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 Occurrence Report
Loss of Control - Stall
Piper J4A C-GFLE
Ponsonby, Ontario
8 June 1997

Report Number A97O0096

Summary

At approximately 1210 eastern daylight time (EDT)\(^{(1)}\), the pilot and passenger were taking-off on a local pleasure flight from runway 14 at the Ponsonby aerodrome, Ontario. The Piper J4A aircraft was in the initial climb after take-off when it was observed by resident witnesses to bank steeply to the right, pitch nose-down, and strike the ground. The aircraft struck soft ground in a near-vertical, nose-down attitude, and a post-crash fire ensued. Some witnesses to the occurrence ran to the accident site to aid in the rescue of the occupants; however, because of the fire, only the passenger was able to be extricated from the burning aircraft. The pilot was fatally injured, and the passenger later died of his injuries at the Hamilton General Hospital.

*Ce rapport est également disponible en français.*

Other Factual Information

The weather reported at Kitchener/Waterloo Regional Airport, 10 nm south of Ponsonby, was as follows: wind 070 degrees magnetic at 3 knots, visibility 15 statute miles, scattered cloud at 4,000 and 10,000 feet, broken cloud at 20,000 feet, temperature 20°C, dewpoint 12°C, and altimeter setting 30.18.

The aircraft had a total airframe time logged as 1743 hours. The aircraft was destroyed by the crash and the post-crash fire. The aircraft flight controls were checked for continuity and all were functional. Upon examination of the powerplant, it was evident that the engine (Continental A-65-8F) was producing substantial power at the time of the impact. Based on estimated fuel and occupant weights, it was calculated that the aircraft was operated near its maximum allowable...
weight of 1301 pounds. Witnesses to the flight observed that the aircraft was flying slower and at a much lower altitude than they normally observed.

The pilot was certified and qualified to conduct the flight in accordance with existing regulations. The passenger had a student pilot permit and was under training towards obtaining his private pilot licence, but he was a passenger on this flight. An autopsy was performed on the pilot and toxicological samples were forwarded to The Centre of Forensic Sciences. Toxicology revealed that the pilot's blood samples contained the prescribed drug Lithium; however, there was no record of this on his medical file with Transport Canada.

Lithium is a medication which has been used since 1949 to treat individuals suffering from a form of mental illness called manic depression or bipolar affective disorder. Lithium is effective in decreasing the intensity and frequency of the episodic mood swings from extreme excitement to deep depression that are characteristic of manic depressive illness. The major concern with lithium therapy is toxicity. The initial symptoms lithium toxicity are usually nausea, vomiting, and diarrhea. With increasing levels of lithium the patient's major target organ is the central nervous system with symptoms consisting of blurred vision, drowsiness, dizziness, vertigo, increasing confusion, slurred speech, transient scotomas (blind spots), and blackouts\(^2\). The concerns with lithium in the aviation environment are the effects on pilot performance of the mental illness for which lithium would be prescribed, the effects of lithium toxicity, and the uncertainty that the patient can maintain blood levels of lithium within the therapeutic range. Because of these concerns medical certification, with regards to pilot licences, is usually denied\(^3\).

There was no evidence that incapacitation or physiological factors affected the pilot's performance.

**Analysis**

There was no pre-accident malfunction of the aircraft found that could have led to this occurrence. The weight of the aircraft was within limits, although it was heavy, and the engine was apparently operating normally. The weather was good and should not have been a factor. From witness descriptions and examination of the crash site, it was established that the aircraft stalled at low level shortly after take-off. Because of the low altitude at which the aircraft stalled, there was insufficient time for the aircraft to recover before it struck the ground. It could not be determined why the aircraft stalled; however, the high gross weight of the aircraft resulted in reduced aircraft climb performance, as observed by witnesses after take-off, which may have had a bearing on the stall.

There was nothing found to indicate that the presence of lithium in the pilot's blood affected his ability to fly the aircraft.

**Findings**
The high gross weight of the aircraft resulted in reduced aircraft climb performance.

The aircraft stalled, for undetermined reasons, at too low an altitude to be recovered.

The pilot had been prescribed the drug Lithium, which was not reported to Transport Canada.

**Causes and Contributing Factors**

The aircraft stalled, for undetermined reasons, at too low an altitude to be recovered.

*This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 13 August 1998.*

1. All times are EDT (Coordinated Universal Time minus four hours) unless otherwise noted.

2. Information was obtained from the following:
   Toxicology - The Basic Science of Poisons;
   CPS - Compendium of Pharmaceuticals and Specialties (32nd Edition 1997); Medical Toxicology - Diagnosis and Treatment of Human Poisoning; and,
   The MERCK MANUAL of Diagnosis and Therapy - 15th Edition

3. Information supplied by Transport Canada Aviation Medicine.

Updated: 2002-10-06
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.

Collision with Terrain
Mountain High Helicopters Limited
Aerospatiale Eurocopter AS-350BA (Helicopter) C-FJJH
Kimberley, British Columbia 10 nm West
11 January 1997

Report Number A97P0009

Synopsis

The pilot, four passengers, and a dog departed from Kimberley, British Columbia, at 1100 mountain standard time (MST)\(^1\) in the Aerospatiale AS 350BA helicopter (serial number 2374), for a visual flight rules flight to an alpine hut located at 6,500 feet above sea level (asl) in the Purcell Mountains, 12 miles to the west of Kimberley. The helicopter did not return to Kimberley and a search was initiated at 1600. The helicopter was found shortly after the search began; it had struck terrain in Boulder Pass, 10 miles west of Kimberley, at an elevation of 7,900 feet asl. All occupants sustained fatal injuries at impact, and the aircraft was substantially damaged.

Other Factual Information

The pilot was the owner of Mountain High Helicopters Limited. At the time of the accident he was the sole pilot flying the helicopter, the company's only aircraft. He was certified and qualified for the flight in accordance with existing regulations and was experienced on the Aerospatiale Eurocopter AS-350BA. He was not instrument rated and had very little instrument training. The pilot's most recent pilot proficiency check was conducted with a Transport Canada inspector on 5 November 1996; the inspector noted that the occurrence pilot was a capable pilot. The pilot was familiar with the Boulder Pass route to the alpine hut, having flown it many times in the past.

Three groups were to be flown to the alpine hut for avalanche training by a tour operator. On the morning of the accident, the flight was delayed because of low cloud and poor visibility along the route. When the low cloud in the vicinity of Boulder Pass began to dissipate, the
pilot and the members of the first group decided to make the first flight. The helicopter departed from Kimberley, with the passengers and their supplies, at 1100. The helicopter was expected to return at 1130. When it did not return on schedule, the tour operator's representative felt it was possible that the helicopter had arrived safely at the hut, and that the pilot had decided to wait for conditions to improve before making the return flight. The representative thus delayed reporting the helicopter as overdue.

A high-frequency radio at the alpine hut normally permitted communication with the tour operator's base in Kimberley. This radio required scheduled maintenance, which the tour guide was to have begun once the helicopter arrived at the hut. This task would likely have taken several hours. A search for the missing helicopter was organized after the representative had waited a reasonable time for the radio maintenance to have been completed, and after the weather had improved enough to preclude the possibility that the flight delay was weather-related.

The helicopter was found beside Boulder Pass by another local helicopter operator, just before nightfall. It had struck terrain at an elevation of 7,900 feet asl, 1,000 feet to the left of the centre of the pass, and 60 feet below the top of the obstructing peak. Based on wreckage deformation and occupant injury patterns, the helicopter's speed at impact was estimated to have been between 50-70 knots. The heading at impact was about 300 degrees magnetic, which is consistent with the track leading to the destination.

The main rotor blades had made a slash in the snow, just before impact, while the helicopter was still airborne. From an analysis of this slash, the helicopter's attitude was estimated to have been nose-down, 40 degrees relative to the horizon and about 80 degrees relative to the steep terrain.

The fuel tank was ruptured at impact and its contents spilled, so a precise weight and balance of the helicopter could not be established. However, based on calculations of the fuel load required for the return flight, including reserves, and on (estimated) occupant and cargo weights, the helicopter's centre of gravity and gross weight were computed to have been well within the allowable limits, and were considered normal for this type of flight.

There is no official weather reporting facility close to Boulder Pass. At the time of the occurrence, the weather at the Cranbrook airport (22 miles east of the accident site) was as follows: ceiling estimated at 3,300 feet asl broken, visibility 25 miles with snow showers in the vicinity, temperature minus 4 degrees Celsius, dewpoint minus 14 degrees Celsius, wind 140 degrees magnetic at 11 knots, and altimeter setting 30.12 inches of mercury.

The outside air temperature at 7,900 feet asl was estimated to have been minus 15 degrees Celsius at the time of the accident.

At 1100 on the day of the accident, a helicopter pilot flying at 7,500 feet
asl through a mountain pass eight miles south of the accident site reported that the visibility was restricted to one-half mile or less, in heavy snow showers. He also observed low cloud at higher elevations. The pilot's onboard global position system navigation equipment calculated a 40 knot east wind at his level. This strong wind caused blowing snow on the surface, which obscured terrain features. Visual reference with the ground was further restricted by low cloud and flat ambient light that tended to create whiteout conditions, particularly in areas above the tree-line, such as the accident site.

Another witness, at the alpine hut, reported that around the time of the accident the wind was very strong and was blowing long plumes of snow off the surrounding mountain peaks. This witness could not establish the visibility or cloud conditions at Boulder Pass at the time of the accident.

Whiteout is an atmospheric optical phenomenon in which the observer appears to be engulfed in a uniformly white glow. Neither shadows, nor horizon, nor clouds are discernible, and depth perception and orientation are lost.

The wreckage was recovered and the airframe, engine, fuel control unit, transmission, drive train, flight controls, and control actuators were examined. No pre-impact mechanical deficiencies or defects with respect to this aircraft or its component parts were identified.

There was evidence of torsional loading on the engine and rotor drive train components. This evidence included torsional deformation of the engine-to-main-rotor transmission drive shaft, and bursting of the tail rotor drive flexible coupling. There was substantial damage to the main rotor blades, all of which revealed compressive, mid-span buckling. The rotor head Flexstar arms and sleeves were severely damaged or completely fractured.

The Turbomeca Arriel 1B engine, serial number 4275, was removed from the airframe and disassembled. Of particular note was a substantial 3.8 mm shift in the alignment marks on the module 05 muffcoupling nut. During assembly, the muffcoupling nut is installed with a torque of approximately 20 dekanewtons (about 89 foot pounds). After torquing, the assembler marks the assembly with a scribe line. If the engine experiences a substantial over-torque, as would happen with a rotor strike, the muffnut will tighten and the scribe lines will shift. This shift of the alignment marks, the torsional damage in the drive train, and the extent of rotor head damage are conclusive evidence the engine was producing power and driving the rotor systems when the main rotor blades struck the ground.

**Analysis**

The slash in the snow, immediately forward of the wreckage, indicates that the helicopter was in a 40-degree nose-down attitude when it struck the mountain. This attitude at impact suggests that the helicopter had a loss of control, while the relatively slow speed at impact suggests that the helicopter had been in this nose-down attitude for only a short
time. If the helicopter had been at a higher altitude when it turned nose-down, and had remained at this pitch for a longer time, the impact speed would have been greater.

The loss of control may have been the result of a technical malfunction, or of some exterior influence such as weather conditions that limited the pilot's visual reference. The wreckage examination determined that the engine was developing power at the time of impact. Given that there was no evidence of technical malfunction with the airframe, the control systems, or any other system, weather conditions were considered.

Adverse weather--such as the strong winds and whiteout conditions reported eight miles south of the accident site--probably existed throughout the Purcell Mountains and may have been encountered by the pilot en route to the alpine hut. If his visibility had been restricted by these conditions, he would have found it necessary to reduce speed. If whiteout conditions in blowing snow had caused him to lose visual reference with the ground, even momentarily, he would have faced an increased risk of losing control of the helicopter. Such a loss of control could have resulted in the nose-down attitude evident at impact.

As there is no evidence of mechanical malfunction of the helicopter, its systems, or its engine, and no reports of actual site weather, nor any witnesses to the occurrence, the causal elements of this accident are undetermined.

Findings

1. The pilot was certified and qualified for the flight in accordance with the existing regulations.

2. The weight and centre of gravity of the helicopter were computed to have been within the allowable limits.

3. No evidence was found of any airframe failure or system malfunction prior to, or during, the flight.

4. The pilot may have encountered adverse weather and low visibility en route to the alpine hut, and these may have affected the pilot's ability to maintain visual contact with the ground.

Causes and Contributing Factors

The cause of this accident was not determined.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 30 April 1998.

1. All times are MST (Coordinated Universal Time minus seven hours) unless otherwise noted.
Air 1997

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 Occurrence Report
Collision With Terrain
Nelson Mountain Air Limited
Cessna 337D Super Skymaster C-FYOC
Salmo, British Columbia, 11 nm SE
3 August 1997

Report Number A97P0211

Summary

The Cessna 337 aircraft departed Nelson, British Columbia, at 1313 Pacific daylight saving time (PDT)\(^1\) for a fire-patrol flight over the south-east region of British Columbia. The aircraft was crewed by a pilot and an observer, and they had been tasked by the British Columbia Forest Service to detect and report smoke or forest fires. The flight was uneventful for the first two hours, and at 1511 the pilot reported by radio to the Forest Service Fire Centre dispatcher that they were five nautical miles (nm) east of Salmo, heading north. Witnesses reported that at about 1518 they saw the aircraft fly at low level up a valley, commence a steep, left turn at the end of the valley, and crash into the mountain side. The aircraft was destroyed at impact, and the two occupants were fatally injured. There was no fire.

*Ce rapport est également disponible en français.*

Other Factual Information

The accident occurred in a steeply-rising mountain bowl at the end of a rising valley. As the valley rises, it makes a 60-degree bend around a knoll. To a pilot flying up the valley toward the knoll, the valley ahead would appear to continue around the knoll for a long distance; however, around the knoll there is the mountain bowl, which cannot be seen until the turn is completed. The mountain bowl walls rise steeply, and the aircraft struck the side of the mountain at the 5,800-foot level, in a steep, nose-down attitude, and flipped onto its back. The wreckage trail was short, characteristic of an aircraft that had struck the ground at a steep impact angle. Witnesses reported that the aircraft did not hit any trees prior to impact, and no evidence of a tree-strike was found at the...
accident site.

The pilot began his flying training in Castlegar in 1989. He had been employed by the company since 1996 as flight instructor and charter pilot. One of his duties as a flight instructor was to teach courses on mountain flying. The pilot had a total flying time of approximately 1,200 hours, with about 34 hours of multi-engine experience, including 21 hours on the Cessna 337 type. He received his ground and flight training on the Cessna 337 in April 1997, and successfully completed his Transport Canada pilot proficiency check (PPC) on 29 April 1997. The pilot was certificated and qualified for the flight in accordance with existing regulations.

The aircraft maintenance documents record that the aircraft, serial number 337-1107, was certificated, equipped, and maintained in accordance with existing regulations and approved procedures. There was nothing found to suggest any airframe failure or system malfunction had occurred either before or during the flight.

According to the aircraft manufacturer's performance data, the stall speed of a Cessna 337 at its maximum gross weight of 4,400 pounds, with the landing gear and flaps retracted and the wings level, is 80 miles per hour (mph) indicated airspeed; in a 60-degree bank turn, it is 114 mph. The maximum rate-of-climb that an aircraft could achieve, in the same environmental conditions that existed at the time of the accident, was calculated to have been about 600 feet-per-minute at 105 mph indicated airspeed.

When the Protection Branch of the BC Ministry of Forests (the Forest Service) requires an aircraft to patrol an area of their interest, it is normal practice for them to submit the flight request to the aircraft company by facsimile. The proposed flight route is assigned by the Forest Service, and is based upon the areas they feel are potentially endangered by fire. The pilots and observers dispatch themselves in accordance with the 'self-dispatch' procedures in the company operations manual. Once the aircraft are airborne, en route flight-following is provided by the South-east Fire Centre of the Forest Service. The crews communicate with the Centre at specific points or times on their route, or when they spot a fire.

The BC Forest Service provided a four-hour training course to the pilots and observers of the aircraft company at the beginning of the fire season to familiarize them with the procedures of detecting and reporting of forest fires. The Forestry Service's manual, Air Patrol Course, states that "...rock slides, pollen flights and low hanging wispy clouds can give the illusion of smoke." In such cases, the pilot must check it out.

On a previous flight, the pilot of the accident aircraft made several low passes at what initially appeared to be smoke, but was found to have been dissipating cloud. The Air Patrol Course manual instructs pilots to fly overhead and conduct a high-level reconnaissance of the smoke or fire prior to any low-level reconnaissance. Furthermore, it states that "...the aircraft must always be in a position to leave the area without
climbing, and up-valley flight toward a dead-end must always allow room for a safe 180-degree turn to downhill."

There were four witness to the accident. Two of the witnesses were hiking on a ridge about 0.75 nm from the crash site when the sound of the aircraft caught their attention. They saw the aircraft flying up the valley, come around the knoll, continue flying until it reached the bowl, then commence a steep left turn; they described the wings as being nearly vertical during the turn. They reported that the aircraft had almost completed the turn when it hit the side of the mountain bowl. Two other witnesses were in the valley driving motorcycles down a dirt road, when they stopped and turned off their engines. They then saw the aircraft flying up the valley at 300 to 400 feet above the valley floor, proceed overhead up the valley, and crash about 0.25 nm from them. They reported that because the weather was hot and dry, the roads were dusty, and their motorcycles had been raising some dust. All of the witnesses reported that the aircraft was in a climbing attitude, with the wings level, while coming up the valley. They also reported that the engines sounded as if they were at high power, and that the aircraft appeared to be under control, with no indication of any difficulties. They also noted that the landing gear and flaps were retracted.

The witnesses describe the weather conditions at the time of the accident as sunny, clear, and hot. The temperature was possibly as high as 30°C. The wind at the crest of the mountain was estimated to have been about 15 knots and going across the tops of the mountains; however, the wind down in the bowl was calm.

