Investigation report

C12/2010L

In-flight Upset of a Business Jet in the Moscow Terminal Control Area on 23 December 2010

OH–FLM

Bombardier BD–100–1A10 Challenger 300

This is an abridged translation of the original Finnish report

Safety Investigation Authority

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SUMMARY

IN-FLIGHT UPSET OF A BUSINESS JET IN THE MOSCOW TERMINAL CONTROL AREA ON 23 DECEMBER 2010

An accident took place in the northwestern part of the Moscow Terminal Control Area (TMA) on Thursday, 23 December 2010 at 16:10 UTC. While enroute from Moscow to St Petersburg, a Bombardier BD–100–1A10 Challenger 300 business jet, registration OH-FLM, experienced a sudden in-flight pitch upset during the climb. There were three passengers and three crew-members of the on board. As a result of the occurrence two passengers were injured and some of the cabin interior was damaged. The aircraft returned to Sheremetyevo Airport and the injured passengers were taken to hospital in Moscow.

The flight was a familiarisation flight for the co-pilot in accordance with the European Union Regulation on Air Operations (EU-OPS). Before the flight it was agreed that the co-pilot would act as the Pilot Flying (PF).

The course of events began during the initial climb when the Engine Indication and Crew Alerting System (EICAS) annunciated an Autopilot Stabilizer Trim Failure (AP STAB TRIM FAIL) warning. In accordance with the fault checklists the captain disengaged the autopilot. This resulted in a porpoising oscillation which was quickly brought back under control. Whereas the aircraft's checklists advise the pilots to firmly grip the control column prior to AP disengagement, they do not instruct the flight crew to consider adjusting the airspeed to correspond to the horizontal stabilizer angle. Neither did the checklists include any mention of turning on the Fasten Seat Belt sign.

The cause of the occurrence was the overcontrolling of the aircraft's pitch attitude immediately after the autopilot was disengaged. Contributing factors included the pilots' unfamiliarity with the characteristics and operating principle of the aircraft's artificial pitch feel system as well as shortcomings in system training. Further shortcomings were also observed in the flight crew's checks and in crew cooperation. High airspeed was yet another contributing factor to the considerable acceleration (g) forces experienced during the upset.

The investigation commission issued three safety recommendations.

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ABBREVIATIONS

AFCS	Automatic Flight Control System
AFCS Mode Display	Automatic Flight Control System Mode Display
AHRS	Attitude-Heading Reference Unit
ALT	Altitude
AP	Autopilot
ATIS	Automatic Terminal Information Service
BKN	Broken (clouds 5–7/8)
CB	Cumulonimbus
DG	Directional Gyro
EASA	European Aviation Safety Agency
EFHK	Helsinki-Vantaa airport
EFIS	Electronic Flight Instrument System
EICAS	Engine Indication and Crew Alerting System
EU-OPS	European Union Regulation on Air Operations
FAM	Familiarisation flight
FCOM	Flight Crew Operating Manual
FD	Flight Director
FEW	Few (clouds 1–2/8)
FGC	Flight Guidance Computer
FGP	Flight Guidance Panel
FL	Flight Level
FLC	Flight Level Change
FMA	Flight Mode Annunciator (Used in the Operator's OM-B. In Bombardier's FCOM, AFCS Mode Display is used instead)
FMS	Flight Management System
FPL	Flight Plan
ft	Foot (feet)
GAFOR	General Aviation Forecast
GS	Ground Speed
h	Hour(s)

HDG	Heading
hPa	Hectopascal
HSTECU	Horizontal Stabilizer Electronic Control Unit
IAS	Indicated Airspeed
kg	Kilogramme
km	Kilometre
km/h	Kilometres per hour
kts	Knots
l	Litre
LTC	Line Training Captain
m	Metre
MDC	Maintenance Diagnostic Computer
MFD	Multi-Function Display
METAR	Aviation routine weather report
min	Minute
MSL	Mean sea level
MSW	Master Wheel Disconnect
NM	Nautical mile
NOTAM	Notice to airmen
OM	Operations Manual
OM-A	Operations Manual Part A
OM-B	Operations Manual Part B
OVC	Overcast (clouds 8/8)
PF	Pilot Flying
PFD	Primary Flight Display
PFI	Pre-Flight Inspection
PIC	Pilot-in-command
PIO	Pilot Induced Oscillation
QFE	Atmospheric pressure at aerodrome elevation
QNH	Altimeter setting to indicate elevation above mean sea level
QRH	Quick Reference Handbook
RWY	Runway
s	Second

S/N	Serial number
SCT	Scattered (clouds 3–4/8)
SID	Standard Instrument Departure
SKC	Sky clear
SOP	Standard Operating Procedures
SSCVR	Solid State Cockpit Voice Recorder
SSFDR	Solid State Flight Data Recorder
Stab	Stabilizer
SWC	Significant Weather Chart
TAF	Terminal Aerodrome Forecast
TEMPO	Temporary
TOGA	Take-Off Go-Around
ULLI	St Petersburg Pulkovo airport
UTC	Co-ordinated Universal time
VOR/DME	VHF omnidirectional radio range with distance measuring equipment

SYNOPSIS

An accident took place in the northwestern part of the Moscow Terminal Control Area (TMA) on Thursday, 23 December 2010. A Bombardier BD–100–1A10 Challenger 300 business jet, registration OH-FLM, owned by Sadco International Ltd and operated by Jetflite Oy, which was on a business flight from Sheremetyevo to St Petersburg, experienced a sudden in-flight pitch upset during the climb. Following the occurrence the aircraft returned to Sheremetyevo Airport.

Safety Investigation Authority, Finland (SIA) reported the occurrence to the Russian Interstate Aviation Committee (IAC), the investigation authority of the State of Design (Transportation Safety Board of Canada, TSB Canada), the Finnish Transport Safety Agency (Trafi), the International Civil Aviation Organization (ICAO), the European Commission and the European Aviation Safety Agency (EASA).

Since one of the passengers was seriously injured, Safety Investigation Authority, Finland categorised the occurrence as an accident, pursuant to ICAO Annex 13. The Russian Federation has notified ICAO of a difference to Annex 13 according to which they do not define an occurrence such as this as an accident. On 31 December 2010 Safety Investigation Authority, Finland (SIA) appointed commission C12/2010L to investigate this occurrence. Investigator Ari Huhtala was appointed investigator-in-charge, accompanied by investigators Kari Laine and Jan Nordlund as members of the commission. Mr Juha-Pekka Keidasto was invited to serve as an expert to the commission.

Pursuant to ICAO Annex 13 TSB Canada designated their accredited representative to the investigation. Under the supervision of the investigation committee, Finnair Oyj copied the aircraft's flight data recording at which time it was noticed that the cockpit voice recording from the occurrence had been overwritten. TSB Canada downloaded the flight data recorder information. The investigation commission contracted the laboratory of the Defence Forces Technical Research Centre (FI-34111 Lakiala, Finland) to analyse the grease used on the jackscrew of the horizontal stabilizer trim actuator.

On 27 November 2012 the draft final report was sent to the interested parties: Jetflite Oy, the Finnish Transport Safety Agency Trafi, EASA, TSB Canada, the Federal Aviation Authority of Russia (Russian CAA) and Bombardier Aerospace, the aircraft manufacturer, for comments. The comments were received by 19 April 2013 and they are taken into account in the final version of the investigation report.

All times in this investigation report are in Co-ordinated Universal Time (UTC). Appendix 1 describes the documentation that guides the company's flight operations, and the aircraft's flight control systems.

The Finnish language version of the report is the official version. It was translated into English. The investigation report and the material used in the investigation are archived at Safety Investigation Authority, Finland.

1 FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Pre-flight preparations

The intention was to fly the Bombardier BD–100–1A10 Challenger 300 business jet from Sheremetyevo (UUEE) Airport in Moscow to Pulkovo Airport (ULLI) in St Petersburg on Thursday evening, 23 December 2010. The crew arrived at Sheremetyevo approximately two hours before the estimated time of departure and began the pre-flight preparations. The flight was a familiarisation flight (FAM) for the co-pilot, as part of his operator training. It was agreed that on this particular flight he would act as the Pilot Flying (PF).

The flight crew conducted an expanded Pre-Flight Inspection (PFI) which is the norm prior to the first flight of the day. The captain made the walk-around inspection and noted that a thin layer of dry snow had accumulated on the surfaces of the aircraft during the previous night and on the day of the accident. It was easily brushed off. The snow on the top surfaces of the horizontal stabilizer was not removed because the other surfaces were devoid of ice and the snow was not sticking to the wing. The co-pilot began the general inspections of the cockpit and the cabin while the captain made the checks in the cockpit as per the checklists. The co-pilot then entered the pertinent flight data into the Flight Management System (FMS). The co-pilot, too, made a walk-around check of the aircraft prior to engine start.

On 21 December 2010 the aircraft had been flown from Helsinki-Vantaa Airport to Pulkovo Airport in St Petersburg and on the following day to Vnukovo Airport in Moscow. At the end of the day it was flown to Moscow Sheremetyevo where it stayed overnight. The same crew flew all of the abovementioned legs.

1.1.2 The accident flight

Before requesting taxi clearance the flight crew had listened to the Sheremetyevo Airport Automatic Terminal Information Service (ATIS) information Oscar. As per information Oscar RWY 25L was in use. Nonetheless, in conjunction with the taxi clearance the flight crew were instructed to taxi to holding point RWY 07R because the takeoff runway had changed. At 15:35 the captain began to taxi from the apron to the holding position via TWY 1 and TWY 11. The flight crew received their route clearance while taxiing, including Standard Instrument Departure (SID) BUZHAROVO 07 DELTA (AR 07D). The assigned new runway and the new standard departure were entered into the FMS. The new takeoff performance parameters caused by the takeoff RWY change were calculated with a software program on the cockpit laptop.

