Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A08Q0051

OUT-OF-TRIM NOSE DOWN CONDITION LEADING TO AN AIRPLANE UPSET

AIR TRANSAT
AIRBUS A310-308 C-GPAT
QUÉBEC INTERNATIONAL AIRPORT/JEAN LESAGE, QUEBEC
05 MARCH 2008

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Aviation Investigation Report

Out-of-Trim Nose Down Condition Leading to an Airplane Upset

Air Transat
Airbus A310-308 C-GPAT
Québec International Airport/Jean Lesage, Quebec
05 March 2008

Report Number A08Q0051

Summary

The Airbus A310-308 (registration C-GPAT, serial number 597) operated by Air Transat was on a flight (TSC211) from Québec International Airport/Jean Lesage to Montréal International Airport/Pierre Elliott Trudeau, Quebec. At about 1439 Eastern Standard Time, TSC211 was cleared for take-off from Runway 06 and climb to 3000 feet above sea level (asl) on a heading of 110° magnetic. The aircraft lifted off at 182 knots, 44 knots above the calculated rotation speed. During the climb, the rate of climb reached 6300 feet per minute with a pitch attitude of 19°nose up. To level off, the pilot flying used the electric trim for the nose-down trim. The aircraft stopped climbing at 3100 feet asl and started a descent to the assigned altitude. However, at 3000 feet asl, TSC211 in an out of trim condition continued its descent until 1300 feet asl before pitch control was regained. The crew declared an emergency. The aircraft proceeded to Montréal where it landed without further incident. An inspection of the aircraft did not reveal any damage or deficiencies. There were no injuries.

Ce rapport est également disponible en français.

Appendices

Photo

Figures

Tables

1.0 Factual Information

1.1 History of the Flight

Air Transat Flight 211 (TSC211) [1] was on its final leg of a two-leg flight. Earlier in the day, the Air Transat Airbus A310-308 arrived from Paris International Airport/Charles de Gaulle, France, and landed at Québec International Airport/Jean Lesage, Quebec, where 134 passengers disembarked. After the stop, the aircraft was to proceed to Montréal International Airport/Pierre Elliott Trudeau, Quebec, with 9 crew and 89 passengers on board. At about 1415 [2], Québec ground control issued an air traffic control (ATC) clearance authorizing TSC211 to fly to the destination airport, to depart Runway 06 and fly the SID 2 [3] standard instrument departure.

While the aircraft was taxiing to the runway, the crew checked the flight controls. No malfunctions were noted when the elevator was checked.[4] The trimmable horizontal stabilizer (THS) was trimmed to 1.9° nose up [5] with the electric trim, and the slats/flaps were set at 15/15.[6]

At 1438, the crew received new departure instructions. After taking off from Runway 06, the aircraft had to turn right to a heading of 110° magnetic (M), level off at 3000 feet above sea level (asl) and once it was established on its heading, the crew was to contact the Québec terminal. Following this new instruction, the crew reviewed the company's low-altitude level-off procedure.

At 1439, the captain who was the pilot flying (PF) engaged the Go Levers,[7] and power increased to the target thrust, 100 per cent N1 [8] in compliance with the instructions for taking off on a contaminated runway. The runway visual range (RVR) for Runway 06 was measured at 1800 feet, the wind was easterly from 090°M at 24 knots gusting to 32 knots. During the take-off run, the co-pilot's headphones became partially unplugged (see section 1.8.5) which hindered

---

[1] See Appendix C - Glossary for a list of abbreviations and acronyms used in this report.

[2] All times are Eastern Standard Time (Coordinated Universal Time minus five hours).

[3] SID 2 Runway 06: climb to "BV" non-directional beacon (NDB) and then track 064° outbound or on assigned heading by air traffic services (ATS) for radar vectors. All aircraft must maintain 4000 feet asl or assigned altitude.

[4] The elevators moved from 29° trailing edge down to 15° trailing edge up.

[5] The weight and balance form shows that the horizontal stabilizer should be trimmed to 1.82° up.

[6] Position 15/15 corresponds to slats/flaps extended at 15°.

[7] Take-off/go-around levers

[8] Low-pressure turbine speed

his warning the captain that the aircraft had reached Vr. [9] The aircraft accelerated rapidly, and the captain rotated the aircraft at 182 knots after the co-pilot's call.

At 1440:04, TSC211 lifted off. Three seconds later, at about 40 feet above ground level (agl) (about 260 feet asl), the aircraft started a right turn to the assigned heading of 110°M.

At 1440:18, the flight director switched from speed reference system (SRS) to altitude acquisition mode (ALT*) [10]; the aircraft was at 900 feet agl, 19° nose up, the rate of climb [11] was about 6300 feet per minute (fpm) and the indicated airspeed was stable at 213 knots.[12]

At 1700 feet asl, the co-pilot set the flap lever to 15/0 and then retracted the landing gear. At 1760 feet asl, the co-pilot engaged the autopilot (AP). Five seconds later, the captain disengaged it. The AP disengage warning alarm activated and sounded during part of the incident.

At 2350 feet asl, engine power decreased momentarily and reached 87 per cent N1 before increasing to 98 per cent N1. At 3000 feet, the rate of climb was 3100 fpm and the THS went from 0.3° nose down to 2.7° nose down.[13]

At 1440:44, the aircraft reached 3100 feet asl, and transitioned from a climb to a descent. Four seconds later, the aircraft crossed its assigned altitude of 3000 feet asl at 230 knots with a nose-down angle of 2.8° and a rate of descent of about 2000 fpm. The co-pilot firmly warned the PF that the aircraft was in a nose-down attitude. At the start of the descent, the PF pulled on the control column and the elevator fluctuated between 6.7° nose up and 8.7° nose up. The aircraft's pitch attitude varied between 0.4° nose up and 2.5° nose down. The aircraft continued to descend, and the aircraft's speed increased.

At 1440:53, the PF rapidly retarded the throttles so as not to exceed the maximum flap extended speed.[14] As the PF pulled on the throttles, he inadvertently pressed the Go Levers. Within a second of go-around activation, the slats began to retract and as soon as the PF let go of the throttles, the throttles advanced, with N1 momentarily increasing to 99 per cent. The aircraft's speed continued to increase, and in a nose-down attitude of 2.8°, the aircraft crossed 2800 feet asl at a rate of descent of 1730 fpm. Since the aircraft's attitude remained the same and the PF did not respond to the warning that the attitude was nose down, the co-pilot made a second call.

---

9 The rotation speed (Vr) calculated for take-off was 138 knots. It could not be determined if the 100 knots and V1 (decision speed) calls were made. However, the "Rotate" call was missed.

10 The flight director uses the SRS at take-off and during a go-around to maintain a reference speed. When the aircraft approaches the selected altitude, the flight director switches to the altitude acquisition phase of the altitude mode.

11 The vertical speed is derived from the flight data recorder.

12 The maximum flap extended speed (Vfe) at 15/15 is 210 knots.

13 The electric trim was activated for three seconds.

14 Vfe at 15/0 is 245 knots

While the PF was pulling on the control column to stop the descent and reduce the speed, he was surprised to notice on the flight mode annunciator (FMA) that the aircraft was in go-around mode. At 2750 feet asl, or 250 feet below the target altitude indicated on the flight control unit (FCU), the altitude alert sounded, and the caution light was flashing.[15] Since the aircraft continued to accelerate,[16] the PF concluded that the indicated airspeed was incorrect.

Since the co-pilot perceived no change in the aircraft's attitude, he told the captain that he was taking control of the aircraft.[17] The captain let go of the control column, and fearing that the aircraft would enter a stall, he placed his hands in front of the control column to limit its movement towards the back.

At 1440:58, the co-pilot disengaged the autothrottle and rapidly reduced power to 45 per cent N1. At about the same time, the first overspeed warning activated just before full retraction of the slats; the aircraft descended through 2600 feet asl, the aircraft's attitude went from 2.4° nose down to 4.2° nose down, and the speed exceeded 259 knots.

At 1441:05, while the aircraft continued its descent, the THS went from 1.8° nose down to 1.6° nose down and then to 1.2° nose down over a 20-second period. The elevator position fluctuated between 8° nose up and 1.2° nose up and the aircraft's attitude varied between 0.8° nose down and 4.2° nose down. During this time, the aircraft continued to accelerate and reached 324 knots at a rate of descent of 1300 fpm.

At 1441:22, the aircraft's attitude increased to 6.7° nose down. During this time, the engine power and elevator were modulated. However, the rate of descent increased to 3900 fpm.

At about 1454 feet agl, the enhanced ground proximity warning system (EGPWS) activated a Sink Rate alert for four seconds. At the same time, at 345 knots, a second overspeed warning [18] activated and lasted 30 seconds.

From 1441:35 to 1441:43, the EGPWS successively activated the Don't Sink, Terrain, Sink Rate alerts, the Pull Up alarm, and finally, the Too Low Terrain alert.

At 1441:39 the aircraft momentarily descended to a minimum indicated altitude of 1393 feet (radio altitude of 995 feet agl), then transitioned into a climb.

At 1441:45, the THS went from 1.2° nose down to 0.8° nose down. During this time, the aircraft reached its maximum speed during the flight of 370 knots; nose up control column inputs were applied; power increased from 60 per cent N1 to 88 per cent N1; the aircraft pitched nose up and began to climb.

---

15 The altitude alert sounds as long as the aircraft is more than 250 feet beyond the target altitude.

16 In go-around mode, the throttles move forward to the take-off/go-around (TOGA) position.

17 During a flight, if a pilot does not respond after a second consecutive call from another crew member, the pilot must be considered to be incapable of carrying out his or her functions.

18 The maximum operating limit speed (Vmo) is 340 knots.

During a 39-second period while the co-pilot was pulling on the control column to stop the descent, the co-pilot inadvertently made four transmissions on the tower frequency. From these transmissions it was possible to determine that the pilots understood the urgency of the situation, but they did not understand its cause.

At 1442:04, the captain transmitted a PAN PAN message, and then announced that there was a small problem on board and requested clearance to climb to 10 000 feet. The airport controller informed TSC211 that they were transmitting on the tower frequency. At 1442:27, the captain transmitted another PAN PAN message and indicated a problem with the airspeed indication. The airport controller cleared TSC211 to climb without restrictions and reminded TSC211 that they were still on the tower frequency. The aircraft climbed normally.

Afterwards, TSC211 checked its altitude and airspeed with the Québec terminal controller and confirmed the proper functioning of the aircraft's airspeed indicator and altimeter. The electronic centralized aircraft monitor (ECAM) did not generate any fault messages related to the aircraft's control problem, and no warning or indicator lights in the cockpit showed an aircraft malfunction.

The captain took control of the aircraft, and the flight continued to Montréal International Airport/Pierre Elliott Trudeau, at flight level 220 and at a reduced speed of 250 knots.

At 1449, TSC211 informed air traffic services (ATS) that it was cancelling the emergency, that everything had returned to normal and that the problem had likely been caused by an airspeed indicator error. However, the crew was not able to identify the source of the loss of control during the flight. The aircraft landed without further incident.

1.2 *Damage to Aircraft*

After the aircraft landed at Montréal International Airport, it was inspected for severe turbulence and exceeding Vmo. The inspection did not reveal any damage or malfunctions.

1.3 *Personnel Information*

The flight crew consisted of one captain and one check pilot who was acting as co-pilot. The check pilot was evaluating the proficiency of the captain as part of an ETOPS [19] line check.

1.3.1 *Captain*

The captain held a valid Airline Transport Pilot Licence. He worked for the company since March 1997. He started working as a co-pilot on the Lockheed L-1011. In 2004, he qualified on the Airbus A310.

---

19 ETOPS: extended range operations by twin-engine aeroplanes

In 2007, after meeting the company's requirements, he started his captain training. He completed classroom instruction and then simulator training given by Air Transat instructors. He passed the pilot proficiency check (PPC) as captain on the A310 on 05 December 2007. During a line indoctrination flight on 19 January 2008, the unreliable airspeed indication procedure was reviewed. His last check flight for initial qualification as captain completed under the supervision of an approved check pilot (ACP) was done on 24 January 2008. All training complied with the company's training program. At the time of the occurrence, the captain had less than 100 flying hours as pilot-in-command on type.

1.3.2 Co-pilot

The co-pilot held a valid Airline Transport Pilot Licence. He worked for Air Transat since 1997. He started as a co-pilot on the Lockheed L-1011. He became a captain in December 2000. In 2001, he qualified on the A310. He has been an instructor on the A310 since February 2002. In November 2005, he was authorized by Transport Canada to act as an ACP Type B,[20] and in June 2006, he became an ACP Type A. In this capacity, the co-pilot acted as an instructor during simulator training sessions.

1.4 Meteorological Information

According to the 1400 ATIS [21] in use at the time of take-off from Québec Airport, the weather conditions were:

- wind from 90°M at 24 knots, gusting to 36 knots;
- visibility ⅜ of a mile, snow, low drifting snow;
- vertical visibility 1700 feet;
- temperature -10°C, dew point -13°C, altimeter setting 29.54 inches of mercury;
- recent blowing snow and variable visibility between ¼ mile and ½ mile.

The RVR for Runway 06 was variable in the minutes preceding the take-off. At 1436, the RVR was 1000 feet; at 1437, 1400 feet; and at 1438, 1800 feet. Fluctuations in RVR at close intervals constitute a relatively common phenomenon during periods of reduced visibility in snow and low drifting snow.

The authorized take-off minimum RVR for Runway 06 at the Québec Airport, as published in the *Canada Air Pilot* (CAP), is an RVR of 2600 feet (½ mile). Air Transat was authorized under an operations specification [22] to take off with an RVR of 1200 feet (¼ mile).[23] However, the aircraft took off in conditions that did not meet the operations specification requirements:

---

[20] An approved check pilot (ACP) Type B is authorized to conduct line checks. An ACP Type A is authorized to conduct pilot proficiency checks (PPCs) and line checks on behalf of the Minister, including the endorsement of a type rating and an instrument rating.

[21] ATIS: automatic terminal information service

[22] Operations specification Part IV, Number 62

[23] Standard 725.34 (1) of the *Canadian Aviation Regulations* (CARs)

- No alternate aerodrome was specified in the operational flight plan;
- The captain had accumulated less than 100 flying hours on type as pilot-in-command.