**Analysis**

Witness information concerning the aircraft immediately before impact indicates that it was operating normally and under control while flying up the valley. As well, because the pilot had called the Fire Centre seven minutes before the occurrence and gave no indication that there was any problem with the flight or the aircraft, it is unlikely that mechanical defect contributed to this accident. After the radio call, however, it is possible that the crew observed the dust being raised by the motor-cycles in the valley and, suspecting that it was smoke from a forest fire, decided to carry out low-level reconnaissance before reporting the fire to the Fire Centre.

In any event, the pilot flew up a valley that would likely have given him the illusion of there being a suitable exit route. Furthermore, because of the high outside air temperature and the high operating altitude above sea level, the aircraft performance was reduced, such that the available rate-of-climb was only sufficient to keep the aircraft at a near-constant height above the rising valley floor.

It is likely that when the aircraft turned around the knoll, the pilot saw the mountain bowl, realized that the aircraft could not out-climb the steep walls of the bowl ahead, and decided to turn around. The combination of the flight path angle, reported by witnesses as being parallel to the rising valley floor, and the steep impact angle is characteristic of an aircraft that has stalled and struck the ground.
When the aircraft entered the steep turn reported by the witnesses, the aircraft's stall speed would have increased; this airspeed would have now been higher than the suspected climb speed of about 105 mph, and, as a result, the aircraft would have stalled in the turn. The aircraft was reported to be 300 to 400 feet above the ground, and, in this situation, there would have been insufficient height for the pilot to recover from the stall before the aircraft struck the ground.

Findings

- The pilot was certificated and qualified for the flight in accordance with existing regulations.

- There was nothing found to suggest any airframe failure or system malfunction had occurred either before or during the flight.

- The valley and surrounding terrain created an illusion that a suitable exit route existed at the end of the valley.

- The combination of high air temperature and altitude reduced aircraft climb performance.

- When the pilot entered a steep left turn to avoid the rising terrain, the stall speed increased; as a result, the aircraft stalled.

- When the aircraft stalled, its height above the ground was insufficient for the pilot to recover from the stall.

Causes and Contributing Factors

While the pilot was manoeuvring to avoid rising terrain, the aircraft stalled at a height which was insufficient to allow him to effect a recovery. Contributing to the accident was the reduced aircraft climb performance and the illusion created by the features of the surrounding terrain.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 25 February 1998.

1. All times are PDT (Coordinated Universal Time minus 7 hours) unless otherwise noted.
Air 1997

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 Occurrence Report
Rejected take-off/Runway excursion
Propair Inc.
Beechcraft Super King Air 200 C-GCEV
Sept-Îles Airport, Quebec
28 January 1997

Report Number A97Q0015

Summary

The Propair Inc. Super King Air 200 (serial number BB-153), with two pilots and ten passengers on board, was preparing to make a charter flight under instrument flight rules from Sept-Îles to Dorval, Quebec. At 1700 eastern standard time (EST)\(^1\), the co-pilot, in the left seat, began the take-off roll on runway 09. At an indicated airspeed of about 90 knots, 5 knots below rotation speed (\(V_R\)), the aircraft began to drift to the left, toward the runway edge. The copilot attempted unsuccessfully to correct the take-off track using the rudder. At around 100 knots, just before the aircraft exited the runway, the co-pilot pulled the elevator control all the way back and initiated a climb. At about the same moment, the pilot-in-command throttled back, believing that a collision with the snowbank at the runway edge was inevitable. The aircraft descended until it struck the snow-covered surface to the north of the runway and slid on its belly before coming to rest on a heading opposite to the take-off heading. The pilot-in-command was slightly injured. The aircraft sustained considerable damage. The occupants used the main door to evacuate the aircraft.

Ce rapport est également disponible en français.

Other Factual Information

The aircraft was originally scheduled to depart at 1645. The flight was delayed because the pilots had difficulty taxiing to runway 09 because of the poor visibility and the blowing snow. The take-off run began about 200 feet from the threshold of runway 09, where Alpha taxiway begins.

The co-pilot, under the supervision of the pilot-in-command, had been authorized by the pilot-in-command to perform the take-off from the left seat in accordance with the operator's policies. Before take-off, the co-pilot had given the pilot-in-command instructions on the division of tasks, the critical speeds, and the procedure in case of an anomaly. The critical engine failure speed or take-off decision speed (\(V_1\)) and the \(V_R\) were the same. The co-pilot had selected a \(V_1\) of 105 knots, 10 knots higher than the speed suggested by Beechcraft and 5 knots higher than the speed that the pilot-in-command thought he heard and that is normally selected by the company's crews. No instruction or particular procedure concerning the existing environmental conditions was discussed during the briefing.

Just before take-off, light snow and blowing snow had been reported. The wind was blowing at 20 knots, with gusts to 30 knots from 140 magnetic. The runway visual range (RVR) at take-off was 1,600 feet. Runway 09 is 6,572 feet long by 200 feet wide and asphalt surfaced. At the time of the accident, a four-foot-high snowbank ran along the edge of the runway. The runway had been
partially cleared, and a runway surface report had been made 35 minutes before the occurrence. The centre of the runway had been cleared over a width of 100 feet, and was 60% bare and dry, 15% covered with packed snow and 25% covered with snow-drifts less than one inch high; 8 to 12 inches of snow covered the remaining width on each side of the runway.

The aircraft, flaps up, was aligned on the runway centre line, and the co-pilot opened the throttles while the pilot-in-command selected take-off power when the engine torque reached 1,000 foot-pounds. At 80 knots, the pilots confirmed that the airspeed indicators were operating and that take-off power had been set and stabilized. Until that time, the take-off roll was normal, although it had been punctuated by bumps that the pilots attributed to the snow-drifts on the runway. At an indicated airspeed of about 90 knots, the aircraft began to drift to the left. The co-pilot tried to correct the track of the aircraft by pressing gradually on the right rudder control until it was fully depressed. The aircraft continued to drift rapidly toward the north edge of the runway. In the meantime, the aircraft reached 100 knots and the pilot-in-command announced V₁. The co-pilot, who did not hear the V₁ announcement, then announced “J’ai la vitesse” [I have reached the speed]. He took his hand off the throttles to take the wheel, and pulled the control column all the way back to avoid a runway excursion.

At about the same moment, the pilot-in-command, who was not aware of the control problems, looked outside to check on the flight’s progress. He suddenly realized that the aircraft was headed off the runway, and that the co-pilot was pulling on the control column to take off. Believing that the aircraft would not clear the snowbank at the runway edge and that a runway excursion was imminent and unavoidable, the pilot-in-command, without informing the co-pilot, immediately reduced power by throttling back. He wanted to slow the aircraft and reduce the force of the impending impact.

The aircraft, which was in flight, descended until it struck the snow-covered surface north of the runway, then slid on its belly before coming to rest on a heading opposite to the take-off heading. The stall alarm never sounded. As soon as the aircraft came to rest, the pilots carried out the appropriate procedures and checks. The pilot-in-command was slightly injured. The aircraft sustained considerable damage.

The pilot-in-command was certified and qualified for the flight in accordance with existing regulations. He had a total of more than 1,300 hours on the aircraft. The co-pilot had taken his pilot proficiency check (PPC) as pilot-in-command in November 1996. Both pilots had little experience with take-offs with an RVR of less than 2,600 feet. The pilot-in-command, who had made five flights with the co-pilot previously, considered the co-pilot a professional and competent pilot. Neither of them had taken a cockpit resource management (CRM) course. Only operators using aircraft carrying 20 passengers or more and weighing over 19,000 pounds are required to provide CRM training. CRM covers the factors associated with effective crew co-ordination, such as communication, decision making, and workload management.

The take-off minimum for runway 09 at Sept-Îles Airport was an RVR of 2,600 feet. Transport Canada (TC) had granted Propair authorization, in the form of an operating specification, to take off with the Beech 200 when the RVR was 1,200 feet. The company was to respect the requirements of Canadian Aviation Regulations (CARs), paragraph 724.26(2)b): Take-off Minima Reported Visibility RVR 1,200 feet (¼ mile) - Aeroplanes without Certified Engine-out Take-off and Climb Performance of the Commercial Air Services Standards.

One of the requirements of paragraph 724.26(2)b) was that, for aircraft with uncertified performance, like the Beech 200, the pilot-in-command was to receive ground and simulator training. The pilot was to carry out a rejected take-off on a simulator for the aircraft type in question in an RVR of 1,200 feet immediately before V₁. However, after studying the supplementary operating data supplied by Raytheon Beechcraft, TC judged that initial and annual simulator training was not compulsory for Beech 200 operators. Neither the pilot-in-command nor the co-pilot had received this simulator training, and no such training was required.

It is a common practice for the role of pilot flying (PF) to alternate between the pilot-in-command and co-pilot on each flight leg, and Propair endorsed this practice. The company also encouraged its pilots-in-command to authorize experienced co-pilots, when the PF, to fly from the left seat. No
operational or environmental restrictions had been specified, and the pilot-in-command had full decision-making authority in this regard. The purpose of the policy was to facilitate the co-pilots' eventual transition to pilot-in-command. In that respect, paragraph 724.115(21) of the Commercial Air Services Standards stipulates that, if the operator authorizes the co-pilot to conduct take-offs in lower than standard weather minima, the co-pilot must undergo the same training as the pilot-in-command. Only the pilot-in-command had the necessary training to take off in an RVR of 1,200 feet. The company and the two pilots presumed that if the pilot-in-command had the necessary qualifications for an RVR of 1,200 feet, the co-pilot was automatically authorized to perform the take-off.

Analysis of the site\(^2\) showed that the aircraft rolled for about 1,850 feet before taking off, that it flew for 500 feet on a track of 78 magnetic before striking the snow, and that it was nose-up at the moment of impact. The aircraft's estimated performance was slightly below that published in the flight manual take-off distance table. On a dry, firm, and horizontal surface, with a \(V_R\) of 95 knots, the Super King Air could take off after a roll of 1,650 feet.

No failure or malfunction of the aircraft systems or components was found to have contributed to the occurrence. The aircraft was certified and maintained in accordance with existing regulations and approved procedures. The aircraft weight and centre of gravity were within prescribed limits. The aircraft manufacturer had not established any maximum cross-wind component.

The Canadian Aviation Regulations (CAR) came into force on 10 October 1996. A new regulatory requirement stipulated that air carriers establish Standard Operating Procedures (SOP). Briefly, SOPs must clearly and precisely state the responsibilities and tasks of the pilot-in-command and the co-pilot, as well as the PF and the pilot not flying (PNF), for each flight leg and in certain specific situations. SOPs must include the following items: co-ordination between crew members; standardized instructions; standardized announcements; and, rejected take-offs.

Some CAR provisions were assessed as requiring time after coming into force to ensure compliance. Air operators were given a 60-day conditional transition period to determine the requirements for amendments to their SOPs. Since Propair had not completed its SOP manual and had undertaken to make major amendments to its operation documents, TC had extended the company's transition period.

A rejected take-off (RTO) is a take-off that is discontinued after take-off power has been set and the take-off roll has begun. Propair's rejected take-off procedure and the training related to RTO were in compliance with TC requirements. The responsibility and tasks for each pilot were defined by the check pilots during training flights on the aircraft in question. If a pilot discovered an anomaly, he was to announce it; it was the PF who was to reject the take-off when the aircraft speed was below \(V_1\). Although the pilot-in-command was responsible for the operation and safety of the aircraft, he was to inform the co-pilot of his intentions before taking control of the aircraft. Although those responsibilities and tasks were not specified either in the aircraft manual nor in the company's operation manual, they were recognized by Propair. Because of the risk, RTO exercises near \(V_1\) were rarely practised by the pilots. Also, the procedure was practised only with the check pilot. Neither the pilot-in-command nor the co-pilot had carried out an RTO at high speed before.

**Analysis**

Because no pre-impact technical anomaly or mechanical failure that could have explained the aircraft's drift to the left was identified, it appears that the loss of directional control was due to the condition of the runway, the environmental conditions, and the late application of corrective measures.

The take-off roll took place at night, on a partially contaminated runway, in a cross-wind of 16 to 23 knots from the right, and in reduced visibility conditions in snow and blowing snow. Analysis of the weather and runway conditions suggests that, at the time of the occurrence, the surface likely was more contaminated than the latest runway report indicated, and that the available width was less than 100 feet as reported.

The pilot-in-command should have performed the take-off, since the co-pilot had not received the training required by the existing regulations for take-off in lower than standard minima. Given that the
pilot-in-command had little experience in taking off with an RVR of 1,200 feet, it is probable that if he had received simulator training that included take-off exercises in these conditions, he would have been more conscious of the risks involved and that he would have performed the take-off himself. It seems that the following factors affected the pilot-in-command's decision: the flight crew and the company believed that if the pilot-in-command had the necessary qualifications, the co-pilot could take off in an RVR of 1,200 feet; the pilot-in-command considered the co-pilot sufficiently skilled to perform take-offs in the existing conditions; the company encouraged co-pilots to fly from the left seat; and, there were no published procedures for take-off in lower than standard minima.

Except for a \( V_1 \) of 105 knots rather than 100 knots, the co-pilot's briefing was completed in routine fashion, although the environmental conditions dictated a more exhaustive briefing. A more elaborated briefing would have allowed the pilots to plan the take-off in light of the existing conditions and to formulate a joint plan in case of emergency. The fact that the pilot-in-command erroneously thought that the co-pilot had selected a \( V_1 \) of 100 knots indicates that the instructions were taken for granted, at least in part, and the take-off was commenced with each pilot having a different decision speed in mind. This misunderstanding did not contribute to the accident, since the co-pilot initiated rotation at 100 knots, however, it indicates a lack of co-ordination even before the roll began. In fact, the briefing did not improve cohesiveness in the cockpit, as it should have done.

Between 90 knots and 100 knots, the co-pilot had three to four seconds to warn the pilot-in-command that the aircraft was drifting to the left. He did not consider it necessary to report the loss of control immediately, believing that he would be able to correct the turn; subsequently, he was too preoccupied by the events to inform the pilot-in-command. Thus, the pilot-in-command was deprived of information crucial to the flight. The pilot-in-command was only partially aware of what was happening around him. Since he did not have an overall and accurate understanding of the situation, he could hardly make an effective decision. Efficient interpersonal communications are crucial to crew co-ordination. The pilot-in-command might have reacted differently if he had had more time to analyse the situation.

The announcements made after the aircraft began to drift were inaudible, non-standard, or non-existent: the co-pilot did not hear the statement "\( V_1 \)" at 100 knots; the co-pilot announced "J'ai la vitesse" ['I have reached the speed'] instead of \( V_1 \), which the pilot-in-command did not hear; and, the pilot-in-command did not announce that he was rejecting the take-off. Thus, the crew members did not have the same understanding of what had to be done. The terms "\( V_1 \)", "\( V_R \)", "Reject" and "Abort" are standard expressions that are unequivocal when they are pronounced clearly. It is possible that the pilot-in-command would not have cut power if the co-pilot had clearly and precisely communicated the loss of directional control of the aircraft and his intention to continue the take-off.

The pilot-in-command was surprised to discover that the aircraft was heading off the runway and that the co-pilot was attempting to take off. Because the emergency was so sudden, he had very little time to analyse the situation correctly. He concluded that a runway excursion was imminent and that the aircraft would crash in the snow. The pilot-in-command immediately decided to reject the take-off on the basis of his understanding of the circumstances, understanding that cutting the power would result in a crash. According to his understanding of the situation, cutting the power to reduce the aircraft's speed was the safest action to take. The crew was confronted with an unusual situation for which they were not prepared.

According to company procedures and the agreements made in the preflight briefing, it was up to the co-pilot, as the PF, to make the decision to continue or reject the take-off when directional control was lost. In fact, he was the person in the best position to make such a decision. Since the co-pilot had followed the flight progression from the beginning of the take-off run, he could analyse aircraft performance more accurately.

When the co-pilot realized that he had lost directional control and that the aircraft had reached \( V_R \), he judged that if he pulled back on the control column, the aircraft would clear the obstacles ahead. Since the aircraft did not stall before settling into the snow, and there was no obstacle along its track, it is clear that the aircraft would have continued its flight if the power had not been cut.

The crew's actions were not coordinated the way they should have been. The following factors,
although not required by existing regulations, contributed to the lack of cockpit coordination: RTO exercises with an RVR of 1,200 feet had never been practised by the crew members; they seldom practised RTO exercises; they had no experience in carrying out a RTO at high speed; the company had no published SOP; and, the pilots had not received CRM training.

Findings

- The co-pilot had been authorized by the pilot-in-command to perform the take-off from the left seat.
- The pilot-in-command believed that the co-pilot had the necessary qualifications to take off in lower than standard weather minima; however, he did not.
- The take-off roll took place at night, on a partially contaminated runway, in a strong cross-wind, and in reduced visibility conditions in snow and blowing snow.
- During the take-off roll, at an indicated airspeed of about 90 knots, the aircraft veered to the left.
- No pre-impact technical anomaly or mechanical failure that could have explained the aircraft's drift to the left was identified.
- The loss of directional control was probably due to the condition of the runway, the strong cross-wind, and to the late application of corrective measures.
- The decision to continue or reject the take-off when control was lost was up to the co-pilot, as the pilot flying.
- The co-pilot decided to continue the take-off because he judged that if he pulled back on the column, the aircraft would take off and clear any obstacles.
- The pilot-in-command decided to reject the take-off because he believed that a collision with the snowbank on the runway edge was inevitable; he wanted to slow the aircraft and reduce the force of impact.
- The aircraft would have continued its flight if the power had not been cut.

Causes and Contributing Factors

The aircraft crashed as a result of the lack of cockpit co-ordination when the pilot-in-command took control of the aircraft as the aircraft was airborne. The following factors contributed to the occurrence: marginal environmental conditions; contaminated runway surface; poor cockpit management; ineffective briefing; and, inadequate training for rejected take-offs.