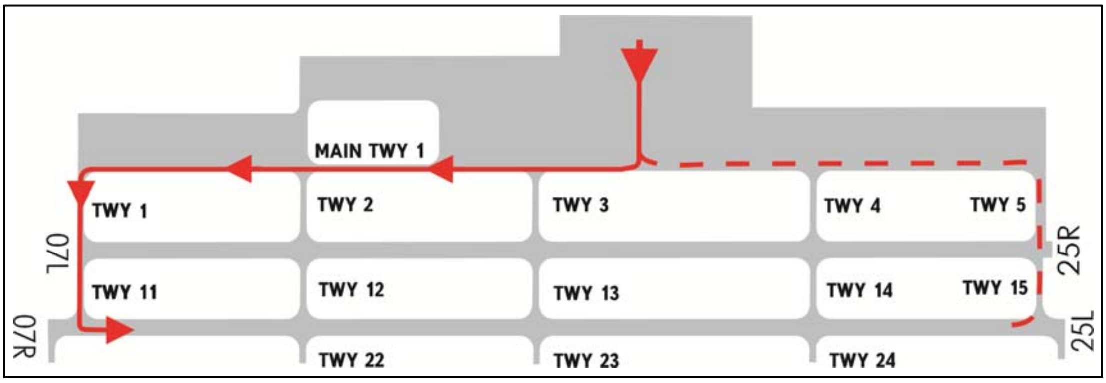

Figure 1. The aircraft's taxi route at Moscow Sheremetyevo.

During the checks before takeoff the flight crew noticed that both the captain's and the co-pilot's compass indications deviated from the runway heading. They selected the Directional Gyro (DG) mode and set their compasses to 066°, the precise magnetic heading of the runway. Once the takeoff checklist had been completed the captain gave the controls to the co-pilot for takeoff.

The takeoff began at 16:03 from RWY 07R. Once the landing gear had been retracted the co-pilot, following the Flight Director (FD), commenced a left turn towards the heading 247º, which was selected to the Heading bug (HDG bug), instead of a straight-ahead climb into the heading of 066°, as per the SID. At the same time they retracted the flaps. Upon noticing the unexpected turn the captain told the co-pilot to turn back to the right towards the SID track. The turn was commenced at a steep bank angle and once the bank became more moderate the Autopilot (AP) was engaged. The HDG bug was aligned with 072°, which was the aircraft's heading at the time, and the flight was continued using the HDG knob for directional control.

The captain assumed the duties of the PF. The flight was continued in accordance with the SID and air traffic clearances. According to the pilots, the operation mode of the compasses was changed from the DG mode to the normal mode. It was impossible to determine the precise moment from Flight Data Recorder (FDR) information when these actions were done. As the climb continued, the FD was set to follow the FMS route.

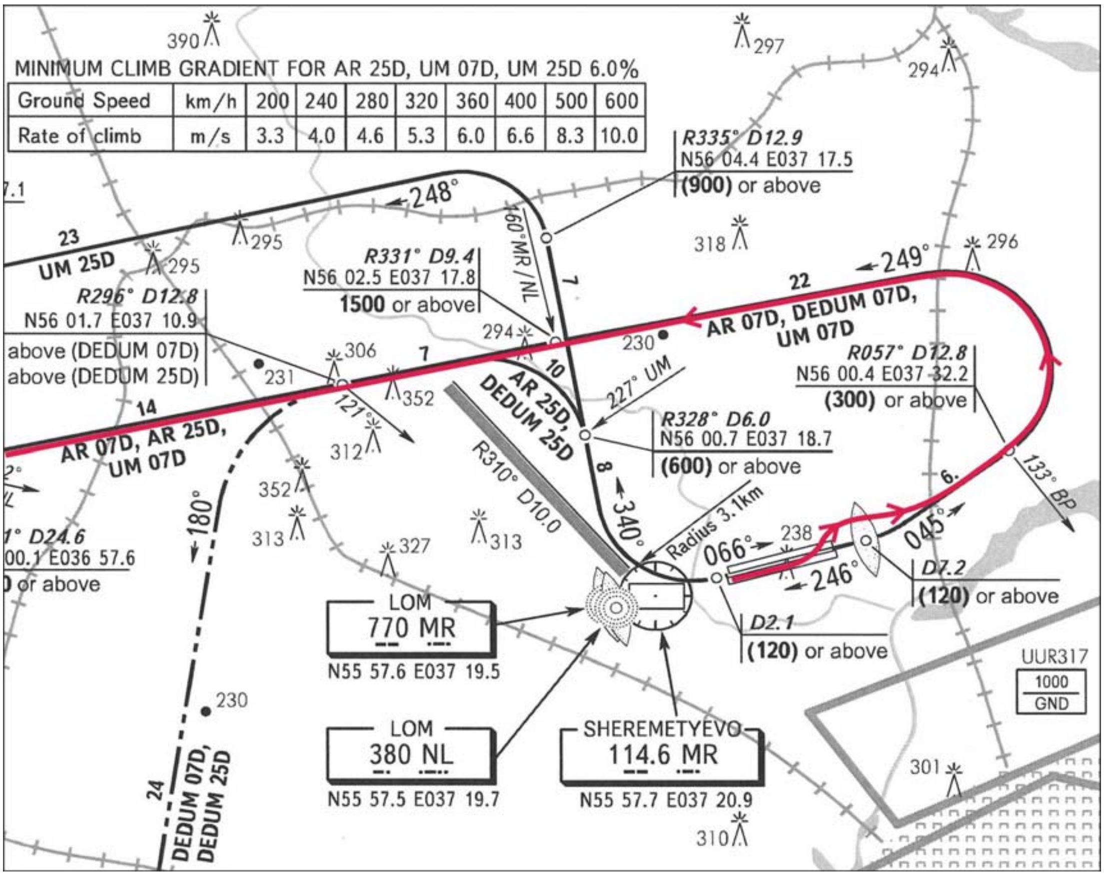

Figure 2. Moscow Sheremetyevo Standard Instrument Departure BUZHAROVO 07 DELTA (AR 07D) and the estimated track of the aircraft (red line). Source: (AIP of the Russian Federation).

Immediately after the AP was engaged the Engine Indication and Crew Alerting System (EICAS) annunciated an AP STAB TRIM FAIL (Autopilot Stabilizer Trim Failure) caution. During the climb they also received several cautions regarding the fact that the autopilot had to keep commanding nose down elevator inputs (AP HOLDING NOSE DOWN). The Fasten Seat Belts sign was turned off and the climb continued towards the cruising altitude. The co-pilot located the checklists related to the annunciated cautions on the Quick Reference Handbook (QRH) and was reading them aloud as the service hostess entered the flight deck.

The service hostess was standing at the doorway to the flight deck when, at approximately 16:10, the flight crew initiated the actions on the QRH's AP HOLDING NOSE DOWN checklist procedure. As they were passing Flight Level (FL) 127 (ca. 3900 m) the captain took a firm grip of the control column and disengaged the AP. The Indicated Airspeed (IAS) at the time was 281 kts (520 km/h). As a result of the forces in the flight control system the control column moved backwards, to which the captain reacted by pushing the nose down. This led to an approximately 7 second-long porpoising oscillation, which the captain managed to bring under control. He then continued the climb under manual control. As a result of the accident three persons were injured, two of whom to the extent that they had to be hospitalised. In addition, the cabin interior was damaged.

The flight was continued as per the flight plan towards St Petersburg. However, having reevaluated the situation, at 16:18 the captain decided to turn back towards Sheremetyevo Airport because of the shorter flight time. The flight crew reported the accident to Moscow Approach Control, requesting an ambulance to meet them at the apron.

After the flight the captain reported the accident to the operator, which relayed the information to Safety Investigation Authority, Finland. The flight crew opened the circuit breaker of the Cockpit Voice Recorder (CVR) which was supposed to be kept open until the recording had been preserved. Pursuant to national Finnish Aviation Regulation GEN M1-4, the captain filed an Aviation Safety Report on the accident.

Following an inspection by a maintenance organisation authorised by the aircraft manufacturer, the aircraft was released for a ferry flight to Helsinki-Vantaa Airport on 11 January 2011. The investigation commission was present when the aircraft arrived at the Airport.

1.2 Injuries to persons

Two of the passengers were seated in the second row, facing forward. They were lifted up out of their seats during the accident. The passenger on the left seat broke the right hand armrest of the seat as a result of falling down back into the seat. These two passengers suffered only minor injuries. The passenger, who was seated in the right hand (RH) seat of the last row, also facing forward, was thrown higher up out of their seat and, deduced from the stains and scratches on the cabin ceiling, possibly hit the ceiling during the accident. Upon falling back down into their seat, the passenger hit their upper torso on the seat and consequently sustained several fractured ribs. None of the passengers had their seat belt fastened during the accident.

The service hostess standing at the doorway of the flight deck fell and suffered bruises on her shoulders and arms. The flight crew did not sustain any injuries.

Injuries	Crew	Passengers	Other
Fatal			
Serious		1	
Minor/none	3	2	

1.3 Damage to aircraft

The aircraft was inspected in Moscow and, as appropriate, its Flight Guidance Systems were tested in accordance with the manufacturer's instructions. A manufacturer-authorised maintenance organisation carried out these tests. No structural or airworthiness-related damage or system malfunctions were found.

The aircraft's cabin interior was damaged. The end plate of the left hand (LH) table had come off and the aisle side armrests on both of the second row's seats were broken.

The plastic panel of the third window on the LH side had come loose. There was an approximately 15 cm (5.9 in) long black mark and liquid stains on the cabin ceiling above the fifth RH side window. In addition, there was a tear in the lining of the front wall of the aft wardrobe storage compartment.

1.4 Other damage

There was no other damage.

1.5 Personnel information

1.5.1 Flight crew information

Pilot-in-command: Age 63.

Licences: Airline Transport Pilot's Licence, valid until 18 May 2015.

Medical certificate: Class 1, valid until 17 February 2011.
Class 2, valid until 17 August 2011.

Ratings: Bombardier BD–100–1A10 Challenger 300 (CL30/IR), valid until 31 October 2011.

The captain was an operator designated and authority-approved Line Flying Instructor, LFI. The operator's manuals use the term Line Flying Captain.

Flight experience	Last 24 hours	Last 30 days	Last 90 days	Total experience
All types				18 810 h 34 677 landings
Type	2 h 2 landings	23 h 16 landings	93 h 52 landings	1 461 h 671 landings

Co-pilot: Age 26.

Licences: Commercial Pilot Licence, valid until 18 May 2012.

Medical certificate: Class 1, valid until 26 April 2011.
Class 2, valid until 26 April 2015.