The aircraft was not de-iced before take-off because the precipitation was not sticking to the aircraft surfaces. It was determined that no aircraft preceding the departure of TSC211 was de-iced. Analysis of the flight data excluded icing as a contributing factor.

1.5 Aerodrome Information

TSC211 took off from Runway 06 at the Québec International Airport. The aerodrome elevation is 244 feet asl. Runway 06 is 9000 feet long and 150 feet wide. According to the ATIS information in use at the time of take-off, the surface condition of Runway 06 at 1400 was as follows: the runway centreline was cleared for a width of 130 feet, of which 55 per cent was bare and dry; 10 per cent was covered with hard snow and 35 per cent with snowdrifts from 0 to 1 inch; 40 per cent of the rest of the runway was covered with 3 inches of snow and 60 per cent, with ice. The friction index [24] (CRFI) was 0.49 at 1400.

1.6 Communications

1.6.1 Air Traffic Services (ATS)

The airport controller changed the departure clearance while the aircraft was taxiing to the runway threshold. The new clearance was given in compliance with an arrangement between the Québec tower and the Montréal area control centre. The clearance, which included a change in heading and altitude, ensured immediate spacing with an aircraft that had just taken off from Québec. In addition, the change in heading allowed the controller to clear TSC211 for take-off earlier, while also directing it to its destination more quickly. The level of traffic was low at the time of the change in clearance. No aircraft was behind TSC211 for take-off.

Shortly after take-off, the captain broadcast a PAN PAN urgency message on the tower frequency. An emergency situation is classified in accordance with the degree of danger or hazard present, as follows:

- Distress is a condition of being threatened by serious and/or imminent danger and requiring immediate assistance. The spoken word for distress is MAYDAY, and it is pronounced three times.

- Urgency is a condition concerning the safety of an aircraft or other vehicle, or of some person on board or within sight, but which does not require immediate assistance. The spoken word for urgency is PAN PAN, and it is pronounced three times.

---

24 The friction index is obtained using a decelerometer. It is represented on a scale of 0 to 1. The lower the number representing the index, the lower the friction index.

The airport controller reacted by informing TSC211 that it was still broadcasting on the tower frequency and asked for confirmation of the broadcasting frequency. TSC211 responded that it would use the Québec terminal frequency. However, three seconds later, the captain again transmitted PAN PAN on the tower frequency and declared an emergency, while also reporting a faulty airspeed indicator. The airport controller immediately cleared TSC211 to climb to the altitude of its choice and again informed TSC211 that it was transmitting on the Québec tower frequency.

The PAN PAN message is rarely used in North America. In general, aircrews inform ATS of a problem by "declaring an emergency." In Canada, controllers may never hear a PAN PAN or a MAYDAY message except in their initial training. The procedure to follow in the case of a distress or urgency message had not been reviewed in the last refresher training for the Québec tower controllers, nor was there a requirement to do so.

1.7 Flight Recorders

The crew deactivated the cockpit voice recorder (CVR) once the aircraft came to a stop in Montréal. Air Transat removed the flight recorders from the aircraft on the day of the incident. On 12 March 2008, the flight recorders were forwarded to the National Research Council of Canada (NRC) to download the flight data and voice data. On 18 March 2008, the TSB took possession of the recorders.

1.7.1 Cockpit Voice Recorder (CVR)

The CVR was a Loral/Fairchild recorder, model A100A. The recording media was an endless tape loop. The rated recording time was 30 minutes. The actual CVR recording time was 33 minutes. The recording began 15 minutes after the start of the flight. As a result, the audio tape for the pre-take-off briefing, take-off and the airplane upset were overwritten. The CVR complied with the requirements of existing regulations. Most new CVRs with semi-conductor memory have a two-hour recording capacity. The conversations and noise in the cockpit before the start of the CVR recording would have been useful for the investigation.

Subsequent to the TSB's investigation into the accident involving Swissair Flight 111 that occurred in 1998 in Nova Scotia (TSB Report A98H0003), the Board issued two recommendations concerning CVRs. One of the recommendations (recommendation A99-02) was that, as of 01 January 2005, all aircraft that require both a flight data recorder (FDR) and a CVR be required to be fitted with a CVR having a recording capacity of at least two hours. Transport Canada supported this TSB recommendation by amending the *Canadian Aviation Regulations* (CARs) in September 2003. However, the new regulation applies only to aircraft manufactured after 31 December 2003.

In 2005, the TSB investigated the loss of rudder of C-GPAT, which was equipped with a 30-minute recording capacity CVR (TSB Report A05F0047). Since the events related to the loss of rudder occurred 60 minutes before landing, important data recorded on the CVR were overwritten. On 03 March 2006, the TSB issued a safety advisory to Transport Canada to reiterate its concern that, in 2005, some commercial aircraft were still not equipped with a CVR having a recording capacity of at least two hours.

In February 2005, the United States Federal Aviation Administration (FAA) issued a Notice of Proposed Rule Making that stipulated the requirements for two-hour recording capacity CVRs. The same year, Transport Canada decided to review the standards governing flight recorders in order to harmonize with the United States regulations. Since April 2008, the United States regulations require that aircraft manufactured before 07 April 2010 be retrofitted with a CVR having a recording capacity of at least two hours. The aircraft retrofit has to be completed by 07 April 2012. Transport Canada indicated its intent to amend the Canadian regulations governing CVRs. However, no Notice of Proposed Amendment has been issued.

1.7.2 Flight Data Recorder (FDR)

The aircraft was fitted with a Honeywell digital flight data recorder (DFDR), model SSFDR. It recorded more than 300 parameters and contained more than 53 hours of data, including the data for TSC211 and the nine previous flights. The DFDR as configured did not record the following information that could have helped determine the crew's actions: the pilot's and co-pilot's control column force, and activation of the trim switch and radio switch located on the pilot's and co-pilot's control wheel. At TSB's request, Airbus calculated the control column force from the data recorded on the FDR (see section 1.11.3).

1.7.3 Image Recording

The cockpit was not fitted with an image recording system, nor is it required to be. Because of their designs, neither the CVR nor the FDR were able to help identify the crucial actions performed by the pilots. Such a recorder would have been useful in this investigation.

Subsequent to the TSB's investigation into the accident involving Swissair Flight 111 (TSB Report A98H0003), the Board issued two recommendations concerning image recording systems. The first was that regulatory authorities develop harmonized requirements to fit aircraft with image recording systems that would include imaging within the cockpit (recommendation A03-08). The second was intended to protect the image recordings to allow investigating organizations to use the recordings for safety investigations while preventing them from being disseminated for other purposes (recommendation A03-09). Transport Canada indicated its intent to harmonize with the FAA once the standards and requirements are established.

1.7.4 Enhanced Ground Proximity Warning System (EGPWS)

The occurrence aircraft was equipped with a Honeywell Mark V EGPWS. The system provides warning of potentially unsafe terrain closure rate. During the descent, the EGPWS was triggered twice. The aircraft was at 1454 feet agl when the first EGPWS warning indicated an excessive descent rate in relation to the terrain. The second warning was triggered near the end of the descent at 1149 feet agl and stopped shortly after the start of the climb; during the second warning, the EGPWS reported, in sequence, a loss of altitude after take-off, excessive terrain closure rate, excessive descent rate, excessive terrain closure rate, and unsafe terrain clearance.

1.8 Aircraft Information

1.8.1 General

The occurrence aircraft, serial number 597, made its first flight in September 1991. The Certificate of Registration and the Certificate of Airworthiness were valid at the time of the incident. The actual take-off weight of TSC211 was about 106 733 kg, or about 50 267 kg less than the maximum allowable take-off weight. The aircraft's systems were operating as designed.

1.8.2 Automatic Flight System (AFS)

The automatic flight system (AFS) is designed to control the aircraft's flight path, speed and engine thrust by integrating the functions of the AP, the flight director and the autothrottle.

The AFS consists of two flight directors, two APs and two autothrottle systems that can be engaged independently or jointly. The AFS is controlled by the flight control unit (FCU), the flight management system (FMS), the thrust rating panel (TRP) and the Go Levers (see Photo 1).

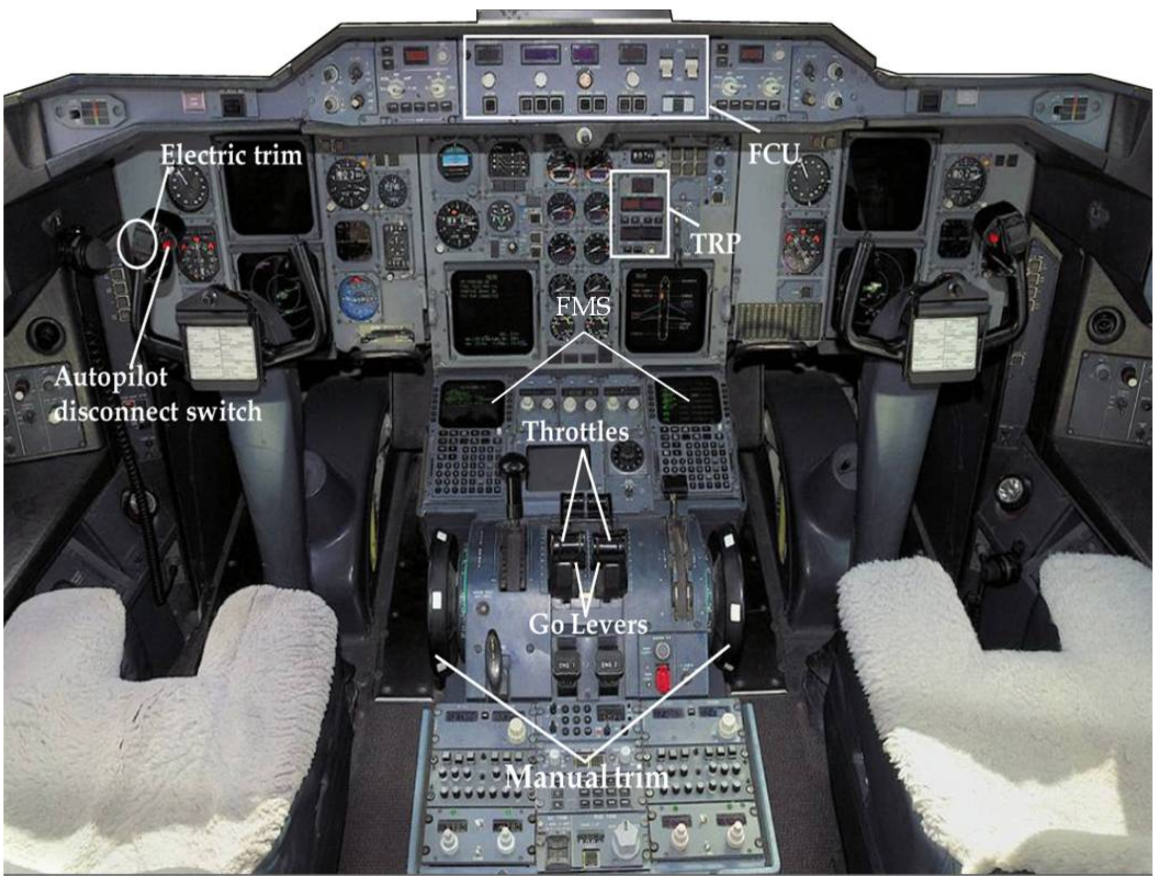

Photo 1. Airbus A310 cockpit

1.8.2.1 Autopilot (AP)

Normally, the flight director operates during the entire flight. The AP is activated by the corresponding FCU lever. The AP is disconnected either by placing the FCU lever in the OFF position, or by pressing the instinctive disconnect switch on the control column (see Figure 3). Disconnecting the AP triggers a simultaneous visual and aural alarm [25] that can be cancelled by pressing the instinctive disconnect switch on the control column a second time.

1.8.2.2 Autothrottle

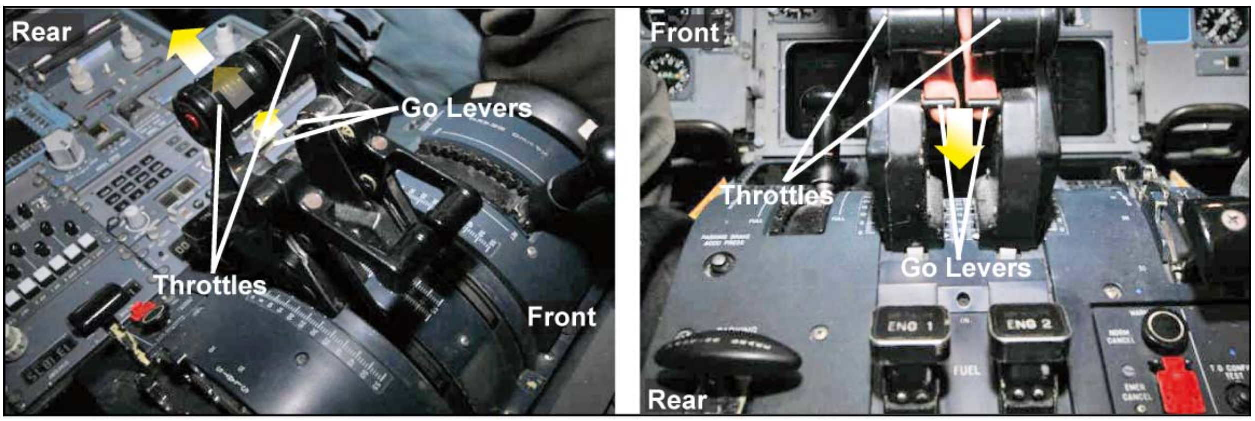

Figure 1. Throttle

Engine thrust is controlled by the throttles; either manually by the crew or automatically by the autothrottle system (see Figure 1). The autothrottle can operate independently from the AP and flight director. The purpose of the autothrottle is to maintain target thrust or target speed depending on the mode selected. The modes in operation are displayed on the FMA (see Figure 2). In addition, the buttons for the different maximum thrusts are illuminated on the TRP.