Safety Action

Since the occurrence, Propair has taken, or is in the process of taking, the following measures to improve cockpit co-ordination:

- The company has initiated a study to develop a cockpit resource management (CRM) training program appropriate to its operations.
- The company has developed a checklist for take-off in lower-than-standard weather minima. The checklist, in the form of a questionnaire, reiterates the requirements of the existing regulations.
The role transfer policy has been changed: co-pilots may occupy the left seat only when the pilot-in-command is a check pilot.

Propair Inc. has committed itself to revising its training program for rejected take-offs.

Propair standard operating procedures manual, which includes general procedures, procedures to be followed in normal situations, and procedures to be followed in abnormal situations and emergencies, has been published.

The company has also implemented an aviation safety program in conformity with the requirements of Canadian Aviation Regulations (CARs), paragraph 705.

Transport Canada is planning to increase awareness within the aviation community through safety programs, briefings on the conclusions of the report and on cockpit resource management.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles H. Simpson and W.A. Tadros, authorized the release of this report on 30 April 1998.

Appendix A - Take-off Process

1. All times are EST (Coordinated Universal Time [UTC] minus five hours) unless otherwise noted.

2. The take-off process is illustrated in Appendix A.
Air 1998

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 Occurrence Report
Loss of Visual References / Flight Into Terrain
Hélicoptère Colibri Inc.
Bell 206L-1 LongRanger (Helicopter) C-GLBH
12 nm SW of
Saint-Michel-des-Saints, Quebec
04 December 1998

Report Number A98Q0193

Summary

At 1202 eastern standard time, the pilot of the Bell 206L-1, C-GLBH, serial No. 45532, alone on board, took off from Dorval Airport, Quebec, to make a visual flight rules (VFR) cross-country flight. He picked up three passengers at the heliport of the horse club in Laval, Quebec, and took off at 1210 towards the north-north-west for Lac Kempt, Quebec. About 12 nautical miles (nm) south-west of Saint-Michel-des-Saints, visibility was reduced slightly in light snow showers and then became nil in moderate snow showers. At about 1300, the pilot was unable to maintain ground visual contact, lost control of the aircraft and flew into the ground at a high rate of descent. The accident occurred in a forest on the side of a mountain. The aircraft was destroyed, and two of the four occupants lost their lives in the accident.

Ce rapport est également disponible en français.

Other Factual Information

Records indicate that the pilot was certified and qualified for the flight in accordance with existing regulations. He had held a helicopter commercial pilot licence since May 1980 and had a total of about 2075 hours’ flight time, including 1525 hours on the Bell 206L. He was night-rated, but not instrument-qualified. He had worked for the company since March 1995 and had performed the duties of pilot and maintenance engineer of the aircraft. He had held an aircraft maintenance engineer licence since 1978.
The private aircraft, owned by Hélioptère Colibri Inc., was certified, equipped and maintained in accordance with existing regulations and approved procedures. It had a total of 3 576 hours' flight time and had undergone a 300-hour periodic inspection on 21 September 1998. The pilot confirmed that he did not have any problems with the aircraft during the flight. The weight and centre of gravity were within the prescribed limits. The aircraft was equipped for instrument flight.

Shortly after take-off from Laval, the pilot communicated by radio with the control tower of Mirabel Airport, Quebec. Once out of the Mirabel control zone, the pilot operated in uncontrolled airspace. The aircraft was visible on radar until about 18 nm south-west of Saint-Michel-des-Saints when it disappeared beyond the limits of the radar. The last recorded altitude was 3 100 feet above sea level (asl). The terrain in this area ranges between 1 300 feet and 1 950 feet asl.

On seeing the light snow showers ahead, the pilot disengaged the automatic pilot to be ready to slow down or descend. The ceiling was about 2 000 feet, and the pilot had to descend and reduce speed to maintain ground visual contact. The visibility was then reduced rapidly in moderate snow showers. The pilot lost all ground visual reference and entered whiteout conditions. He then initiated a right turn in an effort to maintain ground visual contact. On glancing at the instrument panel, in particular the flight attitude indicator, he noticed that the helicopter was descending; he corrected by trying to return it to level flight. The pilot, still not having regained ground visual contact, became disoriented while trying to regain control of the aircraft. When he saw the ground, the aircraft was nose-down at tree-top level. He straightened the aircraft's nose slightly, and it then struck the ground slightly banked to the left at a high rate of descent and almost zero forward speed. The aircraft was destroyed; the left rear passenger died immediately, and the right rear passenger died sometime later. The pilot in the right front seat and the passenger in the left front seat suffered serious injuries.

Environment Canada determined that the following conditions were prevailing in the vicinity of Saint-Michel-des-Saints at the time of the accident: at about 1300 eastern standard time (EST)\(^1\), the ceiling was 2 000 feet asl; the weather radar covering the area showed only weak, very scattered precipitation echoes. At 1325, a cell was observed near the accident site. The precipitation could have been in the form of drizzle, a mixture of drizzle and snow, or even wet snow. Visibility in the precipitation with the presence of fog might have been almost zero. The winds were blowing from the west-north-west at nearly 15 knots gusting to 30 knots. There was probably moderate turbulence in the area. The Cargair bush air service company, based in Saint-Michel-des-Saints, reported an estimated ceiling of 2 000 feet, visibility of 20 miles and scattered snow showers. The pilot had checked the forecasts on the aviation weather site on the Internet and had judged the conditions suitable for flight.

The *Aeronautical Information Publication* (AIP) explains that various phenomena are known to cause whiteout. The phenomenon that best
explains the conditions encountered by the pilot of the LongRanger is precipitation whiteout resulting from small, wind-driven snow crystals falling from low clouds above which the sun is shining. Light reflection complicated by the spectral reflection from the snowflakes and obscuration of landmarks by falling snow can reduce visibility and depth perception to nil in such conditions.

In a three-dimensional environment, pilots use several input sources, including vision, hearing, touch and their body sense, to establish their position in relation to the ground. Sight is the body's most reliable input, but the organs of the inner ear also play an important role in orientation. Semicircular canals in each inner ear detect changes in angular acceleration and respond to linear accelerations and gravitational forces. Due to its form, the inner ear can mislead pilots as to their position in space. Pilots must use their eyes to validate information received from the inner ear. When a pilot enters whiteout conditions, he appears to be engulfed in a uniformly white glow. Neither shadows, horizon or clouds are discernable; sense of depth and orientation is lost. This disorientation occurs very quickly, and loss of control of the aircraft may result.

After impact, the antenna of the aircraft's emergency locator transmitter (ELT) was found to be broken and buried under the snow. Upon checking, the pilot found that the ELT did not appear to be emitting any signal, although the switch was on. In fact, the ELT was operating at low intensity; the signal was not picked up by satellite, but was picked up nearby by helicopters. The pilot and two passengers had cellular telephones. By climbing a few hundred feet up the side of the mountain, the pilot managed to contact the Sûreté du Québec (SQ) by dialling 911. The pilot had to climb up the side of the mountain four times, making four calls from three telephones. Each call was interrupted because the batteries were dead. The first call was made at 1428, the second at 1523, the third at 1610, and the fourth at 1705. In each call, the pilot tried to give directions to the accident site and its vicinity in order to help rescuers locate it, because the SQ took the necessary steps to launce a search and rescue (SAR) operation after receiving the first 911 call. Two SQ helicopters were called, as was Canadian Forces ground support from Longue-Pointe, Quebec, which alerted the Canadian Forces national SAR system. An SQ helicopter located the accident site at 1904, some four and a half hours after the first 911 call.

Examination of the aircraft revealed that all the seat-belts withstood the impact. It should be noted, however, that no shoulder harnesses were installed for the pilot or the passengers. Aviation regulations do not require that safety harnesses be installed in the front of a private aircraft. Section 605.24 of the Canadian Aviation Regulations requires safety harnesses for passengers seated in the rear only for aircraft manufactured after 16 September 1992. The accident aircraft was manufactured in 1981. The pilot and the front passenger suffered chest injuries.

Measurements were taken of the rear cabin space at the accident site to calculate the permanent distortion and elastic distortion of the cabin...
upon impact. By measuring the distance between the rear seats and the ceiling, it was calculated that the permanent distortion of the cabin was 15 inches on the left side and 13 inches on the right side. As a rule, the elastic distortion of the rear cabin on impact is estimated by multiplying the permanent distortion by two, giving an approximate elastic distortion of 30 inches for the left side and 26 inches for the right side. At the time of manufacture, the distance between the seats and the ceiling was 36.6 inches. The cabin space was apparently reduced on impact by 80 per cent on the left side and 68 per cent on the right side. The transmission, mast and blades of the aircraft's main rotor are located right above the cabin. The considerable weight of these components and the rate of descent on impact appear to have contributed to the distortion of the rear cabin. This distortion explains the seriousness of the rear passengers' injuries.

Analysis

The pilot had checked the weather forecasts before departure and had judged the conditions suitable for flight. The weather study reveals that the weather conditions encountered correspond to the forecasts. When the pilot entered the light snow showers, he thought that he could navigate safely, but he lost ground visual contact when the snow showers turned from light to moderate. He encountered whiteout conditions, in which it becomes impossible for the eye to discern the horizon, shadows and clouds, and lost his sense of orientation. While attempting to correct the situation without any ground reference, the pilot lost control of the aircraft. Not until he saw the tops of the trees was the pilot able to raise the aircraft's nose and return it to level flight, just before striking the trees and the ground.

At the time of the accident, the ELT antenna broke at impact and was buried under the snow. The signal could be picked up only a short distance away.

Registered private aircraft or aircraft manufactured before September 1992 are not required to be equipped with shoulder harnesses. It is highly likely that shoulder harnesses would have decreased the seriousness of the injuries of the pilot and the front passenger. Such harnesses, however, would probably not have lessened the injuries of the rear passengers, given the significant elastic distortion that occurred on initial impact.

Findings

- Records indicate that the pilot was certified and qualified for the flight in accordance with existing regulations.

- The pilot encountered whiteout conditions in flight, lost all ground references and became disoriented. While attempting to correct the situation, the pilot lost control of the aircraft and flew into the ground.

- The aircraft struck the ground at a high rate of descent.
The aircraft struck the ground at a high rate of descent.

- The ELT signal was not picked up by satellite because the antenna had broken. The signal could be picked up only very close to the site.

- The aircraft was not equipped with shoulder harnesses.

- The significant elastic distortion of the rear cabin explains the seriousness of the injuries of the rear passengers.

Causes and Contributing Factors

After losing all ground visual reference in whiteout conditions, the pilot became disoriented, lost control of the aircraft and crashed.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 12 August 1999.

1. All times are EST (Coordinated Universal Time [UTC] minus five hours) unless otherwise stated.

Updated: 2002-10-06
Air 1997

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 Occurrence Report Gear-Up Landing
Cougar Helicopters Inc.
Eurocopter AS332L
Super Puma (Helicopter) C-GQCH
St. John's, Newfoundland
01 July 1997

Report Number A97A0136

Summary

The crew of the Super Puma helicopter, serial number 2139, were conducting an instrument landing system (ILS) approach to runway 29 in St. John's, Newfoundland. As the helicopter was about to touch down, the crew realized that the helicopter was lower than normal and that the landing gear was still retracted. The crew began to bring the helicopter into a hover; however, as collective pitch was applied, the nose of the helicopter contacted the runway surface. Once the hover was established, the landing gear was lowered and the helicopter landed without further incident. Damage was confined to two communications antennae, and the supporting fuselage structure of the aircraft. There were no injuries to the 2 crew members or 11 passengers.

Other Factual Information

The flight crew were certified and qualified for the flight in accordance to existing regulations. The occurrence flight was the second flight of the day for the flight crew. For the first flight of the day, the first crew member arrived at 0700 Newfoundland daylight time (NDT)\(^1\) for the planned morning flight. Because of poor weather conditions, the flight to deliver 11 passengers to the newly positioned Hibernia oil platform was delayed for several hours and finally departed at 1148. When the helicopter reached Hibernia, it landed, refueled, and then departed for St. John's; it arrived back at St. John's at 1514 without incident. The occurrence flight began at 1704; however, on arrival at Hibernia, the weather was so poor that the crew was unable to successfully complete an approach and landing, and they returned to St. John's. The flight proceeded uneventfully en route to St. John's at a cruising altitude of 4 000 feet above sea level (asl)\(^2\) and a groundspeed of approximately 145 knots.

Correlation of radio communication records and air traffic control radar data revealed the sequence of events during the flight. At 1926, about 40 minutes prior to landing and approximately 95 miles east of St. John's, the crew, operating under the callsign Cougar 33, contacted Gander Area Control Centre (ACC) by radio and requested clearance to the St. John’s airport. Cougar 33 received clearance direct to the airport at an altitude of 4 000
feet asl and was advised that Runway 29 had the best visibility for landing with runway visual range (RVR) readings of 1 800 feet, but that visibilities were fluctuating up and down. When Cougar 33 was about 12 minutes and 28 miles back from landing, Gander centre issued a clearance for Cougar 33 to descend to 3 000 feet asl and 3 minutes later issued a further clearance for Cougar 33 to descend to 2 400 feet asl. Two minutes later, while Cougar 33 was 16 miles east-southeast of the airport, Gander Centre cleared the flight to the St. John's airport for a straight-in ILS approach to Runway 29 via the TESOX approach fix (see Appendix A).

Less than a minute later, with the flight now six minutes and 11 miles from touchdown, Cougar 33 was issued missed approach instructions that would set them up for another approach to St. John's should they not see the runway environment on completion of their current approach. The captain of Cougar 33, being concerned about the weather conditions and the potential for a low fuel situation developing, replied that in the event of a missed approach he wanted to proceed direct to their alternate landing site of Long Pond, where weather conditions were better. Long Pond is a designated alternate landing site 13 miles to the northwest of the St. John's airport. The Gander centre controller did not immediately comprehend where Cougar 33 wanted to go in the event of a missed approach and over the course of several transmissions during the next 45 seconds and two miles the misunderstanding was sorted out. Approximately one minute later Cougar 33 indicated that they were established on the ILS approach waiting to intercept the glidepath. Gander centre replied and advised Cougar 33 that they were six miles from the runway threshold and instructed them to contact the St. John's control tower on a different radio frequency. The crew established radio contact with St. John's Tower and conducted normal communications throughout the remainder of the approach and landing.

A special weather observation was issued at 2223UTC, approximately 12 minutes prior to the occurrence, for the St. John's airport which indicated: indefinite ceiling 100 feet above ground level (agl) obscured one-eighth of a mile visibility in fog, the wind was from 020 degrees magnetic at two knots, the cloud layer was made up of ten-tenths of fog and the RVR readings for Runway 29 were 1 200 feet and 1 000 feet respectively.

At the time that Cougar 33 received clearance to descend out of 4 000 feet the crew completed the descent check which does not include landing gear. The landing gear is covered in the pre-landing check which consists of setting the engine bleed valves and lowering the landing gear. The pre-landing check is normally accomplished at a point prior to becoming established on the approach but the exact point at which the check should be done is left to the pilot's discretion. Company operating procedures dictate that the check is to be completed no later than five miles from landing. While no technical reference information was found indicating the extent to which setting the engine bleed valves effect fuel consumption, it was indicated that the timing for the execution of the pre-landing check should take into consideration the increased fuel consumption (approximately 5%) when the bleed valves are set. There was no indication that the pre-landing check was completed prior to the attempted touchdown.

The approach was flown by the copilot who operated and closely monitored the automated flight control system (AFCS) while the captain conducted the radio communications and monitored the overall progress of the approach. The crew kept the approach speed of the helicopter faster than normal to provide better separation from the faster traffic that was following them. When the aircraft intercepted the ILS glidepath while it was still near cruising speed, the AFCS first tried to slow down to descent speed which caused the aircraft to fly through the glidepath and placed the aircraft above the glidepath. The pilots were aware of being high on the glidepath, and they made several power adjustments during the approach which resulted in the aircraft reintercepting the glidepath shortly before decision height. Upon reaching decision height and with the runway environment visible,
the captain assumed manual control of the aircraft and conducted the landing. In accordance with company operations policy, the copilot remained focused on his flight instruments, even after the captain assumed control, so that he would be capable of reassuming control and executing an immediate overshoot, should the captain lose visual reference while carrying out the landing manoeuvre. The company’s standard operating procedures also require the co-pilot to assist the captain by calling out airspeeds and altitudes until the aircraft touches down.

Aircraft records indicated that the aircraft was certified and equipped for the occurrence flight and that there were no known system anomalies when the crew accepted the aircraft for the flight.

The landing gear system is electrically controlled and hydraulically operated. The landing gear retraction-extension control switch and gear position indicators are located in the upper right corner of the centre console adjacent to the captain’s (right-side pilot) left knee (see Figure 1). The landing gear warning system consists of flashing red warning light segments that are located in the lower portion of both the captain’s and co-pilot’s instrument panels and a three-second aural warning tone of 285 Hz that is heard in the crew’s headsets. The system is activated whenever the landing gear is retracted, the radar altimeter senses that the aircraft is below 300 feet agl, and the airspeed is 60 knots or less. The landing gear warning system was checked after the occurrence and was confirmed to be operating correctly.

A barometric altimeter is the standard type of altimeter found in most aircraft, and is a special form of aneroid barometer that uses static atmospheric pressure to indicate an aircraft’s height above mean sea level. The occurrence aircraft’s barometric altimeter system did not incorporate an altitude warning device. A radar altimeter (or radio altimeter) is a more specialized device that indicates the exact height of the aircraft above the surface of the earth by transmitting radio waves toward the ground and reading the reflected signals. The instrument face of the radar altimeters were located in the lower portion of both the captain’s and co-pilot’s instrument panels. They were equipped with an altitude alerting function that activates a visual and audio warning when the aircraft reaches the preset height. The preset height is controlled by the pilot and is determined by the setting of a selector bug on the radar altimeter instrument. When the preset height is reached a red light on the radar altimeter indicator illuminates, a large amber decision height light adjacent to the attitude indicator illuminates, and 3 second tone of 454 Hz is heard in the pilots headsets. The crew was conducting a category 1 ILS approach to Runway 29 in accordance with the approach procedure published in the Canada Air Pilot (see Appendix B) with the exception that the decision height was reduced to 549 feet asl and 100 feet...
agl\(^{(3)}\) as had been authorized in an operations specification issued to the operator by Transport Canada\(^{(4)}\). The occurrence helicopter was equipped in accordance with the Commercial Air Service Standards referenced in the operations specification which require that the helicopter is equipped with two serviceable and functioning radar altimeter indicators having an altitude alert function. While setting up for the approach on the occurrence flight, the pilots set their radar altimeter preset height to 100 feet which corresponded to the anticipated height above the touchdown zone elevation (HAT) at the reduced decision height. The Category 1 ILS approach procedure charts published in the Canada Air Pilot are predicated on pilots monitoring the barometric altimeter reading to determine decision height while conducting an approach and do not provide radar altimeter reference altitudes.