Ratings: Bombardier BD–100–1A10 Challenger 300 (CL30/IR), valid until 31 October 2011.

Flight experience	Last 24 hours	Last 30 days	Last 90 days	Total experience
All types				284 h 318 landings
Type	2 h 2 landings	12 h 5min 4 landings	59 h 30min 11 landings	61 h 3min 17 landings

On this flight the captain was acting as a Line Flight Instructor (LFI) and the co-pilot as the Pilot Flying. The flight was one of the co-pilot's familiarisation flights as part of his operator training and in accordance with EU-OPS requirements.

The pilots had complied with the duty and rest periods described in the operator's Operations Manual.

Service hostess

A service hostess who was a member of the crew was on the flight.

At the time of the accident the operator's cabin personnel were referred to as 'service hostesses'. They did not have EU-OPS compliant cabin crew roles in the aircraft. A service hostess only served the passengers in the cabin. In contrast to the duties of a cabin crew the service hostess did not have any duties related to the safety of passengers. Since then the operator has expanded the field of responsibilities of the cabin crew to also include safety-related duties. To reflect this, the operator has changed the title of service hostess to that of flight attendant.

1.5.2 Passenger information

There were three passengers on board. Two of them were seated in the seats of the second row, on both sides of the aisle, and the third one in the RH seat of the last row. The passenger seats were single seats, facing forward. The seats on the first and second row face each other, separated by folding tables.

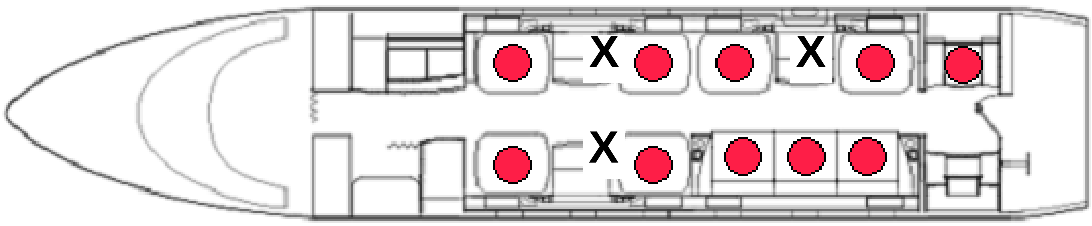

Figure 3. Seating arrangement in the cabin. The seats marked with an X denote seated passengers.

1.6 Aircraft information

Bombardier BD–100–1A10 Challenger 300, registration OH-FLM, is a Canadian-built ten-seat, low wing aircraft, fitted with two Honeywell AS907 (HTF7000) turbofan engines. Its length is 20.92 m (68.64 ft), wingspan 19.46 m (63.85 ft) and height 6.1 m (20.01 ft).

Figure 3. The OH-FLM. Source: Jetflite Oy.

Type:	Bombardier BD–100–1A10 Challenger 300
Registration:	OH–FLM
Serial Number and year of manufacture:	20155, 2007
Max takeoff weight:	17 622 kg (38 850 lbs)
Owner:	Sadco International Ltd, Tortola, British Virgin Islands
Operator:	Jetflite Oy, Finland

Airworthiness information

The Certificate of Registration, no. 2018, was issued on 14 November 2007. The Certificate of Airworthiness was issued on 22 November 2007 and the Airworthiness Review Certificate (ARC) was valid until 22 November 2011.

Following the accident the required maintenance and inspections were carried out in Moscow by a manufacturer-authorised maintenance organisation. A representative of the maintenance organisation e-mailed the operator to confirm that they would dispatch the aircraft to Helsinki with its Cockpit Voice Recorder (CVR) circuit breaker opened as had been requested. From the e-mail it can be inferred that the flight crew had already opened the circuit breaker.

The captain did not make an entry into the Technical Log as regards the flight crew having opened the CVR's circuit breaker at the end of the flight. The maintenance organisation had not made any relevant entry either.

According to the operator's *Minimum Equipment List* (MEL), which is approved by the aviation authority, the aircraft was airworthy for a ferry flight with its CVR circuit breaker opened.

Weight and balance calculation

The gross weight of the aircraft and its centre of gravity were within the permissible limits during the entire flight. They had no role in the course of events. At landing, the aircraft held 6350 lbs of fuel (2880 kg, 3600 l).

1.7 Meteorological information

General Aviation Forecast (GAFOR)

At the time of departure the forecast called for light snow, temporarily more intense snow showers, as well as scattered showers and/or Cumulonimbus (CB) clouds at 1000 ft (305 m) with icing in cloud. Freezing drizzle was forecasted for later that night.

SIGMET 5 from 07:20-11:20 and SIGMET 6 from 11:20-15:20 were valid in the Moscow Flight Information Region. According to them, south of the 55th parallel north (55°N) the region's reports and forecasts included severe icing as well as freezing rain from ground (GND) to 2000 m (6562 ft). Sheremetyevo Airport is located close to the parallel 56°N.

Aviation routine weather report (METAR)

Moscow Sheremetyevo Airport, 23 December 2010 at 16:00.

Wind 050° at 4 m/s (ca. 8 kt). Visibility greater than 10 km. Broken ceiling (BKN, 5/8–7/8), cloud base at 1500 ft (457 m), temperature -7°C (19°F), dew point -10°C (14°F), QNH (altimeter setting to indicate elevation above mean sea level) 1020 hPa (hectopascal). QFE (atmospheric pressure at aerodrome elevation) 998 hPa.

According to the operational flight plan form the flight crew had noted down Sheremetyevo's Automatic Terminal Information Service (ATIS) information Oscar, effective as of 15:00. The markings read as follows: 010° 3 m/s (6 kt). Visibility over 10 km. Ceiling at 1500 ft (457 m), temperature -7°C (19°F), dew point -9°C (16°F), QFE 998 hPa. Runway 25L in use, braking action good, transition level 1500 m (5000 ft).

Terminal Aerodrome Forecast (TAF)

Moscow Sheremetyevo Airport, 23 December 2010 at 13:50.

Valid from the 23rd (Dec) at 15:00 until the 24th (Dec) at 15:00. Wind 090°, 4 m/s (ca. 8 kt). Visibility 6 km. Overcast (OVC, 8/8) at 800 ft (244 m). Temporarily (TEMPO) 23 Dec from 15-18 visibility 2 km, snow showers. OVC at 600 ft, (183 m). Scattered clouds (SCT, 3/8-4/8) at 1000 ft (304 m). Cumulonimbus clouds (CB).

TEMPO from 18:00 on the 23rd until 09:00 on the 24th. Visibility 1000 m, light snow, mist (BR). OVC at 400 ft (122 m). With 40% probability TEMPO from 18:00 on the 23rd until 06:00 on the 24th freezing drizzle (FZDZ). TEMPO from 06:00 on the 24th until 15:00 on the 24th visibility 1200 m, snow showers, FZDZ. OVC at 400 ft (122 m), SCT at 1000 ft (305 m). CB clouds.

SNOWTAM

Moscow Sheremetyevo Airport, 23 December 2010 at 14:31. Extent of runway contamination: 10% or less dry snow, less than 2 mm deep. Estimated braking action was good (friction coefficient 0.45).

The weather and runway conditions were deemed irrelevant as regards the course of events.

1.8 Aids to navigation

Aids to navigation had no bearing on the accident.

1.9. Communications

The radiotelephony or telephone recordings of the communications between the aircraft and the air traffic control were not available.

1.10 Aerodrome information

The incident occurred at FL 127 (ca. 3900 m) in the Moscow Sheremetyevo Terminal Control Area, approximately 16 NM northwest of the airport.

1.11 Flight recorders

The aircraft was fitted with the following flight recorders:

- Solid State Flight Data Recorder (SSFDR), p/n 2100-2043-00, s/n 445033. The storage capacity in this aircraft is approximately 200 hours.
- Solid State Cockpit Voice Recorder (SSCVR), p/n 2100-1020-00, s/n 367690. Recording capacity 120 minutes.

The Solid State Flight Data Recorder (SSFDR) and the Solid State Cockpit Voice Recorder (SSCVR) are fully electronic flight recorders, containing no moving parts. Further on, this investigation report refers to them as flight data recorder (FDR) and cockpit voice recorder (CVR). Both were manufactured by L-3 Aviation Recorders, USA, and belong to the manufacturer's FA2100 series.

Flight Data Recorder (FDR)

Finnair Oyj downloaded the FDR recording in Helsinki under the supervision of the investigation commission. The recording was sent to the Transportation Safety Board of Canada (TSB Canada) for analysis. The recorder had operated normally and the data were uncorrupted. The investigation commission received the first downloaded files in January 2011. The files contained data in numeric and graphic form, which were utilised in analysing the flight and establishing the course of events. TSB Canada delivered the first version of the animation to the investigation commission in April 2011. The final animation was received in September 2011.

Cockpit Voice Recorder (CVR)

It is not clear whether the flight crew opened the CVR circuit breaker immediately after the flight or as they were leaving the aircraft. The investigation commission took possession of the CVR at Helsinki-Vantaa Airport and the recording was downloaded at Finnair Oyj under the supervision of the investigation commission. When the recording was being downloaded it became evident that the incident audio had been overwritten. Only maintenance-related talk and sounds could be heard. Therefore, at some stage the circuit breaker had been closed and the recorder had started. Later, however, the circuit breaker had been opened again because it was open when the aircraft arrived at Helsinki-Vantaa at the end of the ferry flight.

1.12 Wreckage and impact information

Not applicable. The aircraft-related inspections are discussed in section ‘1.3 Damage to aircraft’.

1.13 Medical and pathological information

Two passengers were taken by ambulance to a hospital in Moscow. The other passenger or the crew did not seek medical attention.

1.14 Fire

There was no fire.

1.15 Survival aspects

While returning to the airport the flight crew requested that an ambulance meet the aircraft upon landing. The medical personnel arrived at the side of the aircraft once the aircraft had taxied to its stand. After a long wait they managed to transfer the passenger who had suffered broken ribs to the ambulance on a stretcher. The passenger with an injured leg and hip was helped to the ambulance. They were first taken to the airport terminal and then to a hospital in Moscow. No actual rescue operation was needed.

1.16 Tests and research

1.16.1 Investigation methods

The investigations are based on flight crew interviews as well as the materials they used in the planning and execution of the flight. The investigators had access to the operator’s *Operations Manual* (OM), the manufacturer’s *Flight Crew Operating Manual* (FCOM) as well as the *Quick Reference Handbook* (QRH) that the flight crew used. *The operator’s Standard Operating Procedures* (SOP) are included in the OM. In addition to interviewing the flight crew the investigators met the operator’s postholders.

The detailed technical investigations are based upon FDR and fault memory data, the aircraft’s *Maintenance Manual* as well as the detailed aircraft system descriptions that the investigation commission requested from the aircraft manufacturer. The investigation was hindered by the fact that the CVR recording was not available to the investigation commission.

1.16.2 Flight crew action

Pre-flight preparations

As per *Normal Procedures* in the Operator Operations Manual Part B (OM-B) the flight crew must carry out an expanded external and internal Pre-Flight Inspection (PFI) before the first flight of the day. In practice, the abovementioned checks are done without a checklist. Prior to later flights with the same aircraft on the same day, the flight crew will carry out the same inspection in an abbreviated fashion. All type-rated pilots are trained to carry out this inspection, and will receive annual refresher training. The checks following the PFI are read from hardcopy or electronic checklists. For this flight the captain carried out the walk-around inspection and the co-pilot checked the cabin.

Walk-around inspection

Snow and ice removal from off the aircraft's surfaces is generally explained in the Operator Operations Manual Part A (OM-A). The pilot-in-command (PIC) must verify that the aircraft's surfaces contain no such contaminants that could affect the conduct of the flight. Moreover, the PIC must check that any possible cleaning and anti-icing procedures are appropriately done.

The OM-B prompts the flight crew to check the cleanliness of the aircraft's external surfaces and states that the PIC is responsible for any necessary deicing. Furthermore, the FCOM introduces the "Clean Aircraft Concept", which prohibits a takeoff when frost, ice, snow, or other contaminants are present on the airplane's critical surfaces. The instructions warn against making any decisions purely on the assumption that the contaminants will fall off the aircraft's surfaces once it begins to roll. Section *"Cold Weather Operations"* in the FCOM provides detailed instructions on inspecting the critical surfaces for snow that is stuck to them. The manual states that mechanical snow removal and a subsequent inspection may suffice if the snow is not stuck to the airplane's surfaces.

During the PFI the captain noted that there was no ice on the wings and that the thin layer of dry snow which had accumulated during the previous night had not stuck but could more or less be removed by blowing on the aircraft's surface. This thin layer was removed with a brush. As there were no sufficiently tall ladders in the vicinity, the relatively high horizontal stabilizers were not cleaned. The captain believed that the surfaces of the stabilizers were clean under the thin layer of snow and that it would blow off during taxi, at the latest.

Checks prior to engine starting

The checks following the PFI are either read from hardcopy or electronic checklists. The OM-B defines two ways of carrying out these checks: either "challenge and response" or "silent". The flight crew complete the challenge and response-type checks together. One of the pilots will first read the checklist item (challenge), which is followed by the other pilot confirming the item (response). When it comes to the silent checklist items, the pilot will independently complete them. Once all checklist items have been completed, the pilot will verbally announce the checklist done. The checklist is colour-coded to indicate the type of each item. Code legends are provided at the end of the checklist.

Checklists applicable to normal operations are supplemented in the OM-B by the so-called *Expanded Checklists* which explain the manner of completion of each item in detail. Prior to engine start the checklist-specific action on the flight deck begins in accordance with the OM-B's APU (Auxiliary Power Unit) *Start and Systems Checklist*.

As per the OM-B section *Normal Procedures*, a qualified member of the flight crew can independently complete the aforementioned checklist. Nonetheless, there are three colour-coded (challenge and response) items at the end of the chapter on checklists: *Gear Pins, Take-Off Data and V-speeds as well as the Take-Off Briefing.* They require the presence of both pilots. The abovementioned colour codes are absent in the expanded checklists.

The *Expanded Checklists* explain in detail the manner of completion of the *Take-Off Briefing*. Items include things such as the runway in use and departure procedures. Prior to these items at the end of the checklist are, among other things, setting and checking of the altimeters, primary and multifunction displays, programming of the FMS, setting of the navigation source and setting the radios and navigation aids for departure. According to the colour codes these items can be independently completed. However, the Operator has stated that the aforementioned checklist items are indeed intended to be completed by both pilots together, but the appropriate colour code has been erroneously omitted in OM-B revision process. Nevertheless, the correct practice was explained during operator training.

The OM-B *Normal Procedures* section mentions that the *Take-Off Briefing* must be recompleted as applicable regarding any possible changes in the air traffic control clearance. Although the checklists following the engine start checklist do not revisit this issue, in conjunction with the item *Flight Instruments* it is mandatory to check that the *Primary Flight Display* (PFD) is correctly set for departure.

After start of the engines

Following the *After Engine Start Checklist* in the OM-B, the Take Off and Go Around pushbutton is used to set the Flight Director to the takeoff mode *(Take Off and Take Off, TO/TO)*. In accordance with the expanded checklists pilots must also confirm that the PFD will display the correct takeoff indications *(TO/TO)*. As per the checklists, this function will not be rechecked before takeoff.

The checklists call for checking the aircraft's flight control trim settings after the engine start. According to FDR data the horizontal stabilizer was set to the correct takeoff position (-3.8º) before the takeoff.

Checks during taxi and before takeoff

The airport's ATIS information said that the runway in use was 25L. The magnetic heading of this runway is 246°. According to FDR data the FD HDG bug was set to 247º. However, when they were requesting a taxi clearance the ATC told the pilots to taxi to holding point 07R for departure. Due to the change in runway they had to reprogram the FMS with regard to the new takeoff runway and it's Standard Instrument Departure

(SID). Furthermore, they had to calculate new takeoff performance parameters on the cockpit laptop computer for RWY 07R.

In accordance with the SOP any changes to the FMS or performance calculations will be done by the pilot on the right seat during taxiing. As per the flight crew's interviews the captain entered the new takeoff runway and the changed SID into the FMS while the co-pilot completed the performance calculations.

As a result of the takeoff runway change on the FMS the FD, in line with its operating logic, returned from the TO/TO modes to the basic modes of PITCH/ROLL, which the pilots did not notice. In addition, the HDG bug remained at 247°. The magnetic heading of RWY 07R is 066°. *The Expanded Taxi Check List's* section *Flight Instruments* only instructs the pilots to 'Check EFIS', i.e. check that the *Electronic Flight Instrument System* is set for departure. This section contains no specific mention of checking the navigation aids or any possible changes to the *Take-Off Briefing*.

The FCOM's *Taxi and Before Takeoff* checklist includes the items *Flight Instruments*, *Navigation Aids* and *Take-Off Briefing*. Yet, they do not contain any mention of the TO/GA selection or of checking it. In accordance with the FCOM and the section in the OM-B's *Normal Procedures* that provides instructions on the different phases of flight, Pilots must check before takeoff that the modes displayed on the FMA are TO/TO.

It should be noted that in the operator's OM-B manual, and therefore also in this report, the term FMA is used for flight mode annunciation. The aircraft manufacturer's FCOM uses the term *AFCS Mode Display* instead of FMA.

According to the FDR recording, at the beginning of taxiing the EICAS alerted the pilots that their respective compass indications diverged. In the takeoff position, when the aircraft was in RWY heading 066°, the captain's compass heading was 079.3° and the co-pilot's compass heading was 060.4°. As per the OM-B, they set the compasses into the Directional Gyro mode to rectify the situation. This meant that the Flux Valve-based magnetic course correction function was not in use. The pilots manually set the exact magnetic runway heading on their compasses. The FD's HDG bug was left at the heading of 247°.

Flux Valve -equipped aircraft types may experience inaccuracies in heading displays when operating at airports where there are magnetic anomalies. Among other things, said anomalies are typically caused by structures under aprons or taxiways.

Takeoff and initial climb

The co-pilot was the PF during takeoff. Sheremetyevo's SID Buzharovo 07D (AR 07D) incorporates a straight-ahead climb, tracking the centreline of RWY07R. After having passed the opposite end of the runway one must fly straight ahead to 3.9 NM (7.22 km) outbound from the VOR/DME beacon MR.

The landing gear lever was moved to the up position after liftoff. Whereas the nose rose to a positive 12° angle, the Flight Director's command bars pointed to 12° below the horizon. The flight crew realised that the FD was not in the desired mode. They tried to correct this by pushing the TO/GA button. Since the aircraft was already airborne, the system went into the GA mode instead of the expected TO mode. Then, on the Flight Guidance Panel the flight crew set the FD to track the HDG bug's heading. The vertical guidance was set to the Flight Level Change (FLC) mode.

Following the guidance of the Flight Director's command bars the co-pilot initiated a left turn towards the heading of 247°, selected with the HDG knob, instead of 066° as per the SID. The turn commenced before they had reached the opposite end of the runway. At the same time the flight crew retracted the flaps. The captain told the co-pilot to turn back towards the SID route, and the FD lateral guidance was set to the NAV mode, in order to intercept the SID track calculated by the FMS. In accordance with the FD's guidance the right turn towards the correct track commenced at approximately 1400 ft (427 m) AGL. The maximum bank angle was 36.5° at approximately 2200 ft (670 m). Sheremetyevo runways require straight-ahead climbs over the opposite end of the run-way.

As the flight crew were rolling out from the turn they engaged the autopilot (AP). At that moment, the aircraft's vertical climb rate was still approximately 2800 ft/min (ca. 14 m/s) and the altitude was approximately 2600 ft (ca. 800 m) above ground level. The FD was already in the altitude capture mode for level-off guidance to the preselect altitude of 2960 ft (900 m) above ground level. Immediately after the AP was engaged, the Master Caution (MC) annunciated a caution. This was caused by the EICAS system indicating that the horizontal stabilizer trim system was unable to trim the stabilizer as commanded by the AP (AP STAB TRIM FAIL). The flight crew reset the MC by pressing its switch/light.

According to the FDR data the lateral guidance was again selected to the HDG mode immediately after the caution. The flight crew promptly corrected the incorrect heading (247°) by centring the HDG selection to correspond with the aircraft's magnetic heading at the time (072°). At this stage the captain assumed the duties of the PF. At first the flight crew navigated along the track of SID 07R by using the HDG knob for directional control. A little later FD was again set to track the route in the FMS.

Approximately 15 seconds after the AP was engaged, as the aircraft was levelling out for the first time, the EICAS annunciated a caution regarding the fact that the AP was being forced to use the elevators in an abnormal fashion (AP HOLDING NOSE DOWN) in order to prevent the nose from rising. They continued to receive several AP HOLDING NOSE DOWN cautions during the climb. As soon as the workload so permitted, the co-pilot located the QRH procedures relevant to the caution and read them out loud. They had not yet started the QRH procedures when the service hostess came to the door of the flight deck to inquire about the reason for what she felt to be abnormal oscillations during the departure.

After the flight the captain made a 'Primary Stabilizer Trim Failure' entry into the Tech-nical Log, indicating that the primary stabilizer trim system had failed. The aircraft manu-facturer analysed the systems' fault memories and, on the basis of them it was confirmed that the annunciated EICAS warning was actually AP STAB TRIM FAIL, rather than PRI STAB TRIM FAIL.

Actions before and during the accident

The climb was continued towards the cruising altitude at 281 kts (520 km/h) IAS. As the flight crew began to complete the QRH's AP HOLDING NOSE DOWN checklist procedure, a little over six minutes had passed since the first EICAS warning. According to his account the captain took a firm grip of the control column and disengaged the AP from the flight control system, freeing the Autopilot Pitch Servos from moving the flight controls. The result was that the deflected flight controls tried to return to their neutral position, the control column moved forcefully backwards and the nose pitched rapidly upwards. The captain's attempt to arrest the increasing pitch by counter-steering resulted in Pilot Induced Oscillation (PIO). The aircraft porpoised in pitch three times in 1.5-second cycles after which the oscillation rapidly dampened. In all, there were six oscillations within approximately a seven second timeframe. During the first oscillations, normal acceleration varied from +3.6 g to -1.7 g.

According to his account the captain tried to get the oscillation under control by only adjusting his push on the control column. The FDR recordings showed that the captain had used the normal trim in the nose down direction at the end of the oscillations.

After having regained control of the situation the captain, according to his account, selected the Secondary Trim system for stabilizer trim control and continued the flight by flying manually. The maximum permissible indicated airspeed for the Secondary Trim system is 250 kts / M 0.72 due to the inoperative Mach Trim function. There is a remark of this limitation in the QRH's PRIMARY STAB TRIM FAIL checklist. However, this checklist procedure was not read. During the rest of the flight this limitation was not followed. Instead, the maximum instantaneous indicated airspeed was 300 kts (556 km/h).

1.16.3 The artificial feel of the elevator control system

Operating principle

The elevators of the Challenger 300 are hydraulically powered. As hydraulically powered flight controls do not provide any feedback to the control column of the aerodynamic forces that the control surfaces are subjected to, the artificial feel forces for the elevator control system are provided by a pitch feel simulator. Without this system it would be possible to inadvertently use too large or too rapid a deflection of the control surfaces even at high airspeeds.

The artificial feel is a mechanical system based on spring forces. The forces felt on the control column are regulated by adjusting the spring mechanism. The pilot expects the control forces on the flight controls to be proportional to the airspeed. Several parameters can be used to regulate the artificial feel. Of these, airspeed is the most typical one. Nonetheless, in this aircraft type the artificial feel forces change in relation to the horizontal stabilizer angle. A correctly trimmed stabilizer provides a proper basis for the artificial feel, as, this being the case, it reflects the aircraft's airspeed as well as its centre of gravity and flight configuration. In practice, the horizontal stabilizer is trimmed to the extent that, in stable flight, the elevators are in a neutral position, and no control column forces are needed to maintain the state.

Whereas in manual flight the horizontal stabilizer is trimmed with switches on the control columns, when flying with the autopilot the aircraft's systems provide the required trimming commands. Among other things, the system also automatically adjusts the horizontal stabilizer, even when flying manually, if for instance, flap configuration changes cause the need to retrim the aircraft.

If the Challenger 300 is being flown with the AP and the automatic horizontal stabilizer trim is inoperative, the automatic flight control system will deflect the elevators in relation to the airstream as it attempts to maintain the desired flight path. This being the case, the pitch feel setting may not correspond to the actual airspeed should the automatic trim fail.

The adjustment principle of the artificial feel system is that the control column forces are lighter when the horizontal stabilizer angle corresponds to a lower airspeed. The stabilizer angle that corresponds to lighter control forces ranges from -12° to -3°, from where the required force will gradually increase to its maximum, at a stabilizer angle of +2°. On this flight the stabilizer was set to -3.8° for takeoff, which corresponded to the calculated weight and balance values. When the flaps were retracted the automatic horizontal stabilizer trim system functioned correctly and adjusted the stabilizer to -3.6°. At this setting the pitch feel is still within the range of light control forces.

Training and documentation

The pilots' interviews revealed that the operating principle of the pitch feel system is not, at least not systematically, taught in type training. The OM-B's technical section mentions the system, but it does not provide a description of the operating principle. The QRH's section for the fault on this flight did not advise the flight crew to check the elevator angle, nor to appropriately adjust the airspeed. Neither did the checklist advise the flight crew to turn on the seat belt sign in the cabin when said fault appeared.

Following the incident, on 12 January 2011, the operator published a QRH revision with regard to adjusting the airspeed and turning on the seat belt sign. The aircraft manufacturer published an Advisory Wire (AW300-22-0150, 4.11.2011) to operators related to this accident. This advisory reminded pilots to firmly grip the control column prior to AP disengagement and, time permitting, to notify the passengers of the situation and turn on the fasten seat belts sign.

1.16.4 Technical investigation

The technical investigation of the incident is limited to the aircraft's pitch control system and to the chain of events which began to evolve immediately after takeoff. At first, the aircraft was being flown manually, without trimming the horizontal stabilizer at all. As the airspeed increased, this required a certain amount of pushing on the control column in order to maintain the desired flight path. In conjunction with flap retraction the automatic trim control system made the typical, small change in trim. Since the normal trim system provides this function, it can be inferred that the system was still operational at the time.

The autopilot was turned on, at which time the system successfully completed its built-in test and engaged. In order to maintain the state of flight the AP servo began to push the elevator system with a corresponding force to the one applied by the pilot on the control column.

When the AP is engaged the Automatic Flight Control System (AFCS) calculates the required control commands to maintain the desired flight path. Transient commands or changes are implemented by deflecting the flight controls with the servo and, consequently, the control surfaces. If the change in the flight state is of a more permanent nature, the system aims to achieve a situation in which the elevator servo is not loaded by the pitch feel springs, and that the elevators are aligned with the horizontal stabilizer. This so-called trimming is done by moving the horizontal stabilizer. In stable flight this means that the AP can be disengaged without causing any sudden changes to the aircraft's flight path.

In this case the AFCS normally recognised the need to trim the aircraft, and sent a command to the Horizontal Stabilizer Electronic Control Unit (HSTECU). The fault codes recorded in the Flight Guidance Computer's (FGC) fault memories showed that the trim command was issued by the FGC. However, the command either never arrived or the HSTECU, for some unknown reason, did not accept it. Hence, the horizontal stabilizer did not move, which can be seen in FDR data. No related fault codes could be read from the HSTECU's fault memory. This would imply that the fault was transient, and that the system had not experienced a serious fault.

Since the HSTECU did not respond within its prescribed timeframe by trimming the stabilizer, the FGC units interpreted this as a failure of the automatic trim system, locking it out. This situation was annunciated with an AP STAB TRIM FAIL caution to the flight crew. The AP, by its design, will remain engaged in these types of faults, continuing to control the aircraft by means of the servo alone.

When a change in the flight state causes a need to retrim the aircraft, and the servo is loaded beyond certain limits, the EICAS will annunciate an AP HOLDING NOSE DOWN caution if the servo continues to push the control column. If ignored, this situation carries some risks. Should the system then fail, resulting in the disengagement of the AP or the servo, a sudden change in the flight state will ensue.

On the accident flight the pilots disengaged the AP in a situation such as the one described above. Then, the servo released the flight controls and, accordingly, the elevators as well, which the artificial feel then attempted to centre. The nose of the aircraft pitched up rapidly because the horizontal stabilizer was mistrimmed in relation to the flight state, i.e. it was pulling the nose up, and the elevators would no longer correspondingly push the nose down. As a result of the captain's series of counter-control inputs the aircraft went into a Pilot Induced Oscillation (PIO).

In order to gain control of the aircraft the captain used the control column's trim switch, at which time, as per FDR data, the trim system functioned normally. The aircraft was considerably out-of-trim, and the captain had to use the trim switches continuously for more than three seconds. Since a continuous use of the trim function as long as this is unusual in normal operations, the HSTECU unit made a record of the event. Its fault memory included a Trim3SecWarn warning for using the trim for over three seconds. The timestamp for this warning corresponds to the time of the pilots' trim request. This implies that that the HSTECU unit was functioning and controlled the horizontal stabilizer. Once the AP was disengaged the trim system lock-out set by the FGC was also reset.

Post-flight technical inspections

The troubleshooting carried out by the manufacturer-authorised maintenance organisation in Moscow was typical in nature and extent. The performed trim system's functional and operational tests as well as wiring checks were sufficient. In addition, the electronic rigging of the trim system was checked. Since nothing significant was found in these inspections, the fault code in the FGC's fault memory is the only technical finding of the malfunction. No underlying cause for it was discovered, either. When it comes to modern aircraft, this kind of a case is not unusual. It is possible that a connector had dirt or oxidation that came off as the connectors were disconnected during the inspections.

Analysis of the grease used on the horizontal stabilizer trim actuator jackscrew

For the purpose of analysis, the investigation commission asked the Operator to take a grease sample from the horizontal stabilizer trim actuator jackscrew in Moscow. The local maintenance organisation took a very small sample, which was partly absorbed into the piece of cardboard on which it had been taken. At the end of January the aircraft was flown to Basel, Switzerland for maintenance. During the maintenance a new grease sample was taken. Even though the sample was small, it was properly taken and suitably packaged. Moreover, the operator provided a reference sample of the grease used in the aircraft. On 18 February 2011 these samples were sent to the laboratory of the Finnish Defence Forces Technical Research Centre Lakiala, Finland. The results of the analysis were ready on 14 March 2011.

Judging by the spectra of the grease base oil and the thickener therein it was determined that the samples consisted of the same grease. The samples taken in Moscow and Basel contained many particles which were perceptible with an optical microscope. Because of the manner in which the Moscow sample was taken, it was not intact. Due to absorption into the cardboard it contained less base oil than the reference grease or the sample taken in Basel. The quantity of hydrocarbon oil in the remaining base oil had diminished. When the sample-taking induced changes in Moscow are taken into account, the samples only differ from the reference lubricant in the quantity of particles.

All samples showed similar base oil chemical components. Furthermore, the samples were also similar with regard to the thickener. Chemical elements shown in the following table were determined in the samples' elemental analysis.

	Ca	Bi	S	Zn	Al	Al particles	Fe particles	Cr	Mn	Ni	Ti
Reference	X	X	X	X	X						
Moscow	X	X	X	X	X		X	X			
Basel	X	X	X	X	X	X	X	X	X	X	X

The table shows that the sample taken in Moscow does not contain as many chemical elements as does the Basel sample. The quality of the sample taken in Moscow was poor. Furthermore, it was probably swiped from just one area of the jackscrew. Because of their small volume and, especially the manner in which the Moscow sample was taken and preserved, the moisture content could not be determined from the samples. In order to obtain a good-quality sample, the maximum possible amount of grease should have been taken from the jackscrew and it should then have been stirred to produce a homogenous sample.

The chemical elements detected from the Basel sample are typical to those found in greases used in jackscrews. The samples show that there is no basis for considering the quality of the grease to be a contributing factor to the incident.

1.17 Organisational and management information

The business flight company Jetflite Oy was established in 1980. The company employs in all approximately 80 persons. At the time of the accident the company's fleet included 11 business jet aircraft. The company has an Air Operator Certificate (AOC), No FI.004. The company's own Continuing Airworthiness Management Organisation, as per EASA Part-M Subpart G, sees to the airworthiness of the company's fleet. Maintenance of the aircraft is usually performed by the company's own EASA Part-145 organisation.

In this report Jetflite Oy is referred to as the Operator.

According to the AOC the Bombardier BD-100-1A10 Challenger 300 is intended for use in passenger and cargo operations. As per the AOC, it can be used in the whole world including Artic Spitsbergen only, excluding Antarctic and Pacific.

2 ANALYSIS

2.1 Pre-flight preparations

Walk-around inspection

Relying on his observations of the snow on the wing and his personal experience the captain reasoned that the snow was not sticking to the horizontal stabilizers or elevator surfaces and, therefore, decided to not remove it. Neither the company's OM-B nor the manufacturer's FCOM permit takeoff if snow has *adhered* to the critical surfaces of the aircraft. Elsewhere in the manuals the 'Clean Aircraft Concept' is promoted, which emphasises that no snow whatsoever can be present on the critical surfaces at takeoff. According to Operator's regulations it is permissible to mechanically remove non-adhered dry snow which does not hide any other contamination from the critical surfaces by brushing it off, for example. The captain was certain that the snow on the elevators had not adhered to the surfaces and that there were no other contaminants under the snow, hence, based on experience, the captain thought the snow would blow off during taxiing, thereby fulfilling the Clean Aircraft Concept.

Checks before starting the engines

In accordance with the OM-B, to save time, a qualified crew member can independently complete the *APU Start and Systems Checklist*, excluding the last three items. Among other things, the following checklist items can be independently completed:

- Altimeters
- Flight Management System (FMS),
- Primary Flight Display/ Multi Function Display (PFD/MFD),
- Engine Indication and Crew Alerting System (EICAS),
- Selection of the Navigation Source (NAV SOURCE) and setting of the radios and navigation aids (RADIOS/NAVAIDS).

Nonetheless, the investigation commission believes that the aforementioned items should be marked in this checklist to be jointly completed. Otherwise the cross-checking of critical items by the other pilot, as per good airmanship, is lost. Even though this practice is trained during operator training, OM-B revisions failed to include the appropriate colour code indicating joint checklist completion. This shortcoming may confuse the pilots as to the correct procedure.

In accordance with the expanded checklist some of the aforementioned checks are to be jointly completed during the *Take-Off Briefing* and others during the completion of the *Taxi Checklist* at the section *Flight Instruments*. The exact content of the checklist is, nonetheless, done from memory.

Aircraft manufacturers and airlines are increasingly moving towards the practice of using more memorised items in checklists. However, the probability of error increases, especially in abnormal situations, if critical items are checked from memory alone.

Judging from the history of the flight it can be inferred that not all of the checklist items were properly completed. The investigation could not categorically establish which checklist items were completed by the captain, which ones by the co-pilot and which ones were completed together on this flight. It is evident that, for some reason or another, the actions were not adequately discussed with the pilot in training. A thorough completion of the checklists would have been particularly important given that the flight was a FAM flight included in the co-pilot's operator training programme and that his flying experience was still relatively modest.

2.2 The accident flight

Events preceding the takeoff

The flight crew had set up the aircraft systems in accordance with a RWY 25L departure profile. However, during taxi they found out that RWY 07R was to be used instead. The subsequent changes were done during taxiing. The captain programmed the new Standard Instrument Departure into the FMS and the co-pilot calculated the necessary changes in takeoff performance data on the cockpit laptop. As per operator SOP the pilot in the right seat is responsible for these kinds of actions during taxiing, while the pilot in the left seat concentrates on the taxiing itself.

The investigation could not establish why the tasks were expedited. After all, there was plenty of time available to thoroughly discuss and complete the actions, especially considering that this was a training flight.

Before the takeoff the pilots missed the fact that the FD was no longer in the TO/TO mode and that the HDG bug had not been reset to the correct heading. In section *Take-off and Initial Climb* of the OM-B's Normal Procedures the flight crews are instructed to check the aforementioned settings and in the *Briefings before Taxi* section redo the take-off briefing regarding any changes. The OM-B's checklists do not prompt flight crews to recheck these actions immediately before takeoff. The changed runway as along with having to correct the compass indications strained the flight crew to the point that they did not sufficiently complete the final cockpit display checks.

It is the opinion of the investigation commission that checklists should be prepared so that they better support the flight crews to jointly complete the critical checks, without unnecessarily relying on memory. For example, it would be perfectly appropriate to add a short *take-off briefing* as an independent item to the section *Flight Instruments* on the *Taxi Checklist*, which would include AFCS and FMS settings as well as the navigation equipment in use. Moreover, it would make sense to move the pressing of the TO/GA button onto the *Line Up Checklist*. As regards the SOPs, the final checks in the takeoff position, prior to applying takeoff power, should include the correct mode of the FMA, compass headings and checking the correct runway.

During operator training pilots are trained to check the PFD displays before departure. This was evidently not done on this particular flight: had it been done the incorrect FMA displays and HDG bug settings would have been noticed before takeoff.

The division of duties during taxiing was both unclear and nonstandard. In spite of the training nature of the flight, crew communication was inadequate. Even on a normal flight it is important to jointly brief the procedures as well as any limitations concerning them, the airspace or the aircraft. Last-minute changes should be taken into account with extra consideration.

Takeoff and the initial climb

During the takeoff and the initial climb the co-pilot focused on the duties of the PF, utilising the FD's control commands. According to his account he requested that the FD be set to the NAV and FLC modes, as per the SOP. However, immediately after takeoff the captain noticed that the FD was in the incorrect PITCH/ROLL mode. According to FDR information the flight crew attempted to correct this by selecting other modes in a rapid sequence. First, by pressing the TO/GA button they aimed to achieve the TO/TO mode, but since the aircraft was already airborne, the system went into the GA/GA mode instead. As a result the FD's command bars guided the aircraft into the heading which they were flying at the time of the selection. The guided climb angle was slightly shallower than that of the TO mode.

When they had only been in this state for three seconds or so, at 400 ft (ca. 120 m) they changed the FD mode to HDG/FLC. It is unclear why the HDG selection was done since the request, apparently, was to select the NAV/FLC mode. It is possible that the compasses' DG mode influenced this decision. Since the CVR information was lost the investigation could not establish whether the pilots discussed these mode selections. These selections, together with the improper HDG bug setting, resulted in an inexperienced co-pilot rolling the aircraft in accordance with the FD's command bars.

When the captain noticed the turn he immediately commanded the co-pilot to turn back towards the departure route. As they were turning back the bank angle became momentarily exceptionally high, compared to normal operations. When they rolled out of the turn they engaged the AP. Following the pilots' interviews the investigators formed the opinion that the pilots had no idea why the FD commanded the aircraft in an unexpected manner, or why it had been in an unintended mode at the moment of takeoff. The captain assumed the duties of the PF so as to clear up the situation.

Engine Indication and Crew Alerting System (EICAS) warnings

The AP was engaged in a particularly demanding situation. In addition to the incorrect stabilizer trim setting the need to rapidly capture the selected altitude increased the need to push the control column further forward. In this situation the AP was unable to level out at the clearance altitude. Rather, the aircraft rose almost 200 ft (ca. 60 m) above it. Climb power was only reduced during the descent to the clearance altitude.

The horizontal stabilizer (pitch) trim was not used at all before the AP was engaged even though the airspeed and the resultant need to push the elevator controls had constantly been increasing. Neither did the AP trim the horizontal stabilizer after it was engaged. Immediately after the AP was engaged the EICAS annunciated AP-related cautions. First the system annunciated an autopilot stabilizer trim caution (AP STAB TRIM

FAIL), followed by a caution about the fact that the AP was forced to continuously push the elevator controls in order to keep the nose from rising (AP HOLDING NOSE DOWN). The investigators believe that, due to the events that transpired during the departure and initial climb, the flight crew was unable to sufficiently concentrate on these cautions.

It is evident that the captain interpreted the EICAS caution to indicate a primary stabilizer trim failure (PRI STAB TRIM FAIL). This is not only corroborated by his own account during the interview, but also by the fact that he selected the secondary trim from memory once the oscillation was over. He also entered a note of this caution into the Technical Log. Nevertheless, a technical analysis confirmed that the EICAS annunciated an AP STAB TRIM FAIL caution.

Action immediately before the accident and during the course of the accident

Once the initial climb became more stabilised the co-pilot read out loud the QRH's corresponding checklist actions regarding the EICAS's AP HOLDING NOSE DOWN and AP STAB TRIM FAIL cautions. A little later the captain commenced the actions of the AP HOLDING NOSE DOWN checklist and disengaged the AP. According to his account, even though he held on tight to the control column its backward movement took him by surprise and the nose rapidly pitched up. Since the angle of the horizontal stabilizer corresponded to the situation at takeoff and the airspeed was significantly higher, the movement of the nose was abrupt. Surprised, the captain reacted by rapidly pushing the control column, steering the nose down. As the controls felt unusually light in relation to the airspeed the captain overcontrolled the aircraft, resulting in a Pilot Induced Oscillation (PIO), which he promptly got under control after three large-amplitude fluctuations.

Due to the incorrect angle of the horizontal stabilizer the pitch feel setting was in the range of lighter control forces. The captain was unaware of this, and most likely his training had not prepared him for it. Had the flight crew been familiar with the operating principle of the artificial feel system, they might have checked the angle of the horizontal stabilizer and the elevators from the MFD, and analysed the situation. Nonetheless, the QRH checklist did not provide any instruction for this kind of check. Normally, at this phase of the flight, the control surfaces are at or very close to neutral and, therefore, an unusual deflection would have been clearly detectable.

The QRH checklist item that tells the pilots to disengage the AP did not include a recommendation to consider adjusting the airspeed to the situation prior to disengaging the AP, nor was there any mention of turning the seat belt sign on before implementing the action. Both actions could have mitigated the damage that ensued on the flight and even prevented the passengers' injuries.

Following this accident the operator published a revision to the aforementioned QRH procedures. The revisions instruct flight crews to reduce airspeed to 210 kt (389 km/h) as follows: *If AP HOLDING NOSE DOWN is indicated: Reduce speed to 210 KIAS before disengaging autopilot* and *switch the Seat Belt sign on* prior to disengaging the AP. Flight crews are also warned that *If AP HOLDING NOSE DOWN is indicated with AP STAB TRIM FAIL, pitch control forces may be too light/sensitive with the possibility of overcontrolling the aircraft. Exercise caution, and avoid abrupt pitch control movements*. There is also the following remark: *EICAS position trim indicator of stab trim may give a good idea about the severity of the out of trim condition*. This means that the stabilizer's angle shown on the MFD should be utilised in the analysis of the given situation. It is the opinion of the investigators that these post-accident changes were appropriate.

Later, the aircraft manufacturer published an advisory for operators related to this accident. This advisory prompted the pilots to firmly grip the control column and, time permitting, to notify the passengers of the situation and turn on the fasten seat belts sign prior to AP disengagement. The investigators believe that while these instructions were steps in the right direction, they do not fully suffice.

Action immediately after the accident

The fault that caused the trim fault cleared as the AP was disengaged. The automatic trim system lockout, set by the FGC because of the malfunction, was also reset. The AP STAB TRIM FAIL caution should have also disappeared at this time. According to the flight crew's interviews this is what apparently happened. From a technical standpoint it might have been possible to reengage the AP and its automatic trim.

Since the QRH prohibits the reengagement of the AP in an AP STAB TRIM FAIL situation, the flight was continued to the end under manual control. No reanalysis of the EICAS cautions was made.

The captain interpreted the first EICAS caution to indicate a malfunction of the Primary Stabilizer Trim. His analysis of the situation may have been influenced by the malfunctioning of the Primary Stabilizer Trim system on this very same aircraft in June of the same year. The captain also remembered that the same manufacturer's different types of aircraft had experienced horizontal stabilizer trim system faults. This being the case, he selected the Secondary Stabilizer Trim for use. However, he did not realise that he had already successfully used the Primary Stabilizer Trim at the end of the PIO. It is understandable that in this situation the captain did not want to take any chances. The investigation did not find anything which would imply Primary Stabilizer Trim failure.

The QRH's AP STAB TRIM FAIL checklist does not include a Secondary Stabilizer Trim selection. Therefore, the captain did it relying on his own judgement. The secondary system was engaged without reading the QRH's AP STAB TRIM FAIL checklist and, therefore, the airspeed limitation when using the Secondary Stabilizer Trim went unnoticed. With the inoperative Mach Trim function in mind, the highest attained airspeed was fairly high, but it did not result in any ramifications during this flight.

The flight crew actions may also have been affected by the following remark at the end of the FCOM's checklist, as well as the OM-B's AP STAB TRIM FAIL checklist:

> *NOTE: AP stab trim is not available when STAB trim is selected to SEC, but autopilot may be engaged.*

The purpose of this remark is unclear because the checklist does not request the selection of SEC trim. The AP will not engage if the Primary Stabilizer Trim is not in use.

The return flight

After the incident, having insufficient information regarding the condition of the injured passengers, the captain did not immediately decide to return to the aerodrome of departure. He did not declare an emergency for priority ATC clearance. With the information at hand, he considered that the request he had made for an ambulance to meet the aircraft at the stand would suffice.

It is the investigators' opinion that the co-pilot, due to his inexperience, had difficulties to program the FMS for a direct approach route for the return flight. According to the captain's account he had to edit the route himself so as to make it the way he wanted it. Even though there were shortcomings in crew cooperation, the return flight and the approach progressed without delay.

2.3 Manuals and training

The goal of FAM flights is to provide the student pilot with the necessary proficiency to function independently as a member of the flight crew. The captain, acting as a LFI, had received his operator LFI training several years prior to this as per the training manual valid at the time. No records of this training were available.

When it comes to training flights and, especially, flights on which an inexperienced co-pilot flies FAM flights, the pilots should comprehensively discuss the checklists' actions. Although joint action takes more time, it is the only way in which the instructor can check the student pilot's skills and competence, and provide additional guidance, if necessary. Even though the operator's own checklists may be used during type training simulator flights the SOPs in use are normally provided by the training organisation. Hence, prior to the commencement of the actual flights the student pilot may not necessarily develop sufficient familiarity or experience with the operator's SOPs or checklists.

For their part, the shortcomings in this flight's pre-takeoff preparations caused unnecessary events after the takeoff. In all likelihood these could have been avoided by thoroughly briefing the flight procedures and cockpit settings together prior to taxiing onto the runway. Had the takeoff been more stable the co-pilot might have trimmed the horizontal stabilizer while flying manually, resulting in less severe consequences.

Had they merely rebriefed that the SID calls for a straight-ahead climb, this might have prevented the aircraft's turns during the initial climb. Good airmanship entails that, before takeoff, pilots brief all relevant changes which have not been previously briefed.

Standard Operating Procedures and their training must also include the practice of always checking the FMA displays when the AFCS is given a new command. Checklists should be written in such a manner that they support this kind of practice in critical phases of the flight. The need is heightened when routines are disturbed, such as with the erroneous compass indications on this flight.

The flight crew used the checklists published in the operator's OM-B. In practice, it is impossible to include all required actions in the checklists. Rather, the detailed actions are largely based on the operator's SOPs. They consist of the procedures explained in the OM-B as well as operator training given to the pilot. The OM-B also maintains that:

> *The checklists are supplementary to those checks arising from basic airmanship and procedural practices common to the operation of any modern transport category jet airplane.*

The pilots' type-specific system awareness was also a contributing factor to the events on this flight. If a pilot does not know the artificial feel system in detail, it can be assumed that he will expect that the control forces created by the artificial feel system are proportionate to the airspeed.

The investigators believe that artificial feel system training during type training was either inadequate or altogether missing. This view is based on pilot accounts and the training material provided to the investigators. Additionally, the OM-B does not describe the system's operating principle in any manner. During the situation in flight it was difficult for the pilot to foresee the amount of force with which the control column would move when the AP was disengaged. Since system awareness was limited, the pilots could not realise that the pitch feel forces would not correspond to the airspeed but, rather, that they would be surprisingly small. The operating principle of the pitch feel system had a considerable role in the large control surface deflections following the AP disengagement, and contributed to the violent porpoising.

There is necessarily no need to rush to disengage a modern AP in an emergency or abnormal situation if it is still capable of controlling the aircraft. The situation annunciated by the AP HOLDING NOSE DOWN caution was not an actual malfunction. Rather, it was the AP's notification of a situation which resulted from the horizontal stabilizer trim fault.

It is possible that, with the guidance of a well thought-out QRH checklist, a properly trained pilot having had appropriate instruction would have checked the horizontal stabilizer angle and, based on it, analysed the situation before disengaging the AP. Taking the angle of the horizontal stabilizer into account will prompt the pilot to consider adjusting the airspeed correspondingly. The OM-B's AP HOLDING NOSE DOWN checklist as well as the even more appropriately placed similar list in the FCOM, cautions the pilots as follows: *NOTE: When autopilot is disconnected in a mistrim condition, except (sic) an abrupt change in control force.* This remark is not included in the QRH's similar checklist. This remark alone might have prompted the pilots to be better on their guard when the AP was being disengaged.

Had they reduced their airspeed they would have come closer to the airspeed to which the aircraft had been trimmed, and the AP would not have had to use so much force in pushing the elevators to counter the effect of the stabilizer. By doing so the control column would have moved considerably less in conjunction with AP disengagement.

2.4 Rescue actions

During the return flight the captain did not deem the accident to be an emergency or distress situation because he had insufficient information regarding the severity of the passengers' injuries. The aircrew's view was that the ambulance personnel waiting for them at the stand commenced their actions in a slow manner, paying little attention to the condition of the injured passengers.

3 CONCLUSIONS

3.1 Findings

1. The flight crew had valid licences and the required ratings.
2. The aircraft's certificate of registration and the airworthiness certificate were valid.
3. The gross weight of the aircraft and its centre of gravity were within the permissible limits during the entire flight.
4. The flight was a business flight. There were three members of the aircrew and three passengers on board.
5. As part of his operator training, the flight was a familiarisation flight for the co-pilot. His total flying experience was somewhat modest.
6. Visual Meteorological Conditions (VMC) prevailed at the airport. Light dry snow showers had passed the area during the previous night. The dry snow on top of the horizontal stabilizer was not removed prior to the flight.
7. During the taxi clearance the takeoff runway changed from RWY 25L to RWY 07R.
8. The pilots did not notice that, as a result of having changed the takeoff runway on the Flight Management System (FMS), the Flight Director returned from the takeoff mode (TO/TO) to its basic mode (PITCH/ROLL).
9. The pilots did not notice that the heading bug (HDG bug) was still set to 247°, the heading of the opposite runway.
10. During the takeoff the co-pilot acted as the Pilot Flying and the pilot-in-command as the Pilot Not Flying.
11. The flight crew had trimmed the horizontal stabilizer to the takeoff setting.
12. Instead of flying the track of 066°, as per the Standard Instrument Departure, the co-pilot, following the Flight Director's command bars, turned towards 247°, which was the heading that was set with the HDG bug. The turn commenced before reaching the opposite end of the runway.
13. When the turn began the flaps were retracted, at which time the system automatically made a 0.2° trim adjustment to the horizontal stabilizer. Following this, no trim adjustments were made to the horizontal stabilizer before the accident.
14. On the captain's order the co-pilot turned back to the right towards the SID route and the FD's lateral guidance was set to intercept the route programmed into the FMS.
15. During the unplanned left turn on climb out the aircraft reached its maximum bank angle of 36.5° at approximately 2200 ft (670 m).

16. When the aircraft rolled out from the turn the flight crew engaged the Autopilot (AP) and set again the lateral guidance to the HDG mode. Simultaneously, the flight crew corrected the erroneous heading selection by centring the HDG bug to 072°, which was the aircraft's heading at the time.

17. Immediately after having engaged the AP the flight crew received a Master Caution (MC) annunciation. This was caused by the EICAS system caution indicating that the AP was no longer able to command the stabilizer trim system (AP STAB TRIM FAIL).

18. Based on the Captain's hearing, it was determined that he very likely had interpreted the first warning to be a failure of the primary stabilizer trim system (PRI STAB TRIM FAIL).

19. The captain assumed the duties of the Pilot Flying. It was impossible to precisely determine from the available Flight Data Recorder (FDR) information when this was done.

20. The flight crew received several AP HOLDING NOSE DOWN cautions during the climb.

21. Prior to commencing any action the co-pilot read out the QRH's warning sections related to AP HOLDING NOSE DOWN and AP STAB TRIM FAIL.

22. They had not started to complete the actions when the service hostess came to the door of the flight deck.

23. The Fasten Seat Belt sign was turned off, even though a potential flight control problem existed.

24. The captain was taken by surprise by the rapid backward movement of the control column which followed the disengagement of the AP. As the captain was taking corrective action he overcontrolled the aircraft, resulting in a Pilot Induced Oscillation (PIO) around the pitch axis. During the oscillations the aircraft's normal acceleration varied from +3.6 g to -1.7 g.

25. As a result of the incident two passengers were injured, one of whom seriously. Their seat belts were not fastened at the time of the accident. The flight service hostess was slightly injured. The flight crew reported the accident to Moscow Approach Control and the aircraft returned to Moscow Sheremetyevo Airport.

26. No actual rescue operation was needed. An ambulance was called to the airport to transport the injured passengers.

27. The aircraft's fault memories indicated a transient failure of the autopilot's automatic trim system. Because of the fault the AP was forced to operate the aircraft's elevator controls in a nonstandard manner. The cause of the fault was never established.

28. The Flight Data Recorder (FDR) recording was downloaded at Helsinki-Vantaa Airport. The recording was sent to the Transportation Safety Board of Canada (TSB

Canada) for analysis. The FDR had functioned normally and the recording was intact.

29. The flight crew reported that they had pulled the circuit breaker of the Cockpit Voice Recorder (CVR) out at the end of the flight. The circuit breaker was pulled out when the aircraft returned to Helsinki. However the CVR recording was found to contain only conversations in Russian.

30. Pursuant to ICAO Annex 13 severity classification this accident was an accident.

3.2 Probable causes and contributing factors

The accident was caused by the pilot overcorrecting the aircraft's pitch angle immediately after the autopilot was disengaged.

The pilots' unfamiliarity with the operating principle of the aircraft's artificial pitch feel system, followed by an inadequate situation analysis after the trim fault, were contributing factors. Had they correctly held on to the control column prior to AP disengagement the accident would have been prevented.

The inadequate situation analysis also contributed to the degree of the passengers' injuries because the persons on board were not told to sit down and fasten their seat belts. Neither did the QRH's section pertaining to this situation adequately instruct the flight crew to take correct action prior to AP disengagement.

Despite the nature of a FAM training flight, shortcomings were established in the manner the flight crew performed checks as well as in crew cooperation, both before and during the flight. As a result of these, immediately after the takeoff the pilots were already overloaded to the point that when the trim fault appeared they postponed taking action until a point in time when the aircraft had already reached a high airspeed.

4 SAFETY RECOMMENDATIONS

4.1 Safety actions already implemented

Following the discussions between the investigation commission and the operator, on 12 January 2011 the operator published QRH Temporary Revision 1, NNC-02-1 TEMPO. The revision deals with the reduction of airspeed and turning on the seat belt sign when the autopilot is being disengaged in a trim fault situation. The revision also warns pilots of the possibility of too light control forces, and suggests that the severity of the situation can be estimated from the angle of the horizontal stabilizer.

On 4 November 2011 the aircraft manufacturer published an Advisory Wire (AW300-22-0150, 4.11.2011) for operators, related to this accident. This advisory reminded pilots to firmly grip the control column prior to AP disengagement and, time permitting, to notify the passengers of the situation and turn on the Fasten Seat Belts sign.

4.2 Safety recommendations

1. Good airmanship entails that, before takeoff, pilots brief all relevant changes which were not previously briefed, including any last-minute changes. Standard Operating Procedures and their training must also include the practice of always checking the FMA displays when changes are entered into the AFCS. The final checks in the takeoff position, prior to applying takeoff power, should include the correct runway, compass headings and pressing the TO/GA button and checking the correct modes on the FMA. Checklists should be written in such a manner that they support correct practices in critical phases of the flight. The need is heightened when routines are disturbed, such as with the erroneous compass indications on this flight. Furthermore, on this flight the FMS had to be reprogrammed in a situation in which it cancelled the previously made TO/GA selection during a phase of the flight where, as per the checklists, it would no longer be checked.

   Safety Investigation Authority, Finland recommends that the operator ensure that Standard Operating Procedures as well as pre-takeoff checklists support flight crew action when it comes to confirming the critical takeoff-related issues immediately before takeoff.

2. In a horizontal stabilizer trim fault situation, prior to autopilot disengagement, it is justified to consider adjusting the airspeed to suit the horizontal stabilizer angle. Likewise, the Fasten Seat Belts sign shall be turned on. Both measures can mitigate the risk of serious injury. A airspeed also reduces the stress to the aircraft following autopilot disengagement.

   Safety Investigation Authority, Finland recommends that Transport Canada review the content of Bombardier CL300-type aircraft QRH checklists as regards horizontal stabilizer trim system faults.

3. Pilots must be familiar with the operating principles of the artificial feel systems of the aircraft they fly, and be able to identify any differences therein. This is especially important because all artificial feel systems do not necessarily always proportionately adjust to the airspeed. In this particular aircraft type it is normal for the adjustment of the artificial feel system, according to the angle of the horizontal stabilizer, to consistently follow the airspeed as well.

   However, following the abnormal chain of events on the accident flight the stabilizer, due to a transient fault, remained at the takeoff setting. Consequently, the control forces provided by the artificial feel system also remained at the area of lighter control forces. Their training did not prepare the flight crew for the fact that, following the disengagement of the AP, the pitch control forces would be lighter than expected.

   Safety Investigation Authority, Finland recommends that the European Aviation Safety Agency (EASA) call attention to the content of the type training classroom instruction and simulator training of artificial feel system operating principles, especially with regard to aircraft types in which the system does not directly adjust in relation to airspeed.

4.3 Other observations and proposals

In addition, the investigation commission wants to draw attention to the following topics:

1) The Operator must emphasise the importance of familiarisation flights to its Line Flight Instructors in teaching correct and safe practices to their trainees.

2) The Operator must ensure that the circuit breaker of the Cockpit Voice Recorder (CVR) is opened at the end of an accident or incident flight, and that it remains open for the purpose of preserving the recording.

Helsinki 13.5.2013

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Appendix 1

A SUMMARY OF THE COMMENTS RECEIVED

Comments from Canada

The comments received from the Transportation Safety Board of Canada (TSB Canada) and Transport Canada, Civil Aviation as well as Bombardier, the aircraft manufacturer, were similar.

Apparently, the comments of the Canadian authorities and the aircraft manufacturer were influenced by the fact that they did not have access to the company's OM-B. The OM-B is written by customising the manufacturer's manuals. Hence, it does not always use identical verbiage with them. It is also important to note that the English version of the draft final report did not contain the appendix which describes the company's documentation pertaining to flight operations, and the aircraft's flight systems.

TSB Canada and Transport Canada, Civil Aviation

The comments of the Canadian authorities were taken into account in their entirety and the draft final report was augmented on the basis of them. Transport Canada, Civil Aviation concurred with the second safety recommendation in the draft final report regarding the review of the content of the aircraft's QRH checklists.

Bombardier Inc, the aircraft manufacturer.

The aircraft manufacturer's response included several well-justified and detailed comments. On the basis of the comments the investigation commission made the content of the final report more specific. In particular, the text illustrating the contributing factors was re-edited.

In addition, let it be said that, judging by the comments, the aircraft manufacturer is clearly unaware of the Finnish convention of repeating certain things in different sections of the investigation report.

European Aviation Safety Agency (EASA)

On the basis of the EASA's comments the investigation commission made the third safety recommendation, including its justification, more precise. It seems that the EASA did not have access to the content of the flight crew's type training syllabus, the shortcomings of which the recommendation is based.

Federal Aviation Authority of Russia (Russian CAA)

The Federal Aviation Authority of Russia did not provide any comments to the draft final report.

Finnish Transport Safety Agency, Trafi

In their comments the Finnish Transport Safety Agency did not propose any changes to the draft final report.

Company

In their comments Jetflite Oy did not propose any changes to the draft final report.