER
Abrupt and Large Control Inputs.......... AVOID

Use the sidestick and pedals as in a conventional airplane (controls-to-surface).

WARNING: AOA LIMITER AND AUTO TRIM WILL BE LOST.

CONTINUED...

User: dmarimot - Printed By myTechCare - Dec 18/24 - 15:06:36

REVISION 3 — 4-03-08 — Flight Controls — Page 1/18

Figure 8. Emergency checklist for FLTCTRL N-MODE FAIL. The pilot's system action is marked inside the red frame, added by SHK. Note that the use of manual pitch trim is not included in the checklist. Source: Embraer AOM.

One step in the pilot's emergency procedure is to press the FCS NORMAL MODE button. However, there was no mention of manual trimming. This was clarified in Transport Malta (TM) bulletin SIAN 01/24 and Embraer operational bulletin 550-002/24, which were published after the earlier Le Bourget incident.

1.6.4 Training Requirements[30] for EMB-550 Pilots on the Flight Control System

Among the operational functions included in the EASA evaluation of the EMB-550 was the flight control system.

The only aspect of the flight control system behaviour that must be trained, according to the differences table between the EMB-550 500 and 600 models, is that in Normal Mode, manual trim is available on the ground and there are load alleviation functions.

In the manufacturer's training requirements for type-specific training, there is mention of training for system failures, both theoretically and in the simulator. However, the document does not specify any particular cases of flight control system failures during take-off rotation.

1.7 Meteorological information

According to SMHI's analysis: Wind, south-easterly at 10 knots, with gusts up to 16 knots, visibility between 5 and 10 km, cloud base at 300–800 feet, temperature/dew point +15/+14°C, QNH 996 hPa.

According to the pilots, the incident occurred in clouds, rain, and turbulent conditions.

1.8 Aids to navigation

The pilots followed a GPS-based instrument procedure according to the clearance. After declaring an emergency on the radio, the crew received radar vectors for landing.

1.9 Communications

The pilots were in contact with Bromma Tower during the incident. Simultaneously, the air traffic controller communicated with the rescue services at Bromma and with Stockholm ATCC. During the incident, a trailing aircraft was granted take-off clearance from the same runway, and an aircraft on final approach was cleared to land.

1.10 Aerodrome information

The airport is listed in AIP Sweden[31]. Bromma Stockholm Airport has one runway (12/30), which is 1,668 metres long, and the airport's elevation above sea level is 47 feet. At the time of the incident, Bromma control zone (CTR) was active.

1.10.1 Airspace above the airport

Stockholm Bromma control zone is limited to 2,000 feet above ground level and lies below Stockholm TMA. Departures from Bromma and climbs above this altitude require coordination between Bromma and Stockholm air traffic controllers (see Figure 9).

[30] Embraer/ANAC/EASA Operational evaluation report for EMB-550/545 and EASA OPERATIONAL SUITABILITY DATA (OSD) FLIGHT CREW.

[31] AIP – Aeronautical Information Publication.

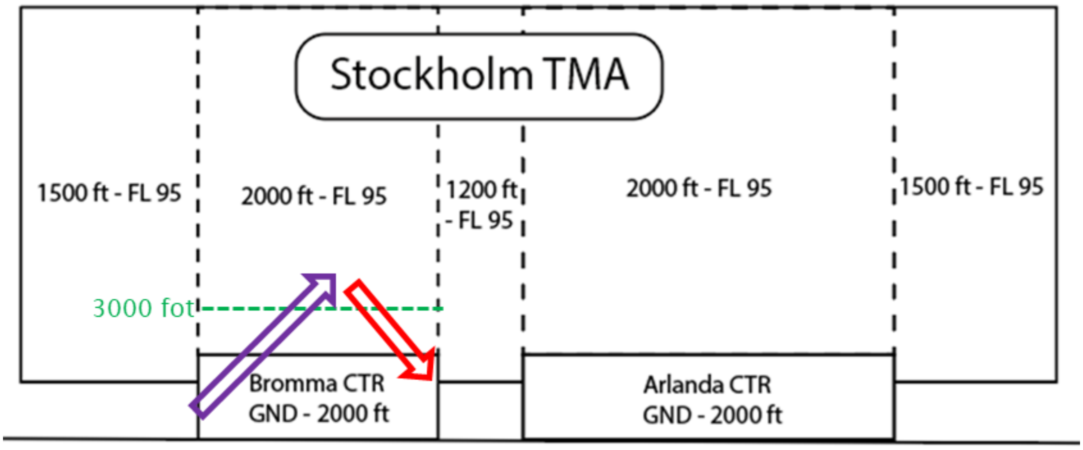


Figure 9. A side view of the airspace above Bromma Airport. The green line indicates the cleared altitude of 3,000 feet. The arrows illustrate the aircraft's approximate flight path within the airspace. The purple arrow shows the aircraft's climb beyond the cleared altitude. The red arrow represents the descent back to below the cleared altitude and the approach to Bromma. Source: Luftfartsverket (provider of Air Traffic Management and Air Navigation Services in Sweden) with graphics added by SHK.

1.11 Flight recorders

The aircraft was equipped with devices for recording parameters related to the flight and various systems. These were stored on a Flight Data Recorder (FDR [32]) as well as on a Quick Access Recorder (QAR [33]). Audio data was recorded on a Cockpit Voice Recorder (CVR [34]).

1.11.1 Flight Data Recorders (FDR, QAR)

The aircraft was equipped with an FDR manufactured by L3-Harris with the model designation 7100-2700-00. The FDR data covered the entire sequence of events related to the incident, as well as three previous flights.

The FDR stores 1,582 parameters, both in the form of discrete status signals such as warnings and as variables including altitude, speed, heading, etc. The various parameters are recorded on the device at different time intervals and at different times. For many of the parameters analysed, the frequency is 1 Hz, while higher-resolution data at 4 Hz is available for the incident flight. Data for the three previous flights, upon retrieval and conversion from binary format, was saved at 1 Hz.

Flight data was also recorded on a QAR of the type Avionica miniQAR, with a memory capacity sufficient to store up to 6,000 hours of data. The data overlaps with what is streamed to the FDR but may include more or fewer parameters.

Binary data from these devices has been retrieved, converted into engineering units, and analysed. Converted QAR data from the incident was obtained from Flexjet and the aircraft manufacturer. The extraction and conversion of FDR data were carried out at the laboratory of the French investigation authority, BEA. Data from the incident is presented in Section 1.16.

[32] FDR (Flight Data Recorder) – Device that records sensor values in flight.

[33] QAR (Quick Access Recorder) – Trip recorder with quick access capability.

[34] CVR (Cockpit Voice Recorder) – Records audio.

1.11.2 Cockpit Voice Recorder (CVR)

The CVR unit onboard was manufactured by L3-Harris with the model designation 5013-5001-50 and serial number 002098474. The CVR had four channels and could store at least two hours of audio recordings. The CVR unit is located in the rear section of the aircraft.

Audio data was extracted and time-synchronised at the French investigation authority's (BEA) audio laboratory. The extracted audio files covered the entire sequence of events related to the incident.

1.12 Site of occurrence

The incident occurred after take-off from runway 12 at Stockholm/Bromma Airport, with the aircraft climbing toward the cleared altitude of 3,000 feet (see Figures 10 and 11).

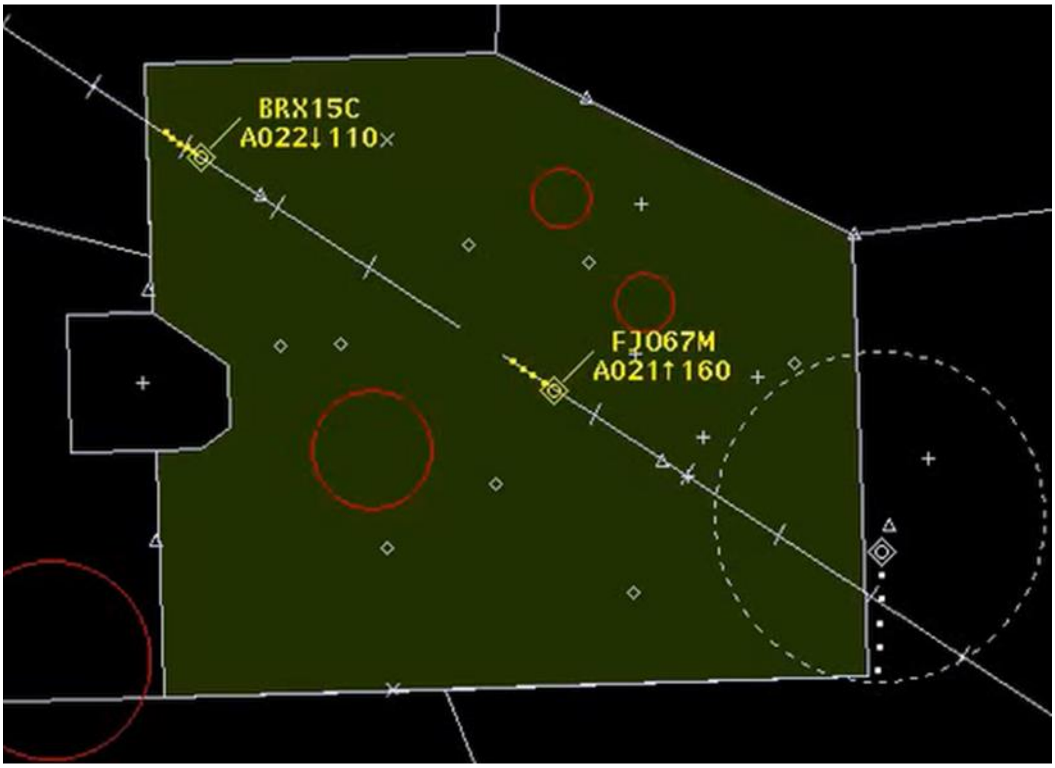


Figure 10. Radar image at 17:03 shows the moment the crew declared Mayday. The aircraft ID, FJ067M, indicates 2,100 feet climbing and an indicated airspeed of 160 knots. The runway is located at the break in the diagonal white line. Source: Swedish Civil Aviation Authority.

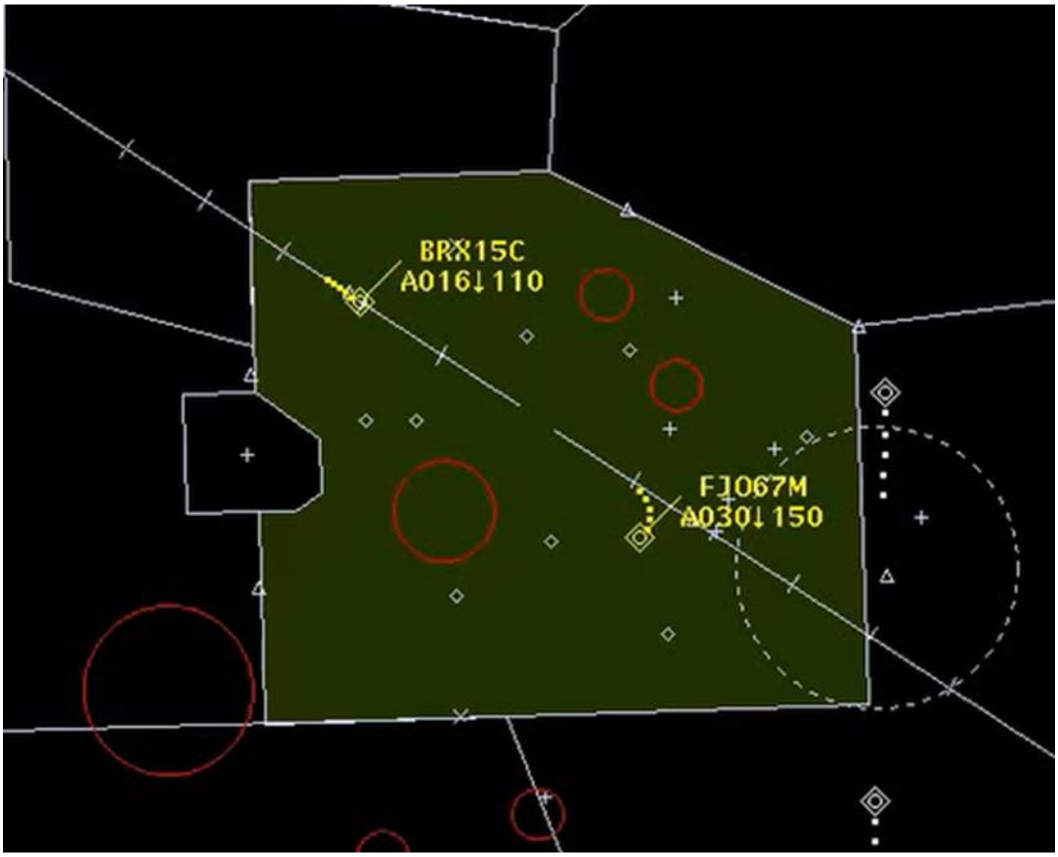


Figure 11. Radar image at 17:04 shows the aircraft descending again below 3,000 feet and turning to a southerly heading with an indicated airspeed of 150 knots. Source: Swedish Civil Aviation Authority.

1.13 Medical and pathological information

Nothing has emerged to indicate that the pilots' 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

Bromma Airport has its own rescue units but can also call-in external units when necessary.

SHK has reviewed the report from the incident commander at Operations – ARN Rescue and Fire Fighting Services, Swedavia.

According to the incident commander's report, the rescue services were alerted at 17:05. The tower informed them that an aircraft experiencing control issues was returning to Bromma shortly after take-off. The incident commander arrived on-site along with units from Solna Fire Station, an ambulance from the regional healthcare service, and the police.

The paramedic who arrived at the scene asked the crew if anyone required medical attention but received a response that no assistance was needed.

The rescue operation was concluded at 17:30.

The Emergency Locator Transmitter (ELT[35]) was not activated.

1.16 Special Tests and Investigations

1.16.1 Recorded Data (FDR and QAR)

The recordings from the aircraft's memory units (FDR and QAR) reveal several parameters of significance for the incident, describing the flight path and the status of the flight control system. Figure 12 provides an overall view of the event and an overview of the sequence, while Figure 13 shows a zoomed-in view of the same parameters around the time of the fault indication.

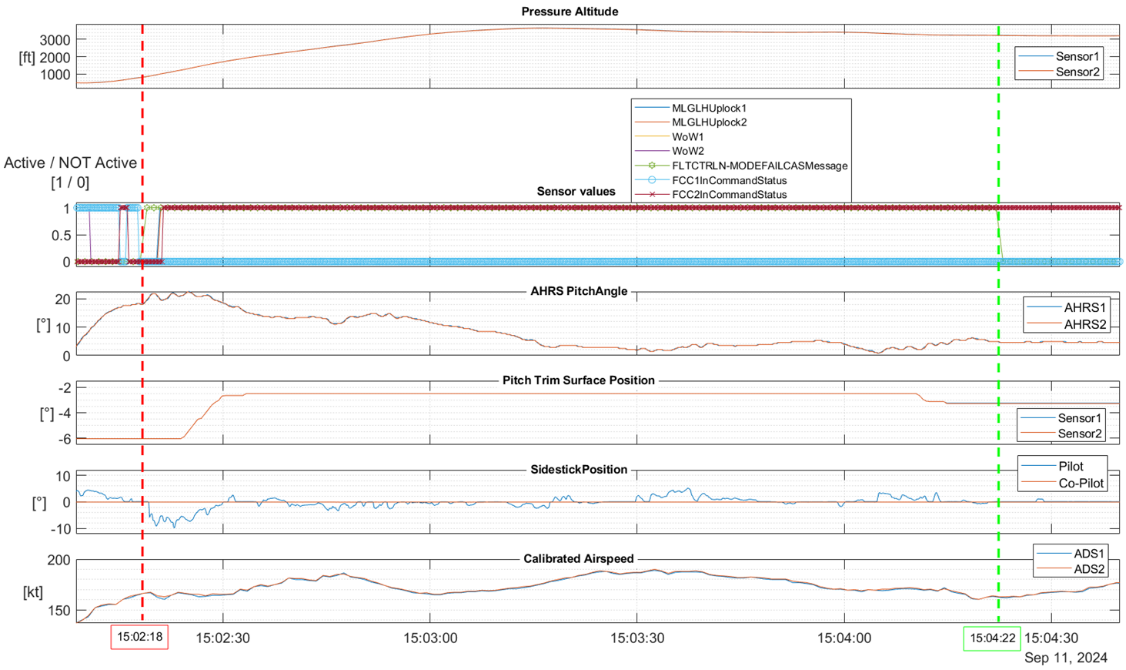


Figure 12. Some important parameters that were recorded on the aircraft's memory unit. The X-axis shows the time in UTC. Top-down graphs: barometric altitude, logical sensor values including FCC control status and landing gear position, aircraft tilt angle, stabiliser trim angle, tilt position and calibrated airspeed (CAS). The error occurred at 15:02:18 and was reset at 15:04:22, which in the figure is marked with a red and green dashed vertical line.

[35] ELT – Emergency Locator Transmitter.

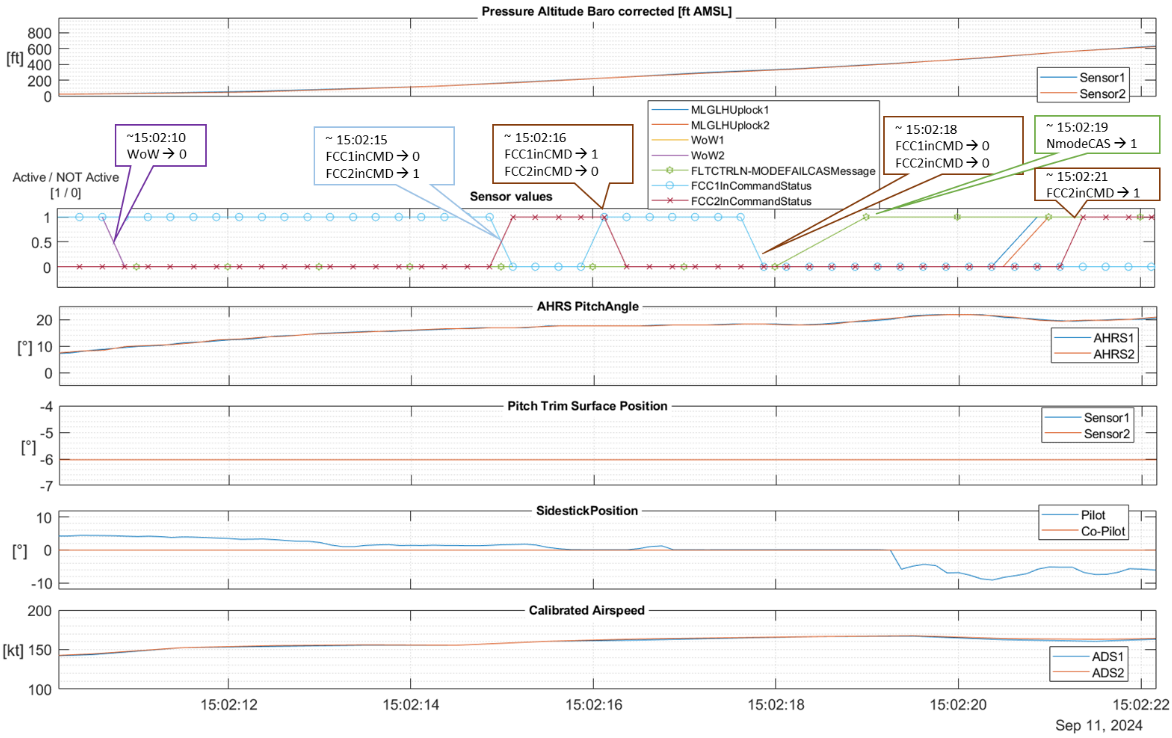


Figure 13. Zoomed-in view of FDR data. Top-down graphs: barometric altitude, logical sensor values including FCC control status and landing gear position, aircraft pitch angle, stabiliser angle, stick position and calibrated airspeed (CAS). In the second graph from above (sensor values), the times of important events are shown, from the left: WoW → 0, first time FCC1 → 0, etc.

The recordings presented in Figures 12 and 13 show that approximately five seconds after lift-off, FCC control of the flight control system switched from FCC1 to FCC2 and then back to FCC1, after which both flight control computers failed, and the FLTCTRL N-MODE FAIL warning was presented to the pilots. The aircraft's Flight Control System was now in Direct Mode.

The data shows that the aircraft continued to climb despite the left-seat pilot applying nearly maximum nose-down stick input (pushing the sidestick forward). When the pitch angle was at its highest (approximately 22°), the left-seat pilot applied a stick input corresponding to -10° out of a possible -12°, with no indication that the aircraft was responding to arrest the climb. The right-seat sidestick showed no movement. Approximately six to seven seconds after the Flight Control System entered DM, trim movements in the nose-down direction began, followed by a reduction in stick input.

The climb continued, and the aircraft passed through the cleared altitude of 3,000 feet.

QAR data, converted by Embraer, has been analysed by SHK. The specific sequence of events is illustrated in Figure 14, which describes the following five events:

1) The difference between FCC1's COM and Mon lanes exceeds the threshold value, and data on the TTP bus becomes stale → FCC2 takes over.
2) The difference between FCC2's COM and Mon lanes exceeds the threshold value, and the CIM issues a priority index of 0, while data on the TTP bus becomes valid (non-stale), making FCC1 available, and FCC2 is disconnected. A reboot of FCC2 is initiated.
3) The CIM in FCC1 triggers a restart of FCC1, rendering both FCC1 and FCC2 unavailable.

4) FCC2 completes its reboot and becomes available (*DM* only).
5) FCC1 completes its reboot (*DM* only).

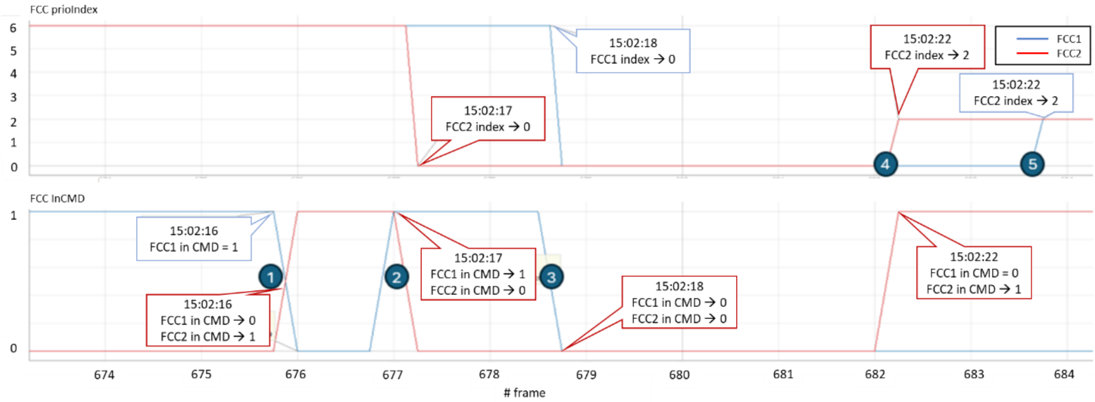


Figure 14. QAR data from Embraer, upper graph priority index for FCC1 & FCC2, lower graph status index for FCC in command, 1 = in command, 0 = not in command.

1.16.2 Trim setting during the incident and during previous flights with 9H-MFX on the same day, 11 September 2024

Earlier the same day, three flights were carried out. FDR data from these flights has been retrieved and analysed. This allowed for a comparison of the take-off sequences across the different flights.

The three previous flights and their take-offs proceeded normally, and no faults or deviations were found in the recorded data. Figure 5 presents a graph showing the stabiliser's trim angle. The times have been synchronised to the moment the aircraft lifted off (WOW → 0). In the figure, it can be observed that during the three previous flights, the stabiliser trim angle began adjusting approximately 8–9 seconds after the aircraft lifted off, whereas for the incident flight, it took approximately 13 seconds.

In the first three cases, the autotrim system sent commands to adjust the stabiliser angle, while during the incident flight, the adjustment occurred because the manual trim button was pressed.

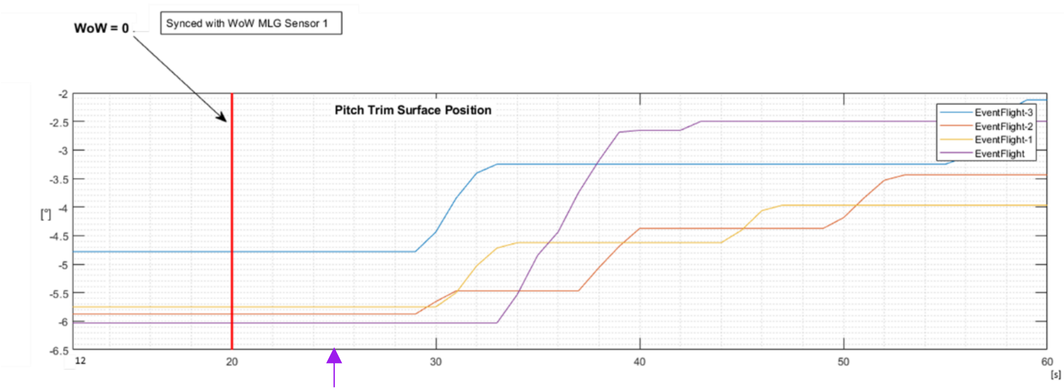


Figure 15. The trim angle of the stabiliser as a function of time. Take-off progress during the incident flight (purple line) compared to three previous take-offs on the same day with the same flight individual (yellow, orange and blue lines). The red line indicates the time when the aircraft takes off from the runway. The purple arrow indicates the approximate time when both control computers were disconnected.

1.16.3 Download of FCC data and rig tests

Investigation of Flight Control Computers (FCC1 and FCC2)

In the aircraft involved in the incident, the two FCCs had the following serial numbers: FCC1: 0710, FCC2: 0712. Both FCCs were removed from the aircraft, sealed, and sent to the manufacturer for data download from the internal NVM. This memory stores status signals, error codes, and fault messages.

The download of the internal memory from each FCC was conducted in October 2024 at BAE System's facilities in the USA, in the presence of an SHK-accredited representative from the NTSB and by Parker representative. The downloaded binary data was shared with SHK, but BAE Systems performed the data conversion and compiled a summary of the error codes and messages recorded at the time of the incident. It was determined that the sequence of events was identical in both FCCs.

The Command Integrity Monitor detected that the command to the elevator had exceeded its allowable limit of 0.81° for more than 100 milliseconds. The system is designed so that in such cases, in order to prevent the error from propagating through the system, communication over the TTP buses is disabled. The threshold was first exceeded on FCC1, then on FCC2, after which the Flight Control System entered Direct Mode when the priority index of both FCCs dropped to 0.

An analysis of an FCC from the incident at Le Bourget revealed the exact same fault sequence. Both SHK and the FCC manufacturer also observed that the fault occurred during the transition between control laws after take-off.

Rig tests at Embraer and Parker in the USA

In order to better understand the faults identified during the retrieval of the FCCs' NVM data and the root cause of these faults, it was necessary to perform a deeper analysis and to obtain improved data collection of the input and output variables and parameters to the Flight Control Computers. For this purpose, existing rigs for testing and certification of the Flight Control System were used. One rig was located at the aircraft manufacturer's premises in São José dos Campos, Brazil, and another at Parker, the manufacturer of parts of the Flight Control System, in Irvine, USA.

However, it was necessary to modify the rigs, including making tailored updates to the software for data acquisition. The rigs represented all components of the Flight Control System. Loads could be applied to the actuators, and a separate data acquisition system was available to measure how the system responded.

Sensor data, input variables, and input parameters were set to values corresponding to the conditions of the incident, specifically the conditions present during a transition between control laws after take-off. Monitoring included parameters such as the priority index and FCC status. Input variables such as load factor, pitch angle, and control stick angle were configured to vary as sinusoidal functions, while the simulated airspeed was set to vary linearly. This subjected the Flight Control System to recurring test cycles.

After extensive work adjusting the input variables, particularly their gradients (how quickly they were allowed to vary), the same fault as in the incident was detected.

If, at the time of a control law transition, there was a time offset (skew) between the data frames on the COM and MON lanes, the difference could exceed the predetermined threshold. The condition required that the input data to the two separate processes resulted in control commands with high gradients.

The system architecture was also such that when the fault occurred, the data was classified as *stale*, leading to switches in the FCC In Command role, and subsequently causing the priority index for both FCCs to degrade to 0, resulting in the system being downgraded to Direct Mode and the subsequent reboot of the FCC. A simultaneous reset condition of both FCC could however not be reproduced during the rig tests.

SHK witnessed the tests on-site at Parker's facilities in Irvine, USA, in May 2025.

1.16.4 Reconstruction of the event in a Training Simulator

With the support of Embraer and Flexjet pilots, SHK reconstructed the events and evaluated aircraft handling, Flight Control System response, and the crew's probable workload under conditions similar to the two investigated incidents. The evaluation was conducted using a Praetor 500/600 simulator (FFS) at the Simcom training center in Orlando, Florida, on 25 September 2024.

A fault equivalent to FLTCTR N-MODE FAIL was introduced under the approximate flight conditions recorded during the actual events, with varying aircraft weight and center of gravity. A normal climb speed prior to acceleration altitude is between 160–180 knots. During the acceleration to higher speeds, the pitch trim demand was higher than expected, resulting in a longer period with an untrimmed aircraft and requiring greater nose-down stick inputs.

The evaluation included recovery from the flight condition using the FCS mode button as well as directly using the pitch trim after a short delay.

SHK's assessment of the probable workload for pilots during such events showed that a dual FCC failure shortly after lift-off could cause surprise and high workload for the crew. The stick inputs required to maintain the pitch angle were initially high, but control could be maintained.

The pitch trim response was satisfactory, and the aircraft could be trimmed to a stable condition with an acceptable workload. It was noted that if the aircraft accelerated beyond a normal climb speed, the need for nose-down stick input and manual trim commands increased.

The manual trim control is normally not used in flight. SHK assessed the trim control to be hard to access, poorly marked, and insufficiently illuminated, making it difficult to locate under time pressure.

1.16.5 Pilots' perceived workload

During interviews, SHK asked the four pilots involved in the two incidents to assess six workload parameters according to the NASA TLX[36] (Task Load Index). The scale ranges from *very low* to *very high*, and the pilots responded verbally to the questions during the inter-

[36] NASA TLX – The Hart and Staveland's NASA Task Load Index is a widely used, subjective, multidimensional assessment tool designed to evaluate perceived workload in order to assess the effectiveness of a task, system, or team, as well as other aspects of performance.

view. Of the six parameters, it was clear that the pilots (PF and PM) perceived mental demand and time pressure (temporal demand) to be quite high.

When comparing frustration levels and perceived performance between the two events, differences were particularly evident between the pilots acting as PF. During the Le Bourget incident, the pilot felt frustrated and rated his performance as below average. During the Bromma incident, the pilot experienced a low level of frustration and perceived the performance as nearly perfect.

1.16.6 Interview with Flexjet's test pilot

Prior to the simulator evaluation, SHK interviewed a Flexjet pilot who is a certified CAT A test pilot and has assisted in pilot evaluations of previous incidents involving the aircraft model.

After the Le Bourget incident, Flexjet became aware of the discrepancy between the pilots' training during type rating courses in the simulator and the desired procedure during such a failure. Specifically, the need to use manual pitch trim in flight was investigated.

According to the test pilot, a crew that is not briefed in advance about the new emergency procedure and encounters such a failure after take-off risks reacting more slowly, resulting in greater deviations from the intended flight attitude.

The pilot also remarked that the manual trim control is not illuminated, making it difficult to see in darkness. The trim switch is normally not used during flight and using it is not an instinctive movement for the pilots.

1.17 Organisational and management information

1.17.1 The Operator – Flexjet Operations Malta

Flexjet is an aviation company operating in both Europe and the United States. In Europe, Flexjet conducts its flight operations from AOCs[37] in the United Kingdom and Malta. Flexjet Operation Malta Ltd received an Air Operator Certificate (AOC.MT.68) from Transport Malta Civil Aviation Directorate on 22 July 2021.

Flexjet Europe is authorised to manage the continuing airworthiness of aircraft under its AOC (CAMO[38]) and has an approved training organisation (ATO[39])).

In total, Flexjet operates over 250 jet aircraft, including 20 EMB-550 (11 in Europe) and 47 EMB-545 (at the time of the event). Flexjet Malta uses a safety management system (SMS) with defined responsibilities for operations and a safety policy. Flexjet has described the system as a safety development cycle within the operational environment, which includes risk identification, risk management, monitoring, and improvement processes.

In addition to the requirements for a safety management system, alongside the mandatory Flight Data Monitoring programme for the larger aircraft, Flexjet has chosen to equip and employs a voluntary Flight Data Monitoring (FDM[40]) system to track flight operations and identify risks in daily activities.

[37] AOC – Air operator Certificate.

[38] CAMO – Continuing Airworthiness Management Organisation.

[39] ATO – Approved Training Organisation.

[40] FDM – Flight Data Monitoring.

SHK was able to review Flexjet's handling of the relevant events within its safety management system, including risk assessments and actions taken. After the first incident at Le Bourget, Flexjet implemented measures that included information sessions for pilots and operational instructions for handling similar events.

Flexjet classified the Bromma incident 2024 as a *significant incident* and reported it to Transport Malta (TM) through its reporting system.

1.17.2 The Aircraft Manufacturer/Design Authority – Embraer

The Embraer Legacy 450/500 and Praetor 500/600 are a family of medium-sized and super-medium-sized business jets designed and manufactured by the Brazilian aircraft manufacturer Embraer. The aircraft family was launched with the Legacy 500 in April 2008 and were the first jets in their size category to feature fly-by-wire technology.

1.17.3 The Airworthiness Authority (Civil Aviation Directorate) – Transport Malta (TM)

Transport Malta oversees and is responsible for, among other things, managing incoming Mandatory Occurrence Reports (MOR[41]) from operators registered in Malta. When necessary, TM informs other authorities in accordance with EU Regulation 376/2014. TM ensures that the details of the incidents are entered into the ECCAIRS[42] system.

On 22 August 2024, Transport Malta issued a safety bulletin (Safety Information and Advisory Notice – SIAN 01/24) describing Flight Control System issues on the EMB-550 and outlining how pilots should identify and handle failures involving loss of pitch control and pitch trim.

1.18 Additional information

1.18.1 Similar Events

The current incident occurred on 11 September 2024 at Stockholm/Bromma Airport. The Swedish Accident Investigation Authority (SHK) notes that two similar cases have occurred in recent years. In addition, Flexjet and the NTSB have identified two further cases.

Le Bourget Airport, 2 August 2024

An EMB-550 600 with registration 9H-XFX experienced a fault message, "FLTCTRL N-MODE FAIL," shortly after take-off.

The fault caused an increasing pitch angle that could not be counteracted through forward stick inputs. Since the neither pilot, nor both together, were able to stop this high attitude, the PF applied the "Flight Control Misbehaviour" procedure and pressed the FLIGHT CONTROLS Normal button.

This action cleared the CAS warning message, and the aircraft returned to normal flight conditions. The crew returned to Le Bourget and landed without further issues.

FDR data and error codes from an FCC indicated the same fault and event sequence in the Flight Control System as in the current incident.

[41] MOR – Mandatory Occurrence Reporting.

[42] ECCAIRS – European Co-ordination Centre for Accident and Incident Reporting Systems.

Flexjet classified the event as a *Significant Incident* and reported it to Transport Malta (TM) through its reporting system. In the ECCAIRS system, the event is classified as an *Incident*.

Stockholm/Bromma Airport, 2 July 2022

An EMB-550 600 with registration 9H-XFX experienced a fault message, "FLTCTRL N-MODE FAIL," shortly after take-off. SHK received a report from the Swedish Civil Aviation Administration (LFV) regarding an "Automatic control mode message" appearing after take-off. The pilots decided to return and land at Stockholm/Bromma Airport.

At the time, SHK assessed that the event only constituted an incident and that an investigation was not warranted.[43]

Flexjet classified the event as a *Serious Incident* and reported it to TM Malta via its reporting system. However, in the ECCAIRS system, the event is classified as an *Incident*, not a serious incident. SHK has not received any pilot reports (ASR) from either Flexjet or the Maltese aviation authority.

In addition to these events, Flexjet and the NTSB have identified two operationally similar events in the U.S. (Teterboro Airport, NJ, July 2024), where a transition to Direct Mode occurred after take-off, and pilots experienced limited stick authority in pitch. According to Embraer, the technical cause was different, and SHK has therefore not investigated these events further.

1.18.2 Reporting, analysis, and follow-up of Civil Aviation incidents

Regulation (EU) No 376/2014 aims to improve aviation safety by ensuring that relevant safety information in civil aviation is reported. Every organisation established in a Member State must, as soon as possible but no later than 72 hours after becoming aware of an occurrence, report events covered by the directive in the regulation to the competent authority.

1.18.3 Notification to investigation authorities of accidents or serious Incidents

Regulation (EU) No 996/2010 focuses on the investigation and prevention of accidents and serious incidents in civil aviation. Article 9 of this regulation specifically addresses the "Obligation to Notify Accidents and Serious Incidents". Any person involved who becomes aware of an accident or a serious incident must, without delay, notify the competent safety investigation authority in the Member State where the accident or serious incident occurred.

1.18.4 Safety Actions Taken

Flexjet

Following the Le Bourget incident, Flexjet implemented measures to enhance flight safety. One risk-reduction measure to allow continued operations with the EMB-550 was the Flexjet's implementation of safety-enhancing actions through videoconferences and safety bulletins explaining the procedures for handling similar faults.

[43] SHK assessment and decision L-61/22.

Embraer

Following earlier incidents and one week after the Le Bourget event, Embraer issued an operational bulletin (O.B. N°: 550-002/24, 2 Sep 2024) containing information on the use of manual trim in Flight Control Systems degraded to Direct Mode.

The bulletin emphasised the importance of using manual pitch trim during Flight Control System failures that lead to Direct Mode. It explained that auto-trim is not functional in this mode and that the pilot must immediately use the trim switch on the central pedestal to reduce the need for large stick inputs during dynamic flight conditions. The bulletin also included images of the trim switch and the FCS NORMAL MODE button in the cockpit.

Embraer plans to revise related pilot procedures to include the step "PITCH Switch .... ACTUATE MANUALLY" as a memory item.

The Aircraft Flight Manual (AFM[44]) is under revision, and as of the report's release, approval from the Brazilian Civil Aviation Authority (ANAC) is pending.

In terms of training measures, Embraer collaborated with FlightSafety[45] to improve practical training scenarios related to FLTCTRL N-MODE FAIL and FLTCTRL N-MODE MISBEHAVIOR. These modified scenarios were introduced in initial and recurrent training by both FlightSafety and Flexjet, as well as its training provider.

New FCC software has been tested by Parker. Initial tests have shown that the fault and the event sequence in the Flight Control System could not be reproduced with the modified software. Embraer intends to test and certify the new software in 2026.

Transport Malta

In response to three reported incidents where pilots experienced a lack of pitch authority after take-off with Flexjet's EMB-550 aircraft, Transport Malta issued a safety bulletin on 22 August 2024 (SAFETY INFORMATION AND ADVISORY NOTICE – SIAN 1/24) applicable to EMBRAER 550–500/600.

The bulletin stated, among other things, that if the control sticks do not respond to pilot input, the first action should be to trim manually as a memory item. Merely selecting Direct Mode may not resolve the situation, as the stabiliser can only be controlled manually in this mode.

EASA

EASA is planning a Safety Promotion Programme 2026, which will cover systemic parts of the aviation system, and within this promotion, the topic of occurrence reporting and safety culture will be covered in detail.

This will include the topic of reporting occurrences that might be considered to be a serious incident to the state of occurrence.

EASA will also include specific communication to the National Aviation Authorities to ensure that serious incidents are shared with the relevant AIBs in a timely manner.

[44] AFM – Aircraft Flight Manual.

[45] Flight Safety – A FAA/EASA-approved simulator organisation for pilot training including the EMB-550 600.

1.19 Special methods of investigations

None.

2. Analysis

2.1 Aircraft behaviour

From interviews and collected flight data, SHK concluded that the Flight Control System fault that occurred during take-off, shortly after lift-off, resulted in the stabiliser failing to trim automatically to the current flight speed. The aircraft entered an untrimmed flight condition and quickly increased its pitch angle. The pilot, who attempted to counteract the pitching motion with forward stick input, lacked sufficient stick authority. By manually trimming the stabiliser and restoring the Flight Control System to normal functionality, the pilot regained full control of the aircraft.

2.1.1 Limitations in control input authority

When the Flight Control System degraded from *NM* to *DM*, approximately 12 seconds after lift-off, the control laws switched from interpreting stick commands as flight path angle rate (gamma dot) to directly commanding elevator deflection based on stick position (with certain gains applied).

The stabiliser angle, which had been trimmed on the ground to provide a trimmed configuration at approximately 140 knots (V2+15 = 143 knots), remained at its initial angle while the aircraft accelerated. The aircraft reached 160 knots; the speed specified in the procedures for the initial climb. This resulted in an untrimmed condition that required the pilot to counteract with significant forward stick input.

During this time, the engines were delivering full take-off thrust, and the pilot followed the flight director commands to maintain the programmed climb profile. This caused the aircraft to climb at nearly 5,000 feet per minute. The recordings show that the pilot initially applied nearly full forward stick deflection, then reduced the input to about half forward deflection.

In this type of dynamic condition, a pilot should increase forward stick movement until the aircraft responds by lowering the nose to a shallower climb angle. The pilot employs what is referred to as closed-loop control, which means that the initial forward stick movement can be slightly excessive.

The pilot quickly recognised the fault and reached across the central pedestal to begin manually trimming the stabiliser in the nose-down direction while simultaneously using the stick for both pitch and roll control. The recordings indicate that the pilot began trimming approximately five seconds after the CAS warning message was displayed, and also informed the co-pilot of the fault and that manual trimming was being applied.

When the stabiliser angle approached a trimmed state, the authority of the elevator increased, and the pitch control inputs (stick movements) could be reduced, stabilising the aircraft's climb.

2.1.2 Pitch trim and stabiliser behavior

After take-off, approximately five seconds after lift-off (WoW = 0), a control law transition occurs, during which the system switches to gamma dot mode. In gamma dot, the autotrim function of the pitch trim system is activated. However, since the system entered Direct Mode (*DM*) during the mode transition, the autotrim functionality was not available. The pitch trim setting remained the same as it had been configured prior to take-off.

As the airspeed increased beyond the speed at which the aircraft was trimmed, the nose-up pitching moment increased, and the nose-down authority of the elevator decreased.

2.1.3 Flight Control System behavior

It has been determined that the degradation of the priority index for both FCCs to 0 due to an exceeded threshold value was related to the TTP architecture's handling of skew between frames written to the data bus by the two processes in the CIM. The fault outcome and resulting chain of events reveal deficiencies in the robustness of the system. The deviation between the COM and MON lanes was handled according to the system design for an individual FCC. However, the chain of events would have been interrupted if the fault had occurred in only one of the two FCCs, or if one FCC had been reset after the reset time of the other, provided that the priority index after either reset had been above 2. In such a case, the control system would have allowed the capable FCC to maintain control.

During the rig tests, the chain of events leading to one FCC failing was successfully recreated, however a dual FCC reset condition at the same time was never confirmed. The tests demonstrated the faults and their cascading effects, as well as the values of input variables, their gradients, and the timing required for the fault to occur. Taken together, this provides a solid foundation for implementing software updates to both minimise the likelihood of the same fault occurring in each individual FCC and to improve the robustness of the logic that governs FCC switching in cases where data on the TTP bus appears as stale during a fixed time interval because of skew.

Proposed corrective actions have been presented to SHK and successfully demonstrated during rig tests. Embraer plans to continue testing, assess robustness, and pursue certification of the updated software. SHK considers that Embraer has a strong basis for preventing the fault and its cascading effects with the updated software, and has therefore not issued any recommendations regarding the system.

2.2 Crew workload

In both incidents, the pilots were surprised by the rapidly increasing pitch angle, which exceeded normal parameters.

In the earlier incident at Le Bourget, the PF (also the PIC) believed that the stick had lost its functionality and handed over control to the first officer. After the NORM MODE button was pressed, the control system returned to normal functionality, and the crew was able to return for landing. The manual trim was not utilised at all during the incident. The pilots were accustomed to a fully "fly-by-wire" control system and were unaware that manual trim might be necessary in flight. SHK assesses that lack of effective training, missing checklist items and lack of system knowledge has contributed to delayed crew reaction.

In the latest incident at Bromma, the PF believed that the stick had partially lost its functionality and began trimming instead. After the NORM MODE button was pressed, the control system returned to normal functionality, and the crew was able to return for landing.

In both incidents, the crew received a CAS warning a few seconds after lift-off, during a dynamic flight phase. The PF rotated to a high pitch attitude to achieve the correct airspeed while also ensuring that the landing gear was retracted in time. The crew had to analyse the warning, with flashing lights and triple audio alerts. The PF had to counteract the surprising upward pitch with significant control inputs, communicate with the first officer about the situation, and, in the Bromma case, manually trim to regain control authority of the stick.

According to both PFs, they perceived the workload as high, and the time pressure as significant. The crews acted quickly and decisively, applied the checklists without delay, and successfully restored normal system functionality.

In the Bromma incident, the PM quickly communicated with air traffic control about the issue. When the communication appeared unclear, the pilot declared "Mayday, Mayday," which alerted everyone on the frequency to the severity of the issue. The emergency call clarified to the air traffic controller why the assigned altitude and subsequent heading could not be followed.

Although the Flight Control System functions were restored after the checklist was completed, the crew was not confident that the issue would not reoccur for the remainder of the flight. Therefore, they took additional risk mitigation measures before landing.

SHK's assessment is that the crews acted in a coordinated and rapid manner despite the high workload, and effectively combined their resources in the cockpit.

2.3 Trim control position in the cockpit

The manual trim control is located on the right side of the central pedestal between the pilots, which means that the left-seat pilot has to reach over to access it. The trim control is not illuminated in darkness (see Figure 2).

The manual pitch trim is not typically used by pilots during flight, but is manually adjusted on the ground before each flight. Based on interviews with the pilots and evaluations conducted in the simulator, SHK assesses that the position of the trim control switch makes it more difficult for the left-seat pilot to reach. However, the position is familiar to a qualified pilot, and the control can be reached and identified by both pilots.

2.4 Actions taken after the Le Bourget incident

The aircraft type is a modern "fly-by-wire" controlled aircraft, which means that during normal flight, trimming is automatic and not a pilot action. Based on this philosophy and how the manufacturer has evaluated incidents involving FLTCTRL-N-MODE FAIL, the fastest action, according to Embraer, was to press the NORM MODE button to restore normal function. Recurrent simulator training for such a failure was conducted during 2024 for the pilots involved in the Bromma incident, during level flight and in a situation where the aircraft was already trimmed when the failure was introduced.

After the incident at Le Bourget in July 2024, Embraer and Transport Malta Flexjet recognised that the manual pitch trim should be activated immediately when required, and an internal instruction was issued. This was shared with Embraer and Transport Malta, who subsequently published operational bulletins.

The Flexjet informed all its crew members about the nature of the failure and the new actions required of pilots in the event of such a failure. Based on interviews and data from the pilot's quick response, it appears that the Flexjet's information campaign was effective and that it contributed to reduce pitch angle deviations after the failure in the latest Bromma incident.

At the time of the Bromma incident, the formal checklist and training requirements had not yet been updated to implement the contents of the bulletin. According to Embraer, these were updated in June 2025.

2.5 ATC aircraft emergency management

Interviews and radio communication indicate that the situation for the air traffic controller was complex. One aircraft was ready for departure, and another aircraft was on final approach for landing. The air traffic controller decided to grant take-off clearance to the aircraft waiting on the runway. This reduced the risk of the waiting aircraft coming too close to 9H-MFX.

The occurrence was reported promptly to SHK as an ATC incident.

SHK assesses that the air traffic controller handled the situation safely and that the departing aircraft did not pose a risk to 9H-MFX.

2.6 Operator risk management of the fault

The Flexjet had a comprehensive safety management system that was proactive and updated following flight safety-related incidents. After reviewing the risks relevant to the incident in the Flexjet's risk management tools, SHK has determined that the specific failure affecting the EMB-550 was identified and assessed following the earlier incident at Le Bourget (involveing 9H-XFX). The measures taken by the Flexjet, including a video information session with all pilots, the publication of an operational bulletin, and discussions with the manufacturer (Embraer), were swift and concrete. Additionally, the Flexjet collaborated with the Maltese airworthiness authorities to formulate a bulletin instructing pilots to use the manual pitch trim in the event of such failures. The Flexjet's actions following the Le Bourget incident were the decisive factor in the crew's ability to quickly identify the nature of the failure, apply the correct procedures, and minimise altitude deviations.

2.7 Reporting to investigative authorities in the event of accidents or serious incidents

There are two separate systems for reporting incidents in aviation. Accidents and serious incidents must be reported to the safety authority in the country where the event occurred, in accordance with Regulation (EU) No 996/2010. The reporting obligation applies to all individuals who become aware of an accident or serious incident. From a reporting perspective, the system is robust and should ensure that a safety authority receives the information without delay. This facilitates the prompt preservation of evidence and the initiation of a safety investigation.

The second reporting system is governed by Regulation (EU) No 376/2014, which aims to improve aviation safety by ensuring that relevant information concerning civil aviation safety is reported, collected, stored, protected, exchanged, disseminated, and analysed. This is achieved by entering event data into the ECCAIRS database, which is often done by the national aviation authority. The deadline for sharing this information is no later than 72 hours after being informed of an event. A significantly larger number of events is reported under this system as it also captures less serious occurrences. However, due to the administrative process, analysis of these reports tends to take a longer time. From an investigative perspective, the reporting timeframe is lengthy, and there is a risk that facts and evidence may not be preserved in time for a subsequent safety investigation.

After the event that occurred at Stockholm/Bromma Airport in 2022, which was reported by LFV, Flexjet reported the occurrence as a serious incident to Transport Malta, which registered it in the ECCAIRS database as an incident. The reason for the reclassification has not been possible to determine, but authorities can adjust classifications based on their assessment of the risk involved. The fact that the event was not classified as a serious incident meant that Transport Malta was not obligated to notify the safety investigation authority. However, if the Flexjet had reported the occurrence directly to SHK in accordance with Regulation (EU) No 996/2010, it is possible that SHK would have assessed the event differently. Consequently, the safety deficiencies that have now come to light might have been addressed at an earlier stage.

SHK has observed that some organisations perceive that they have fulfilled their reporting obligations once they have reported an event under Regulation (EU) No 376/2014. This reporting is typically carried out by the operator to their national aviation authority, which then reports the event to the ECCAIRS database. SHK believes that there may be deficiencies in how organisations' safety management systems handle the obligation under Regulation (EU) No 996/2010 to promptly report directly to the relevant safety investigation authority. Such deficiencies could result in the loss of critical information. Therefore, EASA, through national civil aviation authorities (CAA/NAA), should ensure that organisations promptly report such occurrences directly to the relevant safety authority.

2.8 Events classified as *significant incidents*

The two events involving 9H-MFX at Bromma in September 2024 and 9H-XFX at Le Bourget in August 2024 were reported nationally and classified by Flexjet as *significant incidents*. These events were reported to Transport Malta, but not to the safety investigation authorities in the countries where the incidents occurred.

The classification "Significant Incident" is not defined in Regulation (EU) No 996/2010, but is an available option within the ECCAIRS system used for data collection under Regulation (EU) No 376/2014.

SHK observes that some incidents reported solely by the operator as *significant* do not reach safety investigation authorities in time for effective investigation. Therefore, EASA, in consultation with national civil aviation authorities (CAA/NAA), should consider the necessity of ensuring that information about such events is also reported to the country in which the incident occurred.

2.9 Overall assessment

In both incidents, the PF perceived that the control stick lacked sufficient authority to counteract the pitch movement, which increased abruptly after the fault. Based on the audio recordings, interviews with the pilots, and simulator reconstructions conducted by SHK as well as recorded data, it can be concluded that, immediately after the fault warning, the crew's workload and time pressure were high. A good familiarity with a similar fault one month earlier contributed to the PF's intuitive and quick reaction, as well as the PM's efficient and correct handling of radio communications and cockpit procedures. The altitude deviation beyond the cleared flight level was limited and did not result in a critical proximity to other traffic. Rapid handling by air traffic control enabled the crew to manage the fault in an orderly manner before returning for landing.

The Malta-based operator has encountered two similar incidents within a short period. Following the incident at Le Bourget, the Flexjet updated its safety management system regarding such control system faults and implemented concrete measures to mitigate the effects should such a fault occur again.

Additionally, during rig testing at the manufacturer, the root cause was traced to specific conditions within the CIM and TTP bus systems. The identification of these conditions, the variable values, and their gradients has enabled modifications to the control system software — both to prevent the fault in the individual FCC (Flight Control Computer) and to ensure that, when data on the TTP bus is classified as stale, the switch between FCCs is handled in a significantly more robust manner.

Since the type certificate holder has already taken measures, SHK does not intend to issue any safety recommendations regarding this matter.

SHK would like to highlight a key factor that likely helped prevent the incident at Stockholm/Bromma Airport from escalating into a more serious event. Flexjet Malta, in collaboration with the Maltese aviation authorities (TM) and Embraer, was able to quickly inform all its EMB-550 pilots about the nature of the control system fault and the new crew-actions to be taken in-flight in case of a recurrence of the fault.

3. Conclusions

3.1 Findings

a) The pilots were qualified to perform the flight.
b) The aircraft had a valid airworthiness certificate and a current certificate of review.
c) No technical fault on the aircraft prior to the flight that may have affected the sequence of events has been identified.
d) LFV reported the incident as a “Mayday” event to SHK.
e) A similar incident with the same model was reported in July 2024 during take-off from Le Bourget Airport. This led to actions taken by the Flexjet, the manufacturer, and Transport Malta.
f) The maximum take-off weight and centre of gravity were within the permitted range.
g) The crew followed normal taxiing and pre-take-off procedures.

h) The crew acted in accordance with the latest published bulletin and used the manual pitch trim to regain full control of the aircraft.
i) The crew declared an emergency and informed air traffic control in accordance with applicable procedures.
j) The air traffic controller at Bromma assisted with a new clearance and provided vectors for landing as requested by the crew.
k) The crew managed to regain normal Flight Control System functionality and landed without further issues.
l) The FCC memory showed faults in both units, indicating deviations from the elevator tolerances and TTP bus traffic.
m) System tests at the system integrator demonstrated that the faults could be reproduced.

3.2 Causes to the Serious Incident

The aircraft's rapid and unexpected upward pitch movement immediately after lift-off was caused by a fault causing both Flight Control Computers to reset. This caused the system to downgrade to a simpler control mode, which also resulted in the stabiliser angle not automatically adjusting for the increasing airspeed.

The extremely out-of-trim condition required the pilot to apply almost full stick inputs to regain the commanded pitch attitude and forcing a manual re-trim of the aircraft.

4. Safety recommendations

None.

Given the measures already taken by EASA, Flexjet and Embraer, SHK refrains from issuing further safety recommendations.

On behalf of the Swedish Accident Investigation Authority,

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