While it is not the case with all ILS approach equipped runways, Runway 29 at the St. John's airport was equipped for Category 2 operations. Category 2 approach operations enable suitably equipped and authorized crews and aircraft to conduct an ILS approach to a 100 foot decision height. The published approach procedure for the Category 2 ILS approach to Runway 29 (see Appendix B) indicates that the decision height at 100 feet above touchdown zone elevation corresponds to a barometric altimeter reading of 549 feet asl, and a radar altimeter reading of 164 feet above ground. The instrument approach procedure chart for the Category 2 approach to Runway 29 includes a graphic representation that shows the upslope of the ground towards the threshold of Runway 29 at the St. John's airport.

Although not required by regulation the aircraft was equipped with a digital flight data recorder and a cockpit voice recorder. Unfortunately, by the time the operator was advised of the need to examine the recorder data and the units were submitted for analysis, the information pertaining to the occurrence flight had been overwritten by the recording of a subsequent flight. No useful information was obtained from either the flight data recorder or the cockpit voice recorder.

An audio tape recording of the occurrence aircraft's warning horns was made and analysis of the recording revealed that the actual frequency of the landing gear warning tone was 480 Hz and the frequency of the radar altimeter warning tone was 293 Hz. The derived frequencies may have been affected by a small amount of variation caused by a possible speed differential between the laboratory playback unit and the handheld unit that recorded the tones in the aircraft; however, the frequency values were sufficiently close to the reference values that they were considered to be valid representations of the audio tones heard by the crew. The warning tone recordings were digitally sampled and replayed both independently and simultaneously. While there was no scientific reference data available to establish whether tones of these frequencies could be easily distinguished from each other, the subjective assessment was that the tones are not sufficiently unique to preclude misinterpretation in the context of a busy cockpit environment. Additionally, constant frequency warnings tones such as these were considered to be difficult to differentiate should multiple warnings activate simultaneously.

In July 1992 the TSB submitted a Safety Information Letter (No. 1812) to Transport Canada regarding the similarity of certain aural warning horns as a result of a 1991 investigation (TSB Occurrence No. A91C0053) into an inadvertent gear-up landing of a Piper Navajo. The investigation found that the stall warning horn (675 Hz) and the landing gear warning horn (510 Hz) were of the non-pulsating single tone type and were too similar for easy distinction of their respective warning functions\(^{(5)}\). The issue of potentially confusing aural warning horns was re-identified by the TSB in an Aviation Safety Advisory (No. 950198) submitted to Transport Canada in September 1995. In their reply in July 1997 Transport Canada indicated that an Aircraft Certification Policy Letter (Issue No. 54, Audio Alerts and
Warnings) was released in March 1997 for the purpose of outlining the existing standards and detailing procedures related to the assessment of audio warnings and to provide a mechanism to ensure standardized compliance. Paragraph 4.2(d) of the document states that "audio alerts should not be easily confused with one another."

Analysis

The aircraft records indicated that the aircraft was certified and equipped for the flight and there was no evidence found of any system malfunction during the flight. The crew were certified and qualified for the flight and although they were on their second trip during a long day, the duty times were within allowable guidelines. However, several other factors combined in this occurrence to create a situation where the crew inadvertently did not complete the pre-landing check and then did not recognize the landing gear warning when it activated prior to the attempted landing.

The flight was prolonged because the weather at the oil rig was too poor to allow for landing and refuelling. This placed the crew in the situation where they were unable to accomplish the intended mission and while they had sufficient fuel in accordance with regulations, the available time and options for the return flight were now more restrictive than if they had landed at the rig and refueled. The flight proceeded uneventfully while returning to St. John's. Air traffic control clearance to the airport and then for descent were received while the aircraft was still a substantial distance from landing, and as a result, the pre-landing check was delayed until the aircraft was closer to landing. The crew were advised of the weather conditions and found the ceiling and visibility were decreasing and were expected to be near approach limits by the time that they arrived, which further restricted their options.

The crew were aware that other higher speed aircraft were following them on the approach and the decision was made to maintain their cruising speed and delay slowing down to their normal approach speed. In this now time-restricted context, the crew received their overshoot instructions which would require them to go-around and set up for another approach. The crew knew the weather was slightly better at their alternate of Long Pond. The captain decided that if the approach was unsuccessful he wanted to overshoot and proceed to Long Pond rather than expend precious fuel and time on an extended procedure to re-attempt an approach that had already been unsuccessful. When the captain expressed this desire to air traffic control the controller did not initially comprehend what the captain was requesting and it took several radio transmissions to get things sorted out. This conversation took place during the time that the crew were transitioning to final approach between 11 and 6 miles from touchdown. The pre-landing check would normally have been completed at approximately this point during the approach and it is likely that the discussion regarding the missed approach intentions provided enough of a distraction that the crew missed completing the pre-landing check that they had previously delayed.

Shortly thereafter and just prior to the aircraft intercepting the ILS glidepath, the crew was instructed to change to the St. John's tower radio frequency. The aircraft then intercepted the glidepath and, because of the higher than ideal speed, the aircraft went high on the glidepath, which required the crew to make several power adjustments to slow down and then regain the desired approach profile. Despite having an automatic flight control system, the workload for both crew members would be high in this situation, and it is likely that the successful completion of the approach became a primary focus for the crew.

The crew regained the ideal ILS glidepath shortly before the decision height of 549 feet on the barometric altimeter. Just prior to reaching decision height the captain acquired visual reference and assumed manual control of the aircraft to conduct the landing. The crew were conducting the Category 1 ILS approach to a 100 foot decision height in accordance
with the Transport Canada operations specification, and with no radar altimeter reference heights on the instrument approach procedure chart, the radar altimeter altitude alert was set to the published HAT of 100 feet. When the aircraft reached decision height it was still 164 feet above ground and therefore the radar altimeter altitude warnings activated, sometime after decision height was reached, during the time that the captain had assumed manual control and was slowing down and flaring for the touchdown.

The landing gear warning system is activated whenever the landing gear is retracted, the radar altimeter senses that the aircraft is below 300 feet above ground, and the airspeed is 60 knots or less. When the aircraft reached decision height it was below 300 feet above ground but it was travelling faster than 60 knots so the landing gear warning had not yet activated. The warning system activated sometime during the time that the captain was slowing down and flaring for the touchdown.

To carry out the landing the captain was flying by visual references which required looking ahead through the windshield and not directly at the instrument panel. With the prevailing low visibility conditions this manoeuvre required a high level of concentration on the part of the captain. The red warning lights for the radar altimeter and the landing gear warning are located in the lower portion of the instrument panel and during the landing they would both be at the lower edge of the captains peripheral vision. It is possible that the captain was concentrating on the visual landing manoeuvre to the extent that, when these visual warnings illuminated in his peripheral vision, they were either not noticed, or were interpreted as the radar altimeter warning which would be a normal event during the landing sequence.

After the captain acquired visual reference and took control, the co-pilot was dedicated to monitoring the flight instruments and calling out altitudes and airspeeds for the captain until a stable hover or touchdown was achieved. The red warning lights for the radar altimeter and the landing gear warning are located in the lower portion of the instrument panel on the co-pilot's instrument panel as well. The landing gear control panel, with the gear position indicators, was well out of the co-pilot's field of view on the opposite side of the centre console next to the captain's left knee. The co-pilot did not recognize the landing gear warning when it activated and while it is likely that the co-pilot misinterpreted the visual warnings, an explanation for this phenomenon could not be determined.

The aural warnings for the radar altimeter and landing gear warning systems were close in frequency and both were non-pulsating constant frequency tones. It was discovered that these tones could easily be misinterpreted as one tone should they activate concurrently or in overlapping succession. These tones were heard by the crew through their headsets. At the approximate time that the tones would have activated several verbal calls were being made by the co-pilot and likely some verbal acknowledgements were being made by the captain as he was conducting the landing. It is very likely that both warning systems activated at or about the same time and the crew interpreted them as the radar altimeter warning. A radar altimeter warning would be an expected event during the course of a normal landing procedure and as such would not trigger the crew to change their course of action.

While there was no direct indication of the events inside the cockpit, such as could have been provided by the CVR, the factors and data relating to the occurrence indicate that while operating in a high-workload, time-restricted environment the crew inadvertently did not recall that the pre-landing check was not yet completed before attempting the landing. It is also most likely that the radar altimeter and landing warnings occurred in close succession and because of their similar characteristics were misinterpreted as an anticipated and non-critical advisory, in which case the landing gear warning went unrecognized.
The following Engineering Branch reports were completed:

LP109/97 - FDR/CVR Analysis

Findings

- Aircraft records indicated that the aircraft was certified and equipped for the flight.
- No evidence was found of any system malfunction during the flight.
- The crew were certified and qualified for the flight and duty times were within allowable guidelines.
- The crew delayed the pre-landing check and then while operating in a high-workload time-restricted environment did not notice that the pre-landing check was not yet completed.
- As there was no radar altimeter reference heights on the Category 1 ILS instrument approach procedure chart, the crew used the HAT of 100 feet and set the radar altimeter altitude alert preset accordingly.
- The published approach procedure for the Category 2 ILS approach to Runway 29 at St. John's indicates that a decision height of 100 feet HAT corresponds to a barometric altimeter reading of 549 feet above sea level, and a radar altimeter reading of 164 feet above ground.
- The landing gear warning tone and the radar altimeter warning tone are similar in frequency and duration.
- The warnings activated by the landing gear warning system were not recognized by the crew.
- The crew did not recognize that the landing gear was retracted until touchdown was imminent.
- The nose of the helicopter contacted the runway surface and sustained minor damage.

Causes and Contributing Factors

The crew intentionally delayed the execution of the pre-landing check and then while operating in a high-workload time-restricted environment the crew inadvertently did not recall that the pre-landing check was not yet completed. Subsequently, the crew did not recognize the landing gear warning prior to attempting to land which resulted in the nose of the helicopter contacting the runway surface while the landing gear was retracted.

Safety Action

Since the occurrence the company has taken several initiatives to reduce the likelihood of a recurrence. Company procedures state that the pre-landing check is now completed at 10
miles from the landing site. The company believes that this is much earlier in the approach phase and as a result should ensure the completion of the pre-landing check at a time when other high priority tasks are not competing with each other for the attention of the pilots.

The company has introduced a final landing check that is carried out from memory and silently on short final. The check covers landing gear, warning lights, coupler, radar, engine instruments, bleed valves, and destination. The non-flying pilot carries out the check and reports to the flying pilot the "final check is complete".

At the time of the occurrence the Long Pond approach was an interim procedure that had been used during previous offshore activities. The approach has since been approved and the company has conducted at least three liaison visits to the air traffic control centre to review unique requirements and alternate landing sites.

It was noted that the warning tones for the radar altimeter and the landing gear were similar in frequency and are considered difficult to distinguish when they activate close together. The company is currently investigating optional modifications that may be made to either of these warning systems to make them more distinct.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoit Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 16 September 1998.

Appendix A - Flight Profile

Appendix B - Instrument Approach Procedure Charts
1. All times are NDT (Coordinated Universal Time (UTC) minus two and one-half hours) unless otherwise noted.

2. Units are consistent with official manuals, documents, and instructions used by or issued to the crew.
3. The published approach procedure for the CAT 1 ILS to Runway 29 denotes a decision height of 649 feet above sea level and 200 feet HAT.

4. The operations specification document indicated that it was issued pursuant to Canadian Aviation Regulations subparagraph 704.08(g)(ii) and required operation in accordance with Commercial Air Service Standards subsection 724.08(6).

5. TSB Engineering Branch Report LP17/92 refers to this occurrence.
Air 1997

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 Occurrence Report
Main Transmission Failure - Forced Landing
Universal Helicopters Newfoundland Ltd.
Bell 206L C-GJBC
Goose Bay, Labrador 27 nm N
10 August 1997

Report Number A97A0157

Summary

The Bell 206L, serial number 45096, was returning from a forest fire mapping flight north of Grand Lake, Labrador, with the pilot and two forestry employees onboard. The pilot was following the north shore of Grand Lake eastwards at 400 feet above ground (agl) towards the forestry centre, located at North West River, at a cruising speed of 130 miles per hour (mph). A few minutes before the occurrence, the pilot recalls feeling a very slight, high frequency vibration throughout the helicopter; he glanced at his instruments and caution panel but observed nothing out of the ordinary. The pilot and passengers then heard a loud bang and felt the helicopter yaw sharply to the left. The pilot warned his passengers to prepare for an emergency landing, lowered the collective, decreased the airspeed to 70 mph, and commenced an autorotation towards a spit of land along the shore. During the descent, the pilot believes he may have seen the Engine Out caution light illuminate briefly for about 3 or 4 seconds. He focussed his attention on his approach and landing and does not recall seeing any other lights, hearing any engine out or low rotor warning horns, nor does he recall noticing any readings of his engine or transmission instruments. Nearing the spit of land, the pilot initiated a flare at about 50 feet agl and commenced raising his collective to arrest the descent. He then observed that the intended landing spot was strewn with large boulders and warned his passengers to brace themselves. At about 5 feet agl, the pilot had raised full collective and the main rotor rpm had decreased; the helicopter landed hard. The helicopter then yawed uncontrollably to the left about 45 degrees and came to rest upright, with a 5 degree list to the right. The pilot noted that the engine was still running and he could hear unusual 'hissing' sounds. He rolled the throttle from the full open to the OFF position and
completed the remainder of the engine shutdown. All occupants exited the helicopter uninjured.

_Ce rapport est également disponible en français._

**Other Factual Information**

The helicopter was substantially damaged during the hard landing. Damage included a downward bending deformation of the tail boom and the tail rotor drive shaft as well as some serious structural deformation of the aft fuselage. The helicopter was slung by air to the operator's base of operations where the engine, main rotor, and transmission were removed. The removal of the mast shaft was particularly difficult and gear fragments were found inside the transmission case.

The engine and main transmission were forwarded to the TSB Engineering Branch for examination. The engine was partially disassembled and no signs of internal damage were observed. The engine was subsequently ground run in a test cell and was found to be satisfactory in all respects.

During the examination of the transmission, the sun gear splines were found damaged in the area of engagement with the main ring gear shaft internal spline. When the internal splines of the main ring gear were examined, it was noted that the sun gear had been operating with about 0.30 inches of engagement. A slight wear pattern was observed on the internal spline indicating that a sun gear had previously been installed having a much greater engagement into the main ring gear shaft. The damaged sun gear (part number 206-040-122-103, serial number AFS 004575) removed from the transmission was determined to be a sun gear designed exclusively for use in the Bell 206B helicopter transmission. The overall length of the damaged sun gear was 4.8200 inches. The correct sun gear required for the occurrence Bell 206L helicopter transmission was part number 206-040-122-005. This sun gear, although similar in appearance to the damaged sun gear, is considerably longer at 6.010 inches.

Engine power is input to the transmission by a spiral bevel gear that engages and turns the transmission first reduction stage ring gear. Inner splines of the ring gear assembly drive a sun gear that engages the four planetary gears of the second stage reduction gear assembly. Since the second stage ring gear is permanently fixed to the transmission case, rotation of the planetary gears causes the planetary gear case to turn. The upper gear of the planetary gear case turns the mast shaft which completes the engine power transmission to the main rotor blades. Of note, the first reduction stage ring gear also drives the main rotor tach generator, the transmission oil pump and the system hydraulic pump. The low rotor rpm warning light and horn receive information from the rotor tachometer and activate at 90±2% rpm.

The transmission had been removed on 6 October 1996 for a 1,500-hour inspection, at which time the sun gear was found to exceed maximum wear limits and was replaced. The helicopter had flown 391.0
hours since the replacement sun gear had been installed.

The Board examined how the incorrect sun gear was introduced into the operator's supply system and how the incorrect component could have been installed into the transmission without being recognized as the wrong part.

The operator ordered the sun gear on Sunday, 6 October 1996. During normal working hours, the operator used a computer system dedicated to the Bell Helicopter parts warehouse network in Calgary. However, the part was ordered outside normal working hours and operator staff familiar with parts requisition using the computer system were unavailable. Therefore, maintenance management ordered the sun gear by calling the Bell Helicopter parts warehouse toll-free number in Calgary. The Bell Helicopter employee who received the call at home, accessed the Calgary warehouse parts inventory list (remote access) and confirmed that the part was in their stores. The sun gear was shipped the next day to the operator.

In order to satisfy the operator's record keeping requirements, the person who placed the order completed the purchase order form, identifying the part number of the sun gear that he wanted, the date the part was ordered and the date the part was required. There was no record found to indicate that the purchase order form had been mailed or faxed to the supplier. The supplier's invoice, which accompanied the sun gear, made reference to the operator's purchase order number and the invoice accurately quoted the part and serial numbers of the sun gear found in the occurrence transmission. It could not be determined if: 1) the operator's maintenance personnel had quoted the incorrect part number during the phone conversation; 2) whether the supplier's employee had inadvertently relayed the incorrect part number electronically to the stores in Calgary; or, 3) the personnel in the warehouse in Calgary had inadvertently introduced the incorrect part number in their internal shipping procedures.

When the sun gear arrived at the operator's main base of operations, the records clerk retrieved the original purchase order form, identified that the last three digits of the recorded part number (-005) did not correspond with the part number recorded on the invoice shipped (-103), and overwrote the purchase order part number to correspond with the invoice. The reason for this modification to the purchase order without apparently consulting company maintenance personnel could not be explained.