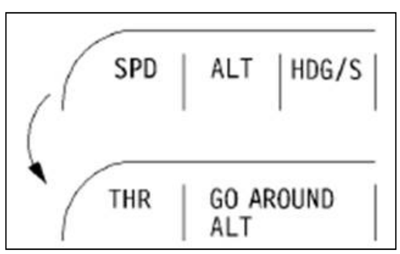

Figure 2. Change in FMA after activation of the mode

25 Cavalry charge

One way to activate the autothrottle is to press the Go Levers on the throttles.[26] In this case, an actuator motor mechanically moves the throttles until the target thrust displayed on the TRP is reached. In flight, when the slats are extended, the Go Levers activate the AFS's go-around mode. One way to deactivate the autothrottle is to press one of the disconnect switches on the throttles.

The autothrottle was activated just before the beginning of the take-off run when the captain pushed the Go Lever buttons. The autothrottle operated until the co-pilot took control of the aircraft.

The investigation into the accident of an Airbus A300 [27] operated by China Airlines at Nagoya Airport in Japan in 1994 [28] determined that inadvertent activation of the Go Levers had been a contributing factor in the accident. The investigation also established that the design of the Go Levers contributed to their accidental activation; normal operation of the throttles allows the possibility of an inadvertent triggering of the Go Levers.

1.8.3 Pitch Control

Pitch attitude is controlled by the elevators and the THS. The elevators are controlled by the control column. The aircraft's pitch trim is provided by the THS whose adjustment range is between 3° nose down and 14° nose up. A trim position indicator on the trim wheel or on the ECAM FLT CTL page (as STAB position) displays the THS position. The THS position is controlled:

- electrically by using the electric trim toggle switches located on the wheels (see Figure 3). It trims at a rate of 0.9° per second when speed is below 200 knots and at 0.17° per second above 240 knots. An aural "Whooler" alarm sounds when it is activated for more than a second and the trim wheel turns in the appropriate direction. The THS stops automatically before reaching the stop. The aircraft was not fitted with any other device except the trim position indicator on the trim wheel to inform the crew that the trim limit has been reached. On the A310, like any conventional aircraft, the natural and immediately detectable indication of an out-of-trim condition is the level of control forces that a pilot is required to apply to the control column. During level-off, the electric trim operated for three seconds.

- manually by the trim wheel located between the pilot seats (see Figure 4). The wheel can override all other THS control modes. Its activation disconnects the two electric command control circuits; as a result, the electric trim becomes non-functional.

- automatically by the AP (Autotrim).

---

26 The Go Levers are activated in the same direction as the direction of movement of the throttles when they are retarded, or in the same direction of movement of the fingers when the throttles are held.

27 The A310 and A300 have the same throttle and Go Levers.

28 Investigation 96-5 conducted by the Aircraft Accident Investigation Commission of Japan

- automatically by the Flight Augmentation Computer (FAC) used to optimize management of the flight envelope. One of the functions of the FAC is speed trim (Vc). Vc trims the THS nose up to optimize the longitudinal stability and handling of the aircraft. It operates at a rate of 0.05° per second when speed is above 200 knots and the flaps are retracted.
-

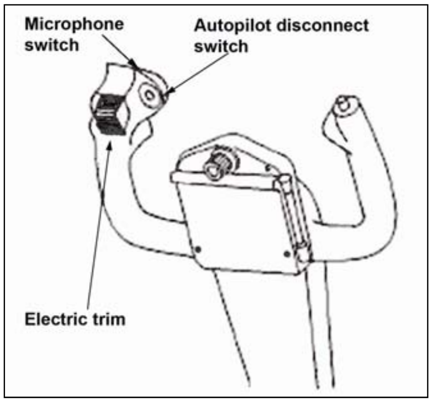

Figure 3. Control column

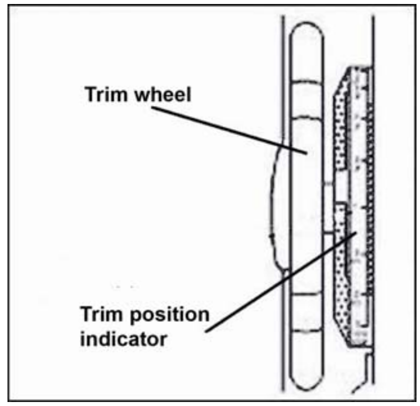

Figure 4. Trim wheel

A review of the flight data indicated that the crew activated the electric trim six times during the 54 seconds of the descent. The duration of each activation was about one second.

The weight and balance calculation done before take-off determined that the aircraft's centre of gravity was 22.46 per cent of the mean aerodynamic chord (MAC). Based on the centre of gravity, the THS was trimmed to 1.8° to balance the aircraft for the climb.[29]

1.8.3.1 Pitch Feel System

Two separate pitch feel systems, controlled by the Feel and Limitation Computer (FLC), gradually increase the forces felt on the control column according to speed, elevator position, Mach number and THS position. Both systems operate during flight; one is active while the other validates the operation of the first.

1.8.4 Wind Shear Alert System

The aircraft was equipped with a wind shear alert system. The system operates during take-off and go-around up to 1300 feet radio altitude. The flight did not generate any shear alerts.

---

29 The desired climb speed was 152 knots (V_2+10 knots).

1.8.5 Communication within the cockpit

Air Transat provides its crews with Sennheiser HMEC-46 headsets. These are manufactured with a dynamic noise compensation feature which reduces cockpit noise by approximately 15 decibels (dB) so the radios need not be loud. The headsets are also equipped with boom microphones that incorporate peak level protection which safeguards ears from volume peaks above 110 dB.

Crews communicate with each other via a voice-activated intercom. External communications require activating the transmit switches located on the control yokes. While Air Transat does not have a specific policy on the use of headsets in the cockpit, both pilots were wearing their respective headsets at the time.

During the take-off roll, however, the co-pilot's headset became partially unplugged. The nature of the contact between the male and female portions of the jack created a loud squeal. This distracted the co-pilot at the moment the aircraft was reaching V1/Vr. The squeal persisted until the co-pilot reinserted the jacks at 2000 feet asl.

1.9 Company Information

Air Transat holds an Air Operator Certificate issued by Transport Canada. The company operates 14 Airbus A310 series 300 and five Airbus A330. The company has, among others, a Flight Operations Division and a Flight Safety Department. The fleet is operated in compliance with Air Transat's quality safety management system (QSMS). The company chief executive officer is directly responsible for the QSMS. In short, the QSMS provides an official, organized process in which the benefits of a reactive system, integrated with a proactive system, work in collaboration to constantly improve safety. The system covers all levels of activity and the documentation related to safety management. One of the elements of the QSMS is to report any unusual operational event to identify the risks and assess them, and adopt strategies to reduce them.

According to the Transportation Safety Board Regulations, operators must file a report with the TSB as soon as possible when difficulties in controlling the aircraft are encountered due to any aircraft system malfunction, weather phenomena, wake turbulence, uncontrolled vibrations or operations outside the flight envelope.

Immediately after the flight, the crew reported the incident to the company, which opened a safety investigation right away. The next day, Air Transat informed the TSB that, while the flaps were being retracted, TSC211 experienced a loss of altitude and exceeded the Vmo by 20 knots as a result of strong wind shear. The company also informed the TSB that, shortly after the crew declared a PAN PAN, the flight returned to normal and the aircraft continued to climb normally. Taking this information into account, the TSB concluded that the weather conditions were the source of the problem and that an investigation into this occurrence would not reveal any safety deficiencies that could compromise transportation safety.

Two days after the incident, Air Transat's assessment of the risks related to the event based on the probability of recurrence and its impact indicated a high risk. According to the company's QSMS, immediate temporary measures had to be implemented within 48 hours. Corrective measures were implemented within the appropriate time frame.

Due to additional information received several days after the incident, the TSB investigators were able to listen to the ATS tapes only 14 days after the event. The TSB found that an additional examination of the facts was required to clarify some items noted during the listening of the tapes. Air Transat provided all data requested by the TSB. After examining the flight data, it was determined that the aircraft experienced a loss of control and that wind shear as reported by Air Transat was not a factor in the incident. Consequently, the TSB decided that a full investigation of the occurrence was necessary to determine the circumstances surrounding the incident and contributing factors, as well as the safety deficiencies, if any.

1.9.1 Standard Operating Procedures (SOPs)

1.9.1.1 Take-off Performance Calculation for Contaminated Runways

The criteria to determine whether a runway is contaminated, is found in three reference documents : the FOM [30], the SOPs manual, and the FCOM [31] in which certain discrepancies have been observed as to use of the term "contaminated runway."

According to the FOM, a runway is contaminated when it is covered with a contaminant and the contaminant is qualified as thin (3 mm or less of water equivalent) or thick (exceeding 3 mm of water equivalent). Although the SOPs manual requires the use of TOGA power on a contaminated runway, it does not take the thickness of the contaminant into account.

Airbus offers operational recommendations [32] to calculate take-off performance on a contaminated runway. These data are not certified, but constitute a guide in selecting the take-off power and speeds. The depth of the contaminant and its water equivalent is used to determine if a runway is wet or contaminated, and consequently which FCOM tables to use. To calculate take-off performance, a runway is considered to be wet when the depth of the contaminant (water, melting snow, wet snow or dry snow) does not exceed the equivalent of 3 mm of water. When the depth of the contaminant exceeds the equivalent of 3 mm of water, the runway is considered to be contaminated and the TOGA take-off power must be used. The FCOM also provides the water equivalents of various types of contaminants.[33] However, these equivalents are not published in the FOM.

---

[30] Flight Operations Manual (FOM)

[31] Flight Crew Operating Manual (FCOM)

[32] Section 2.18.50 of the FCOM

[33] The FCOM states that 0.59 inches (15 mm) of dry snow equals to 3 mm of water.

At the time of take-off, 35 per cent of the cleared runway surface was covered with 0 to 1 inch of snowdrifts. According to the FCOM, the runway conditions corresponded to the criteria for a contaminated runway. In this case, the TOGA power and the take-off speeds for a contaminated runway were to be used. Although the crew used the contaminated runway data to select the take-off power, the wet runway data were used to determine the take-off speeds.

Based on the aircraft's weight and the atmospheric conditions at the time of take-off, the decision speed (V1), Vr and take-off safety speed (V2) should have been 117, 132 and 137 knots respectively. The speeds selected by the crew were 126 knots, 138 knots and 142 knots.

1.9.1.2 *Normal Take-off*

The company's standard take-off procedures provide a sequential detailed description of the take-off actions and calls that the flight crew must complete (see Table 1).

Table 1. Standard operating procedure (SOP) for a normal take-off

Event	Calls/Actions	
	PF	PM [34]
Engage Go Levers	Take-Off FMA call [35]	Checked
Before 80 knots		Power Set
At 100 knots	Checked	One Hundred Knots
At V1		V1
At Vr		Rotate
Positive climb		Positive Climb
	Gear Up	Select gear handle in UP position
When AP is selected	Engage AP	AP Engaged
Acceleration altitude[36]	Accelerating	
Speed F [37]	Flaps 0	Speed Checked Flaps 0
		Select flaps at 15/0
Speed S [38]	Slats Retract	Speed Checked Slats Retracted
		Select flaps at 0/0

34 PM = Pilot Monitoring (In this occurrence, the co-pilot was the PM.)

35 Typically "Thrust, SRS, Runway"

36 3000 feet agl when departing Québec

37 Minimum speed at which flaps can be retracted

38 Minimum speed at which slats can be retracted

The low-altitude level-off procedure differs from the normal take-off procedure in that the climb thrust is selected manually at 1500 feet agl.

Table 2. A low-altitude level-off requires additional action (see section 1.9.1.3)

1500 feet agl	Climb Thrust	Select CL [39] on the TRP

According to the crew's plan, the climb should have occurred as follows:

- Rotation starts at 138 knots, and the aircraft accelerates to 152 knots, V2 + 10 knots.
- The PM raises the landing gear after the aircraft displays a positive climb.
- The AP is engaged and maintains speed at V2 + 10 knots.
- At 400 feet above the ground, the PF starts a right turn to a heading of 110°M using the FCU.
- At 1500 feet above the ground, the PM selects CL on the TRP, and engine thrust is reduced.
- At 3000 feet asl, the AP levels off, the aircraft accelerates to 250 knots, and the PM retracts the flaps and slats.

In fact, some actions prescribed in the take-off procedure were performed either late, or not in sequence, or were omitted:

- The aircraft's rotation occurred at 182 knots rather than 138 knots (that is, the calculated Vr).
- The turn in the direction of the assigned heading was started at a height of about 40 feet agl rather than at 400 feet as specified in the FOM.[40]
- During the initial climb, the aircraft's speed was about 210 knots or almost 60 knots above the standard climb speed.[41]
- Climb thrust (CL) was not selected on the TRP.
- The AP was engaged at 1670 feet agl and then disconnected five seconds later.

---

39 Climb thrust

40 Section 5.1.25 of the FOM: Such turns should never be commenced below 400 feet agl during the day.

41 The climb speed should be 152 knots.

- The flaps were retracted at 1770 feet agl instead of 3000 feet agl.
- The landing gear was retracted after the flaps were retracted; normally, the landing gear is retracted immediately after take-off when the rate of climb is positive.
- Levelling off occurred with a pronounced pitch correction, 100 feet above the authorized altitude. At the time of level-off, vertical acceleration reached 0.25 g.

