Accident Resulting in the Death of a Captain at Kittilä Airport on 4 January 2018

L2018-01

SYNOPSIS

The Safety Investigation Authority, Finland decided to initiate an investigation under Section 2 of the Safety Investigation Act (525/2011) into an accident that resulted in the death of a Captain at Kittilä Airport on 4 January 2018. The objective of an accident or incident investigation is to promote general safety, prevent accidents and incidents and prevent the loss resulting from accidents. It is not the purpose of this activity to apportion blame or liability.

Flight Officer (ret) Pekka Alaraudanjoki was appointed as Head of the Investigation Team, Aviation Maintenance Engineer Jukka Jylö and Air Traffic Controller (ret.) Tauno Ylinen were appointed as members. Chief Safety Investigator Ismo Aaltonen served as Investigator-in-Charge. Aeromedical examiner, Adjunct Professor, Alpo Vuorio, MD, PhD, was appointed as the medical expert to the team.

The Ministry of Transport and Road Safety of Israel, the US National Transportation Safety Board Organization (NTSB) as well as the Austrian (SUB) and the German (BFU) air accident investigation authorities designated their accredited representatives to the investigation in accordance with 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) designated a technical adviser to the investigation. Under Section 12 of the Safety Investigation Act the Safety Investigation Authority, Finland (SIA) decided that the designated representatives and advisers could participate in the investigation.

The data from the Cockpit Voice Recorder and the Flight Data Recorder were downloaded in Germany at the BFU's laboratory. The Cabin Pressure Control System unit was sent to the NSTB, under whose supervision Honeywell Aerospace analysed it.

Safety investigation examines the course of events, their causes and consequences, search and rescue actions as well as the 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 also examines possible shortcomings in the authorities' provisions and orders regarding safety.

The investigation report includes an account of the course of the accident, the factors leading 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 the operations of search and rescue and the other authorities.

Prior to the completion of the investigation report, 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. A summary of the comments is included in the investigation report. However, no comments given by private individuals may be included in the investigation report.

The investigation report was translated into English by R&J Language Service. The images in the investigation report were edited by Graphic Designer Sole Lätti.

The investigation report, including its summary, is published on the internet page of the Safety Investigation Authority at *www.turvallisuustutkinta.fi*.

Cover photo: SIA

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1 FACTUAL INFORMATION

1.1 Sequence of events

OE-GKA, a Gulfstream G150 type business jet, arrived at Kittilä airport in the afternoon of Tuesday, 2 January 2018. The jet carried four passengers and a three-person crew. The aircraft was parked at the north end of the apron. Once the passengers had left, the flight crew put covers on the engines and external sensors.

The next planned flight was a positioning flight on Thursday evening, 4 January 2018, to Yekaterinburg, Russia, without passengers. The crew arrived at the airport to prepare for the flight at approximately 15:00[1]. Take-off, as per the flight plan, was to happen at 17:00.

The ground handling company transported them to the aircraft by bus at approximately 15:20. The captain opened the door at which time the cabin assistant entered the cabin. The captain and the co-pilot placed their flight bags behind the cockpit and went back outside. The co-pilot placed the aircrew's baggage into the rear baggage compartment which opens from the outside. The captain and the co-pilot removed the engine covers which they had put in place on the day of their arrival. These were put into their own storage bags and also placed in the baggage compartment.

Following this, the captain went into the cockpit and started the APU[2], which generates electricity for aircraft systems and bleed air for heating the cabin. The co-pilot began to brush off the snow that had fallen on the aircraft. A moment later the captain came out to help the co-pilot. At first, he worked with his bare hands. Due to the extremely cold conditions, however, he went back inside to fetch a pair of gloves. When he came back out, he closed the door.

A little later the cabin assistant inside the cabin felt strange pressure in her ears and chest. She went into the cockpit and attempted to get the attention of the pilots working outside by knocking on the window. The pilots noticed the knocking and the captain went to open the door. According to the co-pilot's observations it was unusually difficult for the captain to get the door open. Then, the captain pulled harder on the door handle at which time the door blew open with excessive force, hitting the captain who was standing underneath the door and knocking him to the ground[3]. The pressure wave also knocked the co-pilot down, who had been standing approximately one metre from the left side of the door.

The co-pilot stood up and saw the captain lying on his back on the ground. Realising that the captain was unconscious, the co-pilot turned him on his side. Then he entered the cabin and saw the cabin assistant in a semi-seated position on the floor of the cabin. The co-pilot shook the assistant's shoulder and advised her to go outside.

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1 All times are Finnish standard (winter) time UTC+2 h

2 APU Auxiliary Power Unit

3 According to ICAO (Annex 13) and Regulation (EU) No 996/2010, an accident is defined as *An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight… in which a person is fatally or seriously injured as a result of being in the aircraft, or direct contact with any part of the aircraft.*

The captain died as a result of the serious injuries he sustained at the site of the occurrence. The emergency medical personnel also checked whether the co-pilot and the cabin assistant had sustained any injuries. Later in the evening they were taken to a private medical centre at Levi ski resort for a check-up. The co-pilot had not sustained any physical injuries. The cabin assistant had bruises on her right arm, continued to feel chest pain and was diagnosed with a mild concussion.

Image 1. Post-accident photo of the doorway. (Photo: SIAF)

1.2 Alerting and rescue operations

As a result of the accident the captain was unconscious, lying on his back on the ground in front of the open door with his legs partly under the door. The air pressure also knocked the co-pilot down, but he was not hurt. Once he got back onto his feet he turned the captain on his side and went inside the cockpit. He called Kittilä air traffic control at 15:40 and reported the accident. The radio call was made in a panick-stricken voice and, therefore, it was not clear at first to the air traffic controller which aircraft had made the radio call. Once the air traffic controller asked the co-pilot to repeat the message, the matter became clear.

The air traffic controller alerted the Emergency Response Centre of Oulu by phone at 15:41, reporting an accident at Kittilä airport. The ERC requested more detailed information on what had happened. At this stage the air traffic controller did not have precise information at hand and had the impression that a passenger had been injured.

At the same time the airport maintenance shift supervisor was in a friction measuring vehicle waiting for permission to enter the runway to measure the friction. The supervisor was also on the same frequency and heard the co-pilot's radio call to the air traffic control. The shift supervisor informed the air traffic controller on the ground control frequency that he would

go and see what had happened. According to his estimate it took him 2-3 minutes from the time of the co-pilot's distress call to reach the site. At the accident site he saw one person lying on the ground and two panicked-looking people near him. They told the supervisor that some kind of explosion had taken place in the aircraft.

The ERC dispatched an ambulance from Kittilä health centre. Once the ERC operator had more information from the accident site the operator urged those at the site to continue with cardiopulmonary resuscitation (CPR), which the shift supervisor and the co-pilot had already started doing. The air traffic controller called the aircraft for more detailed information but there was no answer. The co-pilot did not hear this call because, after sounding the alert, he went back out to help the victim. The air traffic controller relayed the instructions received from the ERC by radio to the accident site.

A moment later the airport's apron supervisor arrived at the accident site and began to participate in the CPR. The airport maintenance shift supervisor told the other person on the shift to escort the ambulance to the accident site. A public address call was made inside the terminal to find out whether there was a doctor or a nurse present. Two nurses were almost transported to the accident site but then the ambulance arrived and the nurses were no longer needed. The airport defibrillator was also being brought to the accident site.

The first ambulance arrived at 15:51, i.e. approximately 10 minutes after the alert. The first responders then relieved the people that were providing CPR and continued with the resuscitation. They also had a defibrillator. The second ambulance arrived at 15:53. At the request of the first responders the co-pilot turned off the very noisy APU. Later, the first responders were in contact with, and received further instructions from, an emergency care doctor on duty in Oulu. At 16:08 the doctor decided that resuscitation be stopped and declared the victim dead.

A police unit arrived at the site at 16:21. They initiated an investigation of the scene by photographing the accident site and its surroundings. Following this, they cordoned off the area. For the purpose of investigating the scene, police investigators were dispatched from Rovaniemi. They arrived in the evening. On the basis of their investigation the police classified the accident as an occupational accident.

Table 1. Rescue and police units

Callsign	Dispatched	At site	Location	Type
ELE221	15:41	15:51	Kittilä	Rescue
ELE233	15:46	15:53	Kittilä	Rescue
Poliisi610	15:50	16:21	Kittilä	Police unit

Kittilä airport has an occupational health care contract with a private clinic operating at Levi ski resort. After being notified of the accident the clinic opened. Some of the people that had witnessed the event sought post trauma[4] treatment there later in the evening.

In order to organise psychosocial support following accidents and incidents, airport operator Finavia has prepared a post trauma system for their own personnel which lays out instructions for different situations. It is possible to prevent a possible stress disorder or prolonged stress by providing help through trained support persons to sufferers. Individual

[4] A post trauma system can be used following air accidents or close-call incidents, serious occupational injuries, violent situations or deaths within the working community.

or group discussions, led by the support person, play an important role that provides the opportunity for immediate debriefing. The goal is to provide the employee with mechanisms with which to handle and manage the situation.

The following day, at 14:00, occupational health care organised a debriefing session at the airport; all Finavia and Airpro employees which were on duty at the time of the accident were invited. They were together during the general segment, following which it was possible to hold private conversations. Moreover, all of the participants were also able to seek support later from occupational health care.