The sun gear was then shipped to the operator's satellite base in Goose Bay where an aircraft maintenance engineer (AME) installed the component in the transmission. The sun gear was shipped with a company release certification tag indicating the correct part number of the shipped sun gear. The AME, and his supervisor, apparently relied on the main base of operations to send the correct part. They did not physically compare the two components nor did they refer to the Bell Helicopter Illustrated Parts Catalogue (IPC) to verify that the correct part number was being installed.
The sun gear that was installed was about 1.2 inches shorter than the correct sun gear. When installed in the main ring gear shaft, the amount of gear engagement cannot be determined. In this case, the shorter sun gear end that engaged with the planetary carrier gears sat lower, physically contacting the main ring gear shaft face with the side of the sun gear. The gear engagement was minimal, roughly 0.30 inches.

**Analysis**

The incorrect sun gear was inadvertently installed in the helicopter's transmission over 10 months prior to the occurrence. As a result of this relatively long time period since its installation, individuals directly involved could not recall specific details concerning the ordering, shipping, and installation of the component. It was evident; however, that at some point during the ordering and shipping process, a breakdown in communications occurred which resulted in the incorrect component being shipped to the operator. The specific time at which this breakdown in communication occurred or its cause could not be determined.

The normal supervisory checks and balances in place within the operator's maintenance practices for the reception and installation of the correct components into the operator's aircraft were ineffective in this case. There are two readily identifiable critical points during the events leading to the installation of the component by the operator's maintenance personnel during which the wrong component should have been identified. The first occasion was when the component was initially received at the main base of operations. The records clerk, noting the different part number of the sun gear, amended the part number in the purchase order to correspond with the part number of the part received apparently without consulting with maintenance personnel. The new number appearing on the amended purchase order then took on the appearance of being a legitimate part number for that specific transmission, possibly setting the scene for a later misidentification by the maintenance engineer. The records clerk could not recall amending the purchase order or the reason for doing so.

The second occasion at which the error could have been noticed occurred when the AME, and his supervisor, installed the sun gear into the transmission. Had the AME, or the supervisor, physically compared the two sun gears, it would have been apparent that, despite their similar appearances, the replacement sun gear was noticeably shorter than the sun gear which had been removed from the transmission. In addition, had they verified the part number of the replacement sun gear with the part number of the sun gear removed from the transmission or with the part number contained in the parts catalogue, they would have become aware of a discrepancy and the replacement sun gear would likely not have been installed.

In any case, the specific reason why the AME and his supervisor installed the replacement sun gear without first verifying its authenticity could not be determined. As previously suggested, they may have been misled by the amended part number on the purchase order, or
they may have relied on the maintenance personnel at the operator's base of operations for having verified that the sun gear was in fact the correct component.

It was determined that, when the splines of the sun gear and the inner splines of the ring gear failed, the engine essentially became uncoupled from the main rotor. The main rotor rpm then began to decrease; this decrease was checked when the pilot lowered the collective and entered an autorotative descent. It is interesting to note that, since the ring gear was still being driven by the engine, the hydraulic pump and the main rotor tachometer generator were still being driven. In this instance, the main rotor rpm indicator may have produced a momentary indication above 100% but then the rotor rpm indication would have returned to 100% and remained at that reading as long as the throttle was kept in the full open position. Since the low rotor rpm warning light and horn are initiated by the rotor tachometer, there would have been no low rotor rpm warning regardless of the actual rotation speed of the main rotor.

The unusual sharpness of the left yaw which accompanied the uncoupling of the engine from the main rotor was a result of two factors: 1) at the time of the sudden failure, the tail rotor was in a trim position for powered flight and there was suddenly no torque; and, 2) the engine, which was still providing power to the tail rotor, surged due to the sudden loss of drive to the main rotor and the tail rotor rpm increased momentarily as a direct result of the engine power surge. The maximum increase in engine speed would have been controlled by the fuel governor.

The decrease in main rotor rpm and left yaw reported by the pilot is consistent with an engine power loss. The pilot's reaction to the apparent engine malfunction of lowering the collective was the correct response in this situation. The cause of the Engine Out light illumination observed by the pilot during the autorotative descent could not be determined.

Findings

- An incorrect sun gear was installed in the helicopter's main transmission by the operator's maintenance personnel.

- It could not be determined why the incorrect sun gear was shipped to the operator by the supplier.

- It could not be determined why the operator's maintenance personnel did not identify the sun gear as being an incorrect component for this helicopter's transmission.

- The sun gear failed causing the failure of the main transmission after the helicopter had flown 391.0 hours since its installation.

- The helicopter was substantially damaged during the
The helicopter was substantially damaged during the autorotational landing.

Causes and Contributing Factors

The cause of the transmission malfunction was the failure of the incorrect sun gear installed in the main transmission. Contributing to the occurrence was a breakdown in communications between the operator's maintenance personnel and the supplier with respect to the ordering, shipping, and receiving of the sun gear. Also contributing to the occurrence, was an inadequate degree of attention and supervision by the operator's maintenance personnel during the installation of the sun gear.

Safety Action

Following this occurrence, at the operator's request, the Transport Canada Airworthiness District office in St. John's, Newfoundland approved an amendment to the Company Maintenance Control Manual. The amendment was designed to address the issue of proper supervision and record keeping for critical maintenance tasks performance by its maintenance staff. All maintenance staff have been briefed on these new procedures and all holders of the Company Maintenance Control Manual have been provided with a copy of the amendment to the manual.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 07 July 1998.
Air 1997

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 Occurrence Report
Power Loss - Forced Landing
Aviation Career Academy Limited
Zenair CH2000 C-GSOA
Bell Island, Newfoundland
05 September 1997

Report Number A97A0170

Summary

The aircraft departed the St. John's, Newfoundland airport at 1955 Newfoundland daylight time en route to the Bell Island flight training area, about 10 miles to the west. The right fuel tank was selected for the departure and after reaching the training area the left tank was selected. The electric fuel boost pump was selected on for the duration of the training exercise. The chief flight instructor (CFI), who sat in the left seat, was giving a type check out to the right-seat instructor. The first sideslip manoeuvre was initiated at 3 000 feet above sea level (asl) by applying a co-ordinated partial-travel left aileron and right rudder input. The abrupt nose-down pitch that resulted startled the right-seat instructor and he reacted by recovering the aircraft from the manoeuvre. A faint fuel smell was detected in the cockpit during the manoeuvre, a smell that had always been noticeable when in the sideslip. After the right-seat instructor was briefed that the pitch-down was normal, the CFI instructed him to initiate a second sideslip, this time applying full left aileron and full right rudder input. The aircraft pitched down and the negative gravitational forces that resulted caused the crew to be restrained hard against their shoulder harnesses; the fuel smell in the cockpit was much stronger this time. When the pilot recovered from the descent, he advanced the throttle, but the engine did not respond. A check of the fuel gauges confirmed there was an adequate fuel quantity indication in the selected tank and the engine fuel pressure indication was normal. He briefly advanced the throttle but returned it to idle after the engine did not restart. The propeller was windmilling as the aircraft descended and the pilot set up for a forced landing to the Bell Island airport, joining the circuit downwind after crossing overhead the field. The CFI then took control of the aircraft since her left-seat position provided a better view of the runway.
However, because of darkness, she lost sight of the unlit runway after turning onto final approach and the aircraft struck a grassy knoll about 700 feet short of the threshold of runway 26. Both pilots received minor injuries, the aircraft was destroyed.

*Ce rapport est également disponible en français.*

**Other Factual Information**

The emergency locator transmitter (ELT) was not armed, and consequently did not activate during the ground impact. The ELT was not a checklist item and its switch position went unnoticed by the flight crew during their preflight checks.

The structural integrity of the cockpit was compromised as a result of the impact forces. The fuselage side structure that secures each latch portion of the seat belts had separated causing the outboard lap belts to become unsecured. The main landing gear, a one-piece spring steel gear that is externally bolted to the fuselage, rotated aft at impact causing the lower fuselage structure above it to be forced upward. This action forced the seat back adjustment rods (attached to brackets on the fuselage lower skin) to move forward forcing the seat backs forward.

Several other safety related issues were identified during the course of the investigation. The latch bar (P.N. 20-F-32-3) of the door latching mechanism exhibited excessive wear considering the aircraft's low time in service (41.1 hours). The exhaust stack on the number-2 (front left) cylinder is slip jointed. Exhaust stains on the air heater indicate there was an exhaust leak. Examination of the aircraft cabin heat box supply hose indicated that exhaust gases had entered the air box. The aircraft owner's manual, as it pertains to the operation of the alternate static, could result in confusion and incorrect interpretation by the reader. Firstly, Section 3, (emergency procedures, icing ), states: "When the pitot is not frozen and the alternate static is used, the airspeed reading must be increased by 20 KT". Pilots report that the airspeed indication actually increases by 20 kt. Secondly, Section 4 (normal procedures, before take-off) states: "Check alternate static (if installed) switch (normal: switch down)". In the occurrence aircraft, the switch is not placarded "Normal", rather it is placarded "Alternate Static" and the placard location and wording would indicate that when the switch is in the down position the alternate static is selected "on", which is contrary to the owner's manual. Additionally, Section 4 (Normal Operations, Pre-Landing Check, Note:) states: "Large or full rudder deflection side-slip may cause some pitch oscillation at or below normal approach speeds. This does not affect control of the aeroplane. Remove pro side slip input as required". Pilot's report that the CH2000 side slips can result in a steep nose down pitch attitude, even when entered at speeds greater than normal approach speeds.

Aircraft records indicate there was about nine gallons of fuel in the left tank and seven gallons in the right tank at impact. The aircraft fuel selector was on left tank at impact. The fuel supply hose had separated at the engine firewall fitting during the ground impact and the fuel
The carburettor received impact damage, emptying the contents of the left fuel tank onto the ground. The investigation identified that, other than the impact damage, all the fuel lines were correctly secured, all fuel filters and screens were clean, and the fuel supply lines were unrestricted.

The aircraft was leased by the operator from the aircraft manufacturer; it had a total of 41.1 hours air-time since manufacture in May, 1997, and records indicate that it was maintained in accordance with existing regulations.

The engine, which exhibited only minor impact damage to the exhaust system, induction air box, and alternator mount bracket, was transported to an engine overhaul facility for running in a test cell. Prior to running the engine, it was identified that the carburettor (MA-3PA) needle valve was jammed in the closed position. An attempt was made to test the engine using the carburettor in that condition. An inlet air box was installed on the carburettor using two diagonally placed bolts (for time saving purposes). When the fuel supply was introduced to the carburettor a massive fuel leak was observed. Fuel poured from an air box attach bolt hole in the rear of the carburettor that was left void for the test. The two rear bolts thread into the bottom of the carburettor and appear as a raised boss on the bottom of each float chamber. The carburettor was dismantled and one of the bosses was found broken off of the carburettor bowl and was against the float chamber wall. The carburettor was re-assembled and the engine successfully test run to maximum power. When the carburettor was disassembled after the test run it was observed that the broken boss had moved. Surface finish discolouration on the broken boss and float bowl indicated that the carburettor had been damaged for some time.

Upon completion of the engine manufacturer's certification process, the carburettor is removed, drained and shipped with the engine to Zenair for installation. The inlet air box and the bolt hardware for the installation is supplied by Zenair. During the inlet air box installation, if the rear attach bolt is too long, further bolt tightening can damage the carburettor by breaking off the boss. This can result in fuel leaking out through the threaded bolt bore of the carburettor. It can also result in the broken boss interfering with normal operation of the engine by restricting proper float movement. The carburettor has no fuel in it when installed at Zenair and internal damage resulting from incorrect bolt length would be difficult to recognize.

The float type carburettor is required to ensure an adequate fuel supply and correct fuel/air ratio is available under all normal operating conditions and flight attitudes. Also, the fuel level in the float chamber must always remain at a level below the discharge nozzle outlet to prevent fuel entering the carburettor throat when the engine is not operating. This is accomplished by the float operated needle valve which regulates the flow of fuel into the float chamber. As the fuel level increases, the float repositions the needle valve towards the closed position. The valve is completely closed prior to the fuel level increasing to the height of the nozzle outlet.
The pilot operated throttle lever is manually connected to the throttle valve. As the throttle lever is advanced, the throttle valve opens allowing more air to flow through the throttle body. The airflow increase and pressure drop that results provides a fuel flow increase to the engine.

A disadvantage of the float type carburettor is that abrupt aircraft manoeuvres may interfere with the function of the float mechanism resulting in fuel flow interruptions and sometimes a complete loss of engine power.

Analysis

One of the raised bosses in the carburettor float chamber had been broken off for some time as evidenced by the surface finish wear on the broken boss and on the float chamber floor. Had the carburettor been damaged at the engine manufacturer’s facility, it should have been identified during the numerous post-run inspections. Fuel would have drained from the carburettor as soon as the test cell inlet air box was removed.

It is probable that the carburettor was damaged at the Zenair facility when their inlet air box was installed. Since the carburettor was void of fuel during the air box installation, any internal damage resulting from incorrect bolt application would have been difficult to detect.

The aircraft fuel system/components were inspected and found to be serviceable. Aircraft records, flight crew reports, and information gathered at the accident site confirmed that there was sufficient fuel onboard and in each tank to complete the flight. The damaged carburettor was found to be the only part of the aircraft fuel system that could have caused the engine power loss. Had the engine power loss been due to fuel flow interruption during the sideslip, engine power should have returned shortly after recovery from the manoeuvre.

The momentary negative "g " that occurred during the sideslip would cause the broken boss to move about in the float chamber. Although the carburettor needle valve was jammed in the closed position following the ground impact, the strong fuel smell experienced during and following the engine power loss does not support the conclusion that the valve was jammed closed prior to impact.

Had the broken boss caused the needle valve to remain open, fuel under pressure (electric fuel pump on) would continuously discharge into the carburettor throat. Since the fuel delivery would far exceed the engine’s fuel demands, the result would be a quickly flooded engine, a complete power loss, and a strong fuel odour in the cockpit.

Findings

- The internal damage to the carburettor was most likely the result of an incorrect bolt application during the inlet air box installation at the Zenair facility.
It is probable that the broken boss jammed the carburettor float and needle valve in the open position, flooding the engine with fuel and resulting in a complete engine power loss.

The ELT was not armed and, consequently, did not activate during the ground impact.

The outboard portion of each lap belt became unsecured when the fuselage structure, to which it attached, separated at impact.

The door latch bar (P.N. 20-F-32-3) exhibited excessive wear given its low time in service (41.1 hours TTSN).

Examination of the occurrence aircraft cabin heat box supply hose indicated that exhaust gases had entered the air box.

The alternate static switch placarding does not provide clear indication of the static source selected.

The CH2000 owner's manual does not provide clear direction as to how the airspeed correction should be applied when the alternate static source is selected.

The CH2000 side slips can result in a steep nose down pitch attitude, even when entered at speeds greater than normal approach speeds.

Causes and Contributing Factors

It is probable that the engine power loss was caused by pre-impact carburettor damage that interfered with the normal fuel scheduling to the engine during the sideslip manoeuvre. It is also probable that the carburettor was damaged as a result of an incorrect bolt application during the inlet air box installation.

Safety Action

Zenair has removed all of the air box attach bolts that were in their parts inventory at the time of the occurrence and has replaced them with shorter bolts. Zenair has also issued Service Bulletin (SB) 97-10, requiring aircraft owners and operators to inspect the carburettor for damage and inspect the air box attach bolts to ensure they are the correct length. All of the affected aircraft were inspected. As a direct result of operator compliance with the Service Bulletin instructions, twelve production aircraft have been identified with similar carburettor damage.

Transport Canada has reviewed the owner's manual for the Zenair CH2000 and revisions have been made. The service manual, the pilot reports on the flight characteristics during side slip manoeuvres, and the operation of the alternate static selection will also be verified.
Corrective actions will be initiated as required.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 22 July 1998.
Air 1997

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 Occurrence Report
Power Loss/Collision with Trees/Terrain
Manan Air Services Inc.
Piper PA-31-310 C-FZVC
Grand Manan Island, New Brunswick
12 September 1997

Report Number A97A0173

Synopsis

The aircraft departed Grand Manan, New Brunswick, at 1938 Atlantic daylight time (ADT)\(^1\) on a charter flight to Yarmouth, Nova Scotia, with the pilot and five passengers on board. After dropping off the passengers at Yarmouth, the aircraft departed at 2106 ADT for a night visual flight to return to Grand Manan. The pilot was unable to land at Grand Manan off the first visual approach because of low weather conditions and conducted a second visual approach. During the second approach, he noticed that he required increasing right rudder to maintain direction, and that the left engine manifold pressure was low. The pilot feathered the left propeller and, despite the application of full power on the right engine, the aircraft would not accelerate or climb. The aircraft began a shallow descent into a fog layer, and the aircraft collided with some trees, pitched nose-down, and struck the ground. The aircraft was destroyed by the impact and a post-impact fire. The pilot suffered serious injuries, but managed to get out of the aircraft and make his way to a nearby cabin where he was found by a ground search team about three hours later.

Other Factual Information

The pilot had been flying in the Grand Manan area since 1978 and, over the course of the intervening 19 years, had become familiar with the local area. He was current and qualified on the Piper PA-31-310 aircraft. During his recent pilot proficiency check, engine-failure procedures were assessed as satisfactory. It was determined that at the time of the occurrence the aircraft was approximately 1,200 pounds below its maximum allowable take-off weight of 6,500 pounds, and the centre of gravity was within the permissible limits.
The aviation forecast for the area of Yarmouth and Grand Manan included the possibility of localized ceilings of 500 to 1,000 feet above sea level (asl) with visibilities of two to five statute miles in fog at the time of the occurrence. According to regulations, the weather conditions were marginally acceptable for visual flight rules (VFR) flight in uncontrolled airspace.