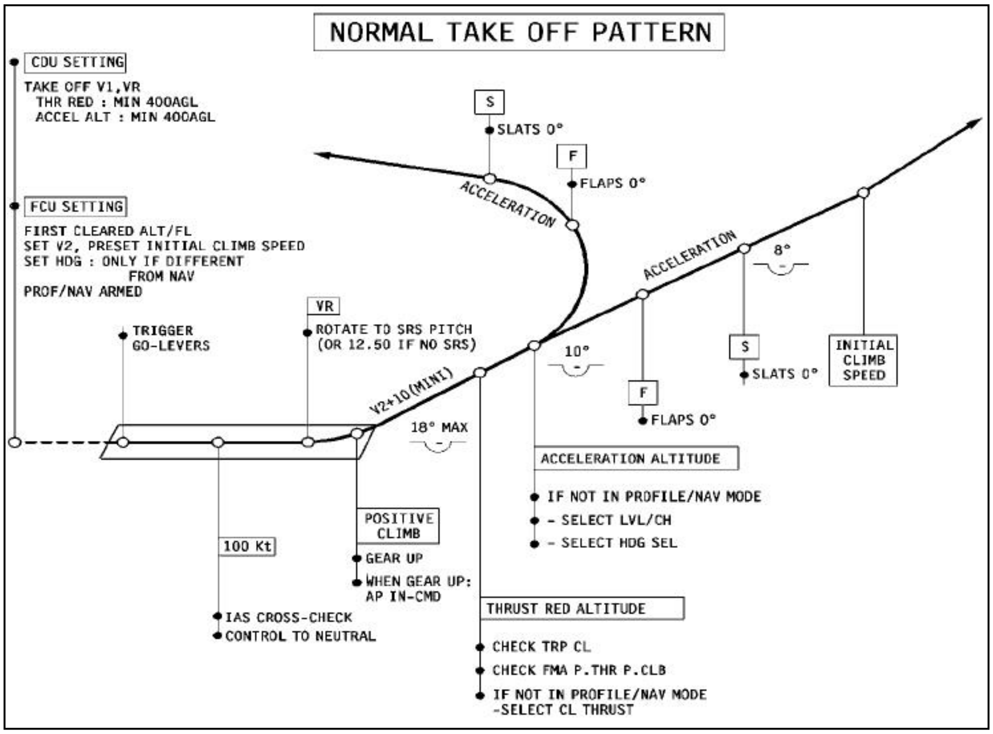

Figure 5. Normal take-off pattern

1.9.1.3 Low-Altitude Level-Off

When levelling off below 3000 feet agl is required, Air Transat flight crews must perform the company's Low-Altitude Level-Off Procedure. In short, the crew performs a normal take-off using the SRS function without vertical mode. At 1500 feet agl, the PF asks the PM to select CL on the TRP. After level-off, the PF controls the speed using the FCU. The flaps and slats are set to the appropriate position for the speed. To continue the climb, the Level Change (L/CH) function is used to maintain the speed displayed on the FCU until 3000 feet agl, at which point the profile (PROF) mode [42] is selected. Although the crew had reviewed the procedure before take-off, none of the actions specified in the procedure were performed.

---

42 In the profile (PROF) mode, the flight management system (FMS) automatically controls the vertical profile (altitude, speed, thrust and time).

1.9.2 Abnormal Procedures

The A310 is equipped with an electronic centralized aircraft monitor (ECAM) that monitors the aircraft's different systems. Some abnormal, urgent situations are reported by the ECAM. Either the ECAM displays the abnormal procedure and the diagram of the system involved, or it refers to the quick reference handbook (QRH). In this incident, the crew was confronted with abnormal pitch behaviour that could be associated with an elevator jam, a pitch trim runaway, an airspeed indication error, a physical interference caused by an incapacitated pilot, or a reduction in aerodynamic characteristics caused by icing. None of these malfunctions were reported by the ECAM. In such circumstances, the crew must identify the abnormal condition and perform the entire appropriate procedure in the QRH.

The abnormal procedures are performed by reading them and carrying them out. However, some urgent situations require immediate action that the pilots must have memorized. These actions can be carried out by the PF or the PM. The memorized actions are in framed boxes in the QRH checklists.

To improve flight crew reactions, management and communications, Air Transat has identified six calls intended to report that the flight is in a situation that requires memorized actions [43] to be followed, including airspeed indication errors. However, a call related to abnormal pitch behaviour or pitch trim runaway is not specified in the SOPs manual.

1.9.2.1 Elevator Jam or High Pitch Force

For an elevator jam or high pitch force, the crew must perform the "Elevator Jam or High Pitch Force" procedure (see Figure 6). Since the procedure is identical for both situations, the actions to perform are presented on the same list.

---

43 Section 2.03.30 of the FCOM

ELEVATOR JAM
or HIGH PITCH FORCE

- **If elevator jam** :
  ELECTRICAL PITCH TRIM .... USE

MAX SPD 285/.78

FOR APPROACH

MANUAL PITCH TRIM .... USE
THROTTLES CONTROL BY PNF .... CONSIDER

- **If alpha-floor activation** :
  ATS .... OFF

NOTE : For approach, normal slats and flaps configuration applies. However, flaps should be selected 15 above 3000 ft, when Slats 15/S-speed is established.

FOR GO AROUND

A/THR .... OFF
Apply GO AROUND thrust smoothly but gradually.

Figure 6. Section 6.09 of the quick reference handbook (QRH)

The first action specified in the procedure is to use the electrical pitch trim. This procedure was not followed by the crew during the undesired descent.

1.9.2.2 Abnormal Pitch Behaviour or Pitch Trim Runaway

Abnormal pitch behaviour can be caused by an out-of-trim situation or pitch trim runaway. The first five actions in the QRH procedure (see Figure 7) must be completed from memory to stop the pitching movement.

ABNORMAL PITCH BEHAVIOR
or PITCH TRIM RUNAWAY

CONTROL WHEEL .... HOLD FIRMLY
TRIM WHEEL .... HOLD FIRMLY
AP (if engaged) .... DISCONNECT
PITCH TRIM LEVERS .... CHECK BOTH OFF
PITCH TRIM .... MANUAL

- **If STAB MAN CTL inop** :
  PROC : STAB JAM (6.09)
- **If high pitch force** :
  PROC : HIGH PITCH FORCE (6.09)

Figure 7. Extract of the "Abnormal Pitch Behavior or Pitch Trim Runaway" procedure

The PF holds the control column and trim wheel firmly. He then disconnects the AP and ensures that the pitch trim levers are off. The manual trim is used to control the pitch while checking to see if there is a stab jam or high pitch force to guide the crew in performing the applicable procedure.

When there is high pitch force, the crew must complete the "High Pitch Force" procedure (Section 6.09 of the QRH) (see Figure 6). The first action consists in trimming with the electric trim. However, when performing the "Abnormal Pitch Behavior or Pitch Trim Runaway" procedure, using the manual trim first disarms the electric pitch trim levers, making it inoperative. This procedure was not used during the pitch control problem.

1.9.2.3 Airspeed Indication Error

An airspeed indication error is caused by partial or complete blockage of the pitot tubes or static vents. The procedure in the case of unreliable airspeed indication is displayed on the control wheels of the aircraft. The procedure is intended to provide pilots with the following information and instructions:

A310 air transat	MISC	REV 28 / SEQ 020	13.01

ALL AIRSPEED INDICATIONS .... DISREGARD
AP/FD (except in level flight), A/THR .... DISCONNECT

■ **To climb :**
SET PITCH .... WITH SLATS EXTENDED : **12.5**° NOSE UP
WITH SLATS RETRACTED – BELOW FL 100 : **7.5**° NOSE UP
– ABOVE FL 100 : **5**° NOSE UP

SET THRUST .... **100** % N1

■ **To level-off/maintain level flight (at safe altitude) :**
SET PITCH .... **2**° NOSE UP

SET THRUST .... BELOW FL 100 : **70** % N1
FL 100 – FL 250 : **80** % N1
ABOVE FL 250 : **90** % N1

■ **To descend :**
SET PITCH .... **1.5**° NOSE DOWN

SET THRUST .... IDLE

Figure 8. Extract of the QRH "Unreliable Airspeed" procedure: memorized elements

- signs to help pilots recognize an airspeed error;
- memorized elements for short-term control of the aircraft;
- read-and-perform elements and pitch/N1 data to maintain control of the aircraft until landing.

According to the FCOM [44] for Air Transat's A310, one of the following observations can be interpreted as a sign of a faulty airspeed indicator:

- abnormal fluctuation in indicated airspeed (IAS);
- difference between the pilot's and co-pilot's IAS;
- divergence between the airspeed indicator and the target speed;
- abnormal behaviour of the autothrottle or AP/flight director (FD) in SPD [45] mode;
- increase in IAS in a pronounced nose-up attitude;

---

44 Section 2.05.80 of the FCOM

45 Speed maintenance mode

- drop in IAS in a pronounced nose-down attitude;
- constant speed during a climb or descent;
- positive or negative climb speed when levelled off;
- unexpected activation of the stall warning and stick shaker;
- simultaneous activation of the overspeed warning device and the stall warning system/stick shaker.

1.9.2.4 Incapacitated Pilot

According to the company's FOM [46], if a pilot does not respond after a second consecutive call from another crew member during a flight, it must be assumed that the pilot is incapable of carrying out his or her functions. The first responsibility of the other pilot is to ensure safe operation of the flight and to control the aircraft. Since the incapacitated pilot may interfere with flight controls, the other pilot must take all necessary actions to maintain control of the aircraft.

Simulator training consists of duplicating the sudden serious incapacitation of a pilot during take-off. Subtle or incomplete incapacitation [47] is not duplicated in the simulator.

1.9.3 Training

Air Transat has its own certified training structure for issuing type ratings. The training program is approved by Transport Canada whose representatives attend some simulator sessions. During simulator sessions, flight command malfunctions, cases in which a pilot is incapacitated and situations involving unreliable airspeed indicators are covered.

Air Transat, like several carriers, uses a training matrix based on the Airbus one.

During initial A310 training, an elevator jam is duplicated once in the fourth session of full flight simulator training (FFS4). According to the training matrix, pitch trim runaway is practised once in the fifth simulator session (FFS5). When a co-pilot receives upgrade training to become a captain, pitch trim runaway is also reviewed in the second full flight simulator training (FFS2) session. Since the simulator used by Air Transat cannot duplicate pitch trim runaway, the practical training is replaced by a briefing from the instructor.

Neither the high pitch force nor the abnormal pitch behaviour is included in the initial, upgrade or recurrent training matrix.

As an instructor in the simulator, the co-pilot had often observed crews in training lose control of an aircraft due to their over use of the electric trim in situations of simulated elevator jam. The co-pilot also erroneously believed that use of the trim in abnormal situations had been a factor in some A310 accidents.

---

[46] Section 8.3 of the FOM

[47] The victim may have lost skills or judgement, may not respond to stimulus, may make illogical decisions, or may appear to be manipulating controls in an ineffective or hazardous manner.

1.10 Tests and Research

1.10.1 Simulator

Pilots of the company's A310 series 300 aircraft train on a Reflectone A310-221 full-flight simulator operated by Canadian Aviation Electronics (CAE) in Montréal. The simulator has been certified by Transport Canada as a Level C simulator [48] since December 2003. CAE uses a Qualification Test Guide (QTG) to certify that the performance and controllability qualities of the simulator conform, within the prescribed limits, to those of the aircraft, and that all regulatory requirements are satisfied. According to CAE maintenance files, the simulator met the certification criteria at the time of flight crew training.

Since Air Transat operates only A310 series 300 aircraft and the simulator recreates the operation of an A310 series 200, flight crew training includes a course on the differences between the two platforms. The differences related to cockpit layout, pressurization, engines, electrical systems, QRH and performance are covered in the training. Two simulator sessions were conducted to support the incident investigation findings. The TSB conducted a series of flights on the Reflectone A310-221 simulator used by Air Transat. The CAE simulator used for the tests was a flight crew training simulator, and not a technical simulator.

1.10.1.1 First Simulator Session

The purpose of the first session was to get a general idea of the aircraft's behaviour and the piloting technique used according to the Air Transat SOPs. The simulator tests enabled investigators to observe different automatic and manual operating modes based on the flight profile of TSC211. Various profiles were completed. During these flights, the aircraft's performance was assessed after applying the relevant procedures for aircraft control problems. The simulator was set to configurations similar to those of TSC211 at various times during the first 10 minutes of the flight.

Since the engines of the A310-221 produce less thrust than the engines of the A310-308, the performance of TSC211 during the take-off and climb could not be duplicated. It was therefore not possible to establish a correlation between the behaviour of the different systems, such as the AP and the engines, of the simulator and C-GPAT. Furthermore, some Air Transat pilots consider that the aircraft reacts differently from the simulator when the AP, flaps and slats are activated.

---

48 *Aeroplane and Rotorcraft Simulator Manual* (TP 9685). There are four levels of aeroplane simulators: levels A, B, C and D, with Level D simulators being the most sophisticated. The more sophisticated the simulator, the more training and checking may be approved for that simulator.

The TSB's key findings during a simulator session done in a configuration similar to the occurrence aircraft during the loss of control were as follows:

- Use of the electric trim resulted in a positive climb.
- Use of the manual trim resulted in a positive climb.
- Use of TOGA power resulted in a positive climb.
- Use of force only on the control column resulted in a positive climb.

Pitch trim runaway cannot be recreated on the A310-221 simulator used for pilot training.

1.10.1.2 Second Simulator Session

The purpose of the second session was to assess simulator control column forces to compare the data obtained with those calculated by Airbus for C-GPAT.[49] The simulator was configured to recreate the conditions of TSC211 at the time of the incident.

The tests showed that the indicated trim wheel position was about 1.1° less than the actual THS position and that the trim's nose-down stop was 2.3° instead of 3.0°. It was observed that simulator control column forces corresponded to the control forces calculated by Airbus for the aircraft up to 250 knots. Above 250 knots, the control forces on the simulator control column were significantly lower than that of the aircraft when the trim was in neutral or nose-down position.

1.10.1.3 Transfer of Training

Transfer of training is defined as the impact that skills and knowledge acquired during training have on operational performance. In some cases, this impact is not always positive. The transfer may be neutral (no impact) or negative. Negative transfer constitutes a risk since the training can lead to faulty or inappropriate decisions or operational actions.

In the case of simulator training, there is a tendency to associate the quality of the transfer of training with the simulator fidelity. Generally, a positive transfer is associated with high fidelity. The fidelity of simulators can be qualified using three criteria: physical fidelity, environmental fidelity and psychological fidelity (Kinkade and Wheaton, 1972).[50] In general, the environmental and psychological fidelities are the most difficult to recreate. Although simulator sessions follow a structured format, it is difficult to recreate unusual and emergency situations that include all environmental and psychological elements such as the dynamic between crew members. Fidelity is not the only element that determines the quality of the transfer of training. Depending on the training objectives, high fidelity is not necessarily required, such as for training in using procedures. High physical fidelity is important for training related to

---

49 TSB Laboratory Report LP 014/2009.

50 D. Meister, "Simulation and modeling" in J.R. Wilson and E.N. Corlett (Eds.), *Evaluation of Human Work*, Chapter 8, pp. 205-209.

situational awareness (perception, analysis and understanding of the information). This importance is justified in particular by the fact that pilots work in an environment that includes checklists used to recognize a problem or malfunction. An accurate physical representation of these situations promotes the memorization of procedures.