The co-pilot and the cabin assistant went to the private clinic for a check-up. Psychological support was also offered. The following morning they received voluntary support, comparable to crisis support. The Finnish Air Line Pilots' Association SLL takes part in international voluntary crisis support activities. They focus on aircrews which, while in Finland, become involved in accidents or incidents. At the time when the accident happened a retired airline pilot was at Levi ski resort in Kittilä. The safety committee of SLL notified him of the accident and he took it upon himself to provide support. He contacted the co-pilot and the cabin assistant. He and his wife took the shaken co-pilot and cabin assistant to their vacation home. During the meeting it became evident that they needed to talk about what had happened. In addition to providing crisis support, the airline pilot helped the ones who were involved in the accident with practical arrangements.

1.3 Consequences

1.3.1 Injuries to persons

The captain died at the accident site as a result of serious cranial injuries.

The co-pilot was not injured, even though he said he fell on his back as a result of the pressure wave. Once he got back onto his feet he was able to function and provide first aid as well as to call for help over the radio.

The cabin assistant was inside the aircraft and, according to her account, she fainted before the moment of the accident. She had no recollection of the door opening. She said that she did not try to open the door from the inside. Apparently, as a result of falling, she sustained minor injuries. She had several bruises, especially on her right arm, but the X-rays did not reveal any fractures.

Judging by her injuries it is evident that the bruises on the right arm were caused by some kind of collision with the cockpit's aft bulkhead which had come loose. As a result of this she fell onto the cabin floor into the semi-seated position in which the co-pilot found her. Her momentary loss of consciousness is probably associated with this event. It is unlikely that the high pressure made her lose consciousness.

Immediately before the moment of the accident the Cockpit Voice Recorder recorded the cabin assistant's voice as she was knocking on the cockpit window. Judging by her speech it can be estimated that she was functioning normally. When people are subjected to high pressure they may lose some functional capacity because of nitrogen narcosis, but in this case there is no evidence of this happening.

It was not possible to accurately calculate the pressure that existed in the cabin at the instant of the accident because not all of the measured values needed to make such a calculation were available. Among other things, cabin pressure is affected by the volume of the cabin, the bleed air flow generated by the APU, the temperature and the bleed rate of the relief valve.

Image 2. In the forefront of the photo are the loose items ejected from inside. (Photo: Lapland Police Department)

1.3.1 Damage to aircraft

The investigation determined the visible damage to the aircraft. However, damage to equipment, systems or structures was not assessed.

There was minor damage to the outside of the aircraft. The external surface of the door had small dents and a few scratches. During testing the door appeared to close and open normally once the wall panels that were damaged or displaced during the accident sequence were repositioned.

The cabin sustained substantial damage. The cockpit's aft left bulkhead and the cabin's forward left bulkhead were nearly torn off, left hanging by only a few fastenings near the doorway. The airstairs' acoustic entry curtain and the extinguisher, flashlight and crash axe,

which were fastened to the cockpit's aft bulkhead, came loose from their fastenings and were ejected out approximately 5 m from the door. When the front cabin bulkhead came loose, the tableware storage drawers on the bulkhead broke and the dishes were broken. Several cabin wall panels came loose from their lower fastenings. The cabinets in the aft cabin toilet had opened. The oxygen box in the headliner, closest to the door, had opened and two oxygen masks were hanging on their air hoses.

There was no damage to the environment.

2 BACKGROUND INFORMATION

2.1 Environment, systems and equipment

2.1.1 Environment

The accident happened on the apron of Kittilä airport when the captain opened the main entry door of the aircraft from the outside. Significant differential pressure caused the door to hit him.

Both chartered and scheduled flights use Kittilä airport. Its runway is 2500 m long and 45 m wide. Runways 16 and 34 are numbered according to their magnetic headings. There is no separate taxiway parallel to the runway. Instead, aircraft taxi along the runway. The stands in front of and close to the terminal are mainly intended for airliners. This area is also monitored by surveillance cameras. The parking area meant for, among other things, business jets is at the north end of the apron where there is no camera surveillance.

2.1.2 Aircraft

The Gulfstream G150 is a twin-engine business jet. It is designed by and type certified through Gulfstream Aerospace Limited Partnership (GALP) and manufactured by Israel Aerospace Industries (IAI), both located in Israel. The accident aircraft, serial number 300, was built in 2012. The engines' type is Honeywell TFE 731-40AR made by the US manufacturer Honeywell Aerospace. The registration of the accident aircraft is OE-GKA and it has a certificate of registration and an airworthiness certificate issued by the Austrian aviation authority.

The cabin has seven passenger seats. According to the operator's brochure, the typical seating arrangement comprises of up to four passengers and an aircrew of two pilots and, when needed, a cabin assistant.

2.1.3 Aircraft systems and equipment

Aircraft systems were assessed to the extent that they were relevant to this occurrence. The reference material includes the aircraft designer's, manufacturer's and operator's manuals and other instructions. According to the manufacturer, only AFM[5] is FAA[6] approved manual and in case of contradicting data or procedures with another manual, AFM has the final authority.

The Auxiliary Power Unit (APU) is a turbine engine used by many aircraft. It runs on the aircraft's own jet fuel. It generates electricity for aircraft systems and bleed air for the air conditioning system to heat or cool the cabin, depending on the conditions. It is routine practice to turn on the APU on the ground before starting the engines. It can be started with the aircraft's batteries, as was the case here, or with an external power source. The APU can also be used in the air.

OE-GKA's APU type is Honeywell RE100. It is mounted in the aircraft rear fuselage and is enclosed within a fire protection shield. In case of a fire, it is also furnished with an automatic fire detection system which, in the event of overheating or fire, will shut down the APU and close its fuel shutoff valve. The APU is computer controlled and it is started and otherwise

5 Airplane Flight Manual
6 Federal Aviation Authority

operated through the cockpit panel. The commands the pilots give to the APU and the information it sends back to the cockpit travel through an Electronic Control Unit[7].

The captain started the APU at 15:25 and then went outside to help the co-pilot with snow removal. A moment later he returned to the cockpit to fetch a pair of fire gloves, part of the aircraft's equipment, because he had no gloves of his own with him. At this juncture the captain told the cabin assistant that it would be possible to turn on cabin heating in five minutes. What he meant by this, remains uncertain.

When the captain went back outside he closed the door from the outside. The Cold Weather Operations Manual[8] mentions in several places that heating can be expedited by closing the door. At the end of the manual's supplementary checklist there is an instruction "If APU operating, check outflow valve full open".

The Main Entrance Door[9] is on the left side of the fuselage right behind the cockpit in a Gulfstream G150. It is opened and closed manually from the outside or the inside when the aircraft is unpressurised. When open, the door also functions as airstairs for the purpose of boarding and deplaning. When the door is opened a door support leg is first released from the top of the door. The door rests on the support on the ground when fully open.

The airstairs door rotates around two lower hinges and it opens from top down. Door opening is limited by two telescopic rod assemblies on both sides. Its free fall is controlled by a damper assembly. In order to make it easier to use the airstairs, a collapsible handrail automatically deploys when the door is opened.

The door has two seals. One is an inflatable seal which is automatically pressurised with engine or APU bleed air when the door is closed. When the door handle is moved, the pressure port fitted on the door automatically deflates the seal. The other seal is a conventional seal which is, according to AFM, designed to maintain cabin pressurisation even if the inflatable seal malfunctions.

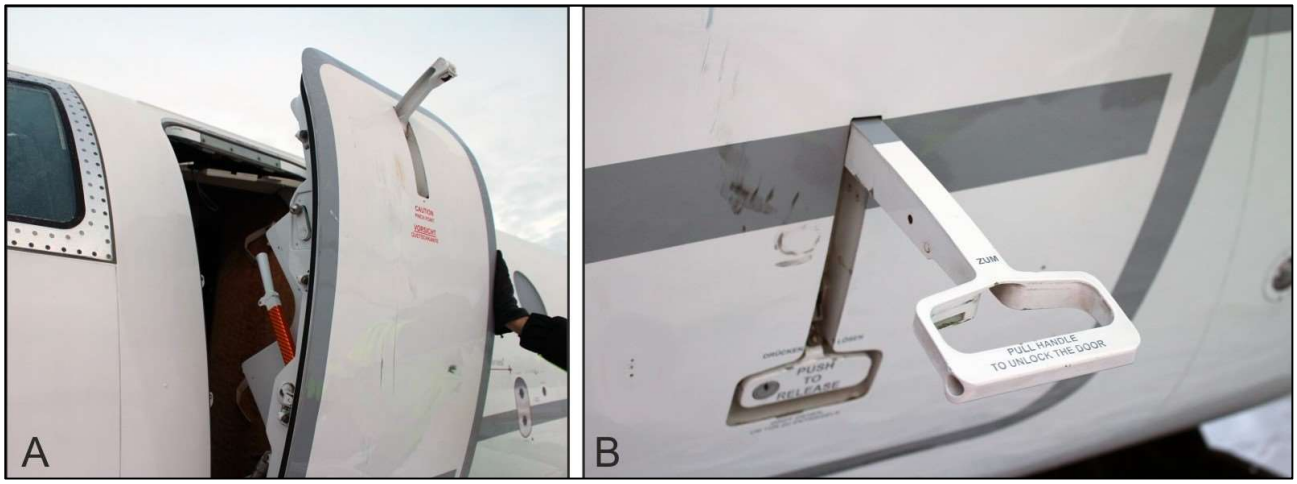

Image 3: 3A: The door in the process of opening, the ground support leg has come out.
3B: A close-up of the stirrup handle. Photo: SIAF

7 ECU Electronic Control Unit
8 CWOM Gulfstream G150 Cold Weather Operations Manual
9 MED Main Entrance Door

According to the Cabin Operating Manual during the door opening process from outside the aircraft, the door seal is first deflated to allow the door to open properly. This begins once the stirrup handle is pulled out in the first ½" of travel and takes 2-3 seconds to complete. The door seal pressure release is indicated by the sound of air being bled off through the pressure port in the door. Then, the stirrup handle is raised to its upper position while simultaneously pulling the door upwards, whereby it opens. The door is balanced and normally takes little force to open.

The Cabin Operating Manual[10] warns that the door is heavy and that it must be operated carefully to prevent damage or injury. Among other things, the manual warns against standing directly underneath the door when it is being opened from the outside. In addition, one must make certain that the door pathway is clear when the door is being opened.

According to the co-pilot's observations the captain had to use much more force than usual when he was opening the door. This difficulty was caused by the differential pressure between the cabin and the outside ambient pressure. During onsite testing, the door appeared to close and open normally once displaced wall panels that had come loose in the accident sequence were repositioned.

The Environmental Control System[11] monitors cabin airflow, pressurisation and temperature. The ECS comprises the air conditioning system and the pressurisation system. The system uses either engine bleed air or APU bleed air, depending on the position of the ECS knob. If it is turned to the RAM position, both engine and APU bleed air are shut off to the cabin and the cabin is simultaneously depressurised through the outflow valve when on the ground. It is not possible to control cabin temperature when the knob is in the RAM position. One of the first things on the engine shutdown checklist involves turning the ECS system to RAM and setting cabin pressurisation to MAN, i.e. manual control.

The Air Conditioning System can be used on the ground and in the air. The system defaults to automatic; there is no indication light for this. Cabin temperature can also be adjusted manually by pressing the CABIN TEMP MAN pushbutton. The indication light will then turn on. In both cases temperature is controlled with the CABIN TEMP knob. When the aircraft is on the ground, the APU or at least one engine must be running in order to use the air conditioning system.

The Cabin Pressurisation System[12] is controlled by the digital Cabin Pressure Control System (CPCS)[13], normally operated in automatic control. When the system is in manual, the MAN light illuminates on the switch. When the system is in automatic, the switch is not illuminated. The CPCS directly controls the outflow valve which, according to the signals it receives, regulates the outflow volume of air. In order for the CPCS to operate automatically at least one of the avionics power switches must be turned on.

During the flight the pressure control system automatically sets the cabin pressure differential, based on aircraft altitude. The automatic, independently operating relief valve opens when differential pressure reaches 8.95 +/-0.1 psi[14]. The relief valve is positioned on the front plate of the pressurised fuselage and its exhaust port is inside the nose cone. Both the outflow valve and the relief valve functioned normally in the onsite tests carried out after the accident.

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10 Gulfstream G150 Cabin Operating Manual
11 ECS Environmental Control System
12 Cabin Pressurisation System
13 CPCS Cabin Pressure Control System
14 Pounds per square inch

Image 4. 4A: The ECS control panel where the bleed air is selected to APU and the temperature control knob is turned to approximately the one o'clock position.
4B: The Cabin pressurisation control panel. (Photos: SIAF)

In normal conditions the pressurisation system gets its electric power through the avionics power switch, at which time the automatic system runs a built-in-test and turns on the FAULT light momentarily. If the CPCS detects that engine power is below 70% and the "weight on wheels" sensors indicate that the aircraft is on the ground, it will fully open the outflow valve.

The outflow valve exhaust opening is positioned below the cockpit, on the right side of the front fuselage. The opening is protected by a metal grill and the actual valve is deeper inside the fuselage. According to the cold weather operating instructions the pilot must check the outflow valve during the walkaround check. It must be ascertained that no packed snow or ice has accumulated inside the valve. In Kittilä, in the conditions that prevailed at the time of the occurrence, this would have required the use of a flashlight or some other light source. According to the co-pilot's statement the outflow valve was not checked visually at this stage. The outflow valve opened and closed normally during testing, and no snow or ice was detected. The aircraft was parked outside in sub-zero temperatures after the accident and before testing. This was done so as to preserve the conditions that prevailed at the time of the accident, so that a possibly frozen outflow valve could not have thawed in the meantime.

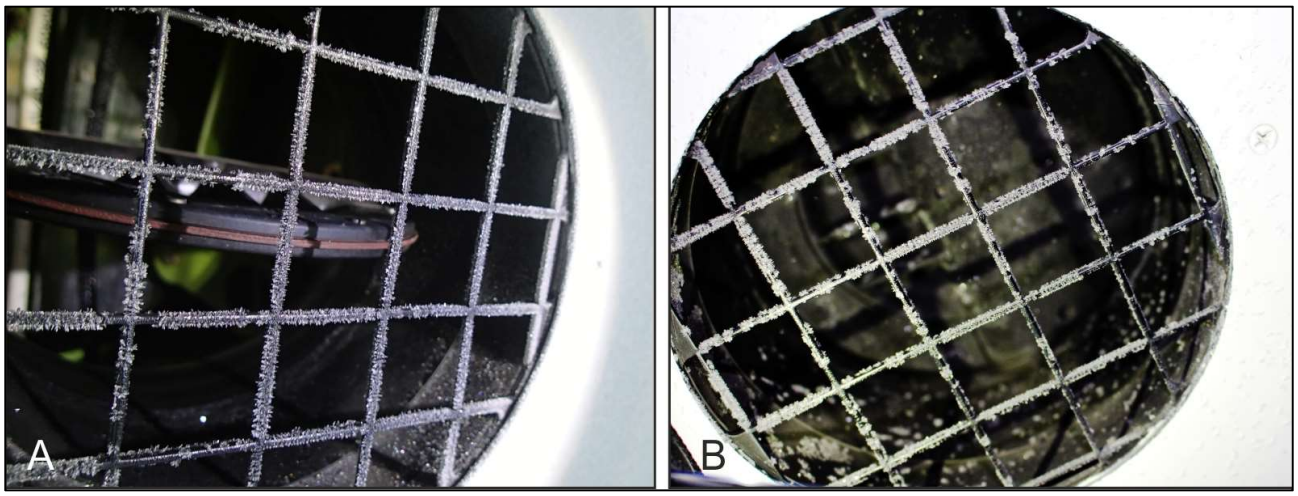

Image 5. 5A: Outflow valve open.
5B: Outflow valve closed. (Photos: SIAF)

In addition to the automatic setting, pressurisation can be controlled manually, for example, during an in-flight malfunction, by pressing the MAN pushbutton of the MODE SEL pushbuttons. This then turns on the light on the pushbutton. The pilots then control the cabin pressure altitude by adjusting the position of the outflow valve with the CABIN ALT knob. The knob can be turned to INCR which increases the opening of the outflow valve or DECR which decreases its opening. It takes about 60 seconds to fully open or close the outflow valve with the CABIN ALT knob, and the knob must be kept in the desired position the entire time. It is not possible to manually control the valve if the ECS is set to the RAM position.

The purpose of the DITCH pushbutton is to close the outflow valve when an emergency landing is made on water. It takes approximately 15-20 seconds for the valve to close from the time the pushbutton is pressed. When pressed, the DITCH pushbutton lights up, but the light does not indicate the position of the valve, only that the button has been pushed. The investigation revealed that the DITCH pushbutton may from time to time be used during parking to close the outflow valve. This, however, is not authorised practice. The intent of closing the valve is to prevent the ingestion of snow, sand or insects, among other things, into the outflow valve and further upstream in its channel. Pressing the DITCH pushbutton will override any other control commands to the outflow valve.

By pressing the DUMP pushbutton it is possible to depressurise the cabin in an emergency. It takes 15-20 seconds for the outflow valve to fully open. There is also no indication of the valve's position after the DUMP pushbutton has been pressed nor from its light coming on.

According to the manufacturer, both the DITCH and the DUMP pushbuttons are meant for emergencies only.

The chain of events that resulted in the accident can be seen to have begun when the procedures following the previous flight were carried out. After landing, while taxiing to the apron, the pilots turned on the APU. Once the aircraft was parked the engines were shut down, but the APU was still running. According to the engine shutdown check[15] the ECS must be set to RAM, i.e. the bleed air flow is shut off and pressurisation is set to manual control (MAN). With these settings the outflow valve remains open.

When the crew had completed the other tasks associated with parking the aircraft, the captain also turned the APU off. At this stage the co-pilot had already left the cockpit and the captain shut it down on his own. The co-pilot did not know whether the captain had, at this point, possibly closed the outflow valve, for instance, because of blowing snow.

On the accident day, during pre-flight preparations, the captain went alone into the cockpit and started the APU at 15:25. On the basis of the investigation it is apparent that the outflow valve remained closed when the APU was started and that its bleed air was ducted into the cabin. A moment later the door was also closed, which is when pressure began to build inside the cabin.

According to the operating principle of the relief valve, its spring-loaded valve opens when differential pressure reaches the threshold value. If the threshold value was reached with the door closed, the safety relief valve would have, according to the manufacturer, maintained the maximum differential pressure at 8.95 +/- 0.1 psi.

[15] Shutdown Check

2.1.4 Safety nets

Crew Resource Management[16] is one of the cornerstones of flight safety. Smoothly flowing CRM creates a safety net as the pilots double-check each other's procedures. Standard Operation Procedures[17] have been developed for flight crews; their sources include information and lessons learned from aircraft manufacturers, other operators and the authorities. By using SOPs it is possible to reduce pilot workload and improve situational awareness. In this particular case the pre-flight preparations were at the stage where the co-pilot had not even been in the cockpit. The captain went into the cockpit alone to start the APU. According to the checklist this can be done by either pilot, alone. When it comes to the pre-flight preparations it is not possible to assess how successful their CRM was. However, judging by the cockpit voice recording from the arrival flight it can be estimated to have been normal.

Compliance with **the Checklist** ensures that all required procedures are done in the right order and that nothing critical is forgotten, such as the item on the operator's checklist before the APU start. The checklist includes the bolded text **"perform EXT INSP"**, i.e. carry out the external inspection. This includes, among other things, checking the outflow valve.

Technical safety nets that concern aircraft pressurisation are associated with sudden cabin decompression in flight. In normal operations it is not the intention to pressurise aircraft on the ground. Hence, there should be no need for such a safety net. Pressurisation tests associated with maintenance and repair on the ground are an exception to this rule. When performing these, the technical personnel comply with the manufacturer's instructions to ensure safety.

In this accident the outflow valve remained shut, the captain started the APU and closed the door. At this stage none of the warning systems will indicate that pressure is about to build in the cabin. Neither does the CABIN PRESS panel provide any indication as to the position of the outflow valve.

It is not forbidden to run an APU fitted with an automatic fire detection system without there being a pilot in the cockpit monitoring its operation. There are no procedures to shut down the APU from the outside in this aircraft type.

Some aircraft types are fitted with door warning systems that alert the cabin crew and the ground crew of excessive pressure. For example, the cabin doors of the Airbus A320 jetliner provide visual (light) and aural warnings for overpressure. The warning light is positioned inside the door and it is visible from the inside and outside through a window on the door. The warning system has its own power source and, therefore, it operates independently of the aircraft's electric system.

2.2 Conditions

2.2.1 Weather conditions

The aircraft arrived in Kittilä on 2 January 2018 in the afternoon. It was parked at the north end of the apron. At the moment of the accident on 4 January 2018, the aircraft had been standing for approximately two days. At the time of its arrival the temperature was -5 °C (+23 °F) and it was lightly snowing. For the first day the weather remained more or less the same, whereafter the temperature began to drop rapidly. On the morning of 4 January 2018 the

[16] CRM Crew Resource Management
[17] SOP Standard Operating Procedure

temperature was -22 °C (-7.6 °F) and remained the same for the rest of the day. As regards light conditions, it can be noted that in the afternoon, between 15:00 and 16:00, dusk prevailed. Considering the season, this was normal wintertime weather in Lapland.

The decoded METAR[18] on 4 Jan 2018 at 15.50:

Wind 350 degrees, 1 knot. Visibility over 10 km. Precipitation light snow grains. Sky clear. Temperature -22 degrees, dew point -24 degrees. Pressure (QNH[19]) 1006 hPa.

The original METAR 4.1.2018 13.50UTC[20]:

EFKT 350/01KT 9999, -SG, SKC, M22/M24 Q1006 =

2.2.2 Pre-flight preparations

The aircrew arrived at the airport for pre-flight preparations at approximately 15:00. The ground handling company transported them to the aircraft on the apron at approximately 15:20. The aircraft was partly covered by snow and there was frost on the cockpit windows. At first, before opening the door, the captain took several photographs of the aircraft. After the captain opened the door the cabin assistant went inside and the flight crew removed the external covers. At 15:25 the captain started the APU.

The flight crew began to brush snow off of the aircraft. As this work progressed the flight crew intended to evaluate whether they could make the surfaces clean enough by brushing them or if they needed chemical deicing. They took the aluminium stairs from the baggage compartment so as to better reach the snow on the top of the aircraft and to remove the frost from the cockpit windows. The co-pilot first worked from the top of the stairs but, since the captain was taller and wanted to make the work easier, he took it upon himself to remove the frost from off of the cockpit windows. After having fetched gloves from the cabin, the captain came back out and closed the door. In all, the crew was lightly dressed considering the prevailing weather conditions.

The co-pilot went to remove ice from the nose wheel and the captain continued with the brushing. A little later the pilots noticed the cabin assistant knocking on the cockpit window. The captain went to the door and opened it, which is when the accident happened.

According to the co-pilot's account the pre-flight preparations progressed normally up until this moment and, despite the cold weather, everything proceeded as planned and they felt no pressure because of haste or any other reason.

The operator stated that they comply with Gulfstream's Cold Weather Operations Manual[21] and that they have no separate company instructions for this. At the moment of the accident the temperature in Kittilä was -22 °C (-7.6 °F) and the aircraft had been parked outside for two days. According to the manual the aircraft is to be heated by using the APU's bleed air and heating can be expedited by closing the door. The very same manual's supplementary checklist for the external inspection includes the following instruction: "if APU operating, check outflow valve is full open".

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18 METAR, Meteorological Terminal Air Report
19 QNH is the altimeter setting that indicates atmospheric pressure adjusted to mean sea level.
20 UTC, Universal Time Coordinated
21 CWOM Cold Weather Operations Manual

2.3 Personnel, organisations and safety management

2.3.1 Aircrew

The captain was an experienced pilot. He had approximately 13 000 total flying hours and approximately 1 000 hours on this type[22]. He held an Airline Pilot Licence and was rated to operate as flight instructor and as type rating instructor. In the operator's organisational chart he was also the CEO of the company and a crew instructor

The co-pilot had been hired by this operator on a freelance contract in November 2017. In other words, he had been working for the company for approximately two months at the time of the accident. He had approximately 1 000 total flying hours and approximately 100 hours on this type.

The cabin assistant had joined the company in 2012. According to her account she had also completed part of the cabin crew training, but she was working for the company as a cabin assistant. She said that this is routine practice among business jet operators.

It can be estimated that **the crew's alertness** was good. When they arrived in Kittilä on 2 January 2018 the crew checked into a hotel to wait for their next mission. They were informed at the hotel of their next mission, which was to be a flight on 5 January 2018 from Yekaterinburg, Russia, to Milan, Italy. The captain decided to fly the aircraft to Yekaterinburg in the evening of 4 January 2018. The aircrew on the positioning flight was to include the captain, the co-pilot and the cabin assistant.

The interviews revealed that during their stay in Kittilä they were mainly resting in their hotel rooms. The weather was cold and, apart from short outings, they stayed indoors. When they arrived at the airport to prepare for the flight they were well rested.

2.3.2 Operator

The operator of the aircraft is Private Airlines Germany GmbH. They have an Aircraft Operator Certificate[23] issued by the German aviation authority. The company states that their administrative domicile is in Salzburg, Austria, and that their operational division is in Anger, Germany. The company operates with one aircraft.

The operator's Chief of Flight Operations reported the accident to the German aviation and accident investigation authorities on 4 January 2018, on the day of the occurrence.

The existence of **a safety management system** in a company is one of the prerequisites for issuing an Aircraft Operator Certificate. The operator's safety management system is described in the Safety Management System Manual[24]. The manual explains the way in which the SMS is organised in the company and includes the safety management policy, objectives, implementation and individual safety responsibilities and accountabilities.

The operator's SMS-M includes, among other things, the following chapters: Accountable personnel, Document control, Hazard identification, Change management and Reporting. The company's key safety personnel also bear the main responsibility for conducting all activities in a safe manner. According to the organisational chart the Chief Executive Officer has the overall responsibility. In this case the CEO was the captain who perished in the accident.

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22 The information dates back to 2015
23 AOC Aircraft Operator Certificate
24 SMS-M Safety Management System Manual

One of the basic pillars of safety management is an open reporting culture that operates under the 'just culture' principle. It is important to efficiently process all reports and to provide feedback. When necessary, corrective action must also be taken without delay. The operator's manual describes the reporting process. The investigation did not use the operator's individual reports or any statistics compiled from them.

2.3.3 ANS[25] Finland, air traffic control

In the spring of 2017, during a reorganisation of activities, air traffic control services were detached from Finavia. Following this, ANS Finland, a separate air navigation services company, was established. Kittilä airport provides tower and approach control services or flight information services. In the wintertime, due to busy traffic, the services are, for the most part, given as air traffic control services.

There was one air traffic controller on duty at the time of the accident, who provided air traffic control services on aviation frequencies, managed vehicles on the ground frequency and provided alerting services by contacting the Emergency Response Centre (ERC) by telephone.

In the event of different types of incidents and accidents the air traffic control uses an Alerting Manual. According to it the alerting service is a part of air navigation services and its primary objective is to relay information to the appropriate organisations without delay. When any air navigation services unit is notified of a distress call in aviation, it must take the appropriate action. One of the actions mentioned in the manual is to activate the aerodrome's rescue service and to make an emergency call to the ERC. In this case the air traffic controller immediately alerted the ERC, but did not activate the airport's rescue service. Considering the nature of the occurrence, the controller's decision was reasonable.

2.3.4 Finavia Corporation

Finavia Corporation is an airport operator which maintains and develops aerodromes in Finland. Among other things, Finavia takes care of airport maintenance and rescue services. Finavia has two subsidiaries: LAK Real Estate, which maintains aerodrome properties, and Airpro, which, among other things, provides security control and passenger services. Airpro also offers ground handling services to operators, and it provided the ground handling services to OE-GKA in Kittilä.

2.4 Authorities' actions

The explosive discharge of large differential pressure between an aircraft on the ground and the outside when opening a door or emergency exit may cause an incident or an accident. According to available data, in addition to the accident in Kittilä, two cabin crew members have died in such accidents since 2000, and many have been seriously injured. The occurrences that led to these accidents took place in airliners when cabin crew members opened the door from the inside and, owing to sudden depressurisation, fell out or were ejected from the aircraft.

[25] ANS Air Navigation Services

2.4.1 The European Aviation Safety Agency [26]

A study on Cabin Safety Requirements[27], commissioned by the European Aviation Safety Agency (EASA), was published in 2009. It charted the safety threats for cabin safety, based on documentation, and analysed 326 accidents from 1998–2007. The safety threats were divided into categories in accordance with the safety actions they required. One safety threat which was mentioned in the study involved explosive door opening when the cabin was partially pressurised on the ground[28]. This threat materialised in the accident in Kittilä.

The study's conclusions and recommendations state that explosive door openings have resulted in fatal and serious injuries which could have been prevented by better procedures or communication. It was concluded that further research is required and that the research must investigate how these occurrences can be prevented and ensure that any solutions will not adversely affect rapid evacuation and in-flight safety. The EASA has not conducted any further research on the subject.

2.4.2 The Federal Aviation Administration[29]

In 2008 the Federal Aviation Administration (FAA) published the SAFO[30] 08007 safety alert for operators concerning aircraft pressurisation on the ground. The SAFO informs air carriers about the hazard presented by an air conditioning (A/C) cart pressurising an airplane cabin on the ground if all airplane doors are closed. The background for this SAFO was an accident that happened on May 31 2005 when a flight attendant, during ground operations, was ejected from the airplane's galley service door and was seriously injured. The cabin was pressurised because it was being cooled by an A/C cart and all of the doors were closed.

According to the NTSB's[31] investigation report the probable cause of the accident was the opening of the galley service door when the airplane was pressurised. In addition, the report stated that the captain should have ensured that one of the airplane doors was open while an A/C cart was connected to the airplane. The NTSB made the recommendation to amend the cabin crew training manuals and programmes so that they emphasise keeping at least one airplane door open when an A/C cart is connected to the aircraft. Furthermore, the recommendation states that the cabin crew must be warned against opening a door when an A/C cart is providing heated or cooled air to the cabin.

According to the FAA's SAFO, also in many other aircraft types, other than the one involved in the accident, cabin doors can be opened on the ground, even if significant differential pressure exists between the cabin and the outside. The FAA recommended that the persons responsible for operations, safety and aircrew training should be aware of the hazard associated with differential pressure. Air carriers should revise their crewmember training programmes and operating manuals to educate crewmembers on the hazard and to provide training to crews to mitigate the risk presented by it. The NTSB did not consider these actions sufficient so as to consider their recommendation as having been implemented.

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26 EASA, European Aviation Safety Agency
27 Study on CS-25 Cabin Safety Requirements
28 Explosive Door Openings on the Ground
29 FAA, Federal Aviation Administration
30 SAFO, Safety Alert for Operators
31 NTSB, National Transportation Safety Board

The accident in Kittilä had similar contributing factors as the above mentioned occurrence. The aircraft was on the ground, a significant differential pressure existed between the cabin and the outside and, still, the door was opened. The main differences between these two occurrences were the facts that in Kittilä cabin pressure was generated with the aircraft's own APU and the door was opened from the outside.

2.5 Rescue services and preparedness

The key tasks of **Emergency Response Centre Administration** are the provision of emergency response services and associated support services to the rescue service, the police and the social welfare and health authorities. The ERC Administration plays a clear coordinating role within the chain of help providers. ERC operators make risk assessments on the basis of the information received from the caller and, when needed, dispatch appropriate help to the accident site in accordance with pre-planned guidelines.

Airport rescue service arrangements at Kittilä airport are the responsibility of Finavia. The airport rescue service is responsible for carrying out rescue operations associated with on-airport and off-airport aviation accidents during its open hours. The airport has an aerodrome emergency plan; its key objectives are to minimise injuries to persons, ensure the continuation of aviation and to efficiently cooperate with other participating rescue organisations. The personnel working at the airport will immediately launch operations as per the aerodrome emergency plan as soon as they are notified of an accident. Their tasks are detailed in the operating instructions of the aerodrome emergency plan. Aerodrome incident commander *Lento P3* will lead the airport's rescue units until the rescue department takes over. In cooperation with authorities, exercises are organised at regular intervals to rehearse this. Major rescue exercises are held every two years[32], and smaller exercises during the years between[33].

The air traffic control will normally alert the airport rescue when notified of an aviation emergency. The alert is heard on the airport's alerting system and on the airport rescue service's *Virve* terrestrial trunk radio network.

Emergency medical services means the life-saving or injury-mitigating care provided by professionals, mainly ambulance staff, at home or at the accident site, away from a hospital or health centre. Ambulance services are part of emergency medical services.

Lapland Hospital District organises independently the emergency medical services of its member municipalities. The Lapland Central Hospital Emergency Clinic is responsible for coordinating emergency medical services and for implementing the service level decision within the district. Triage nurses work in municipalities' A&E units and they are responsible for providing emergency medical services to patients. The nurses also see to it that the patients are transported to the most suitable health care unit.

An outpatient unit and an A&E unit operate on weekdays at Kittilä health centre. In the evenings, neighbouring municipalities take turns being on duty, Lapland Central Hospital is open at nighttime.

[32] Previous time in Kittilä was 2016
[33] Previous time in Kittilä was 2017

2.6 Recording systems

2.6.1 Kittilä air traffic control recordings

Kittilä air traffic control telephone and radiocommunication recordings were made available to the investigation. On the basis of these it can be noted that the air traffic controller was busy while relaying the different actors' information to each other on different media. Throughout the time of the occurrence there were many departing and arriving flights. The air traffic controller was mainly focusing on emergency communications.

2.6.2 Aircraft recordings

The information on the Cockpit Voice Recorder and the Flight Data Recorder was downloaded at the laboratory of the German Federal Bureau of Aircraft Accidents Investigation.

The **Cockpit Voice Recorder**[34] records sounds through several microphones from the cockpit and, partly, from the cabin as well. The recording contains the recorded voices of the pilots and other aircrew members as well as audible signals from aircraft equipment.

On the basis of the recording it was possible to detail the actions that took place before the accident as well as their time. Among other things, the recording yields the time when the door was closed. Likewise, it is possible to hear the cabin assistant knocking on the window and, finally, the opening of the door and the explosive decompression.

For an unknown reason the recording ends when the door opens, even though the recorder was powered by the aircraft's batteries after the door opened.

The Flight Data Recorder[35] is a digital recorder which broadly gathers information from aircraft systems. Among other things, this investigation used the following data: starting and shutting down the APU, locking position of the door as well as the times when the radio was used. Moreover, the FDR's data were able to corroborate information received from other sources. The FDR does not record pressurisation information. The recording continued until the aircraft's batteries were drained.

The Cabin Pressure Control System unit

The Cabin Pressure Control (CPC) System unit was sent to the United States for analysis. The unit was downloaded under the supervision of the NTSB and inspected by Honeywell. According to the results, the unit was functioning and recording normally. The limit of the measuring capability of the unit, -4 000 FT, i.e. approximately -1 200 m, was reached and, according to Gulfstream's estimate, probably exceeded as well. The limit means the theoretical altitude below mean sea level, which indicates that cabin pressure rose above mean sea level pressure.

[34] CVR, Cockpit Voice Recorder
[35] FDR, Flight Data Recorder

2.7 Rules, regulations, procedures and other documentation

2.7.1 The operator's instructions

The Aircraft Operator Certificate requires the existence of an Operating Manual approved by the aviation authority.

Operations Manual A[36] contains the basic issues associated with the operator and its activities. Among other things, it lists the accountable personnel and their tasks. It includes instructions and procedures which are not associated with any given aircraft type. The tasks and responsibilities of personnel involved in flight operations are given in detail.

The OM-A also lists the operator's other instructions and guidelines that are in use, such as the SMS-M Safety Management System Manual.

Operations Manual B[37] contains the instructions and procedures for each of the operator's aircraft type for safe operations. It must be carried on board. The manual's instructions are based on aircraft manufacturer documentation and the manual also includes guidelines for emergencies.

The OM-B contains the pilots' checklists. For the most part the operator's checklists comply with the aircraft manufacturer Gulfstream's corresponding lists[38]. The operator's checklists are more condensed; two procedures may be shown on one line. However, certain differences between these two lists can be found. According to the operator's checklist, the Cabin Press is set to automatic after engine start. According to Gulfstream's Cockpit Card the cabin pressurisation mode is selected to automatic before engine start.

The Cold Weather Operations Manual was originally drafted by Gulfstream. The operator states that they comply with it. The textual content in the operator's version is identical to the original. The CWOM include, for example, the instructions associated with closing the door, using the APU and the instructions for using the outflow valve: "Heating can be expedited by closing the main entry door" as well as the section "If APU operating, check outflow valve full open" in the supplementary checklist. The chapter that addresses starting the APU repeats the abovementioned instruction that it is possible to expedite heating by closing the door.

According to the CWOM, cockpit systems power up should be delayed until cockpit and cabin temperatures have reached approximately +10 °C (+50 °F). According to the operator's checklist, the temperature should have reached +15 °C (+59 °F) before the cockpit systems power is turned on. This is a significant factor in, for example, the functioning of automatic pressurisation. The automatic pressurisation will only activate once one of the avionics power switches is engaged because, in order to function, the automatic pressurisation needs information from the avionics system.

There are variations in published documents on how to power up the avionics system of the aircraft in cold weather conditions. The manufacturer's AFM does not contain any temperature limitations for turning the avionics switches on. In the CWOM there are the abovementioned instructions to delay power up and a notice: this manual is not FAA approved and in case of contradicting data or procedures, refer to FAA approved AFM as the final authority.

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36 OM-A Operations Manual A
37 OM-B Operations Manual B
38 Gulfstream Cockpit Card

2.8 Other research

No other research was carried out.

3 ANALYSIS

3.1 Analysis of occurrence

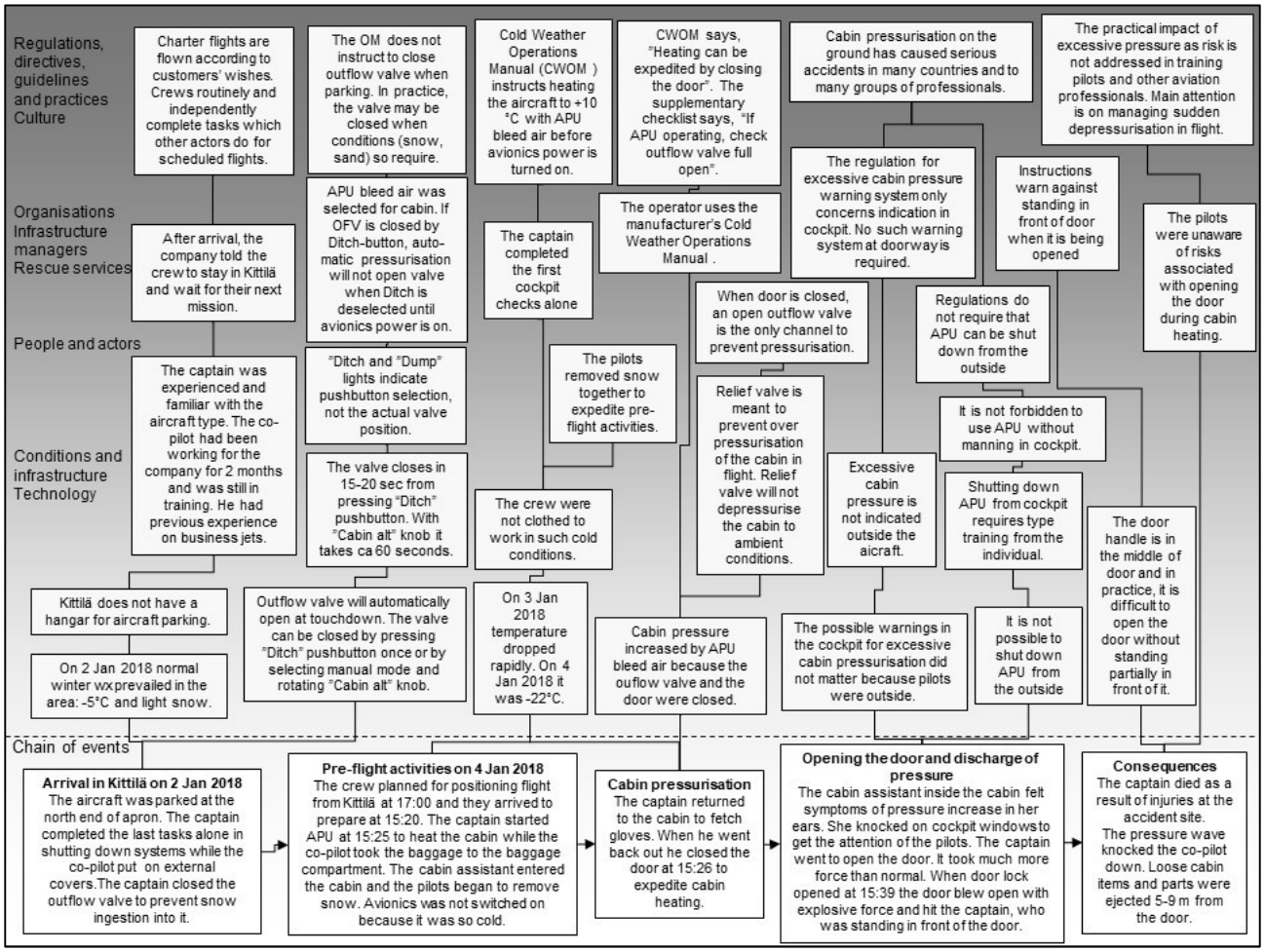

Image 6. Accimap presentation[39]

3.1.1 Arrival in Kittilä on 2 January 2018

The operator is a small charter company, operating with one jet, mainly in Europe and in Russia. The aircraft is registered in Austria and the company has a German Aircraft Operator Certificate which, among other things, approves the company's organisation. The company's CEO was also the chief pilot and the instructor of the company, and he was the pilot-in-command when they arrived from Moscow to Kittilä. After parking the aircraft the captain called the company's office and was informed that the aircrew was to stay in Kittilä at a hotel to wait for the next mission.

Apparently, the operator would normally park the aircraft in a hangar, if one was available at the airport. In Kittilä, however, this was not possible and, judging by the arrival day's CVR

[39] The AcciMap Approach is used in analysing contributing factors, finding the most important conclusions as well as for preparing effective safety recommendations and targeting them to the right entities. The accident is depicted as a chain of events at the bottom of the AcciMap graph. Identified decision-makers and other levels that guide action are marked on the left side. The different elements of the chain of events are shown as a bottom-to-top sequence. The lower part of the graph portrays an assessment of the individual accident which is being studied, from which the process leads to wider perspectives and implications, for example, at the national or international level. Rasmussen, J. and Svedung, I. (2000), *Proactive Risk Management in a Dynamic Society,* Swedish Rescue Services Agency.

recordings, the captain was worried about the cold conditions where they had to leave the aircraft after parking. When they arrived, it was snowing lightly and the weather forecast said that the temperature was dropping.

After landing, during taxiing, the pilots started the APU and the aircraft was parked at the north end of the apron. According to the co-pilot, the engines were shut down normally, in accordance with the checklist, at which time cabin pressurisation was selected to MAN by the manual setting pushbutton. The procedures as per the checklist left the outflow valve open. At this stage the co-pilot left the cockpit to assist the passengers in leaving the aircraft and to lift out their baggage.

The captain remained in the cockpit. The APU was still running so as to keep the cabin temperature suitable for working and to provide electric power to the aircraft systems. After the passengers had left, the cabin assistant continued to work in the galley for about 20 minutes.

The captain completed the final cockpit procedures alone while the co-pilot was outside putting on the aircraft's external covers. The investigation team suspect, because of blowing snow the captain closed the outflow valve by, possibly, pressing the DITCH pushbutton at which time its light came on. As regards closing the outflow valve, the captain did not consult the co-pilot beforehand, nor did he inform him of this after having left the cockpit. According to the aircraft manufacturer's manuals the DITCH pushbutton should only be used for closing the outflow valve when an emergency landing is made on water.

The investigation team learned that the DITCH pushbutton may be used to close the outflow valve even in normal operations. Closing the valve aims at preventing the ingestion of snow, sand or insects through the outflow valve. It is likely that the experienced pilot was also aware of this informal practice.

Normally, after parking, several external covers are placed on the aircraft. This aircraft type has no external cover for the outflow valve exhaust opening. Rather, it is protected by a fixed metal grill. It might be sensible to develop an external cover for the exhaust opening. Then, in normal operations, the valve would not have to be closed on the ground for any reason because the cover would block the ingestion of contaminants into the valve.

3.1.2 Pre-flight preparations on 4 January 2018

On the day of departure the take-off from Kittilä to Yekaterinburg, as per the flight plan, was to happen at 17:00. The crew started brushing snow off of the aircraft and to do the other pre-flight activities at around 15:20. There was ample time to complete all of the necessary tasks unhurriedly because this was to be a positioning flight and the crew did not have to prepare to take on passengers.

At first, the captain took photos of the aircraft which was partially covered by snow and frost. It is possible to make the determination that the conditions in which the crew were carrying out the pre-flight tasks were not typical for them. Nor did their clothing indicate that they were prepared to work outside at -22 °C (-7.6 °F). Their light clothing may have hastened them to heat the cabin and remove snow.

The co-pilot was still in the company's training phase. Yet, the captain went alone into the cockpit to start the APU. For training purposes it would have made sense to have the co-pilot start the APU in these extremely cold conditions. Even though it is permissible for either pilot to start the APU alone, the presence of both pilots in the cockpit might have altered the course of events. Nevertheless, apparently to expedite the pre-flight activities, the captain divided the

duties so that he went alone into to cockpit while the co-pilot started brushing snow off of the aircraft.

When the captain started the APU, he presumably pressed the DITCH pushbutton again to open the outflow valve. At this time, the pushbutton's indication light would have extinguished. Deselecting DITCH would not change outflow valve position because automatic pressurisation was selected and is inoperable when the avionics power switch is not selected on. Had the pressurisation system been in manual mode, the outflow valve would have opened when DITCH was deselected, regardless of avionics power. The light, on or off, does not give any indication of the valve's position, only the switch position.

When inside a hangar or in warmer conditions after parking it is possible to immediately turn on the avionics system, following which the automatic pressurisation will operate. Following the instructions of manufacturer's CWOM and the operator's check list, the captain did not turn on the avionics system at this stage. According to the CWOM, systems power up should be delayed until cockpit and cabin temperatures have reached approximately +10 °C (+50 °F) and according to the operator's checklist +15 °C (+59 °F), before avionics power can be turned on. The manufacturer's AFM does not contain any temperature limitations for turning the avionics switches on.

It may well be that the captain, in deselecting the DITCH pushbutton, assumed that the outflow valve would open with pressurisation in automatic. He missed the fact that automatic pressurisation, in order to function, required that at least one avionics power switch needed to be on. The captain was working alone and there is no certainty on what procedures, and in what order, he completed in the cockpit. The FDR does not record switch positions.

Because of the cold conditions the captain may have deviated from the customary order of completing the procedures. For example, the external inspection was yet to be done when the captain started the APU. The supplementary cold weather checklist includes checking that the outflow valve exhaust is open if the APU is to be used. While the check is done to detect any ice or snow, it also reveals the valve's position. It is possible that the captain planned to carry out the external inspection once the snow and ice were removed.

3.1.3 Cabin pressurisation

At first the captain worked outside barehanded. A moment later he went into the cabin and fetched a pair of gloves from the galley. At this time he told the cabin assistant that he would turn the heating on in five minutes. It is not certain what he meant by that. Possible options include increasing the airflow by selecting the HI FLOW setting or turning the TEMP CONTROL knob to HOT or both of these. They began heating the cabin at a lower temperature setting, which in itself is an indication of careful practice.

Once the captain found the gloves he went back outside and closed the door. It is evident that by doing so he tried to expedite heating the aircraft, as the Cold Weather Operations Manual states. When he was in the cabin he noticed that the cabin attendant was cold, wrapped in a blanket, and this, too, may have influenced him to close the door. It may be that the captain knew that the outflow valve was closed but, since the door was open, he did not consider it a problem at first. However, when he hastily fetched a pair of gloves from the cabin, he may have forgotten that the valve was closed and shut the door. It is also possible that the captain simply forgot that he had closed the outflow valve upon arrival. The captain did not return to the cabin within five minutes, as promised, to adjust the heating.

The volume of the APU's bleed air is great when compared to, for example, the volume of bleed air generated by both engines running simultaneously. Since the manual gives the

instruction to close the door to expedite heating, it is certain that the same volume of air will vent through an open outflow valve without the cabin pressurising.

In this case the APU bleed air was ducted into the cabin, the ouflow valve was closed and also the door was closed. With these settings the cabin, whose volume is approximately 13 m^3, began to rapidly pressurise.

Some time after the door was closed the cabin assistant, working inside the cabin, began to feel pressure in her ears and chest. As this feeling continued she felt panic attack-like symptoms and went into the cockpit. She knocked on the left side window because the pilots were working close by. In this aircraft type it is not possible to open the windows and, therefore, the only way to get the pilot's attention was to knock on the window. According to her account, the cabin assistant did not try to open the door from the inside.

The cabin assistant called the captain by name but, owing to the noise generated by the APU, he probably did not hear this. Still, the pilots heard the knocking and noticed that the cabin assistant seemed distressed. The captain descended from the working platform and went to the door to open it. Neither pilot could expect that the cabin assistant's panic was caused by cabin pressurisation, nor that there would be any risk involved in opening the door.

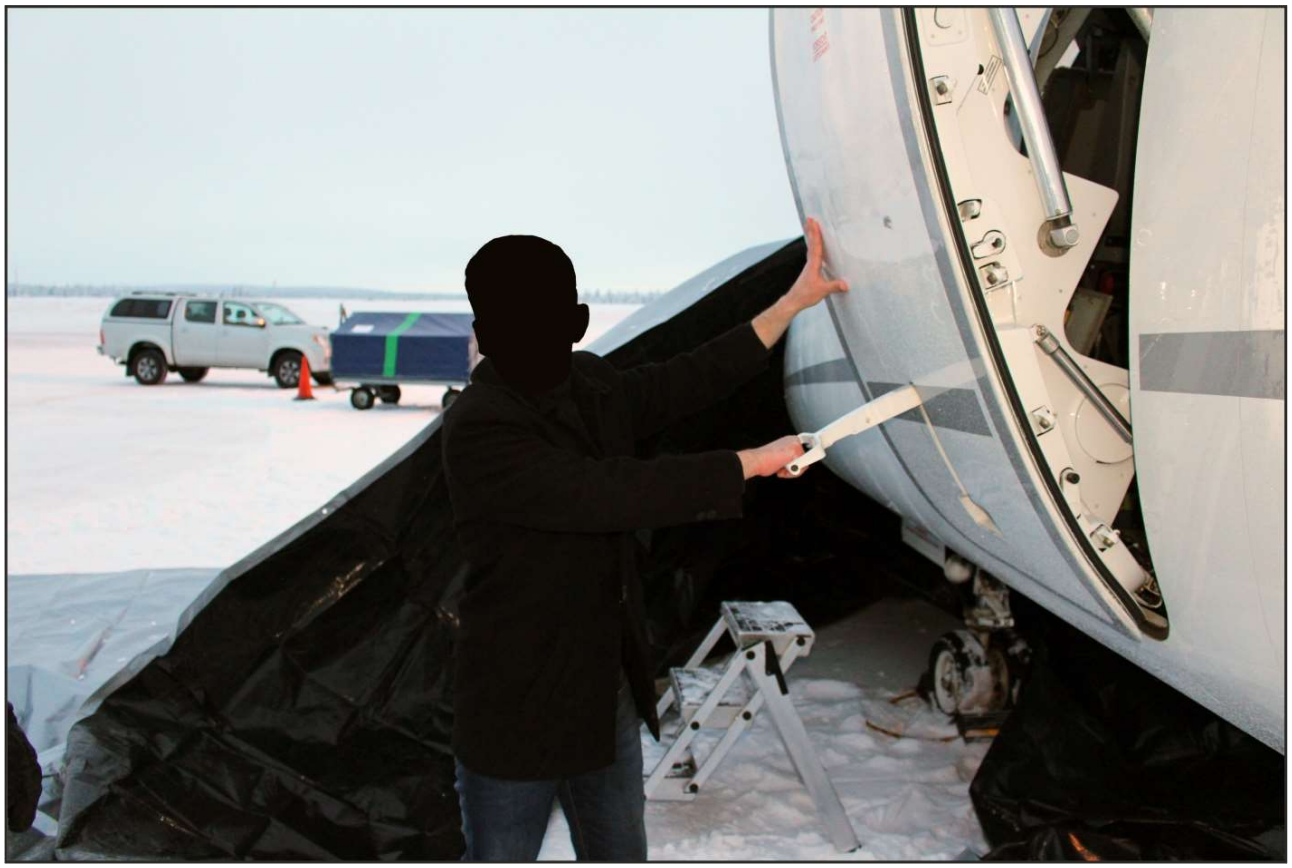

Image 7. Typical hand positions when opening the door. (Photo: SIAF)

3.1.1 Opening the door and discharge of pressure

The co-pilot was standing approximately one metre away from the door by the cockpit. He said that it took unusually high force on the part of the captain to open the door. Once the door was unlocked, the door opened with excessive force. The captain was standing directly underneath the door and he took the whole force of the impact. The cabin manual warns against standing underneath the door because the door is heavy. In practice, it is difficult to open the door by standing completely to the side of it. At a re-enactment in Kittilä it was noticed that the natural manner of opening the door involves standing right in front of it with one hand on the stirrup handle and the other hand held higher, supporting the door.

In a normal situation the dampers slow the free fall of the door to its lower position. Although they are sufficiently effective in normal operations, in this exceptional event they could not adequately brake the movement of the door. The excess pressure in the cabin pushed the door with such a high force that the captain had no chance to step aside. Moreover, when opening the door one hand is on the stirrup handle and it is not necessarily easy to let go of it in a rapid situation.

While opening the door, there is no warning on the door for excessive pressure in the cabin.

3.1.2 Consequences

The captain sustained serious injuries and died at the accident site. So much pressure had built up inside the cabin that it was no longer safe to open the door.

The cabin assistant sustained minor injuries, for the most part because of falling or hitting something. She was evidently in the process of moving from the cockpit to the cabin when the door blew open. As the air pressure pushed her towards the doorway, she collided with the aft bulkhead of the cockpit and got bruises on her right arm. If she had been in the immediate vicinity of the door, she would probably have been ejected outside and sustained more serious injuries.

Cabin pressurisation on the ground has caused accidents in the 2000s where many have died or been seriously injured. In these occurrences cabin crew members have typically opened the door from the inside and, owing to the differential pressure, someone has been ejected or fallen out of the aircraft.

This would have been a difficult situation for the pilots even if they had realised that the cabin attendant's distress was caused by cabin overpressurisation. The door was closed and it would have been dangerous to open it. The APU, too, was running and it continued to generate more pressure inside. It is not possible to shut down the APU or to open the outflow valve from the outside.

The only way for the pilots to resolve the situation would have been to contact the cabin assistant by phone for the purpose of giving instructions. However, it is safe to assume that the task would have been difficult because the assistant was not familiar with the aircraft's systems. However, by providing precise instructions it might have been within the realm of possibilities for her to shut down the APU.

Examples of safety systems which can prevent accidents caused by cabin pressurisation when the cabin is being heated or cooled on the ground:

- A cabin overpressurisation warning light on the door, visible from the inside and outside.
- A pressure relief valve integrated into the door's opening mechanism.
- An outflow valve position indicator in the cockpit.
- A trained person must remain inside the cockpit when the APU is being run, and
- Shutting down the APU from the outside must be possible.

3.2 Analysis of rescue measures

The accident happened at Kittilä airport, on the apron. The victim was lying on the ground and the first person to help him was the co-pilot, who was also knocked down by the force of the pressure wave. He turned the victim onto his side and went inside the cockpit to call the air traffic control for help. The controller immediately alerted the Emergency Response Centre. When the co-pilot went back outside he continued with cardiopulmonary resuscitation (CPR) together with the airport personnel that had rapidly arrived at the accident site.