Approaching Grand Manan, the pilot discussed the local weather conditions with his wife, by radio. From her vantage point, approximately one mile northeast of the airport, she reported a low overcast ceiling in the vicinity of their home, and she reported being able to clearly see the airport. She stated that the visibility to the northeast was good but that the visibility toward the airport was not quite as good, about four or five miles. The weather as described by the pilot's wife is consistent with the observations of witnesses interviewed in the vicinity. The weather to the west of the airport, in the area of the accident site, was described by search and RCMP personnel as being ground-based, heavy mist or fog, which thoroughly soaked the clothing of search personnel.

When he was approximately 10 miles southeast of the airport, the pilot could distinguish the glow of the airport lighting through a thin layer of fog or cloud. He continued toward the airport and then turned right, to a left-hand downwind leg for runway 24, at approximately 800 feet above ground level (agl). On the downwind leg, the pilot momentarily clearly observed the airport and the rotating beacon, but by the time he had turned final for runway 24, he could no longer see any sign of the airport or its lighting through the cloud. He discontinued the approach and elected to attempt a second approach.

The pilot flew the second approach relying on known landmarks, which were reportedly clearly visible. Approximately one mile from the airport, the aircraft was approximately 1,000 feet asl and the airspeed was approximately 90 knots indicated airspeed (KIAS), with the landing gear down, flaps at 15 degrees, and the landing light off. The pilot then descended to just above the cloud or fog bank. From the outset of the second approach, the pilot never regained visual reference with the airport or with any of its associated lighting.

During the approach, the pilot found he had to add more and more power to maintain airspeed and altitude, to the point where eventually both throttle levers were at maximum travel. Coincidentally, he had to use progressively more right rudder to maintain directional control. The pilot then noted that the left engine manifold pressure was lower than the right. The pilot felt that the pressure was somewhere between 20 and 30 inches while the right engine reading was either 42 or 44 inches. In an attempt to decrease the drag that would be created by a windmilling propeller, the pilot feathered the left engine propeller; coincidentally, the aircraft descended into cloud. The pilot selected the gear up immediately after feathering the left engine and raised the flaps. He does not, however, specifically recall the flap selection made nor banking the aircraft five degrees into the good engine as recommended in the aircraft's Pilot Operating Handbook (POH). After
feathering the left propeller, the pilot did not take further steps to secure the left engine.

The airspeed decreased to 80 KIAS, or slightly less, and never exceeded 80 KIAS thereafter, despite there being full power on the right engine. The pilot eased the nose of the aircraft down and then back up a few times in an effort to trade altitude for airspeed, all the while descending, but the airspeed did not increase. Realizing that an accident was imminent, the pilot advised his family by radio of his predicament. Shortly thereafter, the aircraft struck some large trees, pitched nose-down, and struck the ground. At impact, flames erupted near the right engine. The pilot released his seat belt and crawled out the crew door. The Rescue Coordination Centre in Halifax reported that an emergency locator transmitter (ELT) signal had been heard for approximately 20 minutes by overflying aircraft in the area of the crash before the signal ceased.

Fire destroyed all cockpit instrumentation and radios. The engine control quadrant and fuel selector panel were burned, and it was not possible to determine the pre-impact positions of the controls. The fuselage back to the tail section was destroyed by fire, and both wings were heavily fire-damaged. There was no indication that there was an in-flight fire. Because of the degree of impact and fire damage to the aircraft, the pre-impact condition and position of the flight controls could not be determined. However, continuity of the flight control cables was confirmed. At impact, the flaps and landing gear were retracted and the cowl flaps were closed.

Both fuel shut-off valves and the cross-feed valve were found and examined; however, the degree of damage precluded making a determination of the valves' pre-impact positions. The left and right fuel selector valves and the fuel selector panel were not recovered.

The engines were subjected to extreme heat from the fire, which virtually destroyed all of the accessory components. The left engine and both propellers were transported to the TSB wreckage examination facility in Dartmouth, Nova Scotia, for a detailed examination. The examination of the left engine did not reveal any pre-impact mechanical discrepancies, and it was determined that the left propeller was in the feathered position at impact. It was not possible to determine the blade angle of the right propeller at impact. A number of trees, some as large as eight inches in diameter, were sliced off by the right propeller as the aircraft went through the trees, indicating that the right engine was producing substantial power.

The aircraft's inboard and outboard fuel tanks had been fuelled to capacity, at Halifax, earlier on the day of the occurrence. The pilot stated that he had flown from Halifax to Grand Manan, about one hour in duration, on the outboard tanks. Based on the pilot's estimate of the aircraft's fuel consumption of 200 pounds per hour, the total fuel remaining in the outboard tanks should have been approximately 266 pounds. He then flew from Grand Manan to Yarmouth and returned, about one hour flight time, using fuel from the inboard tanks. Based on the same fuel consumption rate, the total fuel remaining in the inboard
tanks at the time of the occurrence should have been approximately 458 pounds.

According to the POH for the Piper PA-31-310, the best single-engine rate-of-climb speed is 94 KIAS, while the best single-engine angle-of-climb speed is 90 KIAS. Following this occurrence, the manufacturer was requested to provide the aircraft's single-engine climb performance given the following conditions; aircraft gross weight of 5,291 pounds, outside air temperature of 17 degrees Celsius, altitude of 800 feet asl, flaps and gear up, airspeed of 80 KIAS, and the POH procedures followed. The expected single-engine rate-of-climb was calculated to be 495 feet per minute.

The POH provides recommended procedures for dealing with engine failures. For example, if an engine fails at an airspeed above 76 KIAS, the POH suggests the pilot take the time to properly identify the inoperative engine and attempt to identify the nature of the problem. The emergency procedures state the following: 1) check to make sure the fuel flow to the engine is sufficient; 2) if the fuel flow is deficient, turn ON the emergency fuel pump; 3) check the fuel quantity on the inoperative engine side and switch the fuel selector to the other tank if a sufficient supply is indicated; and, 4) check the oil pressure and oil temperature and insure the magneto switches are ON. The POH also states that the pilot apply 5° of bank into the operating engine to assist in controlling the aircraft.

For this aircraft, the airspeed during an approach, as recommended in the POH, should be 100 KIAS or more. The POH states that a missed approach procedure for single-engine flight should be avoided if at all possible, and if a missed approach is unavoidable, that 94 KIAS or higher should be maintained. A warning in the POH states that a missed approach (go-around) should not be attempted if the airspeed is below 90 KIAS, the best single-engine angle-of-climb speed.

In the event of an engine failure in a light, twin-engine aircraft such as the Piper Navajo, accurate airspeed control is critically important to maintain level flight or to establish a climb. The airspeed must not be allowed to decrease below the optimum where drag may become so high that the thrust from the remaining engine is not sufficient to overcome the drag. In this situation, the only way to maintain the airspeed above the stall is to descend, thereby trading altitude for airspeed. This option may not be available when operating close to the ground.

Normally, the need for making a decision during flight is triggered by recognition that something has changed. Recognition of this change provides the pilot the opportunity to make a timely decision to control the circumstances of the flight. If no decision is made and as time and the flight progresses, the alternatives available to the pilot to make changes may decrease or disappear completely.

Analysis

The cause of the apparent engine failure could not be determined.
After the left propeller was feathered and the landing gear and flaps retracted, the aircraft should have been able to climb at a rate of 495 feet per minute. The analysis will focus on human performance elements that contributed to the accident and on the single-engine performance demonstrated by the aircraft.

The pilot was aware that it would be dark and that the forecast included the possibility of ceilings of 500 to 1,000 feet asl with visibilities of two to five statute miles in fog at the time of his return to Grand Manan. The weather conditions were marginally acceptable for VFR flight in uncontrolled airspace, and the pilot's decision to undertake the flight, given the weather and light conditions, was considered reasonable.

When the pilot turned final for runway 24 during his first approach, he could not see any sign of the airport or its lighting, believing that he was flying above a cloud layer which was obscuring his view of the airport. During his second attempt, the pilot never had visual reference with the airport or with any of the associated lighting. Notwithstanding the poor weather conditions, the pilot continued with the approach relying on ground features to align himself with the runway, which he could not see. He was skimming the top of the cloud or fog layer at night, close to the ground, and at an airspeed below the recommended final approach speed. This allowed little or no safety margin in the event of an aircraft malfunction. Continued VFR flight into IMC conditions is a leading cause of Controlled Flight Into Terrain (CFIT) accidents.

By the time the pilot diagnosed that he had an engine problem, the aircraft was in a shallow descent into cloud, relatively close to the ground, and the airspeed had decreased to 80 KIAS or less. Given the low altitude and airspeed, the pilot had to take immediate action in order to reduce the drag caused by the windmilling propeller. However, once the propeller was feathered, the pilot lost the opportunity to troubleshoot the engine problem and was committed to handling an engine-out situation under less than ideal weather and light conditions. An approach airspeed of 100 KIAS or more is recommended in the POH to provide more time, in the case of an emergency, for analysing problems and taking corrective actions before the aircraft reaches a state where it can no longer be flown safely.

It could not be determined why the aircraft would not climb or accelerate after the left propeller was feathered. The manufacturer's calculations indicate that the aircraft should have been able to climb; the fact that it did not climb may have been due to the low airspeed at which the approach was attempted, the pilot's actions in raising and lowering the nose of the aircraft, and the pilot not applying five degrees of bank into the good engine.

The pilot distinctly recalls that he had only flown one hour on the outboard fuel tanks and, based solely on this recollection, the possibility of fuel exhaustion would appear unlikely. However, the engine failure described by the pilot is consistent with an engine stopping because of fuel exhaustion. After the aircraft had been fuelled to capacity, it had been flown for approximately two hours. The pilot considered the fuel
consumption rate of each engine to be approximately 100 pounds per hour. Given that the fuel capacity of each outboard tank is 233 pounds, and assuming the pilot had flown with the outboard tanks selected for the two hours, approximately 33 pounds of fuel would remain in each of the outboard tanks. Based upon this approximation of fuel remaining, the possibility of fuel exhaustion in the outboard tanks cannot be ruled out.

Findings

- The pilot was certified for the flight in accordance with existing regulations.
- The aircraft’s weight and centre of gravity were within the prescribed limits.
- For undetermined reasons, the left engine lost power during the approach.
- Because of the low airspeed and height at which the pilot was flying the approach, he had no time to analyse the engine malfunction before feathering the engine.
- After feathering the left engine, the pilot was committed to conducting a single-engine overshoot, at night and in cloud. The airspeed was then 80 KIAS, 20 knots below the recommended approach speed.
- After the apparent engine failure, the pilot did not follow the recommended emergency procedure as outlined in the POH.
- For undetermined reasons, the aircraft would not accelerate or climb despite full application of power on the operative engine.

Causes and Contributing Factors

The aircraft lost power on the left engine during the approach for undetermined reasons and descended into the ground. The cause of the engine power loss was not determined. The low airspeed, at the time of the engine power loss, decreased the time available to the pilot to secure the emergency in accordance with the POH, and contributed to the poor single-engine performance of the aircraft.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 16 September 1998.

1. All times are ADT (coordinated universal time minus three hours) unless otherwise noted.
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 Occurrence Report
Loss of Control
Bearskin Lake Air Service Ltd
Fairchild Metro 23 C-GYTL
Winnipeg, Manitoba 18 nm NE
21 August 1997

Report Number A97C0168

Summary

The Bearskin Lake Air Service Flight 317, a Fairchild Metro 23 serial number CC829B, was en route from Red Lake, Ontario, to Winnipeg, Manitoba, with two crew and eleven passengers onboard. Approximately 18 miles north-east of Winnipeg, the crew completed the approach checks and were in descent to 4 000 feet above sea level (asl). Shortly after, the Captain had advised the passengers to fasten their seat-belts in preparation for landing, as the aircraft approached 4 400 feet asl, it pitched up without warning and without any initiating control inputs by the crew. Although the crew immediately attempted to stop the sudden flight deviation, the aircraft climbed to about 6 900 feet asl at a rate of climb of about 14 000 feet per minute with a maximum pitch attitude of 52 degrees nose-up. The combined effort of both crew members pushing forward on the control yokes was required to counteract the nose-up force and to bring the aircraft in a nose-down attitude. The crew believed the aircraft stalled while they were pushing the nose down and they applied full power. The aircraft then descended, reaching a maximum nose-down attitude of minus 26 degrees before the crew were able to level the aircraft. The crew evaluated the amount of flight control available and executed an approach and landing at Winnipeg. Throughout the approach, the first officer exerted full forward pressure on the control yoke with his hands and pushed on the column with both feet. Following the occurrence, two passengers reported neck and back pain.

Ce rapport est également disponible en français.

Other Factual Information
The aircraft was operating in visual meteorological conditions above a scattered cloud layer. Winds at the Winnipeg airport were 010 degrees true at five knots. The crew followed radar vectors to the airport and, after acquiring the runway visually, completed a visual approach.

The crew were certified and qualified for the flight in accordance with existing regulations. Both crew members held valid airline transport pilot licences. The aircraft captain has flown in excess of 10 000 flight hours. The first officer was 27 years of age and had an athletic physique. After landing, he was physically drained from the exertion required to hold the control yoke forward.

Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. There were no reports indicating that the aircraft had been subjected to heavy turbulence or abnormal flight conditions prior to the uncommanded runway trim condition.

When the sudden nose-up flight deviation occurred, the first officer was at the controls. The pitch-up happened within two to three seconds and he immediately began to push forward on the yoke and attempted to trim nose-down. He was able to stop the nose-up motion as the airspeed decreased. He noted that the airspeed reduced to less than 40 knots indicated airspeed and that the altitude peaked at about 7 000 feet asl. He felt the stick shaker activate and believed the stick pusher had also activated. His attempt at trimming the aircraft was not effective. Both crew members heard the stall warning horn and believed the aircraft attitude had risen to almost 90 degrees. The crew increased engine power as the nose was pushed over. The subsequent descent was arrested by the crew at about 5 500 feet asl. The crew adjusted the power settings and were able to stabilize the aircraft at 6 000 feet asl and at about 140 knots indicated airspeed.

When the crew lowered one-quarter flap, increased nose-down control force was required; the captain elected to conduct a flapless approach and landing. The crew requested that passengers move to the forward seats in the cabin to obtain a more favourable aircraft centre of gravity and thereby assist in keeping the aircraft nose down. The approach and landing were accomplished with the first officer applying forward pressure to the control column with full force using both hands and both feet. The captain controlled the ailerons, rudders, and power levers. Together, the two crew accomplished a smooth and stable aircraft touchdown on the runway.

The aircraft was equipped with a flight data recorder (FDR) and cockpit voice recorder (CVR), which were analysed at the TSB Engineering Branch. The aircraft was also transponding a discrete code assigned by the air traffic control system (ATS); therefore, the Winnipeg area control centre (ACC) radar system recorded the aircraft's flight profile. Data from the FDR and from the ACC radar corresponded closely. FDR data indicated that the aircraft was descending through 4 600 feet asl at about 238 knots when the pitch-up occurred. The stabilizer position moved from -1.5 degrees to +8.5 degrees (full nose-up) at a rate of about 3.5 degrees per second. The peak vertical acceleration was 3.5
The maximum aircraft pitch attitude attained was about 52 degrees nose-up and the minimum airspeed was 54 knots. The FDR also revealed that prior to the sudden flight excursion, the typical rate of stabilizer movement was approximately 0.5 degree per second.

The horizontal stabilizer trim actuator was removed from the aircraft and forwarded to the TSB Engineering Branch for examination. The data plate identified the unit as a Fairchild Aircraft Corp., linear actuator, part number (P/N) 27-1900-002, serial number (S/N) 115, having a date of manufacture of December 1991. The actuator operates at 18-32 volts dc with a maximum current draw of 8 amperes. The actuator was manufactured for the Fairchild Aircraft Corp. by the Barber-Colman Company (as P/N RYLC-51438-1), for use in the pitch trim system of the SA226 and SA227 aircraft. The "-1" portion of the part number indicates that the actuator is made for autopilot or manual use; the incident aircraft was not equipped with an autopilot. The RYLC-51438-1 is a dual-ram jackscrew, electro-mechanical type actuator designed to control the horizontal stabilizer trim surface. One of the actuator output rams is activated by the pilot's control yoke inputs, and a second output ram moves in accordance with the copilot's control yoke inputs. (The report will subsequently use the terminology of "pilot's side" and "co-pilot's side" when referring to components within the actuator). The actuator incorporates a mechanical non-reversible "no-back" mechanism that prevents slipping of the stabilizer trim setting from the selected position and is designed to prevent any uncommanded reversing of the actuator under air-induced loads of up to 2 200 pounds. Redundancy, within the actuator, that prevents unwanted reversing of the pitch trim actuator, is provided by the actuator gear train, in conjunction with the actuator motor brake. This redundancy is designed to hold the stabilizer against the air-load if the "no-back" mechanism fails.

The actuator had been overhauled and updated to the latest engineering order configuration in May of 1996. It was installed on the aircraft at that time and had accumulated 1 439 air hours at the time of the failure.

The actuator was transported to the Barber-Colman Company where component teardown and analysis were conducted (Barber-Colman Company TDR number 254). Testing showed that the "no-back" mechanism would not hold even under minor loading of less than 50 pounds. The outboard ball bearing (Barber-Colman P/N CYRB 158), that supports the trunnion gear on the front end cap assembly on the copilot's motor side, had disintegrated and the majority of the trunnion gear teeth were destroyed. The twelve "no-back" rollers or "no-backs", located on both the pilot's and copilot's sides, were extensively deformed, indicating they had been subjected to heavier-than-normal repetitive loads. The rollers had been installed at the time of the May 1996 overhaul. Barber-Colman representatives indicated that they had not previously seen such a large amount of deformation on any rollers removed from any such actuators returned for overhaul. Material analysis of the "no-back" rollers showed that they were manufactured from the appropriate alloy specified by Barber Colman as UNS R30605.
in accordance with the relevant standard (AMS 5796).

The rear thrust washers on the pilot's and copilot's sides were fractured virtually in half. Of the three "no-back" springs located on the copilot's side, one spring was fractured, one was deformed, and one spring was normal. The failed thrust bearing washers exhibited heavy indentations that were suspected to have been made by a single impact, likely at the time of the actuator failure and trim surface runaway.