In the simulator, the co-pilot was able to overcome the control column force with the THS at its stop, without using the trim.

1.11 Additional Information

1.11.1 Airplane Upset

Over the past few years, several accidents and incidents have occurred in which flight crew had to deal with an unusual aircraft attitude. Airline pilots seldom encounter very steep bank or pitch angles associated with this type of loss of control. There are many explanations for these losses of control, including factors related to the environment, the equipment and the crew, and a large portion of them can be attributed to environmental factors that cannot always be avoided or controlled.

Despite some variations depending on aircraft model, a loss of control occurs when one or more of the following situations arise:

- Nose-up angle greater than 25°
- Nose-down angle greater than 10°
- Bank angle greater than 45°
- An angle within these parameters, but at an inappropriate speed for the flight conditions.

In this occurrence, although the nose-down, nose-up or bank angles were within the parameters, the aircraft's speed was inappropriate; as a result, this occurrence is considered an airplane upset.

1.11.2 Decision Making in a Dynamic Environment

Pilots make decisions in changing conditions where the information available reflects the dynamic environment in which the aircraft is operating. Studies have established that the decision-making process is a loop made up of three sequential steps: situational awareness, decision making and observation of the performance resulting from the decision. The crew must be aware of the actual situation to make an appropriate decision. In a cockpit, counterchecks and effective communication between flight crew members mitigate perception errors.

Situational awareness involves perceiving the elements of the actual situation, understanding the situation, and projecting the situation in time. Among other things, the training, knowledge, experience and preconceived notions of pilots are individual factors that influence their understanding of the situation.

Mental workload is an element that affects the decision-making process. It can be defined as the quantity of information to be analyzed at a given time. Mental workload increases according to the quantity and complexity of the information received. In abnormal or urgent situations, pilots must analyze complex and potentially conflicting information before arriving at an exact understanding of the situation, which is essential for implementing a suitable plan. An information overload can contribute to incorrect situational awareness.

When pilots experience information overload, they frequently concentrate on one part of the information to the detriment of the overall situation. Channelling information this way is beneficial only if the pilot has chosen the relevant information.

1.11.3 Control Column Force During Flight

Since the aircraft is equipped with hydro-mechanical flight controls, the flight control aerodynamic forces cannot be felt by the crew. To avoid the risk of overloading the aircraft, Airbus uses a system that generates an artificial force on the flight controls. Airbus calculated the force placed on the control column by the crew during the incident (see Figure 9). The force felt on the control column is artificial; it is the result of the FLC command which depends on the speed, Mach number and THS position. The control column force is the net force expressed in deca Newtons (daN) [51] at a given time, calculated based on the aircraft's speed, Mach number, THS position and elevator deflection. The accuracy of the data is in the order of +/- 15 per cent to +/- 20 per cent for greater deflection.

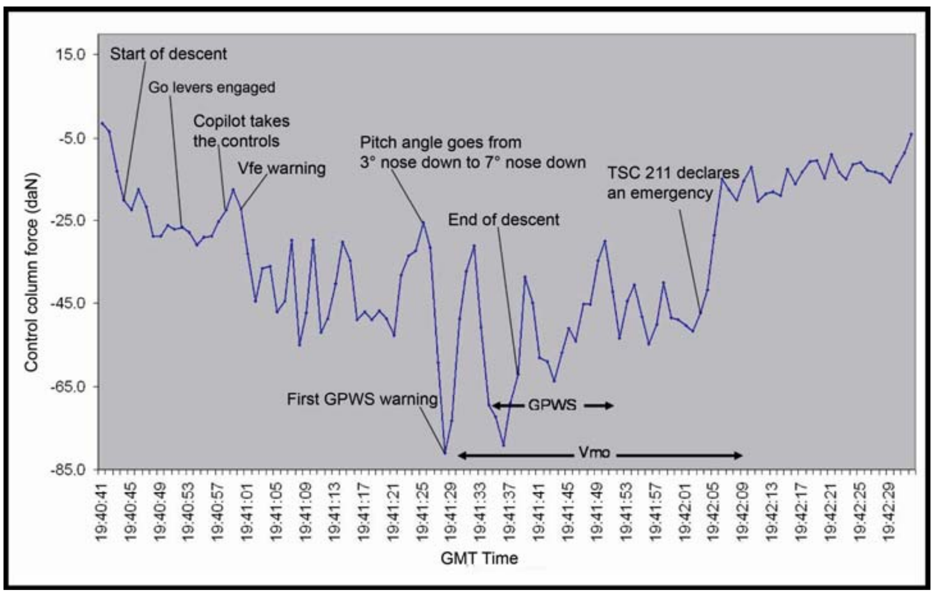

Figure 9. Control column force during descent and loss of control

During the critical phase of the flight, the control column force increased distinctly when the aircraft started its descent and the THS reached the ND stop of the electric trim. The control column force stayed at about -30 daN until the time the co-pilot took the controls. A momentary release of the control column can be observed at this time. Subsequently, the control column

---

51 One daN corresponds to approximately 1 kg of weight.

force varied between -30 daN and -55 daN until the aircraft's nose-down angle reached 7°. From then on, the control column force increased significantly and fluctuated between -30 daN and -80 daN. A significant drop in control column force occurred a few moments later after the beginning of the climb.

The maximum control column force depends on several factors: the strength of individual muscle contractions; mechanical advantages depending on the leverage angles with the body; body position; predominance of right or left hand; emotional state; type of control (conventional control wheel, control column); body position and seat.

According to studies conducted by the United States FAA and Department of Defence, about 5 per cent of the population can pull -80 daN. It was also evaluated that such force could be applied for one to two seconds.

1.11.4 Somatogravic Illusion

The incident occurred in instrument meteorological conditions favourable to somatogravic illusion. The somatogravic illusion occurs in conditions of poor visibility or in darkness when there is an absence of visual cues. Instrument-rated and experienced pilots are not immune to this illusion, which is a subtle and dangerous form of disorientation. The illusion occurs because the body relies on sense organs in the inner ear to maintain balance and, in the absence of visual cues, signals from these organs can produce a very serious disorientation. When the aircraft is accelerating, the sense organs of the inner ear of the pilot send a signal to the pilot's brain that is interpreted as tilting backwards instead of accelerating forward. If the aircraft nose is simultaneously raised, the pilot has a very strong sensation of climbing. The illusion of false climb tends to lead the pilot to lower the nose and descend. The aircraft then accelerates and the illusion can intensify. Pilots cannot rely on their senses and must confirm the aircraft's nose-up position using the attitude indicator on the primary flight display (PFD).

The flight data were used to estimate [52] the aircraft's attitude perceived by the crew (see Figure 10). It was found that:

- At about 1440:44, at the end of the climb, the perceived attitude reached greater than 30° whereas the actual attitude was about -3°.
- Between 1440:44 and 1441:11, the perceived attitude was nose-up and greater than the actual attitude.
- Between 1441:11 and 1441:27, the perceived attitude rose again to +18°.
- A significant decrease in control column forces was noted at 1441:01, 1441:26 and 1441:33, when the pitch attitude was -4.2°, -6.3° and -5.6°, respectively.

---

52 Federal Aviation Administration, *Human Factors Design Standard (HFDS),* 2003, Chapter 14, p. 42-44.

United States Department of Defence, MIL-STD-1472F, Chapter 5, pp. 93-95.

W.E. Woodson et al., *Human Factors Design Handbook*, McGraw-Hill Professional, 1991, p. 615.

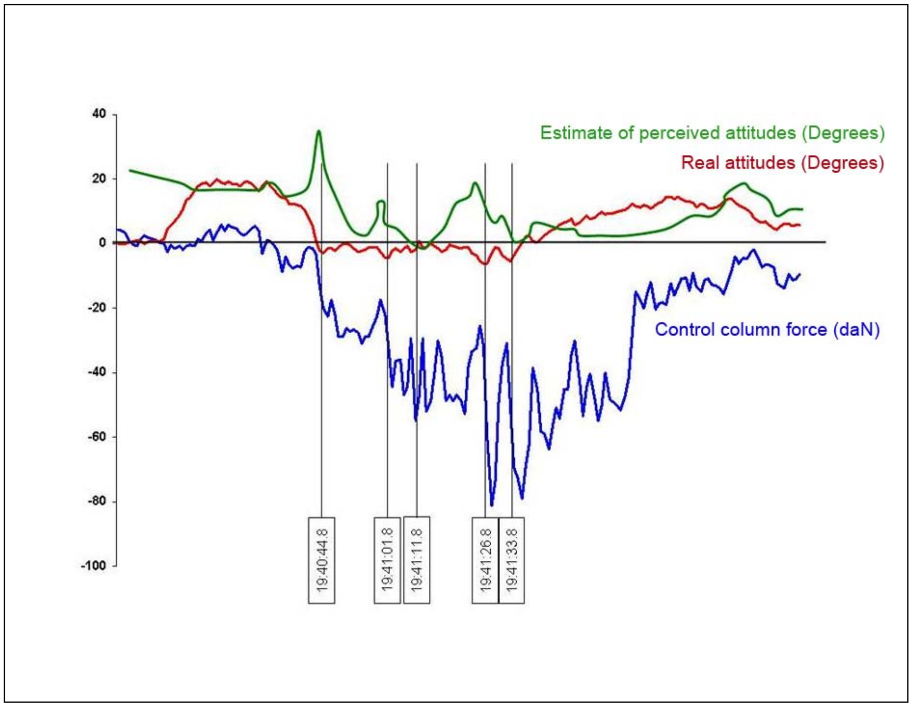

Figure 10. Somatogravic illusion during descent

2.0 Analysis

2.1 Introduction

The aircraft operated normally during the flight and incident. The flight crew was qualified for the flight in accordance with existing regulations, and each flight crew member had received the training required by Transport Canada. The co-pilot, as an ACP Type A, was familiar with the emergency procedures for the A310. Also, given previous experience as a co-pilot and recent captain training, the captain was familiar with the aircraft's systems.

The incident is the result of a combination of operational factors that interacted in such a way that safety standards were not maintained. The loss of pitch control occurred as a result of an abnormal take-off, a climb in which the aircraft's performance was unusual, missed standard calls that were out of sequence, incorrect flight control adjustments, inadvertent engagement of the Go Levers, inaccurate situational awareness and a lack of application of the recommended procedure for pitch control difficulties.

Therefore, the analysis will focus on the crew's decisions and actions, aircraft systems, flight crew training, and conditions that led to a momentary loss of pitch control of the aircraft.

2.2 Air Transat's Reporting of the Event

The day after the incident, Air Transat's Flight Safety Department informed the TSB that TSC211 had experienced a significant loss of altitude and overspeed due to wind shear. Since the actual cause of the aircraft loss of control was unknown, the company assumed that a weather event had caused the undesired descent and Vmo to be exceeded.

A more detailed analysis of the facts and circumstances eliminated the hypothesis of wind shear as a factor in the occurrence. The weather forecast did not mention any wind shear and there were no reports of wind shear before or after the incident. In addition, no flight parameters for TSC211 suggest that the aircraft was subject to the effects of wind shear.

In a QSMS, flight data analysis is an integral part of the company's internal investigation required to identify risks to the safety of operations. Two days after the incident, Air Transat rejected the hypothesis of wind shear. The potentially serious consequences of a loss of control should have prompted the company to update the incident report submitted to the TSB. Despite this fact, for undetermined reasons, the company did not inform the TSB that the report submitted to the TSB was incorrect. In this case, the safety management system failed to report the new known details of the incident. As a result, the start of the TSB investigation was delayed.

The late start of the investigation delayed the taking of statements, which contributed to the loss of information that could have helped determine the crew's actions and the circumstances surrounding the incident.

2.3 *Air Traffic Services Issues*

The controller's relative unfamiliarity with the urgency phrase PAN PAN, and the unexpected radio contact from the crew of TSC211 [53] after they had already been instructed to contact Québec terminal, may have contributed to the lack of a positive response. In a distress or urgency situation, a controller may have only one opportunity to obtain information from the crew. Therefore, it is essential that controllers immediately recognize an emergency situation in order to react correctly. Because this type of situation occurs rarely, and is not reviewed on a regular basis, the risk that the situation may be poorly managed is increased. The controller's actions, however, did not directly contribute to the initiation or outcome of this incident.

2.4 *Before Take-off Preparation*

2.4.1 *Decision to Take off with a Runway Visual Range of 1800 Feet*

The aircraft took off with an RVR of 1800 feet with a captain who had less than 100 flying hours on the A310 as a pilot-in-command. Given his experience, the captain could only take off with an RVR of 2600 feet or more. Therefore, the take-off occurred in visibility conditions below the applicable requirements.

It appears that the crew decided to take off based on the skills of the check pilot who was acting as co-pilot. Since the co-pilot had the proper skills for taking off with an RVR of 600 feet, the crew falsely believed that the low-visibility take-off conditions complied with the applicable requirements. However, according to the company's FOM, for a take-off with an RVR of 1800 feet, the co-pilot had to assume the captain responsibilities and perform the take-off himself, and an alternate airport had to be specified on the flight plan.

The captain had more than 10 years of experience as a co-pilot with Air Transat. However, since low-visibility take-offs may only be done by the captain, it was the first time that the PF was carrying out a take-off with an RVR less than 2600 feet. Although the captain had practised low-visibility take-offs in a simulator, due to the Level C simulator requirements, actual take-off run conditions cannot be simulated. The captain's lack of experience in these conditions may have contributed to the abnormal take-off.

In light of these facts, it is reasonable to believe that pilot training on low-visibility take-offs is deficient since both pilots, one of whom was an instructor and check pilot, incorrectly interpreted the standards.

2.4.2 *Take-off Performance Calculation for a Contaminated Runway*

When a runway is covered by a contaminant, it is essential that the crew can easily determine the take-off speeds and power settings. Although the crew recognized the need to use TOGA power for take-off since the runway was contaminated, the speeds for a wet runway take-off were used. As a result, the V1 used was 9 knots higher than it should have been in the

---

53 Once the aircraft was established on the heading, the crew was required to contact the Québec terminal.

prevailing conditions. Choosing an inappropriate speed can have adverse consequences on a flight in an emergency situation because a V1 higher than the recommended V1 increases the risk of runway overrun in case of an aborted take-off. Nevertheless, selecting speeds for a wet runway rather than a contaminated runway was not a factor in the incident.

The use of inappropriate speeds may have been influenced by the greater difficulty in calculating the take-off performance for a contaminated runway combined with confusion regarding the different definitions of a contaminated runway that are given to crews. Consequently, although the definition of contaminated runway conditions in the company's FOM and SOPs manual are technically accurate, they are different from the definitions used by Airbus in its recommendations for operations on wet or contaminated runways.

2.4.3 Change in the Departure Clearance

Although the crew was advised that the initial departure clearance had been changed while the aircraft was taxiing to the runway, the changes were made in compliance with established standards. In other circumstances, a last-minute change in take-off clearance can increase the crew's workload and thereby also increase the potential for errors. However, since no other aircraft was behind TSC211, the crew had enough time to reconfigure the onboard systems for the new flight profile.

The new clearance reduced the level-off altitude to 3000 feet and changed the heading for the climb. Consequently, the crew followed the low-altitude level-off procedure and, in compliance with the FOM, made the climb in SRS mode rather than PROF mode.

For the following reasons, the crew's workload was heavier during the climb than it would have been, had the aircraft followed the SID initially planned:

- In SRS mode, climb thrust is selected manually on the TRP by the PM after the call from the PF. In PROF mode, speed management occurs automatically. At 1500 feet, thrust is reduced automatically at CLB Thrust. In this occurrence, the CLB Thrust call was not made, and the PM did not reduce the speed at climb thrust.

- The PF had to simultaneously change the heading by 44°, manage a speed that was too fast during the climb, perform the actions set out in the standard take-off procedure and stop the climb at 3000 feet.

- Because the aircraft had to level off 1000 feet lower than specified in the SID and because of an unusually high rate of climb, the crew had less time to complete the required tasks. In fact, actions were not performed,[54] or were completed out of sequence, thereby causing confusion in the cockpit.

---

54 CL on the TRP

In normal conditions, flight crews carry out climb turns concurrently with low-altitude level-off without problem. However, in unusual conditions such as those encountered by TSC211, the additional actions required to follow this type of climb profile can overload the crew resulting in errors.

2.4.4 Planning of Take-off and Climb

The take-off briefing was routine. At the runway threshold, the crew reviewed the low altitude level-off procedure and the SRS mode was selected. Thus, the pilots were familiar with the sequence of calls and actions to complete during the climb and level-off. But the circumstances that influenced the take-off and unusual performance of the aircraft surprised the crew and caused a lack of coordination in the cockpit. Consequently, the sequence of actions and calls during the climb was not followed.

A briefing that would have taken into account the light weight of the aircraft, the TOGA power at take-off and the strong wind would have allowed the pilots to anticipate the aircraft's performance and the consequences on the climb.

2.5 Take-off Run, Climb and Level-off

2.5.1 Take-off Run

The rapid acceleration during the take-off run resulted from the TOGA power, the light aircraft weight and a headwind of 24 to 32 knots. Seventeen seconds after activation of the Go Levers, the aircraft reached the calculated Vr and the aircraft's nose pitched up momentarily for two seconds. THS adjustment before take-off modified the aircraft's static stability and stimulated the aircraft's natural tendency to pitch up at the Vr speed. However, the PF did not recognize that the aircraft's tendency to pitch up indicated that the Vr speed had been reached, and he did not check the speed indicated on the PFD. The PF was fully focused on the outside visual cues and was waiting for the Vr call to rotate the aircraft. Consequently, the rotation was made upon the co-pilot's repeated requests, at 44 knots above the calculated Vr speed. The following factors contributed to the late rotation:

- The co-pilot's headphones became unplugged during the take-off run and the "Rotate" call was not made at the Vr speed.
- The captain was focused on the outside visual cues because visibility was reduced by snow and low drifting snow. Consequently, he did not check the speed on the PFD.
- This was the captain's first take-off on the A310 in low visibility conditions.
- The aircraft was light and reached the Vr speed more rapidly than anticipated by the captain.

2.5.2 Climb

Because the rotation was late, the aircraft lifted off 33 knots above the normal climb speed which was V2 +10 knots. As a result of the late rotation and the rapid acceleration of the aircraft, maximum speed (Vmax) with flaps at 15/15 was reached five seconds later. The PF thus put the priority on managing the speed to the detriment of the other items in the take-off procedure. From that point on, the sequence of actions and standard calls was disrupted, causing a lack of coordination between the crew. The PF put the aircraft into the maximum nose-up angle recommended in the FOM to control the aircraft's speed. The steep nose-up angle and high speed resulted in a rate of climb of 6300 fpm. To avoid increasing the pitch angle, the PF requested that the flaps be retracted at 1770 feet asl rather than at 3000 feet. Because of the high workload, the PF and the PM did not select CL on the TRP. As a result, the engine power was not reduced, and the aircraft maintained its high rate of climb.

The investigation did not determine why the PF initiated the turn before 400 feet. It is possible that the assigned heading was displayed on the FCU [55] before take-off and that the PF followed the command bars on the flight director as soon as the aircraft lifted off. Nevertheless, having to look for the assigned heading as soon as the aircraft took off, and the aircraft's airspeed during the climb, combined with the low-altitude level-off procedure, made the crew's job more complex.

2.5.3 Use of the Autopilot (AP)

Air Transat encourages the use of the AP but does not specify the circumstances in which the AP's use is recommended after take-off. As a result, the captain is free to decide whether to engage it.

According to the FOM (see Figure 5), the PF should have asked the PM to engage the AP shortly after take-off. However, the unusual take-off run and climb sequence delayed the AP's engagement. Engaging the AP immediately after take-off would have reduced the crew's workload by taking control of the aircraft's direction, heading hold, speed management, automatic trim of the THS and capture of the assigned altitude.

Engaging the AP around 1700 feet suggests that the crew wanted to reduce its workload. However, five seconds later, the PF disengaged the AP, but did not cancel the disengagement warning that sounded during the incident. It is reasonable to believe that, although cancellation of the disengage warning is generally a simple task,[56] the flight conditions were generating such a high workload that the pilots felt it was more important to carry out other actions. The warning was one stress factor among others that could have adversely influenced the crew's performance. The PF's decision to disengage the AP was based in part on past experience and conviction that the aircraft would climb through the assigned altitude.

---

55 It could not be determined when the heading selected was displayed on the FCU because the FDR records this parameter only every 60 seconds.

56 To cancel the disengage warning, the autopilot disconnect button must be pressed a second time.

In any case, nothing indicates that, even after late engagement, the AP would not have carried out the level- off correctly. Using it would have avoided the aircraft's out-of-trim situation that occurred when levelling off manually.

2.5.4 Level-off

Levelling off was initiated at 2400 feet at a rate of climb of about 5400 fpm. Since the aircraft was rapidly approaching the assigned altitude, the captain had to push firmly on the control column [57] to arrest the climb at 3000 feet. He therefore used the electric trim for three seconds to reduce the control column force. The THS went from 0.3° nose down on its electric stop at 2.7° nose down. Without realizing it, the captain put the aircraft into an out-of-trim nose-down attitude.

Since the aircraft is not equipped with a warning system to indicate a trim limit condition, the crew must look at the trim position indicator on the trim wheel to determine the THS position or consult the ECAM FLT CTL page. Since they were concentrating on the aircraft instruments, neither the captain nor the co-pilot realized that the aircraft was out of trim and that the nose-down limit had been reached. Although the "Whooler" sounded for about two seconds when the trim was activated, the aural warning was too short to alert the crew.

Although the captain pulled the control column with constant force as soon as the descent started, he did not recognize the aircraft's out-of-trim condition. The force required to move the control column is an important tactile cue that allows the pilots to detect such a condition. Normally, pilots use the electric trim intuitively to cancel the control column force. It is possible that the accumulation of tasks related to flying manually, maintaining the heading, seeking the altitude and managing the speed, and the sounding of the AP disengage warning, overloaded the PF and contributed to his inaction regarding the trim.

2.6 Descent

2.6.1 Start of Descent

As soon as the aircraft began to descend, the captain pulled the control column and maintained the elevator at about 7° trailing edge up. He activated the electric trim four times in the next 14 seconds.[58] The THS went from 2.7° nose down to 1.8° nose down. However, the aircraft's attitude remained below the horizon, and the control column forces varied around 25 daN. Therefore, it can be concluded that the crew actions on the trim and control column were insufficient for the aircraft to adopt a nose-up attitude and to arrest the descent.

---

[57] The gravitational force went from 1 g to 0.25 g.

[58] Each trim activation lasted about one second.

2.6.2 *Inadvertent Activation of the Go Levers*

As the aircraft was descending through 2850 feet, the PF retarded the throttles so as not to exceed the Vfe speed at position 15/0. At that time, he inadvertently activated the Go Levers. Since the slats were partially extended, the go-around mode was activated. As a result, when the PF released the throttles, they advanced automatically to maximum power, and the aircraft accelerated rapidly to the Vfe speed at position 15/0.

The design of the Go Levers allows them to be activated inadvertently. The Go Levers are activated in the same direction as the direction of movement of the throttles when they are retarded, or in the same direction of movement of the fingers when the throttles are held.

2.6.3 *Information Overload for the Captain*

The captain's performance suggests that he was suffering from information overload when he noticed that the aircraft was in go-around mode.

Stress increased on the captain from the beginning of the flight:

- He was on a supervised flight with a company check pilot.
- The rotation was carried out at 44 knots above the Vr speed.
- The initiation of a turn at 40 feet to acquire the assigned heading.
- The aircraft speed varied near the Vfe speed at 15/15 position during the climb.
- The flight was conducted manually.
- The rate of climb was exceptional.
- The climb was carried out at the maximum nose-up angle.
- The completion of normal tasks was disrupted.
- The AP disengage warning was sounding.
- The sequence of calls was not followed, which created confusion in the cockpit.
- The aircraft had climbed through the assigned altitude and then descended below it.
- The co-pilot was advising him to correct the aircraft's attitude as soon as possible.
- The unexpected indication that the aircraft was in go-around mode likely increased the captain's confusion.
- Finally, the aircraft was accelerating towards the Vmo speed.

2.6.4 *Spatial Disorientation and Interpretation of Indications of an Airspeed Indicator Error*

From the start of the descent until the reduction in power, the somatogravic illusion due to the aircraft's acceleration could have suggested that the aircraft had a nose-up attitude when in fact it had a nose-down attitude. The false impression of a nose-up attitude combined with the increase in aircraft speed may have prompted the captain into diagnosing an airspeed indication error.

The misperception of a nose-up attitude and the forces the captain felt on the control column could have inhibited him into further pulling on the control column and trimming the THS. Suffering from information overload, preoccupied by the aircraft's increasing speed, and experiencing a somatogravic illusion, the captain appears to have focused all his attention on the aircraft's speed rather than on the instruments as a whole. This did not allow him to analyze the situation calmly. It is also possible that the recent review of the airspeed indicator error procedure biased his judgement in this respect.

Shortly after control of the aircraft was regained, the captain informed ATS that he thought the incident had been caused by an airspeed indication error. In fact, no flight data suggested that the speed displayed by the PFD was incorrect. Observing various flight instruments would have eliminated a faulty airspeed indicator. The speed was increasing, the aircraft had a nose-down attitude and the altimeter was decreasing.

2.6.5 Captain's Inability to React to the Co-pilot's Calls

Shortly after the descent started, the co-pilot twice warned the captain that the aircraft's attitude did not comply with the desired flight profile.[59] The normal level-off attitude at 250 knots is about 2.5° nose-up. The co-pilot's calls to correct the aircraft's attitude were made while the captain was overloaded. Since the captain did not respond to the warnings or take action to correct the situation, the co-pilot concluded that the captain was incapacitated. It is reasonable to believe that, in a situation of information overload, the captain was concentrating so hard that he did not respond to the co-pilot's urgent requests. The co-pilot informed the captain that he was taking control of the aircraft. The co-pilot's decision was justified and complied with established procedures. After that, since the captain reacted to the stimuli and was rational, it can be concluded that he did not experience any physiological incapacity.

2.6.6 Control of the Aircraft Taken by the Co-pilot

For the reasons stated in section 2.5.4, the co-pilot did not recognize that the aircraft was out of trim when he took control of the aircraft. The rate of descent was about 1640 fpm, the aircraft had a 2.4° nose-down attitude, the aircraft's speed was 259 knots and increasing, and the altitude was 2610 feet and decreasing. To correct the situation, he reduced the thrust, disengaged the autothrottle and pulled on the control column, but without using the electric or manual trim. The decrease in thrust increased the nose-down angle. Since the engines of the A310 aircraft are under the wings, the engine power creates a see-saw effect; a decrease in thrust creates a nose-down moment while an increase in thrust results in a nose-up moment. As a result, despite the co-pilot's force on the control column, the aircraft's attitude went from 2.4° nose-down to 4.2° nose-down and the aircraft's speed continued to increase.

During the descent, the first aural overspeed warning sounded, accompanied by the altitude warning and the AP disengage aural warning (cavalry charge). In such an environment, and seeing that, despite substantial force on the control column, the aircraft was approaching the ground and not pulling up, the flight crew's stress level rose radically. Since he could move the control column a bit and that the trim wheel was immobile, the co-pilot rejected the possibility

---

59 The aircraft's attitude was about 2° nose-down.

that pitch trim runaway or an elevator jam were the source of the problem. The following factors could have contributed to confusing the co-pilot about the aircraft's out-of-trim condition:

- He had just taken control of the aircraft after judging that the captain was incapacitated.
- He did not recognize that the electric trim had reached the nose-down stop during the climb.
- Besides the trim position indicator, nothing suggested that the THS had reached its stop.

2.6.7 Procedures for Pitch Problems

Since the co-pilot was unable to pull up the nose of the aircraft, he was confronted with the problem of a loss of pitch control. The aircraft's speed increased because the aircraft had a nose-down attitude. Since the control column force is partly based on speed, it was becoming increasingly difficult to pull on the control column without using the electric or manual trim. The control forces experienced by the co-pilot should have led him to carry out either the "Elevator Jam or High Pitch Force" procedure, or the "Abnormal Pitch Behavior or Pitch Trim Runaway" procedure. Considering the time frame, the co-pilot had to perform every item of the selected procedure from memory. The fundamental element of these procedures is the use of the horizontal trim to control aircraft pitch. Since both procedures require use of the trim, performing either one would have rebalanced the aircraft and cancelled the control column forces.

The co-pilot did not want to use the trim because he feared using it would worsen the situation. This decision was based on a false perception that use of the trim in abnormal situations had been a factor in previous A310 accidents. This perception seems to have been reinforced by his observations in the simulator after a loss of control during an attempt to regain pitch control with the trim while experiencing an elevator jam. He was also convinced that he could overcome the control column force without using the trim. Therefore, the co-pilot concentrated on pulling on the control column to arrest the descent, without considering the possibility that the aircraft was out of trim.

2.6.8 Flight Crew Performance

Reacting accurately and rapidly in a rare, unusual situation such as a loss of control of an aircraft requires an efficient assessment of the situation. Due to the lack of CVR data, it is not possible to evaluate the interaction between the crew members. Nevertheless, based on the FDR data, the statements and the ATS tapes, it is possible to form a general picture of the performance of the pilots.

Efficient crew resource management requires that pilots agree to a mutual plan after properly understanding the situation. Since the incident occurred relatively close to the ground, the crew had little time to identify the problem and then determine and consider the options in a coordinated manner.

Neither the captain nor the co-pilot was aware of the situation. In this regard, the captain did not realize that the aircraft was accelerating towards the ground. He thought instead that an incorrect speed was displayed, whereas the co-pilot was unaware that the aircraft was out of trim.

At the beginning of the occurrence, the pilots did not work as a team to solve the problem. The evidence supports the possibility that the pilots were applying opposite forces on the control column. Since the captain suspected that the airspeed indicator indicated a higher speed than the aircraft's actual speed, it is possible that he might have wanted to limit movement of the control column towards the back to prevent the aircraft from entering a stall. This confusion continued until the EGPWS sounded.

Had the captain informed the co-pilot that he suspected an airspeed indicator error, this may have improved the performance in the cockpit.

Due to a lack of CVR data, it was not possible to accurately establish when the first attempt at coordination occurred between the pilots. The only communications between the pilots recorded during the occurrence are the co-pilot's inadvertent transmissions on the Québec tower frequency.

From these communications, it can be concluded, in chronological order, that between the first EGPWS warning and the start of the pull-up:

- Both pilots were totally unaware of the nature of the problem.
- The stress level was very high in the cockpit.
- The co-pilot requested assistance from the captain.
- The pilots recognized a pitch control problem.
- The captain attempted to solve the problem.
- Finally, the pilots coordinated their efforts and acted together.

Although the crew diagnosed a pitch problem, neither the captain nor the co-pilot identified the source of the problem. The high stress level probably affected the crew's analytical capacity. As a result, the crew did not perform the appropriate procedure.

2.6.9 Training

The pilots had to call on their experience and knowledge to identify the out of trim condition. Although it was the first time that the pilots had to deal with a problem related to loss of pitch control, the control column forces should have prompted them to perform either the "Elevator Jam or High Pitch Force" procedure, or the "Abnormal Pitch Behavior or Pitch Trim Runaway" procedure. However, neither pilot recognized the signs of a control problem. The fact that the crew, comprised of two experienced pilots including an instructor/check pilot, never came up with a clear diagnosis of the source of the problem, even after regaining control of the aircraft, suggests that training in this respect was deficient.

The crew's performance suggests that some elements of the pilots' ground and flight training did not reach the targeted objectives. In this respect:

- The crew misinterpreted the take-off standards and took off in visibility conditions that were below the applicable requirements.
- The captain rotated the aircraft 44 knots above the rotation speed.
- The captain initiated a turn at 40 feet above ground immediately after lift-off.
- There was a lack of coordination between the pilots.
- Use of the AP was not optimized.
- The captain wrongly diagnosed an airspeed indicator error and then did not complete the memorized tasks required in such a situation.
- The crew did not realize that the aircraft was out of trim.
- The crew did not perform the procedures related to problems with pitch control.

2.6.9.1 Flight Simulator Training

The purpose of the training simulator is to improve safety by avoiding putting crews in risk situations before they are prepared. Air Transat uses a Level C simulator that duplicates the performance of an A310-221. Since the A310-308 aircraft operated by the company are equipped with engines more powerful than those of the simulator, the simulator performance is inferior to that of the Air Transat A310s. However, it should be noted that the differences between the simulator and the A310-308 were deemed acceptable by Transport Canada, which approved its use for the training of Air Transat pilots. Moreover, Air Transat's training program takes these differences into account.

Furthermore, it is not possible to exclude the possibility that the simulator's limitations in recreating the performance of the A310-308 have the potential to generate a nil transfer of training or a negative transfer of training. In this occurrence, the aircraft's performance during the take-off run and climb were clearly higher than the performance that could be recreated in the simulator. As a result, the pilots could not be exposed to such performance during their training. The unusual performance greatly reduced the sequence of execution of the normal tasks, thereby making flight management more complex. The crew had to put off some tasks to carry out others. These disruptions caused the errors that were the source of the aircraft out-of-trim condition. The decision to initiate a turn at 40 feet above ground may have also caused disruptions. Furthermore, as part of continuous training, the company's flight crews cannot benefit from the educational support of using the simulator to duplicate the conditions that led to the occurrence.

During simulator training, one scenario involving an elevator jam at take-off familiarizes pilots with performing the "Elevator Jam or High Pitch Force" procedure. However, high pitch force situation in a context other than take-off is not duplicated in the simulator. As for training in case of abnormal pitch behaviour or pitch trim runaway, the "Abnormal Pitch Behavior or Pitch Trim Runaway" procedure cannot be practised because the simulator cannot recreate this situation. As a result, the simulator training involving a pitch control problem does not enable pilots to call on contextual experience to evaluate the situation.

The tests in the flight simulator used by the company revealed that the simulator had the potential to generate a negative transfer of training. At a speed over 250 knots with neutral or nose-down trim, the control column forces were significantly less in the simulator than it should be. Consequently, the simulator setting can suggest that the control column forces can be overcome without using the trim system.

It is recognized that pilots stricken by complete or subtle incapacitation may involuntarily interfere with flight controls. Although the co-pilot believed that the captain was blocking the control column as a result of incapacitation, he did not use the pitch trim to reduce the force he had to apply to pull on the control column. For this reason, it is reasonable to believe that the training scenarios for incapacitation did not prepare the co-pilot to take all the necessary steps to maintain control of the aircraft.

The investigation did not determine whether the captain restrained the movement of the control column. However, since he suspected that the airspeed indicator was indicating a higher speed than the aircraft's actual speed, it is possible that the captain might have wanted to limit movement of the control column towards the back to prevent the aircraft from entering a stall.

Since the occurrence occurred close to the ground, the effect of the time-related stress could have precipitated each pilot into incorrectly diagnosing the source of the problem. These diagnostics created a bias in the pilots that contributed to their ignoring the critical signs given by the control column forces.

2.7 *Pull-up*

The descent lasted about 54 seconds during which the aircraft went from 209 knots to 359 knots. Since the aircraft was accelerating towards Vmo, the control column forces increased significantly. Although the co-pilot applied pressure on the control column that varied around 50 daN with peaks at 80 daN, the elevator position reached only about half of its maximum deflection. Since the elevator could be moved up to 15° trailing edge up, it can be concluded that the forces generated by the FLC exceeded the co-pilot's physical capacity to move the elevator so as to arrest the descent.

When the co-pilot took the controls, the THS position was 1.8° nose down. After that, the automatic start of the Vc trim and six activations of the electric trim moved the THS to 1.2° nose down over a period of 40 seconds. It is reasonable to believe that the co-pilot inadvertently pressed the trim switch [60] when he was attempting to raise the aircraft's nose since the activations were for a short duration, whereas it would be reasonable to believe that conscious activation of the trim would have been longer if it was being used to reduce the high control column forces.

---

60 The trim switch is on the right yoke of the co-pilot's wheel.

During the initial descent, the elevator deflection (from 7° to 8.7° trailing edge up) did not allow the THS nose down [61] to be countered and the descent to be stopped. It was not until the Vc trim and electric trim moved the THS to under 1.2° nose down that the combined efforts of the co-pilot to move the elevator to about 7° trailing edge up and the increase in power [62] were able to generate enough pitching moment to stop the descent [63] at about 995 feet agl.

The following TSB Laboratory reports were completed:

LP 014/2009 – Simulator Control Force Evaluation
LP 043/2008 – DFDR/CVR Analysis
LP 086/2008 – EGPWS Download

These reports are available from the Transportation Safety Board of Canada upon request.

---

61 THS position was greater than 1.5° nose down.

62 While the co-pilot was pulling on the control column, he increased the engine thrust to CL Thrust.

63 The aircraft's attitude went to 1.5° nose up.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The take-off briefing did not take into account the elements that contributed to the aircraft's exceptional climb performance; as a result, the briefing did not improve cohesion in the cockpit as it should have done.

2. Following the disconnection of the co-pilot's headset, the "Rotate" call was missed during the take-off run. The aircraft lifted off at 182 knots, or 44 knots above the rotation speed calculated by the crew.

3. The actions required to follow the flight path and climb profile contributed to overloading the crew and resulted in errors. The sequence of actions and standard calls during the climb was disrupted. As a result, the crew did not select Climb Thrust (CL) on the thrust rating panel (TRP).

4. When levelling off at 3000 feet, the captain activated the electric trim until the trimmable horizontal stabilizer (THS) reached its nose down stop. This resulted in an out-of-trim condition.

5. To reduce the aircraft's speed, the captain retarded the throttles. However, he activated the Go Levers without noticing. The go-around mode was activated, power increased to the maximum, and the aircraft's speed continued to increase.

6. The unexpected change to go-around mode confused the captain when he had a heavy workload. Exposed to information overload, preoccupied by the aircraft's increasing speed, and experiencing a somatogravic illusion, the captain focused all his attention on the aircraft's speed rather than on the instruments. As a result, the captain did not realize that the aircraft was accelerating towards the ground, and mistakenly believed that the indicated speed was incorrect.

7. The captain did not react to the co-pilot's warnings that the aircraft's attitude did not comply with the desired flight profile. As a result, the co-pilot took control of the aircraft without recognizing that the aircraft was out of trim.

8. When he took the controls, the co-pilot did not realize that the aircraft was out of trim despite the exceptionally high control column forces. As a result, the pitch trim was not used to reduce the control column forces.

9. Because of the proximity of the ground, the crew had little time to identify the problem, determine and consider the options, and coordinate their efforts. As a result, the effect of the time-related stress could have precipitated each pilot into incorrectly diagnosing the source of the problem.

10. The crew's performance suggests that some elements of the company's training program did not reach the targeted objectives regarding the coordination of crew members, the regulations concerning take-off limits, the recognition of an out-of-trim condition, the autopilot use and the understanding and application of abnormal procedures.

3.2 *Findings as to Risk*

1. The different definitions of a contaminated runway given to the pilots can create confusion when it comes to selecting take-off speeds, which can result in the selection of an inappropriate speed for the runway conditions.

2. The airport controller did not help the aircraft after the first PAN PAN message from TSC211. The controller's lack of familiarity with the distress phraseology contributed to his reaction to the declaration of an emergency situation by the crew.

3. Tests in the flight simulator used by the company indicated that the simulator could generate a negative transfer of training.

4. At a speed over 250 knots with neutral or nose-down trim, the control column forces are significantly less in the simulator than it should be. Therefore, the simulator setting can suggest that the control column forces can be overcome without using the trim system.

5. An image recording device would have made it possible to document the actions of the pilots and the environment in the cockpit, which were essential in evaluating the crew's performance. More importantly, image recording would facilitate the identification of safety issues and consequently the corrective action needed to prevent future occurrences.

3.3 *Other Findings*

1. The description of the occurrence submitted in Air Transat's incident report was inaccurate and the TSB investigation was delayed.

2. Since the events related to the loss of control occurred 48 minutes before landing, the audio data related to the occurrence were overwritten. Important information to help understand the events was lost.

3. Only the procedure for sudden serious incapacitation of a flight crew member during take-off with missed calls is practised in the simulator. Therefore, the conditions surrounding subtle or incomplete incapacitation may not be recognized during another phase of flight.

4.0 Safety Action

4.1 Action Taken

4.1.1 Air Transat

Air Transat has, since the occurrence flight, taken the following safety actions:

- The low-altitude level-off procedure contained in the standard operating procedure (SOP) was modified to ensure the initial climb is made in PROF (profile) mode rather than SRS (speed reference system) mode, hence reducing the crew's workload during this maneuver.

- Company procedures applicable to low visibility take-off situations were clarified for the benefit of Company Check Pilots.

- Guidelines on autopilot engagement after take-off have been added to the standard operating procedure (SOP).

- The pilot training program has been modified to include a comprehensive technical and practical training package on Upset Recovery Training. Also, an exercise on Abnormal Pitch Behavior emergency procedure was added to the recurrent simulator training program.

- As a result of a joint initiative, a procedural change was introduced by NAV CANADA at the Québec International Airport/Jean Lesage, Quebec, eliminating the practice of issuing initial departure instructions which require an immediate turn after take-off and a reduced level-off altitude.

- The responsibility for the reporting of reportable accidents/incidents to the TSB has been transferred to the Safety Department and incorporated in the quality safety management system (QSMS) procedures.

4.1.2 Canadian Aviation Electronics (CAE)

CAE examination of the pertinent technical data has shown that there is an error in the simulator's modeling of the force gradient beyond 38 mm of shaft movement in the artificial feel unit. CAE refined the software in the simulator used by Air Transat, to allow the control column force to increase, on an increased gradient, for additional, more realistic control force at high-speed, low altitude, neutral or nose-down trim.

Additionally, CAE decided to verify if the CAE-made Airbus A300 and A310 simulators were also affected by the same issue. As such, on 16 July 2010, CAE wrote a Field Service Bulletin (FSBT-SIM- 438-SW) to all its customers potentially affected as operator of these simulators. This represents approximately 10 simulators around the world. Based on the responses received from customers so far, it seems these simulators may all be affected by the same issue. Therefore, CAE is formally tracking these issues, on a per simulator basis. Also, CAE is pursuing evaluations of these simulators directly with the customers, and will proceed with updates as appropriate.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 05 November 2010.

Appendix A – Summary of Events

The following table is a summary of the important events extracted from the flight data recorder (FDR), air traffic services (ATS) recordings, and enhanced ground proximity warning system (EGPWS).

UTC (hr:min:sec)	SEQUENCE OF EVENTS	IAS (knots)	Alt 29.53 (feet)	Radio Height (feet agl)	Derived VSI (fpm)	Pitch Angle (°)	Stabilizer Angle (°)
19:39:38.4	Take-off run began	37.3	295	-1	0	0	-1.8
19:39:55	Rotation speed was reached	138	295	-1	0	0	-1.8
19:40:02.9	Rotation was initiated	181.8	265	-1	-15	1.4	-1.8
19:40:05.0	Right turn was initiated	188.4	311	40	293	6	-1.8
19:40:18.3	ALT* vertical mode engaged	212.8	1064	897	6282	18.6	-1.8
19:40:24.1	AP #1 engaged	211.9	1668	1442	6240	19	-1
19:40:24.4	Flaps began retracting	212	1770	1469	6358	19	-1
19:40:27.5	Landing gear began retracting	208.6	2017	1766	5920	16.8	-0.7
19:40:29.1	AP disengaged	206.1	2168	1911	5291	18.2	-0.6
19:40:31.8	Pitch angle began to decrease	198	2406	2132	5383	17.1	0.1
19:40:40.9	Trimmable horizontal stabilizer (THS) went gradually from 0.3° nose down to 2.7° nose down	197.5	3018	2632	3120	8.5	0.7
19:40:44.1	Aircraft began its descent	208.9	3112	2685	1202	-2.3	2.6
19:40:46.1	Trim manually activated	218.2	3073	2645	-1060	-1.1	
19:40:48.3	Aircraft descended below 3000 feet asl	230.3	3003	2599	-2063	-2	2.5
19:40:52.1	Trim manually activated	241.9	2862	2501	-2068	-0.06	2.5
19:40:52.2	Captain reduced power by retarding the throttles	242.1	2859	2499	-2058	-0.7	2.5
19:40:53.3	Go-around mode engaged	244	2826	2478	-1718	-1.9	2.3
19:40:54.3	Slats began retracting	244	2793	2454	-2018	-2.5	2.3
19:40:55	Trim manually activated	244.1	2760	2432	-1958	-1.8	2.3
19:40:57.1	Trim manually activated	248	2690	2338	-2117	-1.1	2.0
19:40:58.3	Autothrottle deactivated	252.6	2654	2312	-2044	-1.1	1.9
19:41:00.1	First overspeed warning: Vfe, Vle	258.9	2607	2262	-1667	-2.7	1.8
19:41:05.1	Trim manually activated	277.1	2412	2099	-2003	-2.5	1.8
19:41:19.1	Trim manually activated	300	2082	1793	-1184	-0.7	1.6
19:41:25.0	Pitch angle changed from 3°nose down to 7° nose down	323.2	1970	1649	-1302	-3.7	1.3
19:41:28.2	TSC211 inadvertent transmission on Québec tower frequency	341.2	1826	1480	-3117	-5.2	1.2
19:41:28.6	GPWS Sink Rate warning	342.8	1800	1454	-3443	-4.1	1.2
19:41:29.7	Overspeed Vmo warning ending at 19:41:59.8	345.6	1730	1389	-3789	-1.4	1.2
19:41:30.0	TSC211 inadvertent transmission on Québec tower frequency	345.9	1714	1373	-3470	-1	1.2
19:41:34.6	GPWS Don't Sink, Terrain, Sink Rate, Pull Up, Too Low Terrain warnings ending at 19:41:41.5	356.9	1540	1157	-2719	-4.3	1.2
19:41:37.6	TSC211 inadvertent transmission on Québec tower frequency	359.5	1411	998	-2356	1.6	1.2
19:41:38.8	Aircraft reached minimum altitude of 1393 feet asl	359.3	1393	995	-1119	2.5	1.2
19:41:42.1	TSC211 inadvertent transmission on Québec tower frequency	363.9	1412	1009	392	1.4	1.2
19:41:44.1	Trim manually activated	368	1439	1050	851	3.8	1.2
19:41:46.1	Trim manually activated.	370	1494	1126	1725	4.8	1.1

UTC (hr:min:sec)	SEQUENCE OF EVENTS	IAS (knots)	Alt 29.53 (feet)	Radio Height (feet agl)	Derived VSI (fpm)	Pitch Angle (°)	Stabilizer Angle (°)
	Aircraft reached maximum speed of flight.						
19:41:49.2	TSC211 inadvertent transmission on Québec tower frequency	369	1652	1314	3165	7.4	0.8
19:41:52.6	TSC211 inadvertent transmission on Québec tower frequency	363.1	1888	1630	4316	7.3	0.8
19:41:55.3	TSC211 inadvertent transmission on Québec tower frequency	351.2	2104	1972	4539	7.7	0.8
19:42:03.7	TSC211: "PAN PAN. PAN PAN. PAN PAN. Air Transat, Air Transat 211, Air Transat 211, on a un petit problème, on demande l'altitude en haut de 5000, on demande jusqu'a 10 000 pieds, OK?" [Translation: "PAN PAN. PAN PAN. PAN PAN. Air Transat. Air Transat 211, Air Transat 211, we have a small problem, we are requesting altitude above 5000, we are requesting up to 10 000 feet, OK?"]	326	2857	2670	5512	10.5	0.6
19:42:19.0	Québec tower: "Transat 211, vous êtes toujours avec la tour de Québec. Confirmez sur 118.65?" [Translation: "Transat 211, are you still with the Québec tower. Confirm on 118.65?"]	265.8	4471	4011	6456	13.6	-0.2
19:42:23.6	TSC211: "Oui, OK, alors 127.85, salut."" [Translation: "Yes, OK, then 127.85, out."]	245.2	4890	4373	4838	11.8	-0.1
19:42:25.9	Québec tower: "OK."	238	5066	4536	4540	10.9	-0.1
19:42:26.6	TSC211: "PAN PAN. PAN PAN. Air Transat 110, Air Transat 110, on a un problème. On déclare une urgence. On a un problème d'indication de vitesse." [Translation: "PAN PAN. PAN PAN. Air Transat 110, Air Transat 110, we have a problem. We are declaring an emergency. We have an airspeed indication problem."]	236.1	5122	4590	4771	10.5	-0.1
19:42:36.5	Québec tower: "Transat 211, l'altitude à votre discrétion. Vous êtes toujours avec la tour de Québec." [Translation: "Transat 211, altitude at your discretion. You are still with the Québec tower."]	224.4	5773	5216	3577	10.2	-0.4

Appendix B – Representations made on behalf of Bureau d'Enquêtes et d'Analyses (BEA)

This document does not exist in English.

Observations sur le projet de rapport final sur la perte de maîtrise en tangage de l'A310-308 immatriculé C-GPAT à Québec le 5 mars 2008

La nature de l'événement est considérée comme une perte de maîtrise en tangage par le BST. Le BEA considère plutôt que l'événement est une perte de conscience de la situation dès la course au décollage, qui s'amplifie lors de la mise en palier et se poursuit lors de la descente.

En effet, lors de la course au décollage la vitesse de rotation n'est pas supervisée par l'équipage. Il s'en suit une montée train sorti jusqu'à une hauteur de 1700 pieds.

Au passage de l'altitude palier, l'avion est mis en condition non compensée par l'ordre important de compensateur à piquer du pilote suivi presque immédiatement par un ordre sur la gouverne de profondeur à cabrer, ce qui constitue l'élément pivot de l'événement.

Enfin lors de la descente, l'équipage applique des ordres à cabrer tout en conservant une position du compensateur importante à piquer bien que ce dernier dispose des sensations de raideur au manche pour prendre conscience de cette condition non compensée.

A une hauteur d'environ mille pieds, en dépit de la position du compensateur toujours à piquer, la conjugaison des efforts sur la profondeur à cabrer et l'augmentation de poussée va permettre la mise en palier puis la reprise de la montée.

Durant toutes ces phases l'avion a répondu de manière cohérente aux ordres de l'équipage.

Sommaire
La descente n'est pas volontaire mais elle a été sollicitée par les ordres de compensateur à piquer du commandant de bord.

Chapitre 1.1 (p1)
Le rapport évoque un défaut de fonctionnement du casque du copilote durant la course au décollage qui empêche le copilote de communiquer avec le pilote. Il ne précise pas l'évolution des conditions de communications de l'équipage durant l'évènement.

Chapitre 1.8.3 (p11)
L'indication d'un avion en condition non compensée se trouve dans la raideur de la gouverne de profondeur.
La position du compensateur est indiquée sur le volant de compensateur et sur la page ECAM Flight controls (FLT CTL).

Chapitre 1.9.3 (p21)
Ce que croyait le copilote, qui est instructeur, sur les effets du compensateur lui est personnel et contribue à expliquer son comportement lors de l'évènement. Cependant afin d'éviter d'induire des erreurs de compréhension, il est nécessaire de confronter cette croyance à l'état de l'art du domaine dont les procédures d'utilisations normalisées du constructeur.

Chapitre 1.11.1 (p24)
Dans l'événement, même si les attitudes de l'avion sont restées à l'intérieur des fourchettes prescrites, elles ont évolué ainsi que la vitesse de l'avion de manière *non intentionnelle*. C'est pourquoi l'occurrence peut être définie comme un *Airplane Upset*.

Chapitre 1.11.4 (p26)
Le rapport ne précise pas si à la fin de la montée l'équipage est en IMC, ce qui implique l'absence de repères extérieurs, propice aux illusions somatograviques.

remarques de fond

Chapitre 2.5 (p32)
Ce chapitre est à reconsidérer en tenant compte des observations faites sur le paragraphe 1.8.3.

Chapitre 2.6.3 (p35)
La décision non expliquée de tourner au cap 110 à quarante pieds a vraisemblablement aussi contribué à augmenter le stress du commandant de bord.

Chapitre 2.6.4 (p35)
La phrase sur le manque d'information cruciale est ambigüe. S'il est vrai qu'aucun autre moyen n'existe pour détecter une condition non compensée, la situation n'a pas été analysée de manière efficace car l'équipage n'était plus en synergie. Ainsi le copilote n'a pas analysé les informations disponibles (assiette de l'avion, niveau de la poussée, position du compensateur au moins antagoniste de la position du manche) pour aider le PF à évaluer la situation.

Chapitre 2.6.7 (p37)
Si des accidents sont évoqués d'Airbus A310 dans lesquels l'utilisation du compensateur a constitué un élément contributif, il est nécessaire de préciser en quoi ces accidents sont différents de l'événement C-GPAT où l'utilisation du compensateur à cabrer aurait résolu la situation anormale.

Chapitre 2.6.9 (p38)
La décision d'entreprendre un virage à quarante pieds pourrait être ajoutée à la liste.

Observations sur le projet de rapport final sur la perte de maîtrise en tangage de l'A310-308 immatriculé C-GPAT à Québec le 5 mars 2008

Chapitre 1.1 (p1)

La valeur N1 indique le régime de turbine basse pression.

A 14 h 41 min 45, le THS passe de 1.2° en piqué à 0.8° en **piqué**.

Chapitre 1.8.2 (p9)
Le système de vol automatique comprend aussi les fonctions du directeur de vol.

Les renseignements sur l'accident de Nagoya prendraient plus naturellement leur place dans le chapitre 1.18 Renseignements supplémentaires.

Chapitre 1.8.3 (p11)
Le nombre de Mach participe aussi à la définition de la raideur dans le calculateur FLC.

Chapitre 1.11.3 (p25)
L'effort au manche dépend aussi du nombre de Mach.

Annexe A (p46)
A 19:40:40.9 lire : *Le plan horizontal réglable passe progressivement de **0.3**° en piqué à 2.7° en piqué.*

remarques de forme

Appendix C – Glossary

ACP	approved check pilot
AFS	automatic flight system
agl	above ground level
ALT*	altitude acquisition mode
AP	autopilot
asl	above sea level
ATC	air traffic control
ATIS	automatic terminal information service
ATS	air traffic services
CAE	Canadian Aviation Electronics
CAP	*Canada Air Pilot*
CARs	*Canadian Aviation Regulations*
CL	climb thrust
CRFI	Canadian runway friction index
CVR	cockpit voice recorder
daN	deca Newtons
DFDR	digital flight data recorder
ECAM	electronic centralized aircraft monitor
EGPWS	enhanced ground proximity warning system
ETOPS	extended range operations by twin-engine aeroplanes
FAA	Federal Aviation Administration (United States)
FAC	Flight Augmentation Computer
FCOM	Flight Crew Operating Manual (Airbus)
FCU	flight control unit
FDR	flight data recorder
FLC	Feel and Limitation Computer
FMA	flight mode annunciator
FMS	flight management system
FOM	Flight Operations Manual (Air Transat)
fpm	feet per minute
g	load factor
IAS	indicated airspeed
L/CH	Level Change
MAYDAY	distress message
mm	millimetres
N1	engine compressor speed
NDB	non-directional beacon
PAN PAN	urgency message
PF	pilot flying
PFD	primary flight display
PM	pilot monitoring
PPC	pilot proficiency check
PROF mode	profile mode
QRH	quick reference handbook
QSMS	quality safety management system

RVR	runway visual range
SID	standard instrument departure
SOP	standard operating procedure
SPD	speed mode
SRS	speed reference system
THS	trimmable horizontal stabilizer
TOGA	take-off/go-around
TRP	thrust rating panel
TSB	Transportation Safety Board of Canada
TSC211	Air Transat Flight 211
V1	decision speed
V2	take-off safety speed
Vc	speed trim
Vfe	maximum flap extended speed
Vmo	maximum operating limit speed
Vr	rotation speed
Whooler	aural signal
°	degrees
°C	degrees Celsius
°M	degrees magnetic