Engine Malfunction on Airliner during Takeoff at Helsinki-Vantaa Airport on November 25, 2021

L2021-04

FOREWORD

Pursuant to section 2 of the Safety Investigation Act (525/2011), the Safety Investigation Authority of Finland (SIAF) decided to investigate an engine malfunction that occurred on an airliner during takeoff at Helsinki-Vantaa airport on November 25, 2021.

Airline transport pilot Juha-Pekka Keidasto was appointed the investigation team leader. The appointed team members were air traffic control officer (retired) Kari Alvi, airline transport pilot Jani Holmberg and aircraft maintenance technician Mikko Raatikainen. Airline transport pilot Kimmo Lius was appointed as a subject matter expert. The investigator-in-charge was Chief Air Safety Investigator Janne Kotiranta.

The Dutch Transport Safety Board (DSB), the Transportation Safety Board of Canada (TSB) and the Swedish Accident Investigation Authority (SHK) appointed accredited representatives for the investigation. The European Aviation Safety Agency (EASA) appointed a technical advisor for the investigation.

Flight data recorder information was downloaded at the facilities of the German Federal Bureau of Aircraft Accident Investigation (BFU). The autofeather unit was tested by the engine manufacturer Pratt & Whitney Canada.

The purpose of a safety investigation is to promote general safety, the prevention of accidents and incidents, and the prevention of losses resulting from accidents. A safety investigation is not conducted in order to allocate legal liability.

The safety investigation examines the course of events, their causes and consequences, search and rescue actions, and actions taken by the authorities. The investigation specifically examines whether safety had adequately been taken into consideration in the activity leading up to the accident and in the planning, manufacture, construction and use of the equipment and structures that caused the accident or incident or at which the accident or incident was directed. The investigation also examines whether the management, supervision and inspection activity had been appropriately arranged and managed. Where necessary the investigation is also expected to examine possible shortcomings in the provisions and orders regarding safety and the authorities' activities.

The investigation report includes an account of the course of the incident, the factors leading to the incident, and the consequences of the incident as well as safety recommendations addressed to the appropriate authorities and other actors regarding measures that are necessary in order to promote general safety, prevent further accidents and incidents, prevent loss, and improve the effectiveness of actions conducted by search and rescue and other authorities.

An opportunity is given to those involved in the accident and to the authorities responsible for supervision in the field of the accident to comment on the draft investigation report. These comments have been taken into consideration during the preparation of the final report. A summary of the comments is at the end of the report. Pursuant to the Safety Investigation Act, no comments given by private individuals are published.

The investigation report was translated into English by TK Translations.

The investigation report and its summary were published on the SIAF's internet page at *www.turvallisuustutkinta.fi* on November 22, 2022.

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CONTENTS

1 EVENTS

1.1 Sequence of Events

The flight crew of Amapola Flyg flight APF322 had arrived at Helsinki-Vantaa airport in the evening preceding the date of the incident and had overnighted in a hotel in Tikkurila. The following day they were driven to the airport, where they met the flight's cabin attendant. The crew reported for duty at 1400 h UTC[1], one hour before the scheduled departure time of a domestic service to Joensuu.

After completing normal preflight preparations, the pilots began taxi towards runway 22L[2] at 1501 h. Taxiing was uneventful, and at 1506 h takeoff was begun with the captain as the flying pilot (PF)[3].

During the takeoff run, at a few knots below V1[4], the integrated alerting unit sounded two chimes, of which the second was of markedly shorter duration. The pilots also noticed that a warning flight on the central annunciator panel illuminated. Due to the momentary nature of these indications, neither pilot had sufficient time to diagnose the warnings.

The takeoff was continued past V1, and the PF rotated the aircraft at Vr. At the same moment, the master warning light illuminated and a triple chime aural alert sounded.

The PF should call landing gear retraction after liftoff; however, this call was not made, and the gear remained down throughout the entire flight. When airborne, the pilots normally conduct an after takeoff checklist, in which one item is gear retraction. Now the extended gear created significant drag and restricted the rate of climb to approximately 400 ft/min.

The PM reported a left engine malfunction after the aircraft had become airborne. The PF responded by instructing the PM to check and report the power settings on both engines. The engine instruments indicated that both were operating, but engine and propeller speeds on the left engine were abnormal. Engine speed was below the green arc, indicating that the propeller was providing 50 % of the total thrust. The PM confirmed these indications and added that the left propeller had not autofeathered. The PF then instructed to carry out the engine shutdown procedure. During the procedure, the PM shall ask the PF for an approval for shutting off fuel supply before moving the fuel lever to SHUT. This was given by the PF, who then told the PM to set a new heading in the flight management system.

Amapola Flyg's engine-out departure procedure for runway 22L calls for flying on heading 218 for 5 nm after takeoff before turning to waypoint VAVIS to enter a holding pattern at VAVIS.

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1 The times given in this report are UTC (Coordinated Universal Time). Local time during the incident was UTC + 2 h.

2 Runways are designated by their direction (heading). This report uses the internationally agreed method of depicting runways on aeronautical charts. A runway designation consists of two digits, which represent the direction of the runway and, where applicable, a letter that indicates the relative positions of parallel runways, e.g., 22L for runway 22 left and 22R for runway 22 right.

3 PM (pilot monitoring) and PF (pilot flying). These abbreviations indicate task-sharing between flight crew members. The PF is responsible for operating the aircraft, while the PM monitors the course of the flight and communicates with air traffic control.

4 V1 and Vr are takeoff reference speeds. V1 is decision speed, i.e., maximum speed at which the pilot should initiate a rejected takeoff in order to bring the aircraft to a stop within the accelerate-stop distance available. V1 is also the minimum speed at which the pilot can continue the takeoff after the failure of the critical engine and reach the required altitude within the takeoff distance available. Vr is rotation speed. It is the speed at which the pilot begins to pitch up the aircraft to takeoff attitude. A third reference speed is V2, which is the airspeed at which minimum required climb gradient is achieved in the event of a single engine failure.

As the aircraft was on climb to the single-engine acceleration height, the PM set code 7700 on the transponder and selected the traffic advisory (TA) mode on the traffic collision alerting system (TCAS)[5].

The local controller (Tower, TWR)[6] noted on his display that the flight was squawking 7700 and called the flight. The PM responded by transmitting mayday and reporting a left engine failure. The controller queried the pilots' intentions, adding that all runways at the airport were available for landing. The PM requested runway 15 and stated that the aircraft was on climb to the acceleration height and proceeding to VAVIS.

The controller discussed the situation with the approach controller and asked whether he should hand the flight over to approach control or keep it on the tower frequency, to which the approach controller replied that both options were acceptable. The flight remained on the tower frequency throughout the flight. The controller held an approach radar control rating for the airport and executed a combined local and approach controller's role during the remainder of the flight. He summoned additional controllers from a break into the control tower to assist in alerting actions and handling of telephone calls, while he himself concentrated on providing assistance and control service to the flight.

The aircraft increased speed after reaching the single-engine acceleration height, and at approximately 1,200 ft, about two minutes from takeoff, the PF told the PM to raise the flaps. As lift reduced, the aircraft briefly lost approximately 100 ft of altitude, which triggered a "don't sink" voice alert from the ground proximity warning system (GPWS)[7].

The controller queried the aircraft's climb capability and was informed that the aircraft was able to climb and turn, but performance was degraded, rate of climb being no more than approximately 400 ft/min. The controller cleared the flight to climb to 3,000 ft MSL[8]. The flight had been initially cleared to 4,000 ft MSL in accordance with the standard departure procedure. Soon thereafter he noticed that the aircraft was heading towards a tall transmission tower (see para. 2.2.2) and instructed the flight to turn right, to the north. The turn momentarily took the flight outside the terminal control area into uncontrolled airspace.

The pilots discussed how to notify the cabin attendant of the situation and agreed that the PM informs the passengers of the engine malfunction and explains that the flight is returning to Helsinki in approximately ten minutes. They did not at first make a separate call to the cabin attendant, who received the information via the passenger address system. When the aircraft was on final approach, the PM briefed the cabin attendant on post-landing actions, explaining that the pilots' plan was to taxi to the apron and park the aircraft.

The pilots initiated the Quick Reference Handbook (QRH) engine failure procedure. Because the procedure does not call for raising the landing gear, the gear remained down throughout the remainder of the flight.

The controller advised that runway 04L was also available, but the pilots decided to use runway 15 and responded to this effect.

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5 The TA mode alters the representation of the aircraft on the secondary surveillance radar (SSR) display. TA mode selection indicates to other aircraft that may come into conflict because of crossing flight paths that the TA mode aircraft will be unable to make evasive maneuvers.

6 Unless otherwise stated, the term "controller" refers to the local controller in the subsequent text.

7 The GPWS alerts the flight crew to potentially hazardous situations. A "don't sink" alert may sound after a loss of height following takeoff or due to the aircraft's proximity to terrain and requires immediate action to prevent ground impact.

8 Mean sea level.

The pilots conducted the approach checklist including an approach briefing. While the PF was giving the briefing, the controller advised that visual approach was also possible, but the pilots stated that they would continue on present heading, complete the checklist and call back. They conducted a threat and error management (TEM) discussion on engine-out landing and post-landing actions.

Before the flight began approach, the controller asked, in Finnish, the pilots to report the number of persons on board (POB) and the amount of fuel, and inform the controller of any dangerous goods carried on board. By this point, the controller and the pilots had communicated in English, while intra-cockpit conversations had been in Swedish.

The PM stated that he would pass the required information in English in order to make the discussion understood by the PF. Several messages were exchanged until a mutual understanding was reached and the PM got POB reported. He did not report the amount of fuel and the presence of dangerous goods at first, and neither did the controller make further inquiries.

After the pilots had discussed altitudes, the PM requested that the flight could maintain 2,000 ft and reported ready for approach. The controller cleared the flight to 2,000 ft and advised that it was approximately 13 nm out for landing. He now queried the amount of fuel a second time, and the PM replied that the flight had 2,720 kg of fuel.

During the approach the PM called the cabin attendant advising that they would be landing shortly, and the cabin attendant replied that the cabin was ready.

The controller radar-vectored and cleared the flight for precision approach to runway 15.

Upon intercepting the localizer, the PF reported glideslope alive and told the PM to lower the flaps to the landing position. The aircraft intercepted and captured the glideslope.

The PF told the PM to lower the landing gear, to which the latter replied that the gear was down; the PF then asked whether the gear had remained down during the entire flight, and the PM replied in the affirmative.

The controller cleared the flight to land on runway 15, and landing took place at 1519 h. The aircraft vacated the runway at taxiway YF intersection and was marshalled to stand 124. The flight was completed at 1527 h.

Units of the airport rescue service that were standing by on the apron were stood down after the aircraft was parked.

The flight had remained on the tower frequency during the entire flight. Once the situation had normalized, the controller who had handled the flight asked that he would be relieved, and another controller took over the control position.

In the evening, the captain submitted a flight safety report to Amapola Flyg's safety management organization. The report was sent to the Swedish Civil Aviation Administration before noon on November 26.

1.2 Alerting and Rescue Operations

The controller pressed the red pushbutton of the automatic alerting system at 1507 h. This action alerts an emergency response center (ERC) to respond to a major aircraft accident (code 233). The alert was received at the ERC in Kerava, at airport rescue service and at airport security service. The ERC initiated a preplanned response to an aircraft accident and airport rescue service deployed appropriate units. The air traffic control supervisor called the

ERC and gave additional information, explaining that an aircraft was returning to the airport due to an engine failure.

Figure 1. Air traffic controller's alert pushbuttons. (Photo: ANS-Finland)

The rescue service units proceeded to the apron to meet the aircraft upon its landing, while units from the alerted rescue departments were standing by at the fire station of Central Uusimaa Rescue Department in the vicinity of the airport.

After the aircraft had landed, the on-duty supervisor (call sign ARP30) of the rescue service, who was the incident commander, notified the on-duty fire officer (KUP33) of Central Uusimaa Rescue Department of the successful landing, and KUP33 stood down 14 rescue department rescue units and six paramedic units. The rescue service units repositioned to the vicinity of stand 124 to wait for the aircraft that was taxiing-in. After the aircraft had stopped, the on-duty supervisor stood down the rescue units at 1527 h. Rescue service personnel did not communicate with the crew of the aircraft. Because the ERC alert was not relayed to the police, police units did not check on the aircraft, and the pilots were not breath tested.

1.3 Consequences

There was no damage to persons, equipment or environment, and the aircraft sustained no external damage.

2 BACKGROUND INFORMATION

2.1 Environment, Equipment and Systems

2.1.1 Helsinki-Vantaa Airport

Helsinki-Vantaa airport is located in the municipality of Vantaa. The aerodrome reference point is at 60°19'02"N 024°57'48"E. The airport is in operation 24 hours a day and is the busiest airport in Finland.

The airport has three runways. The main runways (04R/22L and 04L/22R) are oriented at 038/218 degrees magnetic. The third runway (15/33) is oriented at 144/324 degrees magnetic. The length of the paved surface is 3,500 m for runway 04L/22R, 3,060 m for runway 04L/22R and 2,901 m for runway 15/33. All runways are 60 m wide.

Instrument flight rules and visual flight rules procedures and aeronautical charts are available for all runways.

The air traffic services units located at the airport include Area Control Centre Finland (ACC Finland), Helsinki approach control (APP) and local control (TWR).

The facilities of the local control are in the aerodrome control tower, while the approach control and ACC Finland are co-located in a separate building. All units share common information systems, and flight plan and other information is transferred between the units in an electrical format.

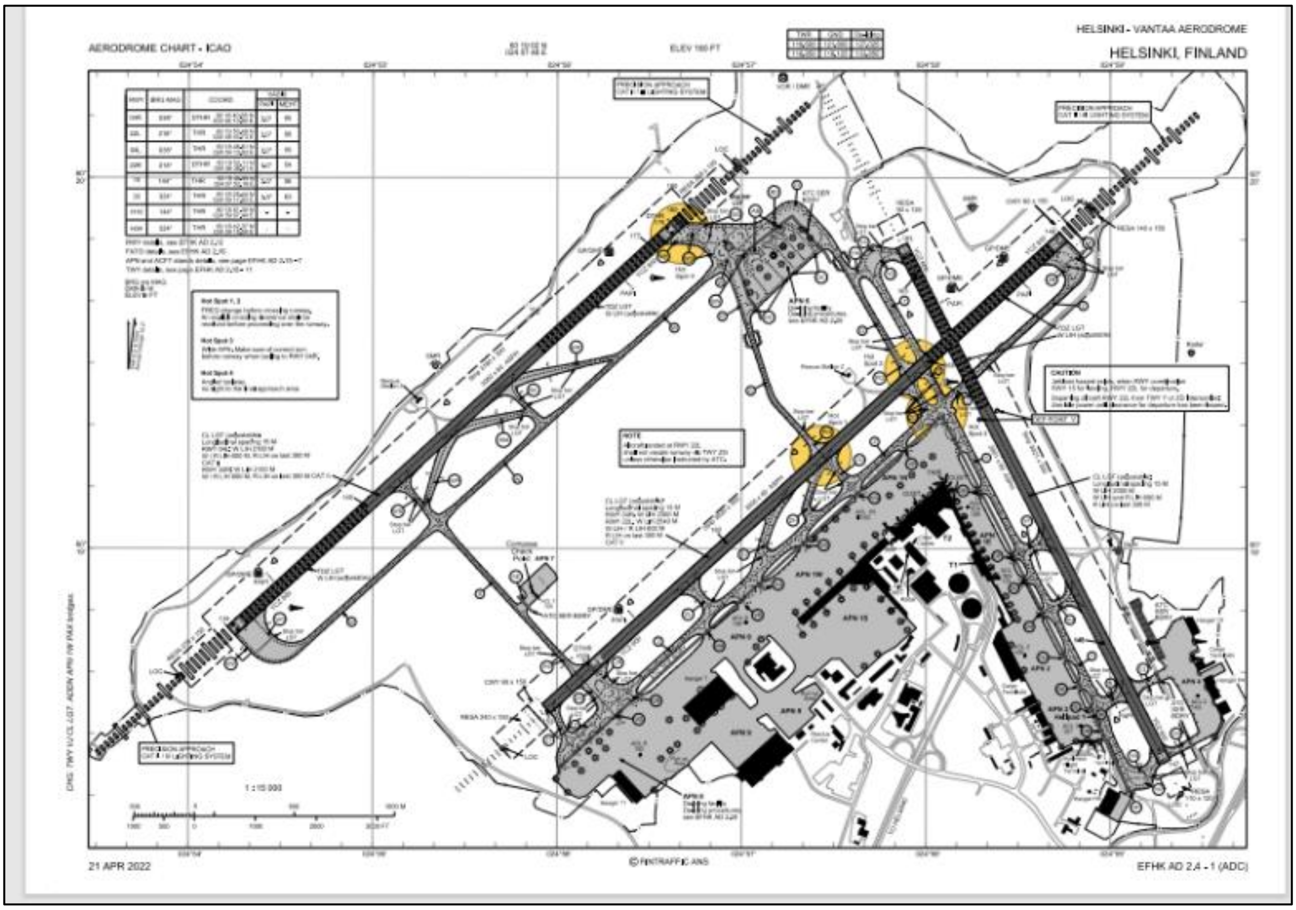

Figure 2. Helsinki-Vantaa Airport. (Photo: AIP Finland, EFHK)

2.1.2 Aircraft

The incident aircraft is a Fokker 50 short- and medium-range airliner. The type is operated by two pilots and one cabin attendant and can carry 50 passengers. Amapola Flyg uses the type on passenger and cargo services.

The incident aircraft bears the registration SE-MFZ. The serial number of the 1989-built aircraft is 20159. It is powered by two Pratt & Whitney Canada PW125B turboprop engines driving variable-pitch Dowty Rotol propellers.

Aircraft length is 25.25 m, wing span 29.00 m and maximum permitted takeoff mass 20,820 kg. By the time of the incident SE-MFZ had accumulated 47,785 hours on 45,902 cycles.

The incident flight began normally with no anomalies noted during start-up and taxi. The aircraft began takeoff on runway 22L. Both engines operated normally during the initial phase of the takeoff run until 24 s from the beginning of the takeoff, at 97 kt airspeed, the integrated warning system activated for 0.3 s. The pilots heard an alert and saw a warning flight but did not have time to diagnose the warnings.

The PM checked the engine instruments, and since everything appeared normal, the takeoff was continued. The PF initiated rotation at 108 kt airspeed, 28 s from the beginning of the takeoff. During rotation, 30 s from the beginning of the takeoff, the left propeller feathered and a L ENG OUT alert activated. Both engines continued operating, and power on the right engine increased automatically. Liftoff occurred 2 s after feathering. The pilots became aware of a malfunction of the left engine when they noticed a change in the engine sound and felt a change in the aircraft's handling characteristics. With the left propeller feathering and the engine operating at takeoff power, engine indications deviated from normal significantly. The pilots shut down the engine 9 s from feathering, at 114 kt airspeed and at approximately 60 ft above ground level, and continued the flight in accordance with the engine-out procedures.

An engine electronic control (EEC) unit commands an increase of power on an engine to compensate for increased propeller drag and maintain the selected power setting. The incorrect blade angle for the prevailing conditions resulted in an abrupt increase of engine torque, and the torque (TQ) reading on the analog indicator went off the scale immediately after the propeller feathered. The maximum indicated torque on this indicator is 120 % TQ. However, the digital display may show higher readings. The flight data recorder does not capture torque values above 120 % TQ, and therefore the actual peak torque value could not be established. The engine was able to rotate the feathered propeller at 50 % indicated propeller speed (Np). A feathered propeller creates considerable aerodynamic drag in the direction opposite to engine rotation.

Figure 3. On the left, engine indications during a normal takeoff. On the right, the left propeller is feathered, but the engine is operating. (Figures: Gabriel Leigh / Flightradar24, edited by SIAF).

If the engine shuts down but the propeller does not feather, the propeller continues windmilling. In this case, propeller speed is a function of airspeed but remains within the indicated range of approximately 70 % to 80 % Np with propeller pitch at 15° to 17°.

After verifying the engine malfunction the pilots focused on propeller speed, which remained at 50 % Np, and concluded that the propeller had not autofeathered. They decided to feather the propeller manually by setting the fuel lever to SHUT. This cuts off fuel supply and shuts down the engine and is in accordance with the engine failure checklist.

Propeller feathering on the Fokker 50 can be activated automatically or manually. The purpose of the system is to reduce the drag created by a windmilling propeller after an engine failure by aligning the blades parallel to the oncoming airflow. The propeller is also feathered during normal engine shutdown.

A propeller is feathered manually by setting the fuel lever to SHUT or START. The lever is set to SHUT for engine shutdown on the ground or in flight. During shutdown, the combined action of oil pressure and counterweights at blade roots moves the blades to the feathered position. The lever is set to START during engine start to keep the propeller feathered during the initial phase of start-up. Setting the lever to OPEN unfeathers the propeller.

Blade motion is achieved by directing engine oil under pressure in a line (beta line) that passes through the propeller hub into an operating cylinder mounted in front of the hub. Feathering uses the combined action of engine reserve oil pressure and the counterweights. During automatic feathering or with the engine shut down in flight, oil pressure is supplied by a feathering pump.

Autofeathering is controlled by an autofeather unit (AFU) and requires no pilot action. Each engine has its own AFU, which receives information from several sources. The AFUs process this information and command the feathering of the respective propeller when required.

During normal operation, the AFUs are activated but cannot be controlled separately from the cockpit. Indicator lights displaying the condition of the feathering system and of the AFU, and separate feather test buttons are located in the instrument panel.

The autofeather units have four selectable conditions: standby, armed, activated and test.

STANDBY: When the landing gear is down or the pilot has selected TO (takeoff), GA (go-around) or FLX (flexible takeoff) on the engine rating panel, the autofeather system is energized but does not control feathering functions. A blue STBY light is illuminated.

ARMED: When the autofeather system is on standby, the power levers are set to takeoff position and the torque values for the engines are above 50 % TQ, the autofeather system will be armed. The AFUs monitor engine operation and command the feathering of the respective propeller when required. The blue STBY light will change to a green ARMED light.

ACTIVATED: When the autofeather system is armed and engine torque decreases below 25 % TQ, the respective propeller will feather. The AFU controls feathering via relays, activates the feathering pump and sends an uptrim command to the engine electronic control unit of the opposite engine. The green ARMED light will extinguish, a red ENG OUT warning light will illuminate and a triple chime alert will sound. Each engine has a separate warning light (L/R ENG OUT). The feathering pump will stop after running for 30 s. The ENG OUT light will extinguish and the aural alert will stop when the fuel lever for the affected engine is set to SHUT.

TEST: The system can be tested when standby is selected and the power levers are set to the idle position. When a test button is pressed, the AFU performs a functional test without feathering the propeller. The system is tested before the first flight of the day.

Each autofeather unit receives signals representing engine operating conditions from a torque sensor. Each engine has two identical sensors; one provides signals for feathering control (AFU / Torque sensor #1) and the other provides signals to the engine electronic control unit (EEC / Torque sensor #2).

The sensors are located on the reduction gearbox and connected to the aircraft electrical system via a plug that engages a threaded receptacle on the sensor.

Each electromagnetic sensor senses variations in the magnetic field resulting from the rotation of the reduction gear drive shaft. It monitors the interval of these variations and sends data on two discrete signal outputs designated LOW TQ and HI TQ. A temperature sensing interface of the connector is not in use.

The engine electronic control (EEC) unit receives, converts and calculates data it receives from a torque sensor and provides a cockpit indication of engine torque in percent. Maximum allowable transient (10 min) torque value is 102 % TQ. Maximum allowable continuous torque value is 87.5 % TQ.

The AFU monitors and processes the signal it receives from a torque sensor and uses this information for autofeathering control. Information from the sensor tells the AFU the operating condition of the engine and whether the engine is producing sufficient torque to turn the propeller. When engine torque is above 50 % TQ and the autofeather system moves to the armed condition, the AFU outputs a torque signal (>50 % TQ) to the EEC of the respective engine and to the AFU of the opposite engine. The EEC compares the signal it receives from the AFU with the signal provided by the respective torque sensor, and if disagreement between the signals is detected during more than 5 s, triggers an ENG EC DEGRADED warning.

The warning system of the Fokker 50 has a takeoff inhibit mode that activates when airspeed exceeds 80 kt during takeoff and deactivates approximately 40 s after liftoff. When the mode is active, the pilots only receive warnings of critical system failures and malfunctions[9], which will alleviate their workload. Alerts of minor system anomalies are issued after takeoff.

The pilots and the station mechanic carried out troubleshooting in accordance with the applicable checklist by opening flight data recorder (FDR) and cockpit voice recorder (CVR) circuit breakers and conducted a ground run before the arrival of SIAF investigators. The purpose of the ground run was to locate the fault for a subsequent corrective action. The ground run included testing of the feathering system of the left propeller and engine-related airframe systems, and no anomalies were noted.

After a fault analysis performed by the aircraft operator, it was decided to inspect the left engine visually and replace its AFU and the respective torque sensor. Component removal and system inspections were performed in the presence of an SIAF specialist.

The visual inspection of the engine revealed no anomalies. The AFU was undamaged externally, and its electrical connections were secure and protected with shrink sleeving. The torque sensor connector was undamaged externally and protected with shrink sleeving. Difficulty was experienced during the removal of the connector plug. Similar connectors can normally be rotated by hand, but now tools were needed to remove the plug. Examination of the male receptacle, which is an integral part of the sensor, revealed a bent pin, while the insulator of the female plug was found damaged.

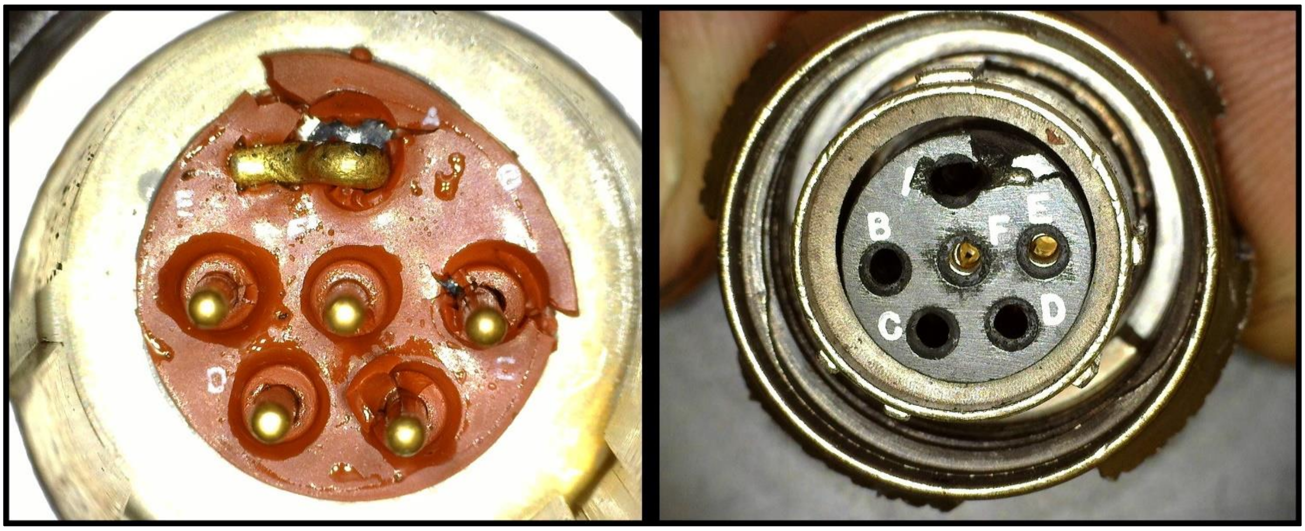

Figure 4. The torque sensor connector receptacle (left) and plug (right, with wiring harness removed). Bent pin and insulator damage are visible. (Photo: SIAF)

A torque sensor transmits data to the AFU via two channels. Torque (TQ) signals are routed via connector interfaces A and B, while temperature signals are routed via interfaces C and D. The temperature sensing function, and therefore interfaces E and F, are not in use. The bent pin was in interface A, which supplies a TQ HI signal to the AFU. The pin had created a depression in the insulator inside the plug, and this depression was deep enough to reach the

[9] The critical system failure alerts that are not inhibited during takeoff are engine failure (L/R ENG OUT), engine fire (ENG FIRE), low engine oil level (ENG LOW OIL) and automatic flight control system failure (AFCS).

respective socket. Measurement of the height of the bent pin and the depth of the insulator damage indicated that the pin could come into contact with the socket.

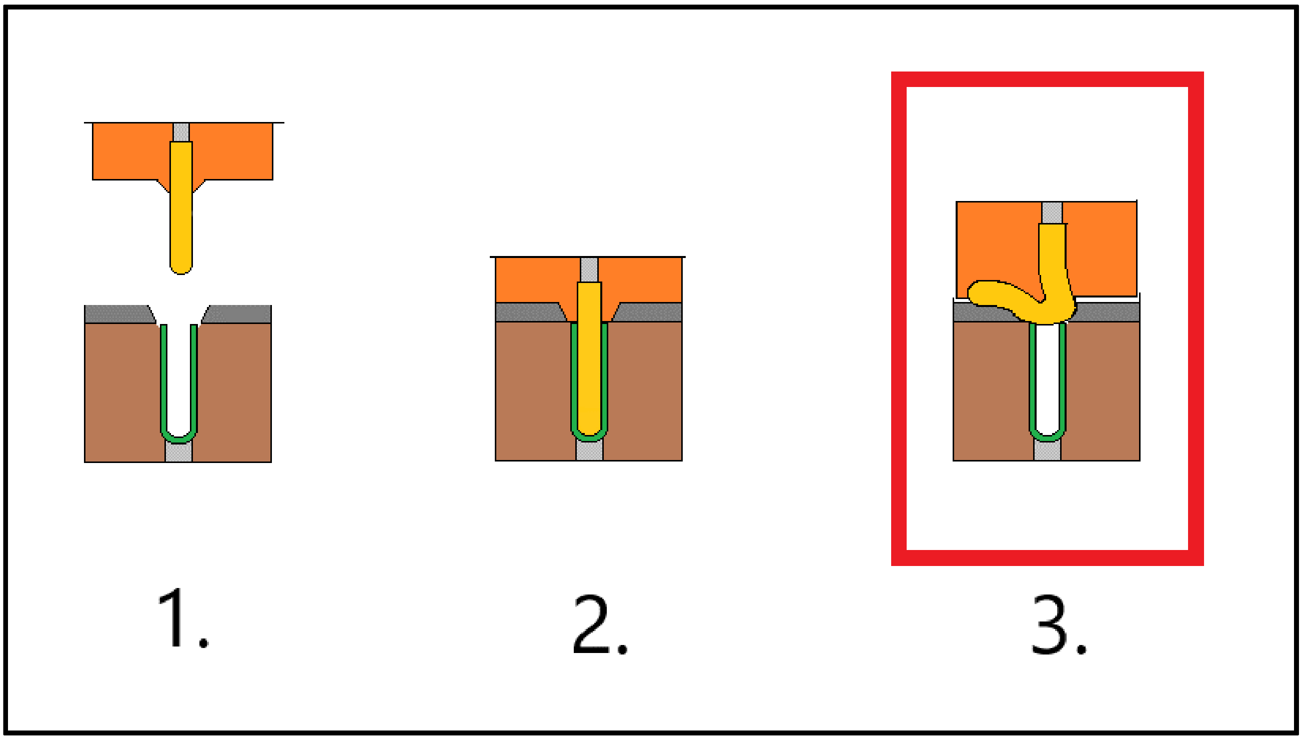

Figure 5. The AFU connector. 1. An undamaged connector with the plug removed. 2. An undamaged connector with the plug installed. 3. The bent pin with the plug installed. (Photo: SIAF)

On completion of the measurements the plug was installed to the sensor and the connector was tested with a multimeter. When the plug was hand-tightened using slightly higher-than-normal force, electrical continuity was created between the bent pin and the socket, but continuity was extremely sensitive to movement: even the slightest vibration or change in connector position led to a momentary or permanent loss of contact.

The pilots of the incident aircraft had received a transient aural and visual alert during takeoff from Helsinki in the previous evening, but they had not been able to diagnose the problem before the warning light extinguished. The event was not entered in the aircraft's technical log. The pilots and the Amapola Flyg station mechanic had discussed the matter after landing at Helsinki.

The propeller will autofeather when the autofeather system is armed and engine torque decreases below 25 % TQ. The torque sensor supplies a maximum torque value signal (TQ HI) to the AFU. When the system is armed and this signal is lost, the AFU interprets the signal loss as an engine failure and feathers the propeller. A logic circuit in the AFU has a 0.12 s delay to prevent system activation due to spurious signal losses; therefore, if a lost signal is restored within 0.12 s, the discontinuity will have no effect on system operation.

It is likely that the system operated normally during engine start, taxi and the initial phase of the takeoff run on the incident flight. The system senses a TQ HI signal failure when engine torque is above 50 % TQ for more than 5 s and triggers a warning in the cockpit. On the incident flight, torque was 85 % to 87 % TQ during the initial phase of the takeoff run.

At 97 kt airspeed during the takeoff, the TQ HI signal was lost momentarily, most likely due to vibration or a slight jolt. The CVR captured two distinct thuds that coincided with the activation of the warning system for 0.3 s. The time interval between the thuds matches the distance of runway centerline lights when the aircraft is traveling at 97 kt.

Since the AFU did not command feathering, it can be assumed that the duration of the signal loss was less than 0.12 s; however, it triggered a L ENG OUT warning that ceased after 0.3 s from the activation. Because airspeed at that point was above 80 kt, the takeoff inhibit mode was active and an ENG EC DEGRADED warning was not received. The pilots found that the aircraft operated normally after the warning had ceased, and a subsequent analysis of FDR engine parameters indicated no anomalies during or immediately after the warning.

Six seconds later, when the PF initiated rotation, the TQ HI signal was lost for more than 0.12 s due to a connector fault; as a result, the AFU commanded feathering and triggered a L ENG OUT warning. The propeller feathered immediately, while the engine continued operation at takeoff power.

The left engine, serial number 125023, had been replaced in October 2021. The engine had been removed from the aircraft and the components of the quick engine change unit (QECU) kit had been stripped from the basic engine[10] at Amapola Flyg facilities.

The basic engine had been shipped to a maintenance, repair and overhaul (MRO) provider for the rectification of an oil leak in an aft-end bearing. Maintenance documentation contains no requirement for disturbing the torque sensor or its wiring harness during engine removal or QECU kit stripping, and no such action was documented in the aircraft's maintenance records.

A replacement engine is installed on the aircraft fully equipped to save time and simplify the workflow. When the engine is in the QECU configuration there will be no need to disturb the torque sensor or its wiring harness because these components are parts of the basic engine.

Most work at the MRO facility had been performed on the aft end of the engine, and a subsequent bench test had revealed no anomalies. For this test, a wiring harness from the test bench had been connected to the engine, and this had involved installing a plug to the torque sensor. The fault history of the incident aircraft does not indicate previous sensor malfunctions or damage to the sensor.

Damage to the sensor and the pin had occurred during installation when the misaligned pin had been subjected to bending inside the connector. Pin misalignment can be detected visually before installation, and maintenance manuals instruct to pay particular attention to the condition of connectors. The engine manufacturer has also issued amplifying instructions for the installation of engine connectors. Although the bent pin had not been visible from the outside, it is likely that higher-than-normal force had been required to rotate the plug, which later led to difficulties during its removal due to the tight fit. Shrink sleeving over the connector reduces vibration and prevents the ingress of contaminants. In this case, the sleeving had provided additional rigidity and thereby prevented an early occurrence of the fault after installation.

Uncommanded feathering on the Fokker 50 has been reported on several occasions. Many of these events have been traced to torque sensor anomalies or erroneous signals. Airframe and engine manufacturers have issued several maintenance, repair and modification instructions to increase the reliability of PW125 torque sensors and of the AFU. After reports of loose connectors, pin fretting and corrosion damage, a new type of connector and sensor

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10 The basic engine of a gas turbine engine includes the power section consisting of the engine core and the reduction gearbox and their internal components.

was introduced and the installation of shrink sleeving for connector protection was recommended. In some cases, internal AFU faults have also led to uncommanded feathering.

All actions required by the airframe and engine manufacturer had been carried out on SE-MFZ prior to the incident flight.

2.1.3 Air Traffic Control

The air traffic services (ATS) units located at Helsinki-Vantaa airport are local control (Tower, TWR) and approach control (Approach, APP). The airspace area of responsibility of local control is the aerodrome control zone (CTR) between ground level and 1,300 ft MSL. The area of responsibility of approach control is the aerodrome's terminal control area (TMA) between 1,300 ft or 2,500 ft – depending on geographical location – and flight level 285 (28,500 ft in standard atmospheric pressure).

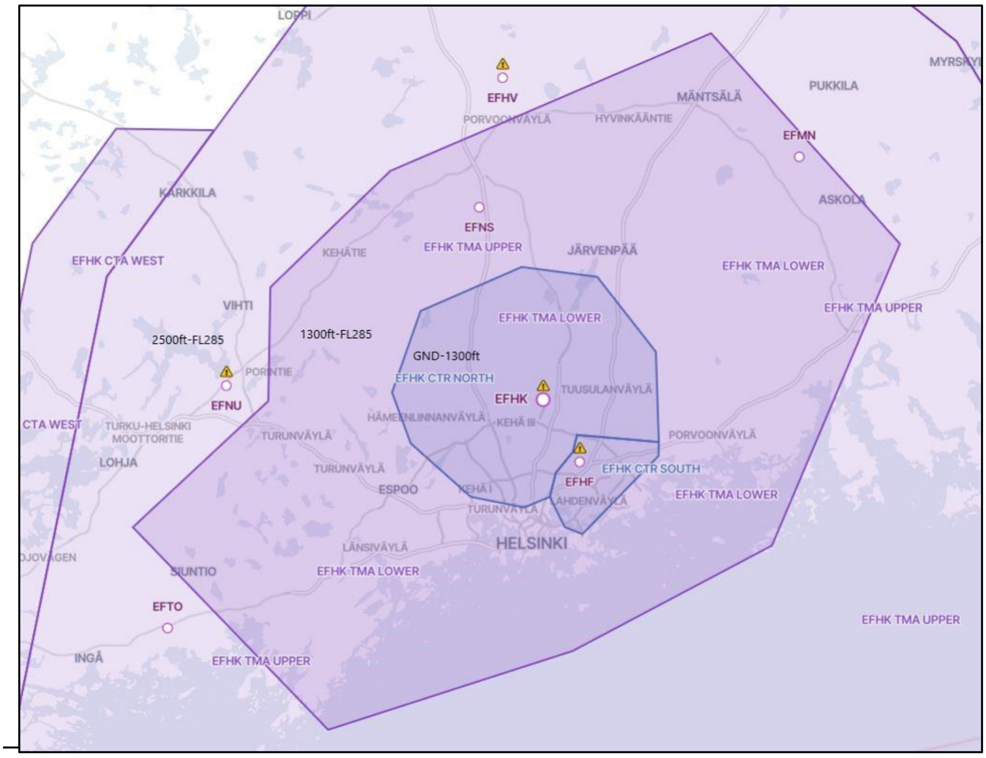

Figure 6. Helsinki-Vantaa control area boundaries and altitude limits (Photo: Aviamaps)

Both local control and approach control use TopSky radar displays that provide an integrated air picture derived from data supplied by radar stations and other systems. The local controller and the approach controller can select an identical picture for viewing. A radar label containing the call sign, speed, altitude and other radar data is attached to the target symbol, and these can be supplemented by selectable flight plan data. The label can be tailored for individual control positions as required. Although labels of flights that are under the control of adjacent ATS units can be filtered out, target symbols will be displayed permanently.

If a flight sets the emergency code 7700 on the transponder, its label will appear on the display regardless of the level of filtering and other selections, but no aural alert will be received. Code 7700 will appear on the display, and the letters EM (for "emergency") will show on the top line of the label in red, but no aural alert will be received.

Figure 7. The TopSky label of the incident flight on the controller's display. (Photo: Fintraffic)

2.2 Conditions

2.2.1 Weather

Dark night conditions with cloudy skies prevailed at the time of the incident. The airport's weather observation facility reported[11] wind from 220˚ at 4 kt. Visibility was over 10 km in light rain. Clouds were few at 1,000 ft and overcast at 4,000 ft. Temperature was +4 ˚C and dew point was +3 ˚C. Air pressure was 993 hPa.

The Helsinki-Vantaa terminal area forecast[12] for the next 24 h indicated increasing cloudiness along with lowering ceilings combined with reduced visibility and increasing winds.

Runway Conditions

Runways 22L and 15 were wet, but braking action was good. The runway and approach light systems for both runways were in working order.

2.2.2 Terrain Features

The sole obstacle reaching above 1,000 ft in the vicinity of Helsinki-Vantaa airport is a transmission tower at Kivenlahti, Espoo. Its height is 1,214 ft (370 m) MSL. The tower is located approximately 11.9 nm (22 km) southwest of the departure end of runway 22L almost on the extended runway centerline at 60°10'38"N 24°38'26"E.

[11] Meteorological aerodrome report: METAR EFHK 251450Z 22004KT 9999 -RA FEW010 BKN040 04/03 Q0993 NOSIG=

[12] Terminal area forecast. TAF EFHK 251435Z 2515/2615 22003KT 9999 -RA FEW010 BKN035 PROB30 TEMPO 2515/2517 BKN009 BKN030 TEMPO 2522/2603 3500 -SNRA BKN004 BECMG 2523/2601 32010KT=

2.3 Recordings

2.3.1 Fintraffic ANS Recordings

Fintraffic ANS provided for the investigation recordings of local controller and approach controller's telephone conversations related to the incident flight, radio communication recordings of tower and ground control, and radar data for the entire duration of the flight. Recorders had been in working order, and the recordings were of good quality.

Recorded radar data and radio communication yielded a good picture of the flight's track, climb performance and altitudes in all phases of the flight.

2.3.2 Flight Data Recorder

The FDR was shipped to BFU[13] where information was downloaded and sent in a graphic format to the investigation team for analysis. The good-quality recording was useful during the investigation of engine parameters and the propeller feathering sequence. FDR data was also used for altitude, heading and speed analyses.

In addition to the above, FDR data was used to generate a computer-animated video for flight reconstruction purposes.

2.3.3 Cockpit Voice Recorder

Flight-related CVR information was downloaded. The CVR had operated normally, and the recording was of good quality. It was used to study intra-cockpit conversation and communication between the pilots and the controllers. The CVR had also captured aural alerts generated by the aircraft's warning system along with internal and external sounds, including the sound generated by propeller feathering.

2.3.4 Emergency Response Center Recordings

The ERC recordings were of good quality. They were used to evaluate the actions of the ERC and the airport rescue service.

2.3.5 Vehicle Camera Recordings from Airport Rescue Service Units

These recordings were of good quality in terms of both sound and imagery. They were used to evaluate the actions of the airport rescue service.

2.4 Personnel, Organizations and Safety Management

2.4.1 Aircraft Operator

At the time of the incident, Amapola Flyg operated 14 Fokker F50s, of which three were used for passenger services and 11 as freighters.

2.4.2 Safety Management System

Amapola Flyg's operational safety department is responsible for the maintenance and monitoring of flight safety within the airline. The airline has instructed all employees to file an occurrence report whenever they observe an accident, a serious incident or an occurrence or have been involved in one.

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13 Bundesstelle für Flugunfalluntersuchung (German Federal Bureau of Aircraft Accident Investigation).

Resulting flight safety reports are stored in the airline's safety management system. As a rule, reports are produced in an electrical format.

Reports of serious incidents are passed to the chief of flight operations and the safety manager at the first opportunity after the event and sent to the national aviation authority.

The operational safety department discusses each flight safety report, assesses related risks and gives a risk classification. The outcome of the risk assessment serves as a basis for safety recommendations.

A total of 273 flight safety reports were filed in Amapola Flyg in 2021, of which 15 were sent to the Swedish Civil Aviation Administration. The airline operated an average of 450 flights per month in 2021, which represented a drop of approximately fifty percent compared with the pre-pandemic period. The airline supports a "just culture," in which an individual who files a report will not be blamed for his or her actions.

2.4.3 Flight Crew

The captain, 52, held all required class and type ratings and valid medical certificates. He had approximately 11,000 flight hours, of which 8,000 were in the Fokker 50.

His English language proficiency endorsement had expired on January 31, 2021. His license contained a level 4 (operational level) endorsement, but no indication of a subsequent language assessment was evident. The captain produced, on request, a more recent copy of the license, which contained a level 6 (expert level) endorsement and the date of assessment of March 10, 2021.

The captain had been on furlough from September 19, 2020, to May 1, 2021 due to Covid-19 pandemic.

The first officer, 33, held the required class and type ratings and valid medical certificates. He had approximately 1,400 flight hours, of which 1,100 were in the Fokker 50.

2.4.4 Cabin Crew

The cabin attendant held the required ratings and qualifications.

2.4.5 ANS Finland

2.4.6 Air Traffic Controllers

The local controller, 43, held local and approach controller ratings for Helsinki-Vantaa airport. He held the required licenses and ratings and a valid medical certificate.

He had completed air traffic controller's basic training in 2000 and started work in the local control facility at Helsinki-Vantaa in 2001. He had held a radar controller rating since 2004.

During the incident he summoned additional controllers into the control tower to assist in alerting actions, handling of telephone calls and other tasks.

2.5 Rescue Services and their Preparedness

Kerava Emergency Response Center provides ERC services in Uusimaa region by alerting rescue units in accordance with procedures established by the competent authority.

Finavia operates Helsinki-Vantaa airport and maintains a round-the-clock rescue service in readiness to respond to aircraft accidents and incidents at the airport or in its vicinity. The service is in compliance with the applicable European Union regulations. The minimum operational manning of the service is 7 persons. The service maintains in readiness a command vehicle, a rescue vehicle, a passenger step vehicle and four foam units deployed in three rescue stations in dispersed locations within the movement area. The service is an integral part of the airport's rescue organization.

The on-duty rescue service supervisor directs rescue operations until the regional rescue department is notified of the occurrence. The service's preparedness for aircraft accidents at the airport and in its vicinity is described in the aerodrome emergency plan that is maintained in cooperation with Central Uusimaa Rescue Department.

Central Uusimaa Rescue Department is in charge of rescue operations at Helsinki-Vantaa airport. The department has in place general guidelines for major accidents, and it maintains a 24-hour situation center. The department's closest fire station is located at the airport perimeter. Pursuant to section 44 of the Rescue Act[14], the local rescue authority is responsible for command and control in accidents that occur at the airport or in its vicinity. The department is prepared for aircraft accidents and incidents by maintaining a separate response plan that is harmonized with the procedures of the airport rescue service.

The Hospital District of Helsinki and Uusimaa is responsible for urgent pre-hospital care in Central Uusimaa region, where Helsinki-Vantaa airport is located. The airport is listed as a high-priority target in the service level agreement. The district has a cooperation agreement with Central Uusimaa Rescue Department for initial response actions and urgent paramedic actions. The district has also in place a cooperation agreement with the airport rescue service for initial response actions at the airport. Special instructions have been produced for emergency medical actions in major and multi-casualty incidents at the airport. Paramedic operations in the district's hospital areas are under the control and oversight of paramedic field chiefs and paramedic supervisors.

2.6 Rules, Regulations, Guidance and Procedures

2.6.1 Air Traffic Control Regulations and Procedures

Under normal circumstances, the local controller uses the TopSky display only for traffic monitoring. He or she should, however, verify visually or from the radar display that a departed aircraft complies with its departure clearance, and check the correctness of the information contained in the radar label before the aircraft reaches a distance of 2 nm from the departure end of the departure runway.

A departing aircraft normally follows a standard instrument departure (SID) route. SIDs are designed to maintain the required safety clearance from terrain and obstacles. A standard procedure at Helsinki-Vantaa requires that an aircraft following an SID route should establish contact with approach control when passing 1,500 ft MSL. The incident flight did not execute this frequency change because the engine malfunction occurred at a low altitude. It resulted in poor climb performance, and the local controller had to intervene with the flight's progress in order to maintain ensure an adequate clearance – which is 3 nm horizontally or 1,000 ft vertically as measured from the highest point of the obstacle – from the transmission tower.

Since traffic density was low, the controller decided to keep the flight on tower frequency throughout the entire flight, even though this was not in compliance with standing instructions and normal practices. This decision also alleviated the pilots' workload. A

[14] Rescue Act 379/2011.

controller should normally coordinate the handover of a flight to another ATS unit in a timely manner and in such a way that a mutual agreement is reached.

Recordings indicate that the controller cleared the flight to climb to the TMA and subsequently controlled it until landing. The available information does not reveal which one of the two ATS units involved was responsible for the last portion of the flight. However, since both controllers recognized the seriousness of the situation and the airspace was clear of essential traffic, this did not jeopardize flight safety.

2.6.2 Language Proficiency

Commission Regulation (EU) no. 1178/2011[15] stipulates that flight crew members shall have a valid language proficiency endorsement. The minimum requirement, in accordance with the definition in an appendix to the regulation, is level 4 (operational level). A level 4 endorsement shall be re-evaluated every 4 years. A level 5 (extended level) endorsement shall be re-evaluated every 6 years. A level 6 (expert level) endorsement has unlimited validity. As a rule, a level 6 endorsement is given, for example, to a person whose native tongue is English.

Interviews indicated that Amapola Flyg's current minimum pre-entry language proficiency requirement for flight crew is level 5.

2.6.3 Amapola Flyg Manuals

Amapola Flyg provided for the investigation its Operations Manual consisting of the general part (OM-A), Flight Crew Operations Manual (OM-B) and Training Manual (OM-D).

The airline operates its aircraft in accordance with the manufacturer's instructions and the instructions and procedures described in OM-B.

OM-B comprises 12 chapters describing, among other topics, aircraft operational limitations, systems operation and aircraft performance. It also includes checklists and procedures for normal, abnormal and emergency situations. Checklist procedures are divided by the phases of flight including taxi, takeoff and climb.

The OM-B emergency checklist do not include procedures for an AFU malfunction or uncommanded propeller feathering.

The normal procedure calls for landing gear retraction during takeoff. After the PM has verified that the aircraft has attained sufficient rate of climb, he or she calls "positive climb," and the PF responds by calling "gear up."

During climb to the cruise level, the pilots conduct a climb checklist, in which one item calls for a gear-up check.

On the incident flight, the left propeller feathered during the takeoff, and the pilots focused on executing the engine-out procedure.

After shutting down the left engine and feathering the left propeller, they conducted the engine-out checklist and started preparations for return to the airport; as a result, they failed to conduct the climb checklist.

For engine malfunctions pilots use an engine-out checklist, which does not call for a gear-up check. Only when the incident pilots initiated the approach checklist did they realize that the landing gear had been down during the entire flight.

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[15] Commission Regulation (EU) no. 1178/2011, Appendix 1, Part FCL, Subpart A, FCL.055 Language proficiency.

The engine-out checklist instructs to cut off fuel supply to the failed engine.

2.6.4 Engine-Out Procedure

Airlines have company-specific flight procedures based on official terrain and obstacle data to ensure that a safe separation between an aircraft's flight path and ground obstacles can be maintained after an engine failure. These engine-out procedures take into account terrain features and nearby obstacles and need to be established for individual runways.

The Amapola Flyg engine-out procedure for runway 22L at Helsinki-Vantaa is:

"After takeoff proceed to five nautical miles from Helsinki DME tracking runway 22L extended centerline (218°), then turn left to waypoint VAVIS and hold at VAVIS as published."

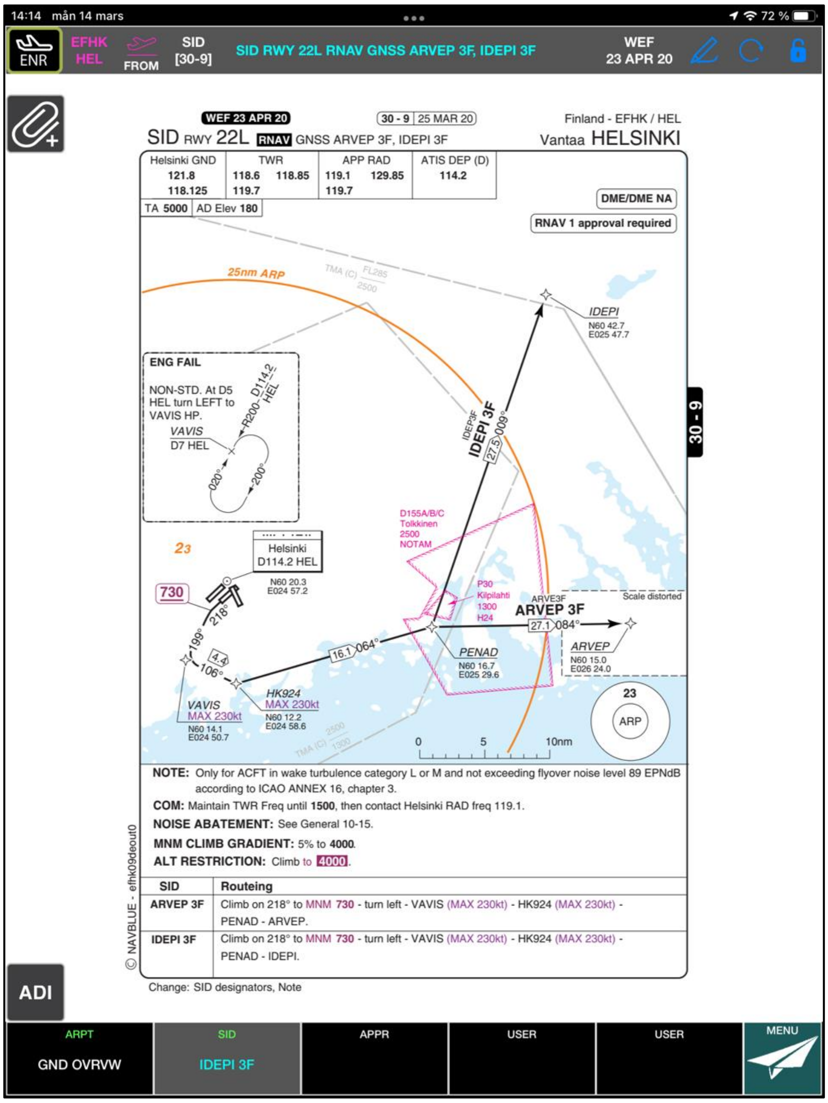

Figure 8. An Amapola Flyg departure chart with the engine-out procedure shown in the inset. (Photo: Amapola Flyg)

2.7 Other Investigations

The autofeathering unit was shipped to the manufacturer for examination for internal damage. No damage or discrepancies were found. The unit was returned to the operator after testing and maintenance.

The PW125B engine is part of Pratt & Whitney's PW100 family of engines that are widely used in many Fokker 50 category aircraft. Although the configuration, accessories and power output of engines vary depending on the variant, the basic construction and operation are identical. The investigation carried out a comparative study on the PW127 engine of the ATR 72. In both variants, autofeathering uses data supplied by a torque sensor, although technical differences exist between the systems.

In Norway, in 2021, a Fokker 50 was involved in an incident in which the right propeller feathered immediately after takeoff on initial climb, and the engine continued to operate. The pilots shut down the engine and returned to the departure airport. The likely cause of feathering was a fractured solder joint on the AFU printed circuit board, which led to a signal discontinuity and the activation of the autofeathering system. The incident was analyzed in the airline's safety management system.

In Australia, in 2017, a Bombardier DHC-8 was involved in an incident[16], in which the pilots experienced airframe vibration and noticed a change in the engine sound. They also noticed that right propeller speed was about 50 % of normal and engine torque was excessively high. They concluded that the malfunction was an uncommanded feather incident, shut down the engine and returned to the departure airport. The aircraft was above the maximum landing weight due to the amount of fuel carried on board. An inspection showed that the right engine had experienced an over-torque event of 146 % TQ for 25 s. Troubleshooting failed to pinpoint the cause of feathering. The DHC-8 is powered by PW123 series engines which are equipped with a torque signal condition unit (TSCU) for torque measurement. Despite this difference, the incident was reviewed due to its similarities with regard to the pilots' actions in the Amapola Flyg incident.

In Taiwan, in 2015, an ATR 72 was involved in an accident[17]. Investigators found that the aircraft experienced an engine failure on initial climb, and the pilots shut down the operating engine. This resulted in significant degradation of climb performance and impact with terrain causing major loss of life.

The accident and the Amapola Flyg incident have similarities. In the ATR accident, a propeller feathered unexpectedly but the engine remained in operation. The pilots analyzed the fault incorrectly, relying on engine instrument indications. The cause of feathering was a fractured solder joint on the AFU printed circuit board.

In Australia, in 2005, a Fokker 50 was involved in an incident[18] when the right propeller feathered uncommandedly approximately one minute after takeoff. This caused engine torque to exceed the maximum permitted value. The pilots shut down the engine and returned to the departure airport. The AFU circuit board showed signs of a voltage spike, but an exact cause of feathering could not be pinpointed.

In Scotland, in 1997, a Bombardier DHC-8 was involved in an incident[19]. The left engine experienced intermittent torque signal inputs, which caused abnormal operation of both engines and a feather command to the left propeller. The pilots' interpretation of engine indications and subsequent actions exacerbated the situation, which led to the partial failure of both engines and shutdown of the right engine. The incident was reviewed due to its similarities with regard to the pilots' actions in the Amapola Flyg incident.

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[16] ATSB AO-2017-045
[17] ASC-AOR-16-06-001
[18] ATSB Investigation 200500925
[19] AAIB Bulletin No: 2/98 Ref: EW/C97/2/3 Category: 1.1.

Similar autofeathering system anomalies have been reported worldwide. Erroneous signals have been identified as a factor in a majority of these incidents.

3 ANALYSIS

A SIAF-developed format of the AcciMap approach[20] was used to support the analysis of the occurrence. The following text is arranged in accordance with an AcciMap diagram created during the investigation and shown below. The occurrence is depicted as a chain of events along the bottom of the diagram. Contributing factors at various levels can be examined by moving up and down the diagram.

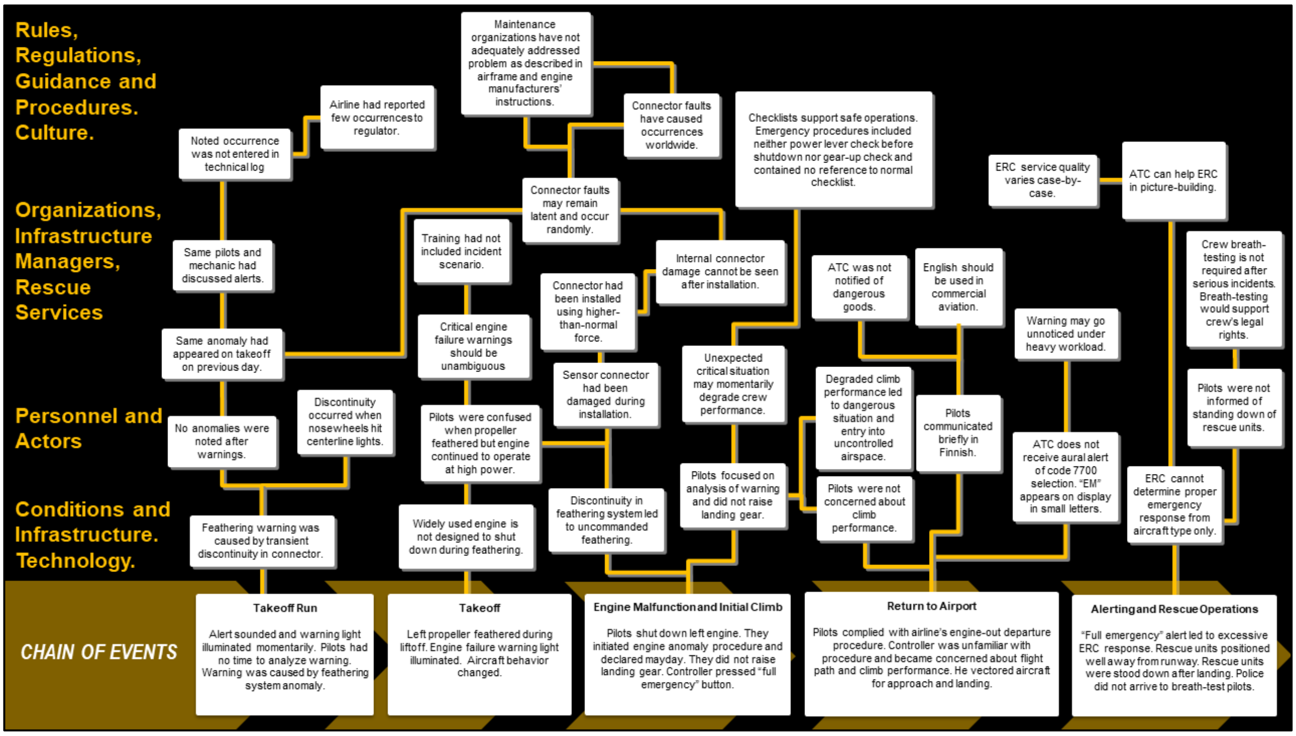

Figure 9. AcciMap diagram, investigation L2021-04. (Photo: SIAF)

3.1 Analysis of Occurrence

3.1.1 Takeoff Run

The transient nature of the alerts that occurred during the takeoff did not allow the pilots enough time to analyze the indications. The alerts activated when the nosewheels rolled over runway centerline lights. Noting that they did not recur, the pilots decided to continue the takeoff.

The same alerts had occurred, also momentarily, on the previous day during departure from Helsinki-Vantaa, but this had not been entered in the technical log. If a noted discrepancy is not shown in the technical log, the company's maintenance organization and other pilots that fly the affected aircraft will remain unaware of its existence. Transient discrepancies that cannot be traced to a specific system can be documented as a remark in the technical log so other pilots can anticipate the occurrence of possible system alerts and warnings. A remark will also notify the maintenance organization of a possible discrepancy, thus enabling early and correctly focused maintenance actions. If a discrepancy is left unreported or is not entered as a remark in the technical log, it may remain latent over an extended time.

Rasmussen, J. & Svedung, I. (2000) *Proactive Risk Management in a Dynamic Society*. Karlstad, Sweden. Swedish Rescue Services Agency.

A total of 273 occurrences had been entered in Amapola Flyg's comprehensive reporting system during the year preceding the incident, and 15 of them had been sent to the Swedish Civil Aviation Administration. This number is relatively small considering the monthly number of flights operated by the airline.

The regulator expects airlines to carry out self-monitoring in safety-related matters. Self-monitoring includes, among other actions, the collection and analysis of reports, which will enable in-house control of operations and ensure the continuous maintenance of an adequate safety level. The regulator's role is to monitor the airline's reporting culture and reporting system and their effectiveness by conducting audits or other applicable actions.

When the airline's flight safety manager receives a report, he or she should determine whether it deals with an occurrence that must be reported pursuant to Regulations (EU) No 376/2014 and EU 2015/2018 of the European Parliament and of the Council. The safety manager will then decide whether the report is sent to the regulator or not.

3.1.2 Takeoff

After the aircraft reached the decision speed (V1), the pilots continued the takeoff. Approximately 2 s after passing V1, when the pilot had initiated rotation, an engine failure alert was received.

The Fokker 50 is powered by a variant of an engine family that is in extensive use in other aircraft types. The engine is not designed to shut down automatically if the propeller feathers. Torque needed to rotate the propeller increases abruptly if the propeller feathers but the engine continues to operate, and if the engine is not shut down, the propeller or the engine may sustain damage.

In the Amapola Flyg incident, the pilots were confused momentarily when the propeller feathered uncommandedly while the engine continued to operate at a high power setting. Warnings and alerts that indicate an engine failure or any other critical malfunction should be unambiguous to permit a correct and expeditious fault analysis.

If engine instrument indications are difficult to interpret or they are not consistent with training situations, the analysis may be prolonged excessively or may be unsuccessful, which in turn may prompt the pilots to carry out an incorrect action. In a broadly similar event, the pilots of an ATR 72 shut down the operating engine – which was of the same type as the engines used in the Fokker 50.

These scenarios are not covered in Amapola Flyg's pilot training syllabi. Simulator training consists of two nearly identical engine failure exercises. In one of them, an engine shuts down and the propeller feathers; in the other, an engine shuts down, but the propeller does not feather. The incident pilots decided that they had an engine failure, even though the engine continued normal operation.

Similar uncommanded feathering may occur unexpectedly in aircraft fitted with the same engine type.

3.1.3 Engine Malfunction and Initial Climb

Recorded data revealed that, after noting that the aircraft's climb performance was degraded, the controller instructed the flight to turn to a heading that ensured an adequate separation from a transmission tower.

On the basis of the alerts received and of engine instrument indications, the monitoring pilot confirmed that an engine malfunction had occurred but the autofeather system had not activated. The left engine operated normally despite the fully feathered propeller.

The indicated propeller speed suggested a situation where an engine shuts down but the propeller does not feather. Although the alerts were indicative of an engine malfunction, the pilots failed to realize that the left engine continued to operate, and based on the alerts and engine instrument indications they elected to move the left fuel lever to SHUT to feather the left propeller. Shutting off fuel supply shuts down the engine and feathers the propeller.

The malfunction was caused by electrical discontinuity that occurred during the takeoff run in a connector in the left propeller feathering circuit and resulted from incorrect connector installation during engine maintenance. The discrepancy could not be detected visually because the connector pins were covered by the connector shell, and a shrink sleeve had been fitted over the connector. The discontinuity caused an erroneous signal that commanded propeller feathering. The engine remained in operation.

Engine power is increased automatically to meet power demands. While the activated feathering system will not adjust the affected engine’s power setting, the drag of the feathered propeller increases power demand on the engine. In this incident, left engine torque exceeded the maximum permissible value due to an excessively coarse blade angle. Instrument indications remained correct throughout.

The pilots were trained for and practised emergency procedures for malfunctions that occur in an engine instead of the feathering system. One simulator exercise emulates a situation where an engine fails but the propeller does not autofeather.

Because the pilots had not encountered a similar problem either in flight or in the simulator, they experienced difficulties in conducting a timely and correct fault analysis. The fact that they were faced with an unfamiliar situation that they had not been trained for hampered the analysis and the handling of the anomaly. This distracted the pilots and contributed to the landing gear remaining down throughout the entire flight.

The pilots intended to continue the flight in accordance with the airline’s engine-out procedure. The controller was not familiar with the engine-out procedures of various airlines, which led to momentary degradation of his situational awareness.

The controller noticed that the letters EM had appeared in red in the incident flight's radar label. This abbreviation will appear on the controller's display when a flight sets the emergency code 7700 on the transponder, but no audio alert will be received. The local controller called the approach controller upon becoming aware of the problem. Both controllers recognized the seriousness of the situation. The local controller asked the approach controller whether he should hand the flight over to approach control or keep it on the tower frequency, to which the latter replied that both options were acceptable. The flight remained on the tower frequency throughout the entire flight.

The controller became concerned when he noticed the aircraft’s poor climb performance, and on top of that the aircraft was nearing a high obstacle. The controller queried the pilots’ intentions, to which the pilot replied that the flight was on climb to the acceleration height and proceeding to waypoint VAVIS.

Because it seemed that the required vertical separation from the tall transmission tower in Kivenlahti could not be achieved in time, the controller instructed the flight to make a right turn to the north in order to maintain the required horizontal separation. Had the controller not intervened with the flight path, separation minima would most likely have been violated.

Even though heading and altitude instructions given by controllers should not take an aircraft into uncontrolled airspace, in this case the controller's intervention was necessary because of the close proximity of an obstacle, and it led to the aircraft exiting the control zone and entering uncontrolled airspace below the terminal control area for approximately 40 s during the turn due to degraded climb performance. Flight safety was not immediately jeopardized because aircraft operating below the terminal maneuvering area shall have their transponders on, which makes them visible on the controller's radar. Moreover, there was no other traffic in the vicinity.

Calculations for of engine-out procedures are based on a gear-up configuration and therefore do not take into account the possibility of the landing gear remaining extended. In this incident, the extended gear increased drag considerably and caused a marked degradation in the rate of climb. Although the pilots noted the degraded climb performance, they did not make attempts to analyse the anomaly or identify its causes.

In a high-workload situation, they initiated a Quick Reference Handbook checklist and failed to conduct the normal climb checklist, in which one item is gear-up selection. The engine-out Quick Reference Handbook checklist does not include a gear-up check.

Checklists describe critical pilot actions that have an effect on the aircraft's flight. Their purpose is to ensure that pilots carry out specified inflight procedures to maintain an adequate level of flight safety. When checklist procedures are performed without omission, no safety-critical actions will be skipped.

A widely used checklist type is the challenge-and-response checklist, whereby one pilot reads the items to be checked and the other pilot confirms the proper status or configuration of the appropriate items. Checklists also contain items that should be confirmed by both pilots.

The controller asked the flight crew to report the number of crew members and passengers, the amount of fuel and any dangerous goods carried on board. The controller had previously identified the first officer as a native Finnish speaker and therefore elected to transmit this inquiry in Finnish. Even though the first officer understood the controller's questions, he asked if he could answer in English. English is the most commonly used language in commercial aviation, and it should be used as much as practical, also in emergencies. Now the flight crew failed to report the presence of dangerous goods due to a momentary confusion caused by the use of two languages.

3.2 Analysis of Rescue Operation

After the pilots had declared an emergency, a "full emergency" alert was accidentally issued from the control tower although the situation met the criteria of a "distress" alert. The controller's alert pushbuttons are differentiated by color but not labeled. In a high-workload situation the controller should have means for the recognition and verification of the potentially critical nature of an occurrence before issuing an alert. Airport rescue service responded to the alert as prescribed and deployed units to the apron to meet the aircraft upon landing. The degree of response was adequate in view of the situation.

A controller called the emergency response center reporting that an aircraft was in distress, and notified the operator of the aircraft type (Fokker 50) and of its call sign. From this information alone the operator cannot build a comprehensive picture of the characteristics of the aircraft in distress. A controller may assist the operator in picture-building by notifying the former of at least the amount of fuel and number of persons on board.

The aircraft taxied to the apron after landing. Airport rescue service units were positioned on the apron so that their crews could easily observe the landing aircraft, but the distance between the units and the aircraft precluded communication with hand signals. The pilots and air traffic control were in continuous radio contact during the incident. After the aircraft had stopped, the on-duty supervisor stood down the rescue units. This information was not passed to the pilots.

At no point were the pilots in direct radio contact with the rescue units. The airport has ground frequencies that can be used for communication between the rescue service and flight crews, but they are not given in airport charts or in airport information. Controllers will not notify pilots of the rescue service frequencies automatically, and pilots should therefore ask air traffic control if they wish to communicate with the rescue service direct. Pilots will remain unaware of the existence of these frequencies because they are not mentioned in their documents, which may in turn lead to delays and disruptions in communication between flight crews and rescue units.

Switching to a common frequency would enable uninterrupted communication between pilots and rescue units and mitigate frequency saturation during emergencies, which would have an additional benefit of easing communication between air traffic control and other flights.

Police did not arrive at the aircraft. The flight crew was not breath-tested.

3.3 Analysis of Authorities' Action

The captain's language proficiency endorsement had been raised from level 4 to level 6 on the date of a proficiency check in a simulator. The Swedish regulator has decreed that only level 4 endorsement can be granted during a simulator check.

4 CONCLUSIONS

Conclusions encompass the causes of an accident or a serious incident. Cause means the different factors leading to an occurrence as well as relevant direct and indirect circumstances.

1. The engine malfunction occurred during the final phase of the takeoff run when a signal discontinuity occurred in the autofeather unit connector and the unit activated. The left propeller feathered but the engine continued to operate. The pilots shut down the engine.

   Conclusion: *Upon signal interruption, the autofeather unit commanded feathering of the left propeller, but the engine continued to operate. Handling of similar situations is not drilled during pilot training.*

2. An engine anomaly in a critical phase of the flight will increase the pilots' workload significantly, which may lead to the omission of procedural steps. Adherence to checklists will eliminate omissions during critical procedures.

   Conclusion: *The pilots failed to raise the landing gear due to high workload and because they did not conduct the after takeoff checklist.*

3. Similar uncommanded feathering may occur unexpectedly in aircrafts fitted with the same engine type.

   Conclusion: *Pilots should be trained to recognize and handle uncommanded feathering.*

4. The engine will not shut down during uncommanded feathering.

   Conclusion: *Engine power cannot be used effectively, while the feathered propeller overstresses the engine.*

5. The captain's license did not contain a valid language proficiency endorsement.

   Conclusion: *Both the pilot and the airline should ensure that the pilot's license contains a valid language proficiency endorsement to enable the pilot to exercise the privileges of a flight crew member.*

6. Helsinki-Vantaa airport has a dedicated ground frequencies. Air traffic control may instruct flight crews to contact the rescue service on these frequencies. These frequencies are not mentioned in flight crew documents.

   Conclusion: *A frequency that enables communication between rescue service and flight crews will help both parties to build situational awareness. The frequency should be readily available for flight crews.*

7. Aircraft electrical connections and connectors cannot be inspected visually after connector installation.

   Conclusion: *Special attention must be paid on the condition and correct installation of connectors.*

8. Air traffic controllers' alert pushbuttons are differentiated by color but not labeled for alert types. The colors are the same as the colors of the corresponding alert forms.

   Conclusion: *Before issuing an alert, controllers should use the color of the alert form to determine the pushbutton to be operated.*

9. The sharing of responsibilities between the local controller and the approach controller could not be positively determined from the recordings.

    Conclusion: *Air traffic controllers shall agree positively on the responsibility for controlling a flight.*

10. The abbreviation EM appeared in small red letters on the air traffic controllers' radar display without any other indications.

    Conclusion: *The appearance of the abbreviation EM in a radar label should be accompanied by an aural alert that would focus the controller's attention to the emergency situation.*

5 SAFETY RECOMMENDATIONS

5.1 Autofeathering Logic

The basic design of any aircraft type commonly caters for system failures and malfunctions. In most systems, protection is achieved by redundancy, which means that in the event of the failure of a single component the system will continue operation using a backup system. The engine of the Fokker 50 is fitted with two torque sensors, and signals transmitted by the sensors are compared actively. Disagreement between the signals normally triggers an alert in the cockpit, but during takeoff the autofeather system uses signals from one sensor only to command feathering.

The Safety Investigation Authority Finland recommends that

Fokker Services as the type certificate holder and Pratt & Whitney as the engine manufacturer co-operate and look at possibilities of building system redundancy to ensure that the failure of one torque sensor will not cause uncommanded feathering. [2022-S28]

5.2 Engine Electronic Control Operation

Engine malfunctions do not commonly involve feathering system anomalies. They usually cause engine shutdown. Feathering system anomalies do not automatically cause engine shutdown. Failure to shut down the engine immediately after a feathering system anomaly may cause overstress and damage to the engine and the propeller system.

The Safety Investigation Authority Finland recommends that

Fokker Services as the type certificate holder and Pratt & Whitney as the engine manufacturer co-operate and look at the need for automatic engine shutdown upon uncommanded feathering. [2022-S29]

Automatic engine shutdown will reduce the likelihood of engine and propeller system damage and improve the pilots' situational awareness. Most engine malfunctions are related to engine operation, and in some cases engine operation can be restored in flight, while gearbox and propeller system malfunctions usually result in the loss of power for the remainder of the flight. Engine failures allow the pilots more time to act than gearbox and propeller failures because a failed engine will create less drag than an engine that has sustained a gearbox or propeller failure.

5.3 Pilot Training

Pilot training includes engine failure procedures. During the incident flight, a failure occurred in the feathering system. Pilot training does not include exercises for inflight feathering system failures.

The Safety Investigation Authority Finland recommends that

Fokker Services as the type certificate holder adds uncommanded feathering procedures in the pilots training syllabus. [2022-S30]

5.4 Additions to Checklists

Fokker 50 abnormal and emergency checklists do not include the verification of landing gear retraction.

The Safety Investigation Authority Finland recommends that

Fokker Services as the type certification holder adds to the abnormal and emergency checklists a separate item that instructs pilots to verify landing gear retraction. [2022-S31]

If landing gear retraction is not verified and the gear remains down, the aircraft's climb performance will degrade significantly during an engine-out situation and obstacle clearance altitudes may be infringed.

5.5 Implemented Measures

Amapola Flyg has updated the landing gear related instruction in its Operations Manual Part B (OM-B). The updated document instructs pilots to raise the landing gear as the first item in sequence after reaching V1 in the event of an engine malfunction. Another addition requires the flying pilot to conduct a briefing on engine malfunction procedures before the first flight of the day.

REFERENCES

Written Material

AAIB (1998) Report: *De Havilland Canada DHC-8 Series 311*, G-BRYP. Bulletin No: 2/98 Ref: EW/C97/2/3 Category: 1.1.

Australian Transport Safety Bureau (2017) Investigation: AO-2017-045 - *Inflight engine shutdown involving Bombardier DHC-8, VH-XKI, Meekatharra Airport, WA, on 18 April 2017*.

Australian Transport Safety Bureau (2005) Investigation: 200500925 - *Fokker B.V. F27 MK 50, VH-FNB*.

Aviation Safety Council (2016) Aviation Occurrence Report: 4 February 2015, TransAsia Airways Flight GE235, ATR72-212A, Loss of Control and Crashed into Keelung River Three Nautical Miles East of Songshan Airport.

Rasmussen, J. & Svedung, I. (2000) Proactive Risk Management in a Dynamic Society. Karlstad, Sweden. Swedish Rescue Services Agency.

Investigation Material

1) Photographs, diagrams, and other material produced during on-site investigation
2) Weather information
3) Interviews
4) Air traffic control recordings and documents
5) Emergency response center recordings
6) Airport rescue service recordings and documents
7) Aircraft manuals
8) Airline Operation Manuals
9) Airline safety management information
10) Cockpit voice recorder and flight data recorder data
11) Fault history of SE-MFZ
12) Engine manufacturer’s report
13) Aircraft manufacturer's maintenance instructions
14) Airport alerting manual
15) Finnish Aeronautical Information Publication
16) Certificates of qualification

SUMMARY OF COMMENTS TO DRAFT FINAL REPORT

The Safety Investigation Authority of Finland submitted the draft final report for comments to Amapola Flyg, Fokker Services, Pratt & Whitney Canada, the Dutch Safety Board, the European Union Safety Agency, Fintraffic, Finavia, the Finnish Transport and Communications Agency Traficom and the Central Uusimaa Rescue Department. Pursuant to the Safety Investigation Act, no comments given by private individuals are published.

Amapola Flyg provided clarifying information of communication between the crew members and of company fleet. Amapola Flyg also explained the discrepancies found in the captain's language proficiency records and related factors.

Fokker Services provided clarifying information on matters related to the propeller feathering system and the operation of the engine-related warning systems. Fokker Services also submitted supporting information on the operation of the power and fuel levers during engine-out situations and on related instructions. In addition, Fokker Services explained that updates in the matters related to pilots' engine-out training will be incorporated in the applicable manuals.

Pratt & Whitney Canada (P&WC) provided clarifying information on matters related to the propeller feathering system and the operation of the engine-related warning systems. P&WC wished to emphasize the fact that the incidents described under Other Investigations had occurred on aircraft types other than the Fokker 50.

The Dutch Safety Board (DSB) did not submit any comments.

The European Union Safety Agency (EASA) wished to clarify the roles of the local controller and approach controller during the incident. EASA also explained the usage of the controller's alerting system.

Fintraffic wished to clarify the matters regarding the course of the events and the rescue and alerting organizations at Helsinki-Vantaa airport.

Finavia wished to provide clarifying information on certain terms and on the arrangements of the rescue service.

The Finnish Transport and Communications Agency Traficom did not submit any comments.

Central Uusimaa Rescue Department did not submit any comments.