The deformation of the "no-back" rollers prevented them from holding the selected actuator position against the loads imposed on the actuator output tubes by the stabilizer. This load was in turn transferred to the geartrain. The geartrain, with the aid of the motor brake, normally provides a redundant system to hold the stabilizer in the selected position. The catastrophic failure of the ball bearing on the copilot's side caused the geartrain to disengage, allowing the unrestrained operation of the actuator output tubes. The air-load on the horizontal stabilizer then moved the stabilizer to the extreme nose-up condition.

Inspection of the actuator showed signs of mis-rigging of the full-retract position of the unit while it was installed in the aircraft; the actuator was not being shut off electrically in the full-retract position by the externally mounted limit switches. Such mis-rigging would cause the actuator to run into the internal mechanical retract stop, thereby placing stress loads onto the actuator gear system. Analysis of the effects of this mis-rigging indicated that it would not have caused the failures seen in this S/N 115 actuator. The pitch trim actuator installation instructions, outlined in the Fairchild Maintenance Manual at the time that the S/N 115 actuator was installed, required the operator to perform an operational check of the pitch trim system and control. The procedure did not specifically direct the operator to adjust or assess the mechanical/electrical stops, a procedure that was provided elsewhere in the manual. Fairchild Aircraft amended the relevant section of the installation instructions on 01 January 1998, requiring the operator to "Perform Adjustment - Mechanical/Electrical Stops procedures and Operational Check - Pitch Trim and Control procedures in this section."

On 03 October, 1997, prior to the maintenance manual change, Fairchild Aircraft issued service letter 227-SL-031 (Subject: Barber Colman Pitch Trim Actuator - Perform Adjustment - Mechanical/Electrical Stops Functional Check and No-back Functional Check), drawing attention to the testing and adjustment procedures for the actuator electrical stops.

When the horizontal stabilizer trim actuator was removed from the aircraft, it was noted that the side opposite from the identification plates exhibited an indentation plus an associated loss of paint in the area of the indentation. Company maintenance personnel could not determine when or how the indentation of the case occurred. The degree of damage and location of the indentation do not appear to be directly related to the mode of failure of the actuator. The Barber-Colman Company, in conjunction with Fairchild Aircraft, has conducted considerable testing but have not been successful in duplicating the failure noted on the S/N 115 actuator.
The FAA has issued Airworthiness Directive (AD) 97-23-01, applicable to all SA226 and SA227 series airplanes that are equipped with a Simmonds-Precision pitch trim actuator (P/N DL5040M5 or P/N DL5040M6) or a Barber-Colman pitch trim actuator (P/N 27-19008-001 or P/N 27-19008-002). The AD calls for the repetitive inspections of the actuators in accordance with the applicable service letters (226-SL-014 etc.) issued by Fairchild Aircraft. In addition to detailing specific inspection time frames, the AD also specifies repetitive replacement times for specific Simmonds-Precision actuators.

Barber-Colman Company has produced more than 300 actuators for the Fairchild SA226 and SA227 aircraft, with no reported occurrences of uncommanded output tube motion caused by actuator failure.

Analysis

The correspondence between the data from the FDR and the recorded ATS radar data indicates that the aircraft reached a maximum nose-up attitude of 52 degrees. The crew's belief that the aircraft's nose-up attitude during the flight upset was steeper than registered in the FDR is understandable. The rapid onset of the pitch-up and the steep attitude achieved would have made accurate assessment of the pitch angle very difficult, particularly while the crew was attempting to regain aircraft control. The visual weather conditions, experience level of the pilot, and the physical strength of the first officer were likely significant factors in the successful recovery of the aircraft. The crew's immediate and coordinated action was critical to avoiding an aerodynamic stall and the probable loss of aircraft control.

The remainder of this analysis will focus on the technical issues regarding the pitch trim actuator. The pitch-trim actuator, S/N 115, failed in a condition which allowed the horizontal stabilizer trim surface of the aircraft to move to an extreme travel position thereby causing an immediate and rapid uncommanded nose-up deviation of the aircraft. The loss of control of the horizontal trim movement resulted when the mechanical "no-backs", within the actuator unit, failed to hold the stabilizer trim surface load. Failure of the "no-back" restraint probably caused the subsequent failure of a bearing in the actuator geartrain. The failure of the bearing permitted the gear that it was supporting to disengage the gear mesh from the rest of the geartrain. Under normal circumstances, the geartrain, in conjunction with the motor brake, provides a redundant system which will hold the stabilizer load should the "no-back" mechanism fail. The combined failures of the "no-back" mechanism and of the gear bearing allowed the uncommanded motion of the actuator output tubes and stabilizer.

No other similar actuator units, that have been returned to the Barber-Colman Company for repair or overhaul, have displayed the type and extent of damage exhibited by the S/N 115 unit. There have been no other similar actuator failures reported, and despite extensive testing by the manufacturers, the noted failure of the S/N115 actuator could not be duplicated. Therefore, the uncommanded output tube movement of this specific unit remains an isolated occurrence that was likely caused by the effects of undefined repeated loading conditions, which
progressively forged the actuator "no-back" rollers into a configuration that ultimately prevented them from holding the actuator output tubes in position against the stabilizer flight loads. There were no reports indicating that the aircraft had been subjected to heavy turbulence or abnormal flight conditions prior to the uncommanded runaway trim condition. Neither the teardown of the actuator nor the examination of the aircraft revealed the source of the repeated heavy loading. The inspection requirements of AD 97-23-01 have been put in place to assess and remove actuators from service before the no-back rollers fail in this manner.

The following TSB Engineering Branch reports were completed:

- LP 130/97 - FDR/CVR Analysis
- LP 132/97 - Pitch Trim Actuator Examination

**Findings**

- During the descent on approach for landing, the aircraft entered an abrupt uncommanded pitch-up.

- The physical force required to overcome the nose-up force of the horizontal stabilizer tasked the strength and endurance of the young and physically strong co-pilot.

- The visual meteorological conditions facilitated the re-establishment of aircraft control and the recovery from the nose-high, low airspeed flight condition.

- The internal "no-back" and geartrain mechanisms failed within the pitch trim actuator (Barber-Colman P/N RYLC-51438-1 / Fairchild Aircraft P/N 27-1900-002 ).

- Unrestrained by the "no back" mechanisms and influenced by air loads, the horizontal stabilizer moved rapidly to a full nose-up trim condition.

- Despite considerable testing, neither Fairchild nor Barber-Colman could duplicate the failure of the actuator "no-back" roller mechanism.

**Causes and Contributing Factors**

While on descent for the approach, the aircraft entered an uncommanded pitch-up because the "no-back" mechanism and geartrain components failed within the stabilizer pitch trim actuator for undetermined reasons, thereby allowing the air-loads to rapidly move the stabilizer to a full nose-up condition.

**Safety Action**

Following this occurrence, the Federal Aviation Administration issued
AD 97-23-01 which specified additional measurements and inspection of the pitch trim actuator. The stated objective of the AD is "to prevent failure of the pitch trim actuator, which could cause loss of control of the airplane" and is applicable to all SA226 and SA227 series airplanes equipped with specific part number Simmonds-Precision or Barber-Coleman pitch trim actuators.

On 03 October 1997, Fairchild Aircraft issued Service Letter 227-SL-031 outlining procedures for conducting adjustment and functional check of the mechanical/electrical stops and a functional check of the no-back system for the Barber Colman pitch trim actuator. Additionally, on 01 January 1998, Fairchild Aircraft revised the pitch trim actuator installation instructions, outlined in the maintenance manual, requiring an adjustment and an operational check of the mechanical/electrical stops when installing pitch trim actuators.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 18 November 1998.
Air 1997

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 Occurrence Report
Collision With Terrain
Mitchinson Flying Service Limited
Cessna 152 C-GZCT
Vanscoy, Saskatchewan 4 nm S
04 October 1997

Report Number A97C0195

Summary

The Cessna 152, serial number 15280919, departed Saskatoon, Saskatchewan, on a training flight. The purpose of the flight was to practice the instruction of spins, stalls, and slow flight. The crew flew the aircraft to the training area, CYA 306(T), in the Saskatoon terminal area. The aircraft's transponder was on mode "C", permitting a radar record of the flight, including altitude, speed, and track information to be stored by the air traffic system (ATS) radar. The recorded information revealed that the aircraft entered the north-east corner of the training area and flew back and forth in the north-east corner as training exercises were accomplished. Several manoeuvres including spins, which took place between 4 000 feet and 4 500 feet above sea level (asl), were recorded. After about 55 minutes of flight, the aircraft entered a spin at 4 000 feet asl. The last recorded transponder signal occurred at 2 000 feet asl in the vicinity of Vanscoy, Saskatchewan. The height of the terrain in the vicinity of the last radar signal is about 1 700 feet asl. The aircraft was observed momentarily by the driver of a vehicle on a road about one-quarter mile from the occurrence site at about the same time as the last transponder signal was recorded by ATS. The witness reported that the aircraft appeared to be at about 200 feet above ground level (agl) and that the aircraft banked rapidly to the left and then crashed in a field beside the road. Both occupants were fatally injured.

Ce rapport est également disponible en français.

Other Factual Information

At the time of the occurrence, the weather at Saskatoon and in the
CYA 306(T) training area was 15 statute miles\(^1\) visibility with scattered cloud at 12 000 feet asl and a broken cloud ceiling at 22 000 feet asl. The winds were calm and the temperature was 17 degrees Celsius.

The aircraft crashed in a field located about one-quarter mile south of an east/west gravel road. The wreckage trail was about 80 feet long and was oriented on a south-westerly heading. Ground scars indicated that the aircraft struck the ground in a nose low, slight left bank attitude. Ground scars made by the wings were of equal length on both sides of the impact point. Several propeller cuts were also evident on the ground surface. The propeller blade cut marks at the scene, the abrasion marking on the propeller blades in the direction of rotation, and the bending of one propeller blade indicated that the engine was operating at a moderate to low power setting on ground impact. Damage to the aircraft was consistent with a high vertical rate of descent. The wreckage was examined in-situ to the extent possible, and no pre-impact failures were found that would have lead to a loss of control.

A plastic carbon monoxide detector was found in the wreckage, soaked in fluids. It could not be used to determine the presence of carbon monoxide in the cockpit prior to the accident. This type of carbon monoxide detector, which is commonly installed in small aircraft, is glued to the instrument panel. When mounted, the user directions that are printed on the back of the detector are no longer visible. These directions indicate that the detector will turn dark brown to grey/black when exposed to carbon monoxide and that, even a slight darkening, may indicate a dangerous level of carbon monoxide. The directions also state that, when the air freshens, the detector will return to its original colour. Whether either crew member understood the directions or checked the indicator during flight could not be determined.

Review of the company maintenance records indicated that the aircraft was certified and maintained for flight in accordance with the existing regulations. Some cockpit instruments, the aircraft engine, and the engine exhaust system were forwarded to the TSB Engineering Branch laboratory for detailed examination. The examination of the instruments determined that, at impact, the engine tachometer was registering at least 1 200 revolutions per minute and that the airspeed and vertical speed indicators were indicating 80 knots and a 2 000 feet per minute descent, respectively.

The engine, an Avco Lycoming model 0-235-L2C, serial number L20218-15, had accumulated approximately 779 hours in service since a major overhaul. The most recent engine cylinder differential compression check was completed approximately 76 hours time-in-service prior to the accident, and the results were within prescribed limits. The engine was disassembled at the TSB Engineering Branch laboratory. The compression rings installed in the number 1, 2 and 3 cylinders were determined to have excessive wear. Measurement of the compression ring end gaps, when positioned in their respective cylinders, indicated that the rings were at, or exceeded the service
limits published by the engine manufacturer. The cylinder number 4 compression rings were approaching the service limit but all oil control rings measured within specification. Exhaust gas by-products were visible on the piston skirts, in and around the piston pin recesses, and at the outer end of the connecting rods. The exhaust gases entering the engine crankcase are vented overboard on the left side of the aircraft's belly. Examination at the occurrence site determined the crankcase vent to be assembled and installed according to the manufacturer's specifications. In summary, the examination revealed no anomalies which would have precluded engine operation.

The exhaust pipe and the gasket from cylinder number 3 were removed during the initial occurrence site engine-condition examination, and there was no evidence of an exhaust leak at the cylinder number 3 exhaust stack. The remainder of the exhaust system, identified by the data plate installed on the muffler shroud as KMR IND., 1-1000, 01542 LYC 0-235 L2C, 1452, was removed from the engine at the TSB Engineering Branch facility. Visual examination showed that exhaust gas was leaking between the exhaust gasket and the cylinder head at the cylinder number 4 exhaust port. The number 4 exhaust port is located to the left rear of the engine. The leak was identified by the staining of the exhaust port, adjacent engine baffle, and cylinder cooling fins; however, the leak was slight as there was no observed erosion of the port or fins. Cylinders number 1 and 2 appeared to have been sealed as required to the exhaust pipe by the exhaust gasket.

Disassembly and examination of the exhaust system revealed no corrosion of the muffler or staining of the muffler shroud that would have indicated that exhaust gases were leaking from the muffler into the cabin heat system. Examination of a chafed area on the number 4 exhaust pipe, 3/4 of an inch below the exhaust attachment flange, revealed three holes in the pipe wall with exhaust gas staining radiating from one hole. Detailed examination revealed that two of the holes were a result of the buckling and tearing of the thin material in the chafed area during the impact sequence. Only the hole with the associated staining existed prior to the accident. Exhaust gases, leaking from this small hole, collected within the engine cowling from where they could potentially migrate into the aircraft cabin.

The 53-year-old pilot-in-command had in excess of 10 000 hours flying time and had instructed for nine years. He held a Class 1 instructor endorsement. He was held in high regard among other staff members as a professional instructor and was well liked by students. There was no evidence that he engaged in risky flying practices. The 30-year-old student instructor was a recent commercial licence graduate of the flying school. Staff of the flying school had suggested that the student instructor obtain an instructor rating, and school management had intended to employ him as an instructor. The flight school management attempts to hire pilots that have been trained at their school as a method of ensuring high instructional standards. The pilot-in-command had conducted the previous flying training of the student instructor, and a friendly relationship of mutual respect had reportedly developed.
Both pilots had valid medical certificates and had no reported history of medical problems. Post-mortem examination found microscopic pathologic evidence that the pilot-in-command had mild atherosclerosis of the coronary arteries. Such a condition would not normally affect performance and would not be detectable during routine examinations. While there was no pathological evidence of hyperglycemia, stroke, or myocardial infarction in either of the crew members, not all types of incapacitation, such as angina for example, can be reliably detected by post-mortem examination and cannot, therefore, be ruled out.

There was no toxicological evidence of alcohol or illicit drugs; however, spectrophotometry indicated blood saturation levels of carbon monoxide of six percent in the pilot and of two percent in the student. The toxicologist estimated that the tests performed for carbon monoxide have an accuracy of plus or minus three percent when the levels of carbon monoxide are this low. There is no appreciable decrease in the level of carbon monoxide after death because there is no respiration or blood circulation. Thus, the carbon monoxide levels found are in the range of three to nine per cent in the pilot-in-command and zero to five per cent in the student instructor. Neither pilot smoked, and the flight school maintains a smoke-free environment.

Levels of carbon monoxide saturation of less than ten per cent are not considered to have a major effect on performance, although such a level would have a greater effect on non-smokers than on smokers. Cigarette smokers, for example, may routinely have saturation levels of six to eight per cent. When saturation levels exceed ten percent, headache and shortness of breath can occur. Lower saturation levels of five to ten per cent can decrease the threshold for angina for those individuals who have an atherosclerosis condition.

The Health Canada publication *Carbon Monoxide* states that "High altitude exposure interacts with CO poisoning. At moderate altitudes, an ascent of 300 metres (approximately 1 000 feet) may be equated to one per cent increase of blood COHb (carboxyhemoglobin) contents. Thus, individuals living above 1 000 metres are particularly vulnerable to small doses of CO." That is, the hypoxic effect of the decreased availability of oxygen in the atmosphere as altitude increases has a similar degradation effect on some aspects of crew performance as an increase in carbon monoxide level of one per cent for each 1 000 feet of increase in altitude. Taking this altitude factor into account, the effective carbon monoxide level of the pilot was in the range of seven to thirteen per cent, while the student pilot had four to nine per cent.

The *Civil Aviation Regulations*(CARs) define an aerobatic manoeuvre as a manoeuvre in which a change in the attitude of an aircraft results in a bank angle greater than 60 degrees, an abnormal attitude, or an abnormal acceleration not incidental to normal flying. A spin is thus an aerobatic manoeuvre. CAR 602.27, Aerobatic Manoeuvres -Prohibited Areas and Flight Conditions, states that no person shall conduct aerobatic manoeuvres below 2 000 feet agl without a special flight operations certificate. To conform with this regulation, pilots operating in the CYA 306(T) area would have to terminate aerobatic manoeuvres at or above 3 700 feet asl. Review of the stored ATS radar data revealed
that after the aircraft entered CYA 306(T), several exercises were undertaken that resulted in vertical manoeuvring, but, at no time, did the crew descend below 3 700 feet asl prior to the accident manoeuvre.

The ATS radar tape showed that a manoeuvre was entered at low airspeed at about 4 000 feet asl and that a high vertical descent rate developed. The recorded speed remained very low and the aircraft heading rotated rapidly. The total elapsed time from 4 000 feet asl until ground impact was estimated to be about 45 seconds. The last three ATS radar signals indicated that the aircraft tracked in a westerly direction for about 15 seconds just before the impact with the ground. A witness, driving in a westerly direction beside the field in which the impact occurred, observed the aircraft for several seconds prior to the impact. Initially, the aircraft appeared in his peripheral field of vision through the side window of the vehicle. He noticed the aircraft was momentarily in a level attitude at about 200 feet agl. The aircraft did not appear to be overtaking the road vehicle which was travelling at about 60 mph. Almost instantly thereafter, the left wing dropped abruptly and the aircraft banked and descended into the terrain.

**Analysis**

The weather conditions at the time of the occurrence were ideal for flying training and were not a factor in the accident.

