Smoke in Cabin and Evacuation of Airliner at Turku Airport on December 3, 2017

L2017-06

SYNOPSIS

Pursuant to section 2 of the Safety Investigation Act (525/2011), the Safety Investigation Authority of Finland (SIAF) decided to investigate a smoke in the cabin event and the subsequent evacuation of an airliner at Turku airport on December 3, 2017. 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.

Master of Arts Kalle Brusi was appointed the investigation team leader. Team members were airline pilot Hannu Halonen, special investigator Heikki Harri and air safety investigator Tii-Maria Siitonen. The investigator-in-charge was Chief Air Safety Investigator Ismo Aaltonen.

The German federal bureau of aircraft accident investigation (Bundesstelle für Flugunfalluntersuchung, BFU) and the Brazilian aeronautical accidents investigation and prevention center (Centro de Investigação e Prevenção de Acidentes Aeronáuticos, CENIPA) appointed accredited representatives for the investigation, and the airplane manufacturer Embraer appointed two accredited advisors for the representative pursuant to Annex 13 to the Convention on International Civil Aviation. Pursuant to Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation, the European Aviation Safety Agency (EASA) appointed a technical advisor for the investigation. Pursuant to section 12 of the Safety Investigation Act, the SIAF decided on the participation of the accredited representatives and advisors in the investigation.

The airplane's air cycle machine was examined at the laboratory of UTC Aerospace Systems in the Netherlands on January 11, 2018. An SIAF representative observed the examination.

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 accident, the factors leading up to the accident, and the consequences of the accident 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 search and rescue and the actions of other authorities.

An opportunity was 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 Swedish-language translation of the summary was provided by Mr. Reino Havbrandt. The investigation report, its summary, and appendices are published on the SIAF's internet page at *www.turvallisuustutkinta.fi*.

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1 EVENTS

1.1 Sequence of Events

The airplane took off from runway 22R at Helsinki-Vantaa Airport, Helsinki, Finland, at 1621 h[1] as scheduled flight call sign FIN4NR to Gothenburg, Sweden. The flight was being operated for Finnair by Nordic Regional Airlines. The Embraer ERJ 190-100LR carried 100 passengers and four crew members with the copilot as PF[2] and the captain as PNF[3].

After takeoff, the flight crew noticed oscillations in the pressurization system, evident as fluctuating pressure indications and a feeling in their ears. They continued the flight normally, monitoring the operation of the pressurization system. As a precaution, they decided to maintain a lower-than-planned cruising altitude of 9,450 m.

As the flight progressed, several intermittent low pressure warnings for the crew oxygen system appeared. At 1638 h, a message indicating an automatic pressurization control anomaly displayed. This advisory requires no check list action from the flight crew. Approximately two minutes later, the flight crew noticed a burning smell and suspected that it was coming from the oven in the forward galley. The smell soon intensified, and the captain decided to return to Helsinki. The captain requested from the area control a clearance for a return to Helsinki due to a technical issue.

After the airplane had initiated a turn-back, the chief of cabin reported by interphone that there was smoke in the cabin and "something was burning." The captain declared a mayday on the area control frequency, stating that there was a fire on board. The captain did not read the smoke/fire/fumes checklist in the QRH[4], and the flight crew did not select code 7700 on the transponder. Shortly afterwards, a PACK 1 FAIL message displayed indicating the failure of one of the two air conditioning packs. Smoke appeared simultaneously in the cockpit, and the captain decided that the flight crew don their oxygen masks. The captain then communicated to the cabin crew that the flight crew had donned oxygen masks and the flight was returning to Helsinki.

The captain actioned the no. 1 air conditioning pack failure checklist in the QRH. The area controller inquired whether the flight crew wished to divert to Turku. The flight crew decided to divert to Turku. The controller vectored the flight towards Turku aerodrome and transferred it to Turku air traffic control (ATC) frequency. Turku ATC vectored the flight for an approach to runway 26. The captain informed the chief of cabin that the flight would land at Turku and the remaining flight time was 12 min. The controller requested specific information on the location of the possible fire, to which the captain replied that there was smoke in the back of the airplane but its source could not be determined by visual observation, and added that the airplane had experienced pressurization problems prior to the appearance of the smoke. One of the two cabin crew members attempted to don protective breathing equipment but was unable to open the protective bag to extract the equipment.

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1 The times given in this report are Finnish standard time (UTC + 2 h).
2 Pilot flying
3 Pilot not flying
4 Quick Reference Handbook, a flight crew booklet that includes checklists and other information in a readily available format.

The airplane landed on runway 26 at 1654 h. The copilot performed the after-landing procedures according to the instructions during the final part of the landing roll. The flaps moved to the retracted position.

The airplane vacated the runway to link E. The chief of cabin informed the flight crew that the smoke persisted and had intensified. The captain elected to evacuate the airplane in its present position. After the copilot had advised ATC of the situation the flight crew actioned the ground emergency checklist and initiated evacuation.

The passengers exited the airplane via door slides and overwing exits. Those who left the cabin via the overwing exits did not get off the wings down to the ground. Since climbing from the wings involved a risk of injury, and smoke was no longer observed inside the airplane, the rescue crews prompted these passengers to return to the cabin and exit via the slides.

The rescue crews examined the airplane for signs of fire and found none. The passengers were taken in buses and rescue vehicles to the aerodrome maintenance unit facility where they were accounted for and their condition was assessed.

1.2 Alerting and Rescue Operations

The ATC controller in Turku called LENTO P3[5] at approximately 1640 h, explaining that an airliner en route from Helsinki to Gothenburg had reported smoke in the cockpit from an undetermined source. During the call, it was confirmed that the airplane would land at Turku.

The emergency response center (ERC) at Turku received an emergency call from the controller at 1641:28 h. The controller notified the ERC of a full emergency at the aerodrome and of a possible fire on board. The controller classified the event as a full emergency using the standing alerting instructions. The ERC alerted rescue units to initiate response[6] to a *major aircraft accident hazard 236 B* at 1644:43 h. At this point, the paramedic field supervisor (EVS01 L4) received a preliminary notification of the alert.

The on-duty fire officer (RVS P2), who was also the incident commander, ordered, at 1646 h, an on-duty fire chief (LÄNSI P3) to assume command at the incident site until P2's arrival. The aerodrome rescue and fire fighting (ARFF) personnel manned two rescue units (AR 1141 and AR 1142) immediately after receiving the controller's call, and at 1648 h LENTO P3 reported to ATC that ARFF units were standing by in the movement area. The controller advised that the airplane would land on runway 26 in approximately 12 min. LENTO P3 requested the total amount of persons on board (POB) and fuel as well as information on any hazardous materials, and was told that POB was 104 and the amount of fuel was 5,840 kg.

On receiving a preliminary notification of a full emergency at the airport the paramedic field supervisor asked the ERC to alert paramedic units. This request was processed before the task monitoring cell of the ERC issued an alert to paramedic units. The units were alerted at 1649 h. After this alert was given, the field supervisor asked the ERC to issue a preliminary notification of an aircraft accident hazard to the TUH[7] emergency room and to request that the hospital activate its SURO[8] procedure. At 1650 h, the field supervisor requested the ERC to alert additional paramedic units while ensuring that one unit would remain available in downtown Turku. The field supervisor also discontinued all patient transfers for the duration of the assignment. After receiving a request from the Turku area field supervisor, who was

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5 Aerodrome maintenance supervisor, who exercises control of aerodrome rescue and fire fighting units.
6 "Response" in this context refers to predetermined paramedic and rescue units alerted on a specific assignment.
7 Turku University Hospital
8 Southwestern Finland Health Care District procedures for a major accident

now engaged in the emergency at the airport, the Salo area field supervisor (L4) set up a situation center to control other paramedic operations within the Southwestern Finland Health Care District.

The first unit of the Southwestern Finland Health Care District to arrive at the airport was T41 from the Kärsämäki regional fire station. It arrived at gate 31 adjacent to the aerodrome maintenance facility at 1652 h and was directed by LENTO P3 to join the ARFF units in the movement area. Gate 31 was designated as the staging area[9] for other arriving rescue department units. The incident commander P2 directed, at 1652 h, a duty officer (LÄNSI P30) to proceed to the central fire station to pick up a command vehicle (RVS 10) and take it to the airport. P2 also dispatched a duty officer (ITÄ P30) to the central fire station to set up an arrangement for the handling of other contingencies. At 1652 h, the paramedic field supervisor directed the paramedic units to join the chief medical officer's talkgroup in accordance with the standing communication system operating instructions and the procedure described in the MOPO[10] folder. The ERC relayed a preliminary notification of an accident hazard to TUH at 1653 h as requested by the field supervisor.

The airplane landed at 1654 h. The ARFF units and T41 followed the airplane on the runway expecting it to vacate the runway onto the main taxiway. The units had no specific information on the fire or its extent inside the airplane. The airplane was cleared to taxi to the apron on-board conditions permitting, and the rescue units had planned to escort it to the apron. During taxi, the flight crew informed that they would stop the airplane on link E and that the rescue units could proceed to the airplane. LENTO P3 advised ATC that the airplane was stationary on link E and the aerodrome was closed until further notice. The rescue units took positions around the airplane and prepared to initiate rescue and firefighting actions if necessary. T41 moved to the right side of the airplane as requested by LENTO P3.

The captain ordered evacuation. The flight crew shut down the engines. Even though the cabin crew ordered the passengers to leave their baggage behind some passengers exited with carry-ons. The doors were opened, and the slides deployed simultaneously. The passengers began to deplane via the slides. The occurrence airplane type has six emergency exits. Two doors in the front of the cabin and two in the back are fitted with slides, and there are two overwing exits. All slides and exits operated normally during the evacuation.

The rescue crews did not see any smoke coming from the airplane during the evacuation. The overwing exits were opened and used by several passengers to move onto the wings, where some congregated at approximately mid-span. Since no fire was observed inside the airplane, the rescue crews told these passengers to re-enter the cabin and evacuate via the slides in order to prevent them from dropping off the wings. The passengers complied. Entry into the airplane to examine it for a fire was possible only after all passengers had exited. The rescue crews assisted the passengers who were evacuating via the slides and guided them away from the airplane. The rescue units' searchlights were used to illuminate the airplane to ensure a safe evacuation. The rescue crews asked for and received interpreter assistance from the cabin crew in order to communicate their instructions to the passengers. An assembly area was designated on the grass adjacent to the airplane. Since some passengers wore only light clothing, they started to feel the cold and were issued with blankets from the rescue units. Children and their parents were taken into the rescue vehicles for protection from the cold.

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9 A staging area is a location designated by the incident commander where units wait for tasking and further instructions.
10 Multipatient situation

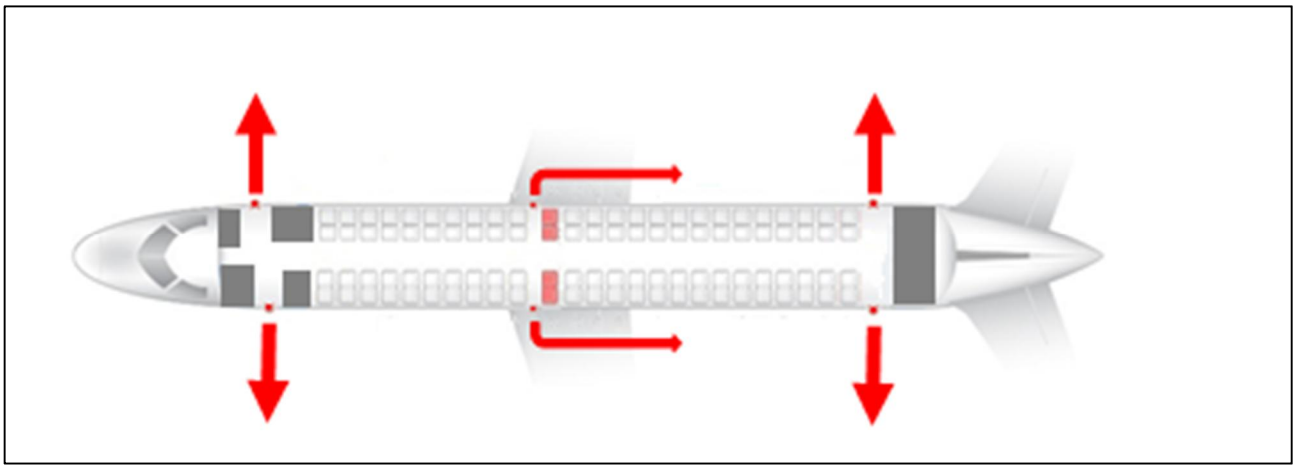

Figure 1. Emergency exits. The exits in the front and back have inflatable slides. Persons evacuating via the overwing exits should stay close to the fuselage and drop off the wing. (Image: SIAF, source data: Nordic Regional Airlines)

The passengers and crew exited within minutes. The evacuation was prolonged since passengers had to be guided from the wings to the forward and aft cabin doors. The first on-duty fire officer (ITÄ P3) arrived at the airplane at 1655 h when the evacuation was about to be complete and was told by P2 to assume the incident commander's duties since LÄNSI P3 had not yet arrived. P2 also told ITÄ P3 to make the necessary decisions pertaining to the evacuation. Meanwhile, additional rescue department units were arriving at the staging area at the gate of the maintenance facility. The rescue unit L11 from Lieto fire station arrived at the airplane at 1657 h. ITÄ P3 passed a situation report to the officer-in-charge and requested that the passengers be moved without any delay to the maintenance facility as the outside temperature was only three degrees above zero. ITÄ P3 estimated that dedicated paramedic care was not needed.

The crew chief (P11) of L11 proposed that LENTO P3 find out whether local buses serving the airport from Turku could be used to move the passengers. The rescue unit T11 from Turku central fire station arrived at the airplane at 1657 h and was directed to ensure that the passengers would not migrate from the assembly area farther onto the movement area.

The Turku area paramedic field supervisor (L4) arrived at the target at 1658 h. On the way to the airport, L4 had repeatedly but unsuccessfully attempted, via the nationwide public safety radio network, to communicate with the incident commander and on-duty fire officers who were also proceeding towards the airport. L4 told L4's partner to assume the duties of the paramedic incident commander (L5)[11]. A total of nine paramedic units arrived at the target. They were augmented by an emergency medical services helicopter (EFH20). The doctor crewmember of the helicopter assumed the responsibility for establishing passenger examination points in the maintenance facility.

At approximately 1700 h, P2 called the paramedic field supervisor and tasked the supervisor to ensure that the passengers would be moved to a sheltered location with assistance from the rescue units. The intention was to have all passengers examined by the paramedics. The field supervisor confirmed that the selected sheltered location was the maintenance facility. P2 acknowledged this and also explained that ITÄ P3 was directing the evacuation at the

[11] A paramedic incident commander is a member of an individual paramedic unit who executes the operational command and control of paramedic actions in an incident or accident and is appointed to the task by the field supervisor or the situation center of paramedic operations.

airplane. ITÄ P3 then informed by radio that all passengers had exited the airplane. In addition, ITÄ P3 judged that paramedic care was not needed and the primary concern was moving the passengers into a warm location.

The copilot advised the rescue units that the evacuation was complete and smoke and the smell of smoke had been detected in the cockpit and cabin. All passengers and crew members had left the airplane by approximately 1700 h. The captain was the last to leave.

ITÄ P3 decided at 1702 h that a city bus then at the airport be requisitioned to move the passengers away from the airplane, and then designated the meeting room of the airport terminal as the evacuation point for the passengers. ITÄ P3 passed this information to the officer-in-charge, who acknowledged its receipt at 1703 h. The initial order to P2 had been to prepare an evacuation point in the maintenance facility, and this order had also been forwarded to the paramedic field supervisor.

Since a stair truck was not yet available, the crew of L11 placed sectional ladders on the escape slides and boarded the airplane. They examined its interior with an infrared camera at approximately 1707 h and found no signs of heat or smoke.

P2 arrived at the target at 1705 h. A mobile command post was set up in the maintenance facility at 1708 h and was manned, in addition to P2, by the police field director and chief medical officer (L4). On arrival at the facility, P2 was advised that the evacuation point would be in the terminal where paramedics were ready to receive the passengers. P2 repeated that the evacuation point would be in the maintenance facility – which was again designated as the evacuation point at approximately 1711 h. This change caused some disruption in the movement of the passengers since the first passenger-carrying rescue units were already on their way to the terminal. At the same time, accounting for the passengers in the movement area had proved difficult, and a decision was made to obtain a passenger count at the evacuation point.

Rescue unit T88 brought the first passengers to the maintenance facility - which by that time had been redesignated as the evacuation point - at approximately 1713 h. In addition, three paramedic units drove to the airplane to pick up passengers.

The bus arrived at the airplane at 1714 h, and after boarding 77 passengers departed for the maintenance facility at approximately 1721 h.

LÄNSI P3 arrived at the maintenance facility at 1721 h and remained there to prepare the evacuation point as requested by ITÄ P3. LÄNSI P3 inspected the facility. The crew of T88 was told to receive the passengers at the facility. At 1724 h, staff at the command post observed that an airport vehicle was escorting the bus towards the terminal, and a marshaler was dispatched to guide the bus to the maintenance facility.

Since the situation had calmed down some of the rescue units were released at 1727 h. An official from the airline arrived at the command post at 1735 h.

Paramedics examined the passengers and crew members in the maintenance facility and terminal building, respectively. The examination included the checking of the main vital signs, possible injuries, and carbon monoxide levels, and the paramedics also gave additional oxygen to one cabin crew member and the captain in order to cater for a possible smoke poisoning. Attempts were made to establish the exact number of POB in conjunction with the examination.

The first command post meeting was at approximately 1740 h. The meeting agreed on a procedure for ensuring the well-being of the passengers after the medical examination.

Representatives of the airline and the ground handling and passenger services agent Airpro also attended the meeting.

P2, supported by the airline, paramedic service and Airpro representatives, began debriefing the passengers in the maintenance facility at 1744 h. P2 explained the conduct of the rescue operation and told the passengers what to expect next. It was also explained to them that the final passenger count would be established before bussing the passengers to the terminal.

At 1803 h, the field supervisor (L4) released most of the paramedic units, and at the same time, TUH was told to cancel the alert. The field supervisor and two paramedic units remained at the scene. The second command post meeting, at 1805 h, decided on further actions and a recheck of the total passenger count. The aerodrome would not be opened to traffic until an unambiguous passenger and crew count was obtained. The total number of passengers was confirmed at 1814 h. A stair truck had meanwhile been obtained to facilitate moving in and out of the airplane. The transfer of the passengers' baggage to the terminal began.

At 1845 h, the command post held its third meeting where the sequence of events and rescue and paramedic operations were reviewed and further actions for passenger handling decided. The meeting agreed that rescue units were no longer needed at the aerodrome.

The rescue operation at the aerodrome was practically over at approximately 1855 h. One paramedic unit and the paramedic field supervisor moved to the terminal and maintained preparedness there until all passengers had left the airport. The field supervisor left the airport at 1921 h. The last paramedic unit left at 2053 h.

Figure 2. The airplane after the evacuation. (Photo: Finavia Corporation)

Table 1. Rescue unit deployment from the ERC alert log

Call sign	Alerted at	At target at	Location	Description
RVS P2	1644:41	1705:00	Turku central fire station	On-duty fire officer
RVS ITÄ P3	1644:44	1655:10	Lieto fire station	On-duty fire chief
RVS LÄNSI P3	1644:48	1700:27	Naantali fire station	On-duty fire chief
RVS T13	1644:57	1704:52	Turku central fire station	Water tender
RVS T87	1644:57	1714:08	Kaarina voluntary fire brigade	Rescue unit
RVS ITÄ P30	1645:00	1730:00	Lieto fire station	Duty officer
RVS T11	1645:00	1657:00	Turku central fire station	Rescue unit
RVS LÄNSI P30	1645:00	1705:00	Naantali fire station	Duty officer
RVS T41	1645:04	1651:59	Kärsämäki regional fire station	Rescue unit
RVS T73	1645:06	1659:27	Maaria voluntary fire brigade	Water tender
RVS T88	1648:26	1704:16	Kaarina voluntary fire brigade	Rescue unit
RVS K31	1644:12	1713:24	Kuusisto voluntary fire brigade	Rescue unit
RVS L16	1644:17	1658:38	Lieto fire station	Mobile elevator platform unit
RVS L11	1644:20	1656:55	Lieto fire station	Rescue unit
RVS 10	1644:27	1726:00	Turku central fire station	Command vehicle
BRH 100	1645:22		Border Guard	Rescue helicopter

Table 2. Paramedic unit deployment from the ERC alert log

Call sign	Alerted at	At target at	Location	Description
EVS01 L4	1648:43	1659:33	Turku paramedic service	Paramedic field supervisor
EVS 1213	1648:27	1703:28	Turku paramedic service, central fire station	Paramedic unit
EVS 1211	1648:44	1700:35	Turku paramedic service, central fire station	Paramedic unit
EVS 1217	1648:45	1703:18	Naantali fire station	Paramedic unit
EVS 1223	1648:54	1715:40	Paimio	Paramedic unit
EVS 1228	1648:59	1707:34	Lieto	Paramedic unit
EVS 1227	1651:14	1716:54	Mynämäki	Paramedic unit
EVS 1218	1707:09	1720:38	Kaarina fire station	Paramedic unit
EVS 1219	1707:11	1715:36	Raisio fire station	Paramedic unit
EVS 1225	1651:13	1709:42	Nousiainen	Paramedic unit
EFH 20	1656:20	1711:47	Turku airport	Emergency medical services helicopter

Figure 3. Paramedic units standing by at the aerodrome maintenance facility. (Photo: Finavia Corporation)

1.2.1 Actions of Turku Social Emergency Services

At 1745 h, the ERC relayed to the social emergency services the paramedic field supervisor's request to dispatch a team to the airport. A duty social worker called the field supervisor at 1748 h and was told that an airliner en route from Helsinki to Gothenburg had made an emergency landing at the airport, the passengers had been evacuated, and paramedic care was not needed. However, the number of passengers was such that the airport staff was unable to take care of them all without assistance.

The supervisor called the social worker again at 1820 h to give additional details and repeated that the passengers were not in the need of medical care. The supervisor explained that paramedic units would, however, remain at the airport until all passengers had left the airport premises, adding that the passengers were calm and most of their inquiries had been about getting some food to eat. The supervisor mentioned that assistance in the English language may be needed. After the supervisor's call, the duty social worker called the chief social worker and explained the situation. It was then decided that a social worker from the TUH joint emergency services would also be asked to join the effort. While on their way to the airport, the social emergency services team alerted the psychosocial support team of the Turku branch of the FRC[12] and received a call from the Social Emergency and Crisis Center at Vantaa[13] requesting preliminary information on the situation.

The team arrived at the terminal at 1855 h and was shown to the designated evacuation area by an Airpro employee. The FRC duty worker called the duty social worker at 1859 h advising that three teams of two persons were about to leave for the airport to arrive in approximately one hour. The social worker called a person responsible for crisis support services at Finnair at 1912 h, inquiring about their wishes for the social emergency services team, and was told

[12] Finnish Red Cross
[13] A unit established by the Ministry of Social Affairs and Health to provide nationwide psychosocial help

that the team members should in the first place maintain visibility at the airport and seek contact with the passengers. They agreed that the Airpro staff in the terminal inform the passengers of the presence of the team and explain that the team is available for consultation. A small area in the airport premises was segregated for this purpose. The first FRC team arrived at the airport at approximately 2015 h.

Five persons contacted the social emergency services team and the FRC helpers. Of these five, four felt they needed to reflect on what they had gone through, while the fifth had sustained a minor injury and was looking for further advice. One of the four persons was traveling with two children. The team and a paramedic crew also met with the airplane crew members in a separate room at 1957 h.

At 2028 h, an Airpro employee briefed the passengers on the way ahead, telling them that they would be transported to a hotel in the capital area close to the Helsinki airport to wait for a flight on the following day. Four FRC volunteers arrived at the airport at 2030 h as the passengers were boarding the buses.

After the buses had departed, a Finavia employee contacted the emergency social services team and said it would be good if they also paid a visit to the aerodrome maintenance unit. As a result, two team members went to the maintenance facility at 2053 h; there they met one member of the maintenance staff, who took the team to see the airplane. The team confirmed that the maintenance staff member could obtain crisis support under the employer's occupational health care scheme. Meanwhile, the other team members reviewed the event with the FRC volunteers in the terminal. The duty worker at the Turku social emergency services made the final telephone call on the matter by contacting the social emergency services at Espoo at 0050 h, informing their colleagues in Espoo of the situation in order to enable them to arrange crisis support to the passengers, who would be accommodated in a hotel in Espoo.

1.3 Consequences

The occurrence did not result in serious injuries. The paramedics interviewed all passengers and crew members and ensured their well-being. The paramedics noticed a slight increase in carbon monoxide levels during the examination of the cabin crew.

The air cycle machine in the left (no. 1) air conditioning pack exhibited mechanical damage. One overwing exit door showed minor damage and it had made a dent in the wing upper skin. A sensor in the crew oxygen system was found defective, but according to the manufacturer the defect was not associated with the air cycle machine breakdown.

2 BACKGROUND INFORMATION

2.1 Environment, Equipment and Systems

2.1.1 Aircraft

The occurrence airplane was an Embraer ERJ 190-100LR airliner manufactured in 2006. It carries the registration OH-LKE and is configured for 100 passengers and four crew members.

2.1.2 Aircraft Environmental Control System

The environmental control system supplies airflow to the cockpit and cabin for ventilation and pressurization and controls the temperature and humidity of the air inside the airplane. Integral BIT[14] provides continuous monitoring of the performance of the system components.

The system has two air conditioning packs designated the no. 1 pack (left) and the no. 2 pack (right). Each pack consists of a primary heat exchanger, a secondary heat exchanger, an air cycle machine, a condenser, a water separator, valves, and temperature sensors. The packs are in the lower fuselage forward of the wing leading edge and are supplied by bleed air from the respective engine. On the ground, they can also be supplied with bleed air from the APU[15].

The packs are controlled from a panel in the cockpit. Both packs can be controlled independently. Setting the control switch to AUTO activates a pack. Setting the switch to OFF shuts down a pack. Switches on the panel also control the recirculation fans and cabin and cockpit temperature. The pressurization system is controlled from a separate panel. Warnings and cautions are shown on the EICAS[16] display.

Both packs are activated during normal operation. If one pack fails, flight can be continued if the remaining pack operates normally, but in that case the maximum altitude is limited to 9,450 m to ensure that a sufficiently rapid descent to a safe cabin altitude can be carried out in the event of a second pack failure.

2.1.3 Bleed Air Pressure Oscillation

Rapid bleed air pressure oscillations similar to those experienced on the occurrence flight had been observed on Embraer ERJ 190/195 series airplanes[17]. According to the manufacturer, oscillations in the range of 8 to 50 psi[18] have only a minor impact on system operation. However, if the oscillation is outside of this range or causes discomfort, maintenance is required. Investigation into the occurrence showed that bleed air pressure oscillated rapidly between 0 and 140 psi.

The manufacturer has traced some of the reported events to the operation of the bleed valve and has modified the valve for increased reliability. The manufacturer states that the anomaly requires no flight crew action if no messages are displayed during oscillation and oscillation is not excessive. According to the airline training material, oscillation may be alleviated by reducing power.

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14 Built-in test
15 Auxiliary power unit
16 Engine indication and crew alerting system
17 FOL N° 170-036/14, 23.7.2014
18 1 psi (pounds per square inch) = 6.894,76 kPa

2.1.4 Air Cycle Machine

An ACM[19] cools down engine bleed air. The ACM has four rotating assemblies[20] running at approximately 16,000–50,000 r/min depending on loading.

The ACM in the no. 1 air conditioning pack seized during the climb to the cruise altitude. The rotors rubbed against the fan shroud producing a bitter smell and whitish smoke. The ACM examination is described in paragraph 2.8.5.

The airplane manufacturer is aware of 15 events that have occurred during the past five years in which a breakdown in the ACM has produced smoke or smell of smoke. The occurrence discussed in this report was the only event that had led to the evacuation of the airplane over a five-year period.

Figure 4. The affected air cycle machine. (Photo: Nordic Regional Airlines)

2.1.5 Protective Breathing Equipment

The Embraer ERJ 190 carries three B/E Aerospace[21] -manufactured PBEs[22] for the crew members. A PBE envelopes the wearer's head and is fitted with a chemical oxygen generator for protection against smoke, toxic fumes and oxygen deprivation. It is packed in a disposable protective bag[23] fitted with a rip tag and stowed in a rigid plastic storage box.

19 Air cycle machine
20 Cooling fan, compressor, T1 turbine and T2 turbine
21 Part of Rockwell Collins corporation
22 Protective breathing equipment
23 PN 119003-21

During the approach, a cabin crew member tried to extract a PBE from the protective bag but could only open the bag by approximately 1 cm. The bag had not been modified in accordance with the manufacturer's non-mandatory service bulletin[24] issued on June 21, 2016. The bulletin recognizes a potential difficulty in the opening of the bag and gives instructions for the making of a 7 mm long cut along the tear-line to facilitate the task.

2.1.6 Location

When the captain declared a mayday the flight was approximately 45 km southwest of Turku aerodrome. Since landing is to be made at the nearest suitable airfield in the event of an emergency, the flight crew decided to land at Turku. After landing, they brought the airplane to a halt on link E and initiated evacuation.

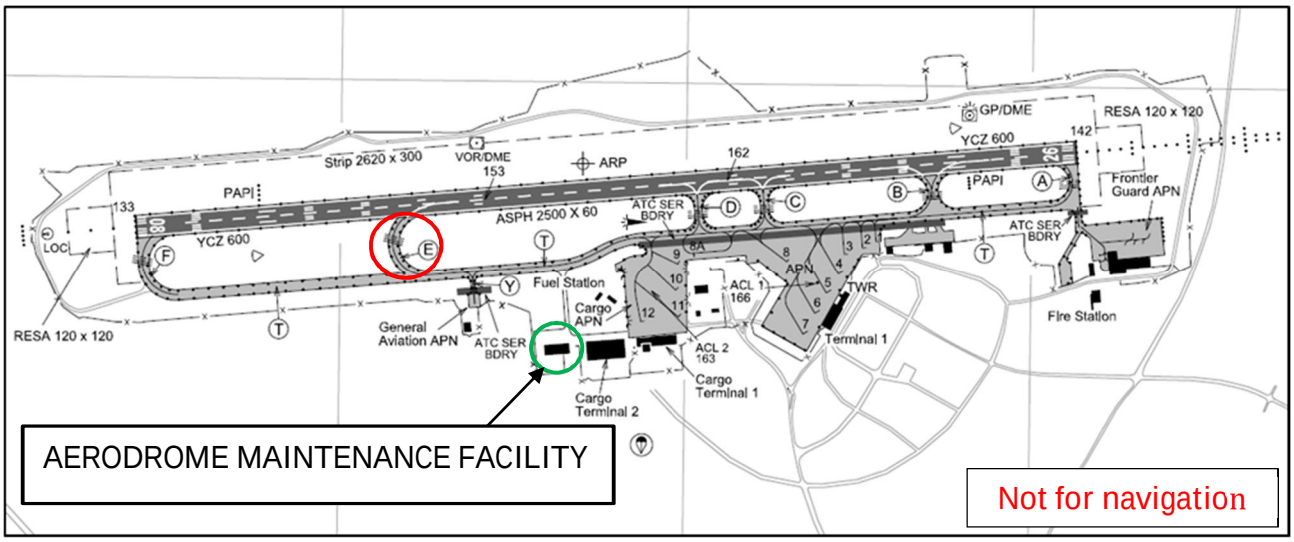

Figure 5. Turku aerodrome chart. The airplane landed on runway 26 and was evacuated on link E. The passengers were moved to the aerodrome maintenance facility (marked with the green circle). (Photo: ©ANS Finland, overlays SIAF)

2.2 Conditions

The airplane departed Helsinki in darkness. It was cloudy, drizzle was falling, and the temperature was five degrees. The landing at Turku took place in darkness and in cloudy weather. Since the passengers wore relatively light clothing and the ambient temperature was only three degrees, they had to be moved quickly to a sheltered location.

The crew observed smoke on board before and during the emergency message and described the smell as if it were caused by an electrical fire. The cabin crew observed light smoke in the cabin during landing. The smoke obstructed vision somewhat and its intensity increased in the back of the cabin as the airplane was taxiing after landing. The paramedics noticed a slight increase in the carbon monoxide levels during the examination of the cabin crew.

[24] B/E Aerospace SB 119003-35-012

2.3 Personnel, Organizations and Safety Management

The airplane carried a captain, a first officer and two cabin crew members. The captain reported 6,300 h total and 1,600 h on type. The first officer reported approximately 730 h total and 530 h on type. The captain had undergone the most recent emergency training on March 14, 2017. The first officer had received the equivalent training during type rating training on March 1, 2017. The cabin crew members had undergone the latest emergency training session on June 15 and March 14, 2017. The training had covered PBE procedures.

Nordic Regional Airlines Oy (Norra) is a Finnish airline owned by Finnair Plc. Its fleet consists of 12 Embraer ERJ 190-100LR jets and 12 ATR 72-500 turboprops. The company operates a significant part of Finnair's domestic and European routes. The company's processes and safety management program are described in company manuals.

Air Navigation Services Finland Oy (ANS Finland) is a wholly state-owned special assignment company that is responsible for airspace management in Finland and the delivery of air route and air navigation services at the Finnish aerodromes. The company maintains an ARCC[25], which in the event of an accident or a serious incident will coordinate search and rescue and provide air search until the lost aircraft is located.

The safety management and other processes of ANS Finland are described in the applicable company manuals. The company maintains the Air Traffic Control Officer's Handbook intended for its personnel for the execution of air navigation services related tasks. The handbook is based on the documents issued by the International Civil Aviation Organization (ICAO) or on approved national regulations. It is supplemented by the local manuals of air traffic services units. ANS Finland has also issued an alerting service manual that contains alerting instructions for local and approach ATC units or flight information units and for other aerodrome personnel as necessary.

Finavia Corporation maintains Turku aerodrome. The company's processes and safety management program are described in company manuals. In addition, each Finavia-operated airport has aerodrome-specific manuals.

2.4 Authorities' Actions

The Finnish Transport Safety Agency (Trafi) issues permits regarding the transport sector and oversees air operators, air navigation services providers and aerodromes and exercises these privileges, among other means, by carrying out audits and inspections. The oversight is based on national and European legislation and other binding regulations governing Finnish aviation and aeronautical organizations. The aerodrome certificates issued by the national authorities were superseded, on December 7, 2017, by certificates that comply with Commission Regulation (EU) No 139/2014 and are valid until further notice.

2.5 Rescue Services and Preparedness

2.5.1 Air Traffic Control and Rescue Services at Turku Aerodrome

In the event of an accident or a serious incident, ATC will coordinate search and rescue and provide air search until the missing aircraft is located. The duties of ATC also include notifying Finavia's rescue service, area control and the ERC of the accident, prevention of further accidents and providing rescue organizations with position information. An alert for a full

[25] Aeronautical Rescue Coordination Center

emergency or an aircraft accident is carried out using a special form[26] that is used to classify an occurrence as a full emergency or an accident and is also useful as a checklist.

Aviation regulations require that all Finavia's aerodromes have sufficient rescue capabilities and the ability to deal with accidents in accordance with the requirements specified for the aerodrome[27]. The rescue and fire fighting category of an aerodrome is based on the overall length and fuselage width of the largest civil aircraft type normally using the aerodrome.

The aerodrome maintenance supervisor (LENTO P3) is responsible for rescue and fire fighting preparedness at the aerodrome and directs aerodrome rescue units in emergencies and during exercises. LENTO P3 is responsible for the maintenance of rescue preparedness and readiness during an entire working shift. Depending on the rescue and fire fighting category, a minimum of two employees shall be in readiness. This number and the type and number of rescue units are determined for each rescue and fire fighting category based on the largest aircraft type that operates from the aerodrome at a given time.

Table 3. Aerodrome rescue and fire fighting categories with minimum manning and equipment requirements. (Finavia manual PETO 2, Preparedness v3.0)

Aerodrome category	Rescue and fire fighting vehicles	Minimum amount of water (l) Level **B** foam	Minimum amount of water (l) Level **C** foam	Minimum manning in readiness (LENTO P3 + crew)
3	1	1,200	820	1 + 1
4	1	2,400	1,700	1 + 1
5	1	5,400	3,900	1 + 1
6	2	7,900	5,800	1 + 2
7	2	12,100	8,800	1 + 2
8	3	18,200	12,800	1 + 4
9	3	24,300	17,100	1 + 6

Turku aerodrome is in category 7. The category is determined and the aerodrome emergency plans are based on an accident involving the largest airplane type (Boeing 757) operating from the aerodrome assuming that an accident takes place during takeoff or landing. Therefore, the maximum foreseeable number of casualties (affected persons) is the same as the type's maximum seating capacity, which is 230.

The ARFF services at Turku aerodrome will respond to aircraft accidents and serious incidents that occur within the aerodrome area. The minimum day and night shift operational manning of the service is 1 + 2 and 1 + 1 persons, respectively. Aerodrome maintenance has two rescue units on 24/7 standby at a single fire station. Their total capacity is 12,700 l of water, 1,240 l of foam and 250 kg of dry chemicals, and they are required to deploy within three minutes to either end of the runway or to any location within the movement area. The aerodrome shall have in place an arrangement for calling additional rescue crew members to report for duty if heavy snowfall is expected or runway and taxiway conditions are poor for any other reason[28]. On the night of the occurrence, LENTO P3 had augmented the maintenance crew by two individuals due to forecast weather conditions. During the

[26] Turku aerodrome air traffic services unit alerting instructions, form LOV-LO. ANS Finland.

[27] On December 3, 2017, the obligation to provide rescue and fire fighting services at Turku aerodrome was based on the Convention on International Civil Aviation of ICAO and national aviation regulation AGA M3-11.

[28] Finavia manual PETO 2, Preparedness

occurrence, one of them was assigned to operate the rescue unit that was manned by LENTO P3. Rescue personnel also attend to other maintenance duties as per their job descriptions. They carry out, among other tasks, runway clearing in winter, perform other maintenance within the movement area and conduct security checks.

According to aviation regulations, Turku aerodrome is responsible for rescue actions and preparedness which, pursuant to the Rescue Act, are not the responsibility of the regional rescue services. In the event of an aircraft accident at the aerodrome, LENTO P3 will direct rescue operations until a regional rescue authority is notified of the accident and assumes operational control. Actions by aerodrome staff are detailed in the aerodrome emergency plans[29].

Emergency exercises are an integral part of emergency planning and enable the testing of the plans in practise. They are divided into two categories called full-scale exercises and partial exercises that are to be held at predetermined intervals. Full-scale exercises are held every two years in cooperation with the rescue services and other authorities to rehearse all aerodrome ARFF functions and all aspects of multiauthority cooperation. Partial exercises are held at the aerodrome between the full-scale exercises to verify that any deficiencies discovered during the full-scale exercises have been rectified. The previous full-scale exercise[30] at Turku had been on September 12, 2017, while the previous partial exercise had taken place on November 4, 2016. Besides the scheduled exercises, organizations resident at the aerodrome shall be provided with sufficient other training.

Aerodrome emergency planning had not catered for the availability of vehicles needed to move a large number of people. During this particular occurrence, city buses could be obtained for the purpose, even though their use in a similar contingency that now developed had not been agreed upon with the operator. The investigators requested from all Finavia-maintained airports information on airport-owned or airport-operated buses that could be used for passenger movement and on any plans the airports had made for that purpose with local bus operators. Four of the 21 airports approached operated their own buses, while two had available vehicles suitable for passenger transportation under some other arrangement. 15 airports had no own vehicles nor had they preplanned vehicle use with operators.

2.5.2 Rescue Department and Paramedic Services

Pursuant to the Rescue Act[31], the Southwestern Finland Rescue Department exercises overall command and control of rescue operations and is responsible for command and control in aircraft accidents that occur at Turku aerodrome or in its vicinity. The general capability of rescue service in the region is adjusted to conform with a decision on the standard of service approved in accordance with the Rescue Act. The procedures include an action plan for a major aircraft accident at the aerodrome. According to the plan, a rescue authority will exercise overall command and control, allocate the necessary resources and issue the appropriate orders.

The department is prepared for aircraft accidents at Turku aerodrome as part of its normal response planning procedure. Response plans also include procedures for the handling of communications over the nationwide public safety network, participation in the full-scale rescue exercises every two years, and the maintenance of an aerodrome emergency plan

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29 PETO 8a Emergency plan for air traffic 2016 and Turku emergency plan for air traffic 2017, prepared together with the Southwestern Finland Rescue Department

30 The exercise complied with the provisions of Regulation (EU) No 139/2014.

31 379/2011

together with Finavia. In addition, the department has established separate procedures for a major aircraft accident. According to the plan, a rescue authority will exercise overall command and control, allocate the necessary resources and issue the appropriate orders. Operational control within the department is executed by three on-duty fire officers positioned in the department's area of responsibility and one officer-in-charge. Driving time to the aerodrome from Kärsämäki regional fire station – which is the department's fire station closest to the aerodrome – and Turku central fire station is approximately five and 15 minutes, respectively. The department also conducts scheduled inspections at the aerodrome's buildings.

The Southwestern Finland Health Care District is responsible for urgent pre-hospital care within its area of responsibility. The Health Care Act[32] requires that a joint municipal authority responsible for special health care decides on the standard of paramedic services within its area. At the time of the occurrence, the operations of the district were governed by a decision effective in 2015–2017. The district uses several paramedic service providers. These include in-house facilities, joint facilities with the regional rescue department and outsourced services purchased from other service providers.

The basics of the paramedic service at the operational level are described in an operating instruction manual that is in use with all paramedic operators within the district.

Paramedic operations in Southwestern Finland are in all situations under the control and oversight of four on-duty area field supervisors[33] and one field supervisor located in Turku, who exercises overall control on the field, supervising paramedic operations within the district. A situation center has operational control on operations and maintains a situation picture of paramedic provision across the entire district.

The on-duty field supervisors (L4) execute on-scene command and control within their assigned areas. They oversee operations and compliance with the currently effective paramedic service standard decision. The supervisor at Turku may transfer the responsibility for the oversight of the Turku area to another area supervisor if the operational situation so requires. The area supervisors may on mutual agreement transfer the primary oversight responsibility to the situation center. In this particular occurrence, the Turku supervisor transferred the responsibility for the Turku service area to the Salo area supervisor.

2.6 Recordings

The investigation team had access to the airplane's CVR[34] and FDR[35] data. QAR[36] data was also available. The times in all recorder data are UTC. In addition, the team examined the telephone and radio conversations recorded at the ERC and ATC radio communication recordings. All recorders had operated normally and the quality of the data was good. CVR data was downloaded at the BFU[37] laboratory in Germany.

32 1326/2010
33 Paramedic service areas of Salo, Loimaa and Uusikaupunki
34 Cockpit voice recorder
35 Flight data recorder
36 Quick access recorder
37 Bundesstelle für Flugunfalluntersuchung

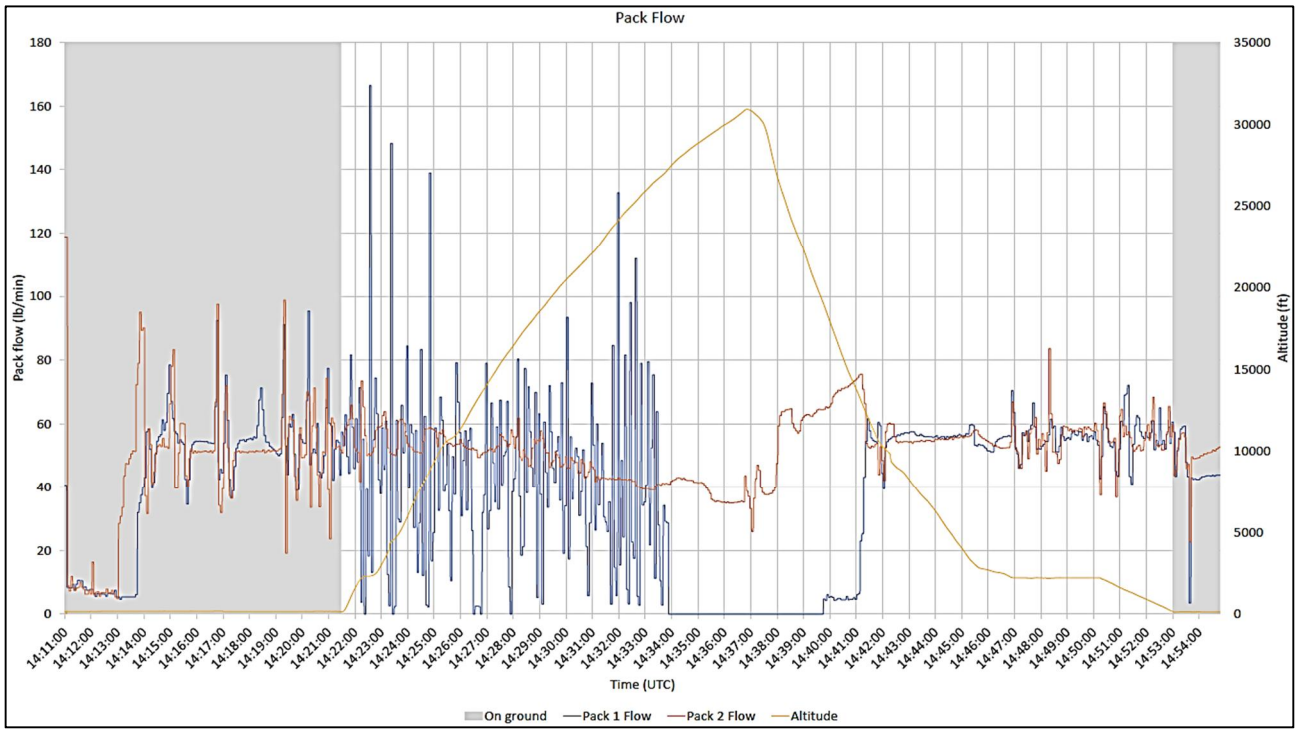

Figure 6. QAR data graph of air conditioning pack operation. The gray areas describe the airplane on the ground. The blue and orange traces represent, respectively, the no. 1 and the no. 2 pack flow (lb/min). The yellow trace represents altitude (ft). (Photo: Nordic Regional Airlines)

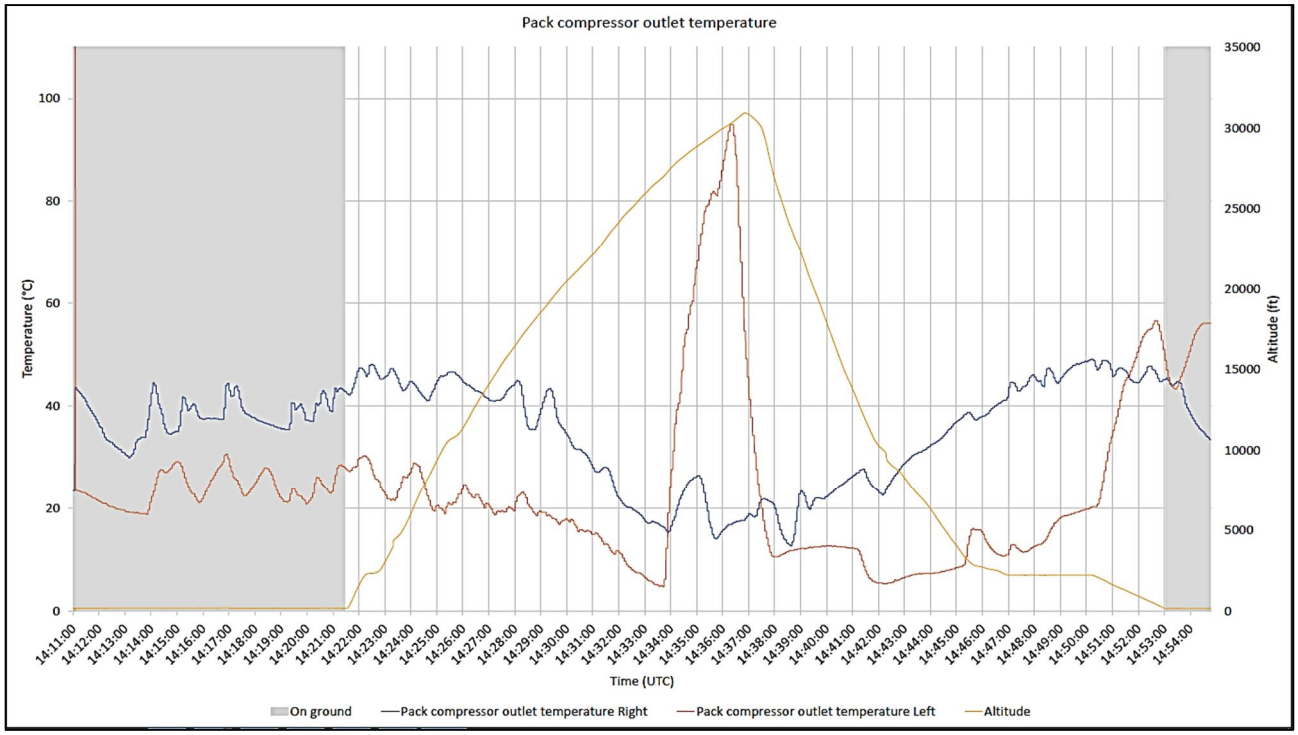

Figure 7. QAR data of air conditioning pack operation. The gray areas describe the airplane on the ground. The orange and blue traces represent, respectively, the no. 1 and the no. 2 pack compressor outlet temperature (°C). The yellow trace represents altitude (ft). (Photo: Nordic Regional Airlines)

QAR data showed that the no. 1 air conditioning pack flow had oscillated significantly already during takeoff compared with the no. 2 pack flow and shut off completely at approximately 1634 h (figure 6). At the same time, the pack compressor outlet temperature began to rise to peak at approximately 1636 h (figure 7). The airplane had reached the maximum altitude (approximately 30,000 ft) when the outflow valve closed at 1637 h. The temperature dropped to reach a low level at 1638 h. The valve reopened at 1641 h, and the no. 1 pack flow was simultaneously restored to the level corresponding to the no. 2 pack flow. The temperature began to rise again at 1650 h.

QAR data showed that the first of several warnings associated with the crew oxygen system was triggered at 1634:42 h. The first warning (PACK 1 FAIL) of an air conditioning pack anomaly displayed 10 s later. The flight crew shut down the no. 1 pack at 1638:52 h and reactivated it at 1641:58 h. No further no. 1 pack failure warnings were received.

An air management system (AMS) controller in the aircraft's SPDA[38] controls the air conditioning system and senses oxygen system pressure. A sensor in the crew oxygen system was found defective and replaced after the occurrence.

2.7 Rules, Regulations, Procedures and Other Documentation

The company operations manual is based on the European Commission regulation governing air operations[39]. During the occurrence flight, the flight crew used the airplane's QRH that contains, among other information, procedures for air conditioning and pressurization system failures and ground emergencies.

If an air conditioning and pressurization system failure occurs (a PACK 1/2 FAIL message appears) the associated temperature controller is set to the 12 o'clock position and the affected pack is shut down. After one minute, the pack is reactivated. If the message extinguishes, the temperature controller can be operated normally. If the message does not extinguish, the pack is to be shut down and altitude shall not exceed 9,450 m (flight level 310) (figure 8).

In a ground emergency, the emergency/parking brake is set and the slat/flap lever is set to "down." The thrust levers are set to idle and the engines are shut down. The fire extinguishing handles are pulled out and rotated, which will shut off fuel flow to the engines and activate the engine fire suppression system. The APU is shut down by pushing in the APU emergency stop button. The airplane is then depressurized. ATC is advised of the event and evacuation is ordered. As the final step, the batteries are switched off (Figure 9).

ANS Finland's alerting service manual defines situations where a controller should notify an ERC of a full emergency or an aircraft accident. In cases where the flight crew has set code 7700 on the transponder, the ERC will be notified of an aircraft accident. In this particular occurrence, the flight crew failed to set code 7700.

The Health Services Department of the Ministry of Social Affairs and Health has issued general procedures governing task monitoring in the ERCs. Those provisions of the procedures that are relevant to aircraft accidents are observed in the ERCs when paramedic services need to be alerted. The procedures, also those described in air traffic -related chapters, are largely based on road accident scenarios.

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38 Secondary power distribution assembly, distributes power to direct-current (DC) systems and controls DC-operated systems.

39 965/2012

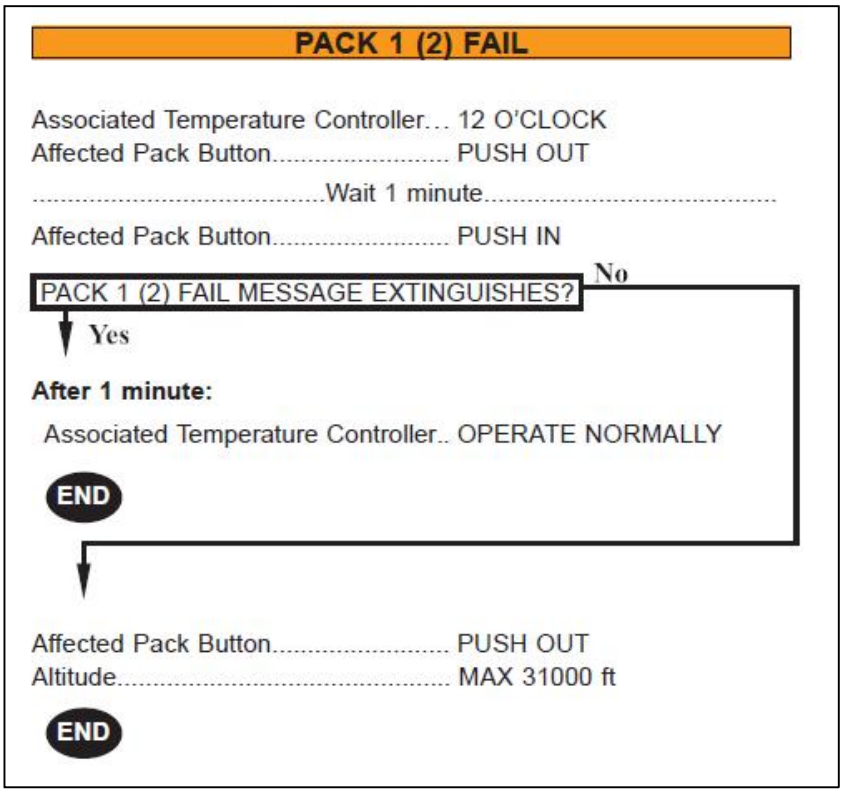

Figure 8. Air conditioning pack failure checklist. Nordic Regional Airlines Quick Reference Handbook OM-B Rev. 3.5 / 15.11.2017 (Photo: Nordic Regional Airlines)

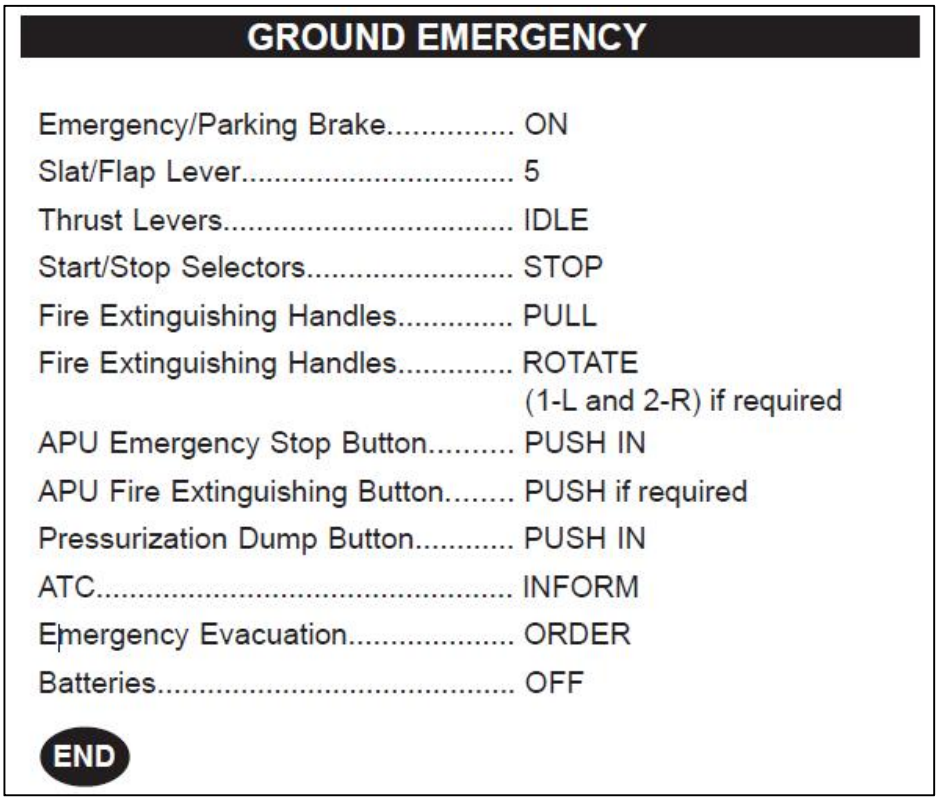

Figure 9. Ground emergency checklist. Nordic Regional Airlines Quick Reference Handbook OM-B Rev. 3.5 / 15.11.2017 (Photo: Nordic Regional Airlines)

2.8 Other Research

2.8.1 Examination of Opening Mechanism of Protective Breathing Equipment Bags

The opening mechanism of the PBE protective bags was examined using the repeated testing method. The tests showed that a pull of approximately 250 N was needed to open the bag from which the cabin crew member tried to extract the PBE. The spring scale used in the test indicated that a force of approximately 25 kp would therefore have been required. The test was conducted and the bag was opened by connecting the hook of the scale to a metal eyelet in the rip tag. In this way a force greater than would have been attainable manually could be exerted on the tag, and it was found that manual opening of the bag would have been extremely difficult. The eyelet detached from the reinforced tag during testing.

Figure 10. A protective breathing equipment bag. (Photo: SIAF)

Five disposed bags were opened. Their part number (119003-11) differed from the bag used on the occurrence flight but the opening mechanism was similar. Two bags were modified as detailed in a non-mandatory service bulletin[40]. The force needed to open these bags was small enough to enable a crew member to open the bag in an emergency. A pull of over 20 kp was needed to open one unmodified bag so manual opening by pulling on the small rip tag would have been very difficult indeed. Another bag opened normally. A factor in the successful opening may be the direction of the pull, which will vary due to the softness of the bag. The limited testing described above was successful in demonstrating a problem that had emerged

[40] B/E Aerospace SB 119003-35-012

during a serious incident and could be rectified by incorporating an applicable service bulletin. The sample was, naturally, too small to enable definitive confirmation to be made. The force needed to open the bag should be small enough to enable opening also in an awkward position. The examination confirmed that the successful opening of an unmodified bag is not guaranteed.

2.8.2 Technical Examination at Turku

The operator's representatives examined the airplane on December 4, 2017, under the supervision of SIAF investigators. The examination confirmed that the smoke and smell observed during the flight was caused by a failure of the no. 1 air conditioning pack ACM.

2.8.3 Technical Examination of Air Cycle Machine

The affected ACM was manufactured by Hamilton Sundstrand (now UTC Aerospace Systems). Its part number was 100070-04, and it had been installed in the airplane during manufacture. The ACM had a running time of 27,176 h and it had accumulated 17,945 cycles. The running time exceeds the mean running time after which ACMs are typically removed for repairs.

The ACM was examined at the UTC Aerospace Systems laboratory in the Netherlands on January 11, 2018, under supervision of an SIAF representative. Various damage was observed in the unit during strip-down. The examination confirmed that the smoke and smell of smoke identified during the flight were caused by the rotating assemblies of the cooling fan, compressor and the two turbines (T1 and T2) contacting the fan shroud as a result of the failure of journal bearings. The examination was unable to determine conclusively which bearing had failed first. The examination of the fan shroud also revealed the presence of moist coffee grounds that had probably migrated from the sink in the forward galley.

The processor card that monitors ACM operation and data stored on the card were also examined. No anomalies were discovered during testing and the card therefore had not contributed to the ACM failure.

During the repairs, the ACM was modified in accordance with the manufacturer's service bulletins to improve reliability and its part number was thereby changed to 100070-06. The modifications included the fitting of a new T1 turbine end shaft, new T2 turbine nozzle vanes and heavier-duty journal bearings.

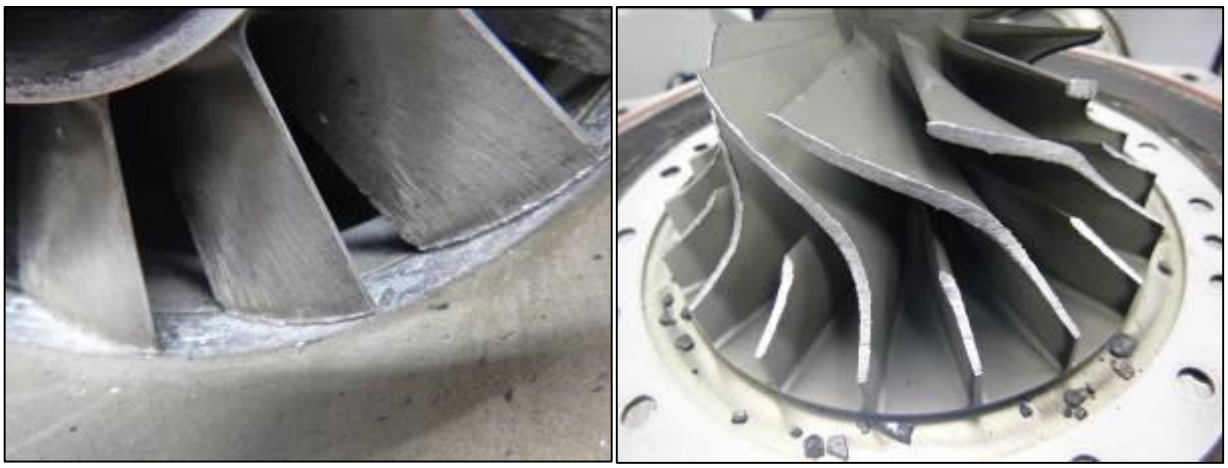

Figure 11. On the left, cooling fan blades showing signs of rubbing. On the right, similarly damaged T2 turbine blades. The T1 turbine exhibited similar damage. (Photos: Hamilton Sundstrand CSC Maastricht BV / UTC Aerospace Systems)

Figure 12. A failed journal bearing and associated damage. (Photos: Hamilton Sundstrand CSC Maastricht BV / UTC Aerospace Systems)

2.8.4 Examination of Overwing Exit Illumination and Drop Height

The illumination of an overwing exit and the drop height were examined at Helsinki. A walkway leads along the wing root to the trailing edge where an evacuee is expected to drop to the ground. The walkway was found well illuminated over its entire length. Flap position determines the drop height. With the flap fully extended, the height is approximately 1.5 m. During the evacuation the flaps were up and the height was approximately 2 m. Flap travel to the fully down position takes approximately 50 s. The drop height is higher at the leading edge and closer to the wing tip in particular. Some passengers who left the cabin via the overwing exits initially moved towards the wing tip but were subsequently directed to reenter the cabin.

2.8.5 Flight Crew Workload

The workload on an aircraft's crew is high in any emergency or abnormal situation. They are required, among other tasks, to analyze the situation, consider alternative courses of action and execute appropriate decisions. In these situations, ATC will ask the flight crew to report the number of POB, amount of fuel and the presence of any hazardous materials. According to the applicable ICAO document[41] this information is obtained from the operator or the flight crew and is used to assist in the rescue operation.

2.8.6 Questionnaire to Passengers

A questionnaire[42] in an electronic format was sent to the passengers. It contained items related to the evacuation, carry-on baggage, smoke detection and the conduct of the rescue operation. Of the 100 passengers on the flight, 38 answered the questionnaire.

49 % of these passengers had left the airplane via the forward left-hand door while only 5 % had used the forward right-hand door. The percentage of passengers to exit via the rear left-hand and rear right-hand door had been 19 % per door. 86 % of the passengers had detected smoke, several of them indicating that this had happened approximately 10–20 min after takeoff and again during landing. The smell was described as if it had been coming from an electrical source or “burning hair.”

41 ICAO DOC 4444, 15.1.1.2e
42 Appendix 1

63 % of the passengers had grabbed their overcoat or carry-on baggage on leaving the airplane. The answers indicated that the cabin crew had issued the evacuation instructions loud and clear and in an efficient manner. They had also ordered the passengers to leave carry-on baggage behind. Some passengers had received minor injuries on tumbling from the slide ends onto the ground.

29 % of the passengers had disregarded the safety announcements. 39 % of the passengers had observed the pre-takeoff safety demonstration. 11 % of the passengers had previewed the safety card located in the seat pocket. 21 % of the passengers had paid attention to both.

2.8.7 Serious En-route Incident in Denmark on December 3, 2016

The left engine of an ATR 72 failed en route from Rønne to Copenhagen and the cabin started to fill with smoke. The cabin crew removed fire extinguishers and PBEs from their stowage. A cabin crew member was unable to open the protective bag of the PBE. The bag type was identical to the type involved in the occurrence discussed in this report, although of an earlier model, and considerable force was needed to open it.

2.8.8 Smoke in Cabin and Evacuation of Airliner on Isle of Man on August 1, 2008

An ACM of an Embraer ERJ 190-200LR en route from Manchester to Belfast City failed and the smell of smoke was detected in the cabin. Smoke also started to ingress the cabin. One air conditioning pack was shut down for the entire duration of the flight. The captain elected to divert to the Isle of Man where the airplane was evacuated via the slides and overwing exits.

Examination revealed identical damage to both ACMs. Turbine blades had failed close to the blade root and the rotor had contacted the fan shroud. The investigation[43] resulted in two evacuation-related safety recommendations.

[43] AAIB Bulletin 6/2010, EW/C2008/08/01

3 ANALYSIS

3.1 Analysis of Occurrence

A SIAF-developed format of the AcciMap approach[44] 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.

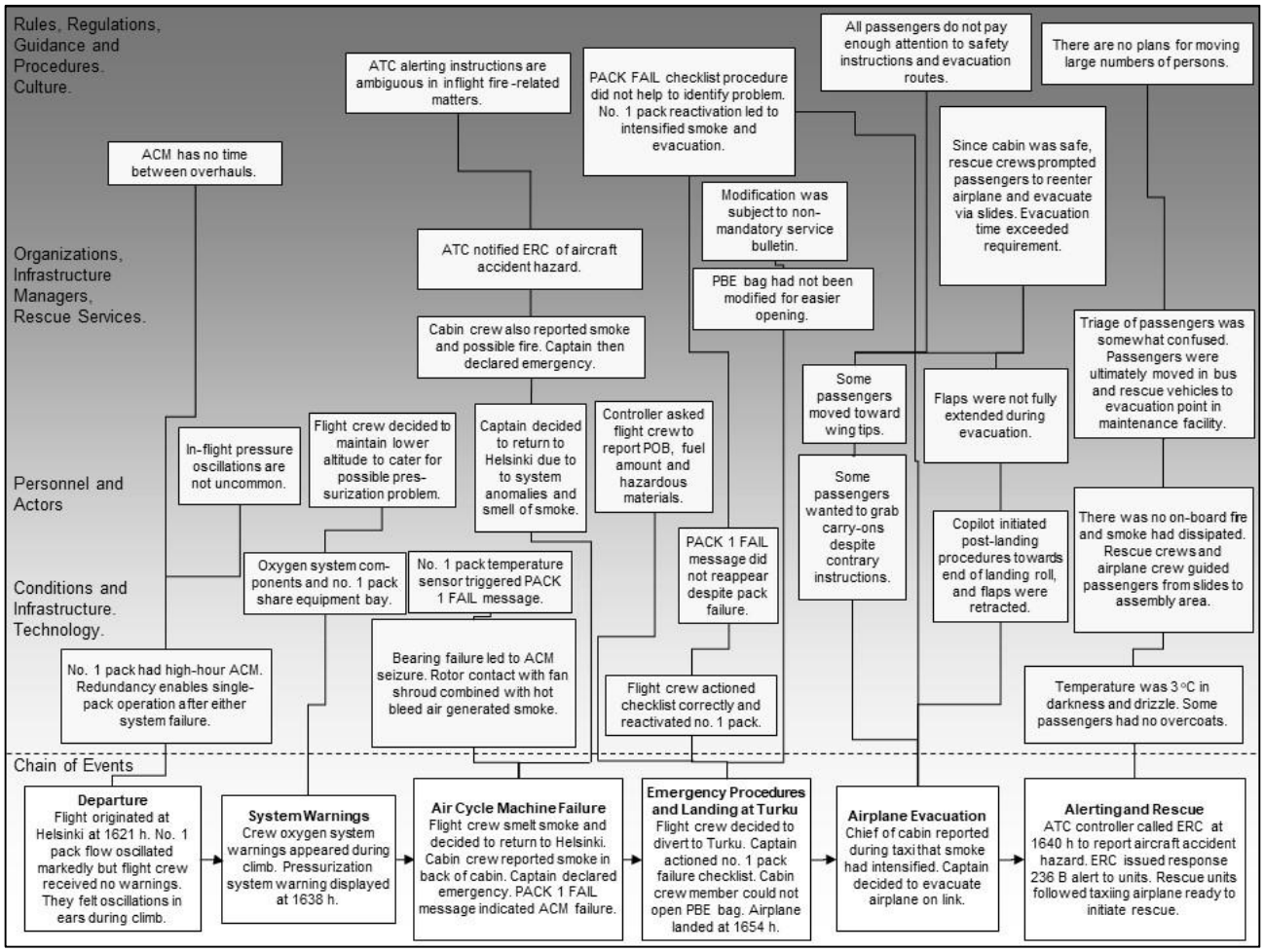

Figure 13. AcciMap Diagram

3.1.1 Departure

The flight originated at Helsinki-Vantaa airport at 1621 h on December 3, 2017, using call sign FIN4NR. The flow of the no. 1 air conditioning pack oscillated markedly but the flight crew received no related warnings. They felt pressure fluctuations in their ears during the climb, but these are not uncommon.

[44] The occurrence is depicted as a chain of events along the bottom of the diagram. The identified decision-makers and other regulatory actors are on the extreme left. The steps in the chain of events are analysed at all levels from bottom to top. The lower levels help understand how the occurrence developed, and by moving up the reader can study higher-level national or international factors and contributors. Rasmussen, J. & Svedung, I. (2000) *Proactive Risk Management in a Dynamic Society.* Karlstad, Sweden. Swedish Rescue Services Agency.

3.1.2 System Warnings

Crew oxygen system warnings appeared during the climb, and a pressurization system warning displayed at 1638 h. The oxygen system warnings were triggered by a faulty sensor that was replaced after the occurrence.

3.1.3 Air Cycle Machine Failure

The failure of an ACM resulted in the ingress of smoke and water mist into the airplane. The ACM had already been defective during the departure, and precursors of the failure had probably developed during the previous shutdown or startup. The smoke was caused by a rotor seizure resulting from a bearing failure. The slight increase in the carbon monoxide levels noted in the examination of the cabin crew was probably associated with the smoke formation. In addition, a combination of hot bleed air flow and disruptions in air recirculation had created water mist inside the airplane.

3.1.4 Emergency Procedures and Landing

The ATC controller asked the flight crew to report the amount of fuel and number of POB in accordance with the applicable instructions, allowing the crew time to pass their response. Nevertheless, responding to this inquiry increased the crew's workload. According to an ICAO document, controllers should obtain the information from the operator or the flight crew. Contacting the operator when possible would be the preferable option.

On receiving a notification of smoke in the cabin the flight crew did not action the QRH smoke/fire/fumes checklist and therefore failed to set code 7700 on the transponder.

The flight crew actioned the no. 1 air conditioning pack failure checklist correctly and reactivated the pack in accordance with the checklist. They did this after declaring an emergency upon receiving a message indicating the system failure. No further PACK 1 FAIL messages appeared during the remainder of flight despite the pack failure.

The checklist procedure did not help the flight crew identify the problem. Pack reactivation possibly increased the ingress of smoke and visible water mist into the cabin. Since the smoke was intensifying, the captain decided to evacuate the airplane.

A cabin crew member was unable to open the protective bag of a PBE. Subsequent tests showed that a pull of approximately 25 kp would have been needed to open the bag. The task would have been easier had the bag been modified according to the manufacturer's non-mandatory service bulletin.

3.1.5 Airplane Evacuation

The first officer already initiated the post-landing procedures during the landing roll, and the flaps were retracted. The chief of cabin reported to the captain during taxi that smoke had intensified so the captain elected to evacuate the airplane on a link taxiway. The flight crew actioned the ground emergency checklist; the flaps, however, remained retracted since flap travel to down position takes approximately 50 s.

If the post-landing procedures had been initiated after the speed had reduced to the taxiing speed and the airplane had vacated the runway, the flaps would have remained extended and helped passengers to climb down from the wings.

Many passengers tried to grab their carry-on baggage, which was not in compliance with the instructions and the cabin crew's orders. Similar behavior has been noted during several

incidents abroad. All passengers do not pay adequate attention to the safety instructions and evacuation route briefings.

A good number of passengers who had exited onto the wings moved towards the wing tips while the instruction shows an evacuation route along the fuselage side. This route is illuminated with exterior lights all the way to the ground; however, illumination alone will not render the overwing routes as conspicuous and easy to use as the door slides. Jumping off the outer wings would increase the likelihood of an injury since the drop will be more than two meters and therefore higher than at the wing root. Since the cabin was found to be safe, the rescue crews prompted the passengers to reenter the airplane and evacuate via the slides. All these factors prolonged the evacuation.

3.2 Analysis of Rescue Measures

3.2.1 Alerting and Rescue

Adequate advance notification of problems on board the airplane was received, which expedited alerting and enabled the prompt launch of a rescue operation both by the aerodrome maintenance unit and the Southwestern Finland Rescue Department. The aerodrome rescue units and one rescue department unit were standing by in the movement area before the landing and then followed the taxiing airplane on the runway. Had a severe fire developed on board they would have been in a position to commence fire fighting and rescue without delay. Moreover, the advance notification and expeditious alerting enabled the quick arrival of additional rescue units on the staging area after the airplane's landing.

After receiving the captain's report of a fire and smoke on board, the ATC controller alerted ARFF and the ERC of a full emergency. A sufficient number of rescue units was deployed. The paramedic field supervisor ordered the ERC to alert paramedic units and tell TUH to ramp up readiness. Owing to proactive alerting, the supervisor and paramedic units arrived at the airport immediately after the airplane had landed.

A suspected or confirmed fire is among the most serious events on board an aircraft. Smoke was smelt on board the occurrence airplane; smoke was also visible, which was an additional indication of a possible fire. Even though the airplane remained flyable and could be landed at an aerodrome the situation could have been classified as an aircraft accident in the first place since dense smoke with its resultant higher carbon monoxide contents could obviously have put the passengers in jeopardy.

The alerting instructions guide the ATC controller to classify an inflight fire as a full emergency situation unless the flight crew sets the emergency code 7700 on the transponder. Therefore, the ERC did not direct the region's hospitals to elevate readiness.

The general procedures of the Health Services Department of the Ministry of Social Affairs and Health are based on road accident contingencies, which can lead to ambiguities in responding to aircraft accidents.

Since outside air temperature was low and several passengers wore only light clothing the focus of the rescue effort after the evacuation was on moving the passengers to a warm location. Although the scene was illuminated by vehicle lights, the immediate vicinity of the airplane remained essentially enveloped by darkness, which hampered the guiding of the passengers to the assembly area.

The aerodrome emergency plan[45] contains instructions for the categorization of passengers for transportation and further actions. This procedure, called triage, is executed by dividing the passengers into four categories indicated by colors. Green means uninjured persons, yellow represents persons with minor injuries, red stands for seriously injured persons and black means deceased. Attempts will be made to move walking passengers (green) into the airport terminal while slightly injured passengers (yellow) will be transported to the aerodrome maintenance facility. In this occurrence, the initial plan was to establish an evacuation point in the maintenance facility. After the evacuation was complete the fire chiefs (LENTO P3 and ITÄ P3) adhered to the emergency plan and decided that the passengers should be taken in rescue vehicles and buses to the terminal as quickly as possible. The on-duty fire officer, who was the incident commander and was at that time driving to the airport, endorsed this decision and also directed ITÄ P3 to assume control of all evacuation arrangements. The field supervisor complied with this decision by ordering the paramedic units to the terminal.

Shortly afterwards, the on-duty fire officer directed, in the incident commander's capacity, that the evacuation point should be set up in the maintenance facility, which was according to the emergency plan to be reserved for slightly injured (yellow) passengers. This change subsequently caused confusion in the transportation of the passengers to the evacuation point. A bus carrying passengers was nearing the terminal when it was rerouted to the maintenance facility. Some variations were observed in the interpretation of the triage instructions. The incident commander based the decision to use the maintenance facility as the evacuation point partly on a desire to not allow passengers into the terminal due to the possibility that some of them might leave the building before the exact number of POB was established and would thereby also have been deprived of paramedic examination. Establishing the total POB was essential to ensure that no passengers remained in the movement area. The aerodrome could not be reopened until the total number of passengers and crew members was ascertained. Furthermore, the incident commander wanted to meet all affected persons and brief the passengers on the way ahead together with the representatives of other resident organizations.

After the airplane had stopped and evacuation was commencing, the rescue crews noted that the situation inside the airplane was not serious. The smoke had dissipated from the opened doors, and no smoke or flames were visible. Some passengers had left the cabin via the overwing exits and were standing on the wings. The rescue crews prompted them to return to the cabin and exit the airplane via the slides, which was a safer option. The rescue crews assisted passengers at the end of the slides and guided them to the designated assembly area. One crew ensured to the best of their ability that the passengers did not stray away from the assembly area. Since the exact passenger count could not be established at the assembly area a decision was made to do this during the transportation to the evacuation point at the maintenance facility.

Turku airport has in place no special plans for transporting large numbers of walking passengers. Since, according to the Rescue Act[46], an incident commander has an authority to requisition any equipment needed for a rescue effort, city buses were diverted to transport the evacuees. The use of the buses had not been agreed upon in advance with the operator.

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45 PETO 8a Emergency plan for air traffic, facility use

46 379/2011 36 §

3.3 Analysis of Authorities' Action

The investigation showed that the authorities' actions did not contribute to the emergence of the incident and they had no significant impact on its outcome. Therefore, the authorities' actions are not analyzed in detail.

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 rotating assemblies – i.e., the cooling fan, compressor and both turbines – of an ACM contacted the fan shroud as a result of the failure of journal bearings.

   Conclusion: The ACM failure generated smoke.

2. A cabin crew member notified the flight crew of smoke and a possible fire. The flight crew also smelt smoke. A warning of the ACM failure was only received after smoke had appeared. The occupants also felt pressure fluctuations. Warnings related to the crew oxygen system appeared and a message indicating an automatic pressurization control anomaly displayed.

   Conclusion: Smoke and a possible fire are extremely serious inflight occurrences and necessitate landing at the nearest suitable airfield. Simultaneous failure indications increased the flight crew's workload.

3. A cabin crew member was unable to open the protective bag of a PBE. Tests showed that a pull of approximately 25 kp would have been needed. The task would have been easier had the bag been modified according to the manufacturer's service bulletin.

   Conclusion: The modification is non-mandatory, but non-compliance may preclude the use of a PBE in an emergency. A crew member must be able to extract and don a PBE easily and expeditiously since it will be crucial to the maintenance of the wearer's functional capability in the presence of smoke and fire.

4. The passengers were transported from the movement area to the evacuation point in two city buses that were requisitioned on a fire chief's initiative pursuant to the provisions of the Rescue Act.

   Conclusion: Turku aerodrome had in place no plans for the use of local buses, and the same applies to most of Finavia's other airports. Under certain weather conditions the moving of the passengers from the accident site without undue delay will be essential.

5. The captain notified area control of a fire on board the airplane and declared emergency. Area control relayed the information to Turku ATC, which in turn alerted the ERC to respond to a full emergency situation.

   Conclusion: The alerting instructions guide an ATC controller to classify an inflight fire as a full emergency situation. Pursuant to the instructions, the Southwestern Finland ERC, among other agencies, will not order the region's hospitals to elevate readiness when a full emergency is reported.

6. The flaps were selected "up" already during the landing roll.

   Conclusion: The flaps will more likely be found extended during an evacuation if the post-landing procedures are initiated only after the speed has reduced to the taxiing speed. This will reduce the drop height from the wing walkway by approximately 0.5 m.

5 SAFETY RECOMMENDATIONS

5.1 Opening the Protective Breathing Equipment Bag

A cabin crew member was unable to open the protective bag of a PBE because considerable force would have been needed for the task. Difficulties in the opening of the bag have also been noted during other emergencies. The reason is that the bag sometimes fails to tear correctly during opening. The problem can be mitigated by incorporating a non-mandatory modification.

The Safety Investigation Authority Finland recommends that

> *the US Federal Aviation Administration (FAA) issues an airworthiness directive requiring a modification to be incorporated in the protective bag part number 119003 manufactured by B/E Aerospace, Inc. to facilitate its opening. [2018-S51]*

Difficulties in the opening may jeopardize a crew member's life, health.

5.2 Transportation in Movement Area during Accident

The passengers were transported from the movement area to the evacuation point in buses that were requisitioned pursuant to the Rescue Act. The procedure was unplanned and had therefore not been rehearsed. Airports have different vehicles available for passenger transportation. Under certain weather conditions the moving of the passengers from the accident site without undue delay will be essential.

The Safety Investigation Authority Finland recommends that

> *the Finnish Transport Safety Agency ensures that airport operators include in their emergency plans contingency procedures for the transportation of evacuated passengers at the aerodrome. [2018-S52]*

5.3 Cooperation in Aviation Incidents and Accidents

Turku ATC notified the ERC of a full emergency, as guided by the ATC's alerting instructions. On receiving this notification, the ERC alerted predetermined units of the Southwestern Finland Rescue Department and the Southwestern Finland Health Care District in accordance with a procedure in effect for an aircraft accident hazard. Differences and ambiguities between ATC's alerting instructions and ERC procedures hamper cooperation between authorities involved in rescue operations to an extent.

The contents of ATC's alerting instructions should be better reflected in the procedures that the rescue authorities issue to the ERCs. An ERC dispatcher will find a controller's notification of a full emergency on one hand, and of an accident on the other, an important piece of information that will guide him or her to execute a subsequent course of action.

The Safety Investigation Authority Finland recommends that

the Ministry of Interior cooperates with the Ministry of Social Affairs and Health, Air Navigation Services Finland and the Emergency Rescue Center Agency to align their procedures governing actions in aircraft accidents and full emergency situations. In conjunction with this, a need to amend the contents of the procedures in matters related to, in particular, the contents of alert calls, response arrangements and inter-organization communications should be investigated. [2018-S53]

5.4 Definition of Aircraft Accident and Full Emergency in Air Traffic Control's Alerting Instructions

The alerting instructions issued by ANS Finland state that the emergency transponder code 7700 stands for an aircraft accident. In this particular occurrence, the flight crew declared an emergency on the radio; the occurrence was therefore classified as a full emergency, and the ERC was notified of an event that initiated a more limited response.

The Safety Investigation Authority Finland recommends that

Air Navigation Services Finland amends the alerting instructions issued to air navigation service units to clearly indicate that an emergency situation communicated on the radio or by setting the emergency code on the transponder are given an identical classification. [2018-S54]

5.5 Implemented Measures

Finnair Plc and Nordic Regional Airlines Oy incorporated the non-mandatory modification in all PBE protective bags after the occurrence.

Helsinki, 28.11. 2018

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REFERENCES

Written Material

AAIB Bulletin 6/2010, EW/C2008/08/01
ANS Finland, Aeronautical Information Publications (AIP)
ANS Finland, alerting service manual (HPO) and other manuals
ANS Finland, Air Traffic Control Officer's Handbook (LJKK), version 3.2, effective from October 12, 2017, and appendices
B/E Aerospace, service bulletin SB-119003-35-012
Finavia, Turku aerodrome emergency plan for air traffic and other manuals
Embraer 190 Aircraft Maintenance Manual. Air Conditioning 21-001-00. Revision 27 – September 22, 2017
Embraer 190 Illustrated Parts Catalogue
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Embraer, Flight Operations Letter FOL N°: 170-036/14
Havarikommissionen, Final Report, Serious incident 3-12-2016 involving ATR72 202 OY-LHA
Rasmussen, J. & Svedung, I. (2000) Proactive Risk Management in a Dynamic Society. Karlstad, Sweden. Swedish Rescue Services Agency.
Southwestern Finland Rescue Department, operational procedure P2 P3 for major aircraft accident at Turku aerodrome

Investigation Material

1) Occurrence reports (ANS Finland, Nordic Regional Airlines, SIAF duty officer, Trafi VOP)
2) Paramedic service alert log and assignment record
3) Pronto alert and event log
4) Finavia report on rescue operation at Turku aerodrome
5) Photographs taken during investigation (Finavia, Nordic Regional Airlines, SIAF, UTC Aerospace Systems)
6) Weather information
7) Records on interviews made during investigation
8) Passenger questionnaire
9) Airplane (OH-LKE) cockpit voice recorder, flight data recorder and quick access recorder data
10) ANS Finland, Turku aerodrome Tower recordings
11) Emergency response center recordings
12) Southwestern Finland Rescue Department recordings
13) UTC Aerospace Systems Teardown Report, Sales Order 5762905

SUMMARY OF COMMENTS TO DRAFT FINAL REPORT

The draft final report was submitted for comments to the Finnish Transport Safety Agency, Emergency Response Center Agency, National Police Board, Social Emergency Center at Turku, Turku University Hospital Paramedic Unit, Social Emergency and Crisis Center at Vantaa, Southwestern Finland Rescue Department, Finavia Corporation, Air Navigation Services Finland, Brazilian and Swedish air accident investigation authorities, European Aviation Safety Agency, Transportation Safety Board and Federal Aviation Authority of the United States, Finnair Plc, Nordic Regional Airlines, aircraft manufacturer Embraer, UTC Aerospace Systems and the crew of the occurrence flight. Pursuant to the Safety Investigation Act, no comments given by private individuals are published.

The Finnish Transport Safety Agency (Trafi) noted that the report only discusses the safety management system of a single company.

About the safety recommendation 5.2, the agency states that Commission Regulation (EU) No 139/2014 on aerodromes does not oblige an aerodrome operator to provide passenger transportation from an incident site to locations specified in the facility utilization section of the aerodrome emergency plan.

The agency sees that a better way to ensure the timely availability of adequate transportation in the event of an accident is to exercise the powers vested in the rescue authorities, to accept assistance from other authorities and to apply existing procedures. The agency points out that it would be difficult to negotiate an agreement that would oblige an operator that is not part of a rescue organization to make preparations for a possible accident.

Air Navigation Services (ANS) Finland states that the air traffic controllers had no doubts about the classification of the alert. The full emergency procedures in the alerting service instructions cater equally for possible and confirmed inflight fires. Furthermore, ANS Finland comments that air traffic control's (ATC) responsibilities do not extend beyond issuing an alert, and therefore controllers are not authorized to determine the response to a full emergency or an accident — this decision will be made at an emergency response center (ERC).

Finavia Corporation states that the regulations do not place aerodrome operators under an obligation to plan transportation of passengers and prepare related instructions. The on-scene commander will carry out predetermined procedures and has powers to requisition equipment in each particular situation.

The Emergency Response Center Agency (ERCA) proposes that the existing procedures for aircraft accidents and full emergency situations should be reviewed. Special emphasis should be put on paramedic operations. The agency also refers to its comments on investigation report L2017-05.

ERCA's comments bring up a need to update the rescue authorities' procedures to better reflect the provisions of the ATC's alerting instructions. ERCA stresses in particular the importance of an ATC controller's assessment when the controller classifies an event as an accident or a full emergency situation. ERCA also proposes that communication procedures between ATC and ERC should be clarified in situations where the aerodrome maintenance supervisor (LENTO P3) assumes responsibility for incident command and control.

The new integrated emergency response approach Erica will bring changes to control room arrangement and enable more effective alerting service. Finally, ERCA states that Turku ERC carried out its task in an appropriate manner under the existing circumstances.

Nordic Regional Airlines (Norra) proposed a small number of specifying changes to the report. The changes were related to aircraft systems. Furthermore, Norra explained that its processes and safety management program are described in company manuals.

Turku University Hospital (TUH) Paramedic Unit proposed a number of specifying changes related to the stations that dispatched paramedic units. The unit also brought up a need to amend the text of paragraphs that discussed dispatching of paramedic units to respond to different contingencies.

The European Aviation Safety Agency (EASA) proposed a small number of changes related to rescue preparedness in view of the regulations that were in effect at the time of the occurrence.

The Brazilian aeronautical accidents investigation and prevention center (CENIPA), Embraer, Finnair Plc, the German federal bureau of aircraft accident investigation (BFU), Social Emergency Center at Turku, UTC Aerospace, Social Emergency and Crisis Center at Vantaa, Southwestern Finland Rescue Department, and the Federal Aviation Authority (FAA) and National Transportation Safety Board (NTSB) of the United States had no comments on the report.