The first ambulance arrived at the accident site in 10 minutes and the second one in 13 minutes from the time of dispatch. From then on, professionals took charge of the emergency medical services. The rescue effort was carried out competently and without delay in a sparsely populated area, and in extremely cold conditions.

3.3 Analysis of authorities' action

A study on Cabin Safety Requirements, commissioned by the European Aviation Safety Agency (EASA), charted safety threats for cabin safety. One safety threat mentioned in the study involved explosive door openings when the cabin was pressurised on the ground. The study's conclusions and recommendations state that explosive door openings have resulted in fatal and serious injuries which could have been prevented by better procedures or communication.

The study's conclusions are clear and it would be important to disseminate its findings among all operators. The EASA should inform operators of the study's conclusions.

4 CONCLUSIONS

1. After the aircraft arrived in Kittilä it was parked on the apron. The captain would have preferred placing the aircraft in a hangar, but there was not one available in Kittilä. The captain completed the final procedures associated with shutting down the APU and closed the outflow valve because of blowing snow.

   Conclusion: *When the aircraft is parked outside for a longer period, some pilots may close the outflow valve to prevent the ingestion of contaminants into the valve, or upstream into the cabin.*

2. During pre-flight preparations the captain went alone into the cockpit to start the APU so as to heat the cabin and to provide power for aircraft systems. A moment later he fetched a pair of gloves from the cabin. When he went back out he closed the cabin door. The cabin assistant remained in the cabin. According to the Cold Weather Operations Manual the door can be closed to expedite heating.

   Conclusion: *When the APU is being run one must check that the outflow valve is fully open. If it is not possible to ensure that the valve is open or to remove differential pressure by other means, the door must not be closed.*

3. While removing snow and frost outside, the pilots noticed that the cabin assistant was knocking on the window and that she seemed distressed. The captain went to the door. He had to use much more force than usual to get the door opened and when opened the door hit the captain with excessive force.

   Conclusion: *The door had no indication warning of excessive cabin pressure, nor an opening for depressurisation. The cabin was pressurised because the APU bleed air was ducted into the cabin, the outflow valve was closed and the door was also closed. Significant differential pressure existed between the cabin and the outside.*

4. The differential pressure between the cabin and the outside when an aircraft was on the ground and the door was opened has caused accidents. Among other things, this safety threat was mentioned in the study on Cabin Safety Requirements published by the EASA in 2009.

   Conclusion: *Cabin pressurisation on the ground also creates a hazard for several other groups of professionals, such as aircraft mechanics, ground handling staff, aircraft cargo loaders and rescue personnel.*

5 SAFETY RECOMMENDATIONS

5.1 Closing the door to expedite heating

Gulfstream G150's Cold Weather Operations Manual states in many places that "Heating can be expedited by closing the door". At the end of the manual's supplementary checklist there is an instruction: "If APU operating check out flow valve full open".

The Safety Investigation Authority recommends that:

The Civil Aviation Authority of Israel (CAAI) supervise that Israel Aviation Industries (IAI) updates the operating manuals of the Gulfstream G150 and other comparable aircraft types. Updates to the sections that address closing the door as a means of heating or cooling the aircraft should include a caution to check that the outflow valve is fully open before the door is closed. [2018-S41]

5.2 Cabin pressurisation on the ground and the hazard it creates

In 2009 the EASA published "Study on CS-25 Cabin Safety Requirements", which it had commissioned. It charted the safety threats for cabin safety. One safety threat which was mentioned in the study involved explosive door openings when the cabin was partially pressurised on the ground. The study's conclusions and recommendations state that explosive door openings have resulted in fatal and serious injuries which could have been prevented by better procedures or communication.

The Safety Investigation Authority recommends that:

The European Aviation Safety Agency (EASA) inform air operators, ground handling organisations and aerodrome rescue and fire fighting organisations of a safety threat which may be caused by aircraft pressurisation on the ground and consequent explosive door openings. The bulletin must include the actions with which the safety threat can be controlled, as well as a reminder to provide the associated training to all persons involved with handling aircraft on the ground. [2018-S42]

The safety issue is relevant for all aviation professions involved with handling of the aircraft on the ground.

5.3 Implemented measures

On 5 January 2018, the day following the accident, Gulfstream disseminated a Maintenance and Operations Letter (ALL-MOL-18-0001) among all Gulfstream operators regarding the accident in Kittilä. The MOL shortly described the events and expressed condolences to the family and friends of the deceased. Gulfstream announced that they would closely cooperate with the authorities and the safety investigation.

On 31 January 2018 Gulfstream disseminated another Maintenance and Operations Letter (ALL-MOL-18-0003) reminding all of their operators of the following things:

- Published procedures must be followed when running the APU on the ground.
- Crews must check that the outflow valve is fully open and unblocked before using the APU on the ground with the cabin door closed.

- Failure to check the outflow valve may result in inadvertent cabin pressurisation when APU bleed air is ducted into the cabin while the door is closed.
- When operating in cold conditions, the instructions in the Cold Weather Operations Manual must be followed.

Helsinki 11.10.2018

Ismo Aaltonen Pekka Alaraudanjoki Tauno Ylinen

Jukka Jylö

REFERENCES

Documents

Federal Aviation Administration FAA:
Safety Alert for Operators (SAFO 08007) 2008
European Aviation Safety Agency EASA:
Study on CS-25 Cabin Safety Requirements 2009
Private Airlines Germany GmbH:
Operation Manuals A and B (OM-A, OM-B)
Safety Management System Manual SMS-M
Normal Checklist Gulfstream G150 OE-GKA
Gulfstream Aerospace:
Gulfstream G150 Airplane Flight Manual AFM
Gulfstream G150 Cold Weather Operations Manual CWOM
Gulfstream G150 Cabin Operations Manual
Gulfstream G150 Quick Reference Handbook QRH
Gulfstream G150 Cockpit Card
Gulfstream G150 Operation FAQs
Gulfstream G150 Aircraft Maintenance Manual AMM
Gulfstream G150 Illustrated Parts Catalog IPC
Gulfstream G150 Wiring Diagram Manual WDM
ANS Finland Oy:
AIP SUOMI / FINLAND
Alerting Services Manual (HPO)
ATC Manual (LJKK)

Investigation material

1) Decision to initiate the investigation
2) CSI photos, measurements, memoranda and other material
3) Investigation material of the police
4) Log data from the ERC's Pronto system
5) Meteorological information
6) Interview recordings
7) The ATC's telephone and radiocommunication recordings
8) Occurrence reports: ANS Finland, Finavia, Private Airlines Germany GmbH
9) Email correspondence
10) The aircraft's (OE-GKA) certificate of registration and airworthiness certificate
11) The operator's Aircraft Operator Certificate (AOC)
12) Copies of the pilots' licences and information of their flight experience

SUMMARY OF THE COMMENTS TO THE DRAFT FINAL REPORT

The draft final report was sent for comments to the following organisations and individuals: the European Aviation Safety Agency (EASA); the German Federal Bureau of Aircraft Accident Investigation (BFU); the U.S. National Transportation Safety Board (NTSB); the Ministry of Transport and Road Safety of Israel; the Federal Ministry for Transport, Innovation and Technology of Austria; Gulfstream Aerospace; Israel Aerospace Industries IAI; Private Airlines Germany GmbH; Finnish Transport Safety Agency Trafi; Finavia Corporation; ANS Finland; the Emergency Response Centre Administration; the interested parties and the immediate family of the deceased. Pursuant to the Safety Investigation Act no comments given by private individuals may be included in the investigation report.

The European Aviation Safety Agency (EASA)

The EASA expressed their gratitude for the opportunity to provide comments to the draft final report.

For the most part, the comments addressed the recommendations.

In their comments the EASA also proposed a clarification to the information associated with the designer and manufacturer of the aircraft.

The German Federal Bureau of Aircraft Accident Investigation (BFU)

No comments.

The Ministry of Transport and Road Safety of Israel

In their comments the Ministry of Transport and Road Safety of Israel referred to the comments of the IAI (and Gulfstream Aerospace) and stated that, apart from the comment pertaining to the addressee of the recommendation, they concur with their comments,.

Gulfstream Aerospace and Israel Aerospace Industries (IAI)

The comments included both organisations' comments to the draft final report. To begin with, Gulfstream expressed their gratitude for the opportunity to provide comments to the draft final report. In this summary 'Gulfstream' means the party providing comments.

Gulfstream proposed clarifications to a few expressions or terms used in the draft final report.

Regarding the paragraph that examines the testing of the functioning of the door, Gulfstream proposed additions to the section of the draft final report that addresses opening the door from the outside.

Gulfstream proposed more specific information on the type certification and manufacturing data.

Gulfstream proposed a clarification regarding APU fire protection.

Gulfstream proposed more specific information to the text in the draft final report that addresses automatic and manual pressurisation and the functioning of the relief valve.

Gulfstream proposed some additions to the information pertaining to cold weather operations.

Finavia Corporation

In their comments Finavia proposed a clarification to SAR exercises organised at Kittilä Aerodrome.

The Emergency Response Centre Administration

The Emergency Response Centre Administration requested that the Emergency Response Centre of North Finland be replaced by the Emergency Response Centre of Oulu.

Finnish Transport Safety Agency Trafi

No comments.

ANS Finland

No comments.