The ATS radar information indicates that during the last vertical manoeuvre that originated at about 4 000 feet asl, the aircraft descended rotationally at a high descent rate. The observed low speed indicated that the aircraft was in a spin and not in a spiral dive. The last three ATS radar returns showing the aircraft continuing its descent while tracking in a westerly direction, together with the ground witness observation of the aircraft appearing to be momentarily level on a westerly heading, support the hypothesis that at least one of the pilots may have succeeded in recovering the aircraft from the spin and was attempting to recover from the ensuing aircraft descent. The subsequent abrupt wing drop and nose-down descent observed by the witness on the ground shortly prior to ground impact likely indicate that a secondary stall was induced during the attempted spin recovery. The very low altitude precluded recovery from the stall.

It is not known why a spin would have been continued below 3 700 feet asl. Based on the experience level and reputation of the instructor, it is unlikely that he would have engaged in a dangerous training practice or intentionally allowed the aircraft to continue spinning below the minimum altitude specified in CARs. Until the occurrence manoeuvre, the pilot had adhered to the minimum altitude required by CARs and shown airmanship consistent with his professional reputation. It is unlikely that either pilot would have intentionally allowed the spin to continue to a low altitude above the ground. It is more likely that some other factor intervened and caused recovery action to be delayed until ground contact was imminent.

It is possible for confusion or conflict to occur with regard to which pilot has control of the aircraft and is taking corrective action, particularly in
a scenario involving an instructor pilot and a student instructor; as a result, a manoeuvre could inadvertently be continued unsafely. Given the experience level of the instructor and the reported harmonious relationship between the pilots, it is unlikely that a poor instructor/student relationship developed during the flight that could have affected their judgement or ability to control the aircraft.

No pre-impact mechanical failure was found in the aircraft control system which would have caused a loss of control or control difficulties. Additionally, the observed probable recovery attempt indicates that the aircraft control system was functioning. Although the amount of power being produced by the engine could not be determined accurately, the engine was functioning and would not have prevented recovery from either the spin or a subsequent stall. The only technical anomaly found was the exhaust gas leak at the number 4 cylinder which could have potentially leaked past the firewall and introduced carbon monoxide into the cabin. Because both crew members were nonsmokers, they were found to have carbon monoxide levels of about three to nine per cent for the pilot-in-command and zero to five per cent for the student pilot; it is likely that some exhaust gases had been introduced into the aircraft cabin from the exhaust leak during the flight and was absorbed in their blood as they breathed the cabin air. Because of the location of the exhaust leak, to the left rear of the engine, it is possible that the concentration of carbon monoxide was greater near the pilot-in-command, and that his blood saturation level was consequently higher than that of the student pilot.

The carbon monoxide saturation levels found in both pilots, as detected by the toxicology testing, are not normally considered of significance in relation to an individual’s performance; however, when a factor of four per cent is added because of the effects of decreased oxygen availability at 4 000 feet asl, the range becomes seven to thirteen per cent for the pilot-in-command and four to nine per cent for the student pilot. Although these carbon monoxide levels would not be expected to have a large effect on their performance, some effect cannot be ruled out. Additionally, the mild atherosclerosis found during the microscopic analysis of the pilot-in-command’s coronary arteries, in conjunction with the low level of carbon monoxide, may have triggered some degree of incapacitation from angina. If any such incapacitation occurred, particularly during a critical manoeuvre such as a spin, control of the aircraft could have been affected. This hypothesis could not be corroborated.

The user directions for the carbon monoxide detector are printed on the back of the detector and are obscured when the detector is installed. Because the carbon monoxide detector returns to its unexposed colour when the air freshens, checking the detector only during pre-start cockpit checks does not alert the crew of any previous carbon monoxide leaks into the cockpit. The detector would have to be checked periodically during flight to alert the crew of the presence of carbon monoxide. It is not known if the crew were aware of the detector’s operating characteristics, or whether the crew noted the condition of the carbon monoxide detector during the flight.
The following Engineering Branch reports were completed:

LP 2/98 - Exhaust System Examination
LP 196/97 - Instrument Examination

Findings

- Records indicate that both crew members were certified and qualified for the flight in accordance with existing regulations.

- Weather was not a factor.

- The company maintenance records indicate that the aircraft was certified and maintained for flight in accordance with existing regulations.

- There was no evidence found of any airframe or engine malfunction prior to or during the flight.

- The engine cylinder compression rings were worn beyond manufacturer's specifications thereby allowing combustion gases to escape into the crankcase, and the combustion byproducts were being exhausted overboard through the crankcase manifold venting system.

- Exhaust gases leaking from a small hole in the number 4 cylinder exhaust stack resulted in a build-up of carbon monoxide in the engine compartment. Some of the carbon monoxide likely leaked past the engine firewall and exposed the crew to a low level of carbon monoxide in the cabin.

- Toxicology tests for the presence of illicit drugs or alcohol were negative.

- Toxicology tests for the presence of carbon monoxide revealed a level of zero to five per cent for the student pilot and three to nine per cent for the pilot-in-command.

- The decreased oxygen availability with altitude would have had the equivalent effect on the crew's physiology as would a carbon monoxide range of seven to thirteen per cent for the pilot and up to four to nine per cent for the co-pilot.

- The crew would have been experiencing some mild physiological effects from a low level of carbon monoxide in the cabin, although normally such low carbon monoxide levels would not be expected to have a large effect on performance.

- The microscopic examination during the postmortem indicated that the pilot-in-command had mild atherosclerosis of the
that the pilot-in-command had mild atherosclerosis of the coronary arteries.

- Although the pilot-in-command's mild atherosclerosis condition could have made him somewhat more susceptible to angina because of the effects of carbon monoxide in the cabin, whether such incapacitation took place could not be determined.

- The manoeuvre initiated at 4 000 feet asl was continued below the CARs minimum aerobatic recovery altitude for unknown reasons.

- An attempt appears to have been made to recover from a secondary aerodynamic stall at low level but could not be accomplished in the altitude remaining.

- The user directions for the carbon monoxide detector are printed on the back of the detector and are obscured when the detector is installed.

Causes and Contributing Factors

During the recovery from a training manoeuvre that was continued below a safe altitude, the aircraft entered a secondary stall at an altitude from which recovery was not possible. It was not determined why the training manoeuvre was continued below a safe altitude. The level of carbon monoxide detected in both pilots would have had some physiological effect on their performance, but the extent could not be determined.

Safety Action

The Flight Training Division of Transport Canada is conducting a study regarding stall/spin accidents in pilot training.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 10 February 1999.

1. Units are consistent with official manuals, documents, and instructions used by or issued to the crew.
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 Occurrence Report
Controlled Flight Into Terrain
McMurray Aviation
Piper PA-34-200T Seneca C-GPRL
La Loche, Saskatchewan 8 nm W
30 October 1997

Report Number A97C0215

Summary

The Piper PA-34-200T Seneca departed Fort McMurray, Alberta, on a 62 nautical mile (nm) charter flight to La Loche, Saskatchewan, with a crew of one pilot and five passengers on board. The aircraft departed at 1750 mountain standard time (MST)\(^{(1)}\), and was expected back in Fort McMurray at 1930. The pilot had filed a flight plan, and when the aircraft did not return, the Fort McMurray Flight Service Station operator (FSS) initiated a radio search to determine its whereabouts. The radio search was unsuccessful, and the FSS contacted McMurray Aviation, the operator. An airborne search party organized by the operator departed from Fort McMurray with several company pilots on board. The search party retraced the route from Fort McMurray to La Loche, but could not find the accident aircraft. Another search was organized using personnel and several fixed wing and rotary wing aircraft from Canadian Forces Base Cold Lake, Alberta, and the wreckage was located on the afternoon of the following day (see Appendix A). The pilot and one of the passengers died at the time of the accident. One passenger succumbed to her injuries the following morning, before help arrived. The three surviving passengers were taken by military aircraft to La Loche and then to Fort McMurray, with serious injuries. The aircraft was destroyed by impact forces and a post-crash fire.

Ce rapport est également disponible en français.

Other Factual Information

The flight was arranged by telephone several hours before the flight departed. The passengers were reported to be anxious to complete the trip to La Loche that day, in order to facilitate an appointment the following day. They arrived at the company hangar, which was its base of operations at the Fort McMurray airport, about one hour before departure. The pilot of the accident flight was away from the company base on a charter flight with a Cessna 206 aircraft at the time the passengers arrived.

When he returned, the pilot called to the FSS to check the weather at Fort McMurray and Buffalo Narrows, and filed a visual flight rules (VFR) flight plan. The passengers’ baggage had already been loaded into the aircraft by company staff before the pilot arrived at the
airport. The pilot consulted another company pilot who had returned from a flight to La Loche at 1500. The occurrence pilot was reportedly advised that the cloud ceiling was about 500 feet above ground level (agl) at La Loche and as low as 200 feet agl in some areas along the west shore of Lac La Loche. He then refuelled the aircraft, loaded the passengers and departed. On his last contact with Fort McMurray FSS, the pilot made a routine radio call advising that he had departed the control zone to the east. A surviving passenger reported that the aircraft was flying below the cloud at a low altitude shortly before the crash.

The wreckage was found at an elevation of about 1,540 feet. The aircraft had struck the tops of poplar trees at an elevation of about 1,600 feet in a shallow descent, with a right bank angle of 10 to 15 degrees. The direct course from Fort McMurray to La Loche is 100 degrees magnetic. The aircraft was on course, with the landing gear and flaps retracted, when it struck the trees. The aircraft's heading at the time of impact was about 105 degrees. After initial impact with the trees, the aircraft bank angle increased, and an impact with larger trees detached the wings and the tail. The aircraft came to rest in an inverted position, toward the end of a crash path 320 feet long. The time of the crash was about 1817. Several post crash fires consumed much of the cockpit, the fuselage, and the wings. An examination of the wreckage indicated that both engines were developing power at the time of impact. The aircraft structure and systems were examined to the degree possible, and no evidence of a pre-crash malfunction was found. No evidence of frost or ice on critical aircraft surfaces was found. The aircraft's Narco ELT-10 emergency locator transmitter was destroyed in the crash and did not activate.

The relevant records from the Fort McMurray ISSR secondary radar receiver were reviewed. The radar is designed to record signals from aircraft transponders, and is not able to detect primary radar targets. No information pertaining to the accident flight was received by the radar.

The pilot held a commercial pilot licence, and a medical certificate valid to 01 April 1998. He had suffered a disabling hand injury in February 1997, but he resumed active flying duties after successfully completing a re-certification flight test in June 1997. The pilot held a Class 3 instructor rating and an instrument rating valid to 01 August 1999. His total flight time was 2,154 hours, 175 of which were on multi-engine aircraft, and 25.5 hours on multi-engine aircraft at night. He successfully completed a pilot proficiency check flight with C-GPRL, the only Piper PA-34-200 in the operator's fleet, in July 1997, and had accumulated 109 hours on type. He had completed five VFR flights at night with C-GPRL in the Fort McMurray area and several instrument flight rules (IFR) flights, within the previous 30 days. The pilot was one of the more experienced company pilots. He had reportedly completed a pilot decision making (PDM) course, and was described as proficient and safety-conscious.

Toxicology testing was conducted at the Royal Canadian Mounted Police forensic laboratory in Regina, Saskatchewan. Test results indicated the presence of 20 milligrams of ethyl alcohol in 100 millilitres of blood in the sample which was submitted. Alcohol can be produced in the blood when the body is subjected to severe trauma, as was the case, and putrefaction has the time, nutrients, and temperature to develop. The sample tested was taken from the cranium which was subjected to sufficient heat to sustain bacterial action, and the sample was not taken until 3 November, four days after the crash. A study reported in the Journal of Forensic Sciences\(^2\) concluded that "Specimens from 1989 and 1990 showed postmortem ethanol ranging on concentration from our cutoff of 0.01% (10 mg/dL) to 0.18% (180 mg/dL)." and, "The concentration of ethanol in postmortem blood, in the absence of additional information, cannot be used with any degree of certainty to verify the ingestion of ethanol." Thus the finding of 20 milligrams of alcohol in the pilot's blood sample is inconclusive as to the blood-alcohol content of the pilot prior to the accident.
The observed weather at Fort McMurray at 1800 was as follows: winds 120 degrees at 8 knots, visibility 10 statute miles, a ragged overcast cloud ceiling at 1,000 feet above ground level (agl), and temperature minus 2 degrees Celsius. The terminal area forecast for Fort McMurray, valid from 1600 to 0400 was: winds 120 degrees at 8 knots, visibility greater than 6 statute miles, and an overcast ceiling at 1,000 feet agl, with a temporary fluctuation of the visibility down to 4 statute miles and a temporary fluctuation of the ceiling down to 500 feet agl, from 1600 to 2200. The area forecast included the possibility of light to moderate icing in cloud.

The observed weather at 1700 at Buffalo Narrows, 53 nm south-east of the accident site, was as follows: winds 120 degrees at 10 knots, visibility 15 statute miles, an overcast ceiling at 700 feet agl, and temperature minus 3 degrees Celsius.

La Loche is not served by an official weather reporting agency. The weather in the La Loche area was observed by several pilots. Their reports indicate that at the time of the accident, La Loche was experiencing overcast cloud ceilings of about 500 feet agl and that ceilings were lower over the higher ground west of La Loche, in the direction of Fort McMurray. A small amount of virga and freezing precipitation was noted in the area just west of La Loche.

The airport at Fort McMurray is located at an elevation of 1,211 feet, and is served by several instrument approaches. The lowest descent altitude for these approaches is 200 feet agl. The airport at La Loche is located at an elevation of approximately 1,500 feet, and is served by a company non-directional beacon (NDB) approach. The minimum descent altitude for the approach is 600 feet agl. The accident aircraft was equipped with instrumentation to carry out the approaches at Fort McMurray and La Loche, and en route navigation between the two points.

The aircraft was equipped with six forward-facing seats. The two cockpit seats were equipped with lap belts and shoulder harnesses, and the cabin seats were equipped with lap belts only. The damage sustained by the cockpit area during the crash sequence and the post crash fire made the accident unsurvivable for its two occupants.

A post-crash calculation of the aircraft's weight and balance after the accident indicated that the gross takeoff weight on departure from Fort McMurray was about 4,500 pounds and that the zero fuel weight was about 4,050 pounds. The centre of gravity was within the allowable limits. The maximum allowable gross weight for the PA-34-200T is 4,570 pounds and the maximum zero fuel weight is 4,000 pounds. The maximum zero fuel weight is a structural specification and is not dictated by handling or performance considerations.

The aircraft was maintained for the operator by a contract maintenance organization. Most of the day to day maintenance work was performed by an aircraft engineer employed by the operator at its Fort McMurray base. His work was then approved and signed out by the contract maintenance organization. The operator was in the process of seeking approval to form its own approved maintenance organization.

The aircraft's journey log book was destroyed in the post-crash fire. Examination of the available technical records indicated that the aircraft was equipped and maintained in accordance with existing regulations for VFR flight. At the time of the accident, the aircraft had accrued a total flight time of about 2,653 hours. Its last inspection was completed on 08 September 1997 at 2,603.6 hours.

The aircraft was not equipped with propeller or airframe de-ice or anti-ice devices. Such devices are required by regulation for an aircraft operating in known icing conditions. The aircraft was equipped with an autopilot, but the autopilot was unserviceable at the time of the accident flight. A functioning autopilot is not required by regulation for VFR flight, but it is required by regulation for a commercial, passenger-carrying operation of an aircraft by a
single pilot under IFR. Aircraft which are flown under IFR require an altimeter calibration every two years. The aircraft's altimeter had last been calibrated in May 1995.

In VFR flight, pilots are required to use visual reference to the ground to manoeuvre and navigate their aircraft. The Canadian Air Regulations (CARs) section 602.115 provides that night VFR flight requires a visibility of three miles; no minimum altitude is specified. However, CARs section 703.27 requires that an operator of an air transport service flying at night maintain an obstacle clearance height of 1,000 feet agl. Commercial night VFR flight must be conducted on a route; CARs standard 723.34 provides a formula for the establishment of a route for night VFR flight.

Air operators are required to maintain a record of company routes. The accident aircraft was reportedly not equipped with a route manual, nor was a route manual found at the operator's base after the accident. The other pilots employed by the operator were interviewed after the accident. They were not familiar with the obstacle clearance requirement found in the CARs, nor with the requirements of a route for night VFR flight.

The operator's Flight Operations Manual (FOM) is dated 01 January 1997 and was approved by Transport Canada on 06 June 1997. Section 3.5 of the FOM summarizes the CARs requirements for day VFR flight. Sections 3.6.2, 3.6.3, and 3.6.4 outline the requirements for IFR flight. Section 3.6.1 of the FOM is entitled "Routes in Uncontrolled Airspace", and provides the following:

Pilots may fly under IFR or Night VFR using routes in uncontrolled airspace that are not yet contained in the record of company routes provided that all requirements of Standard 723.31 have been met.

Standard 723.31 sets out certain requirements for no-alternate IFR flight, and does not refer to night VFR. The pilot was reportedly familiar with the FOM and had referred to it frequently during his preparation for an examination required for an airline transport pilot licence. He successfully completed the examination several weeks before the accident. The company operations exam completed by the pilot on 29 June 1996, does not refer to the requirement for an obstacle clearance height for night VFR.

The time of official sunset at the accident site was 1641. The amount of sky illumination available at 1800, shortly after the time of takeoff from Fort McMurray, was 11.5 millilux. At the time of the accident, it was 1.12 millilux. The amount of sky illumination is affected by any cloud layer between an observer and the sky. The amount of visual reference available to a pilot is further affected by the reflectivity level of the surface of the earth. Snow has a high reflectivity level and trees have a low reflectivity level. On departure, the lights of the town of Fort McMurray would have provided illumination to assist the pilot with ground reference. La Loche is a much smaller centre than Fort McMurray and provided little ground lighting visible at low altitude from the area of the accident. There is little or no ground lighting in the area between Fort McMurray and La Loche.

Company pilots were routinely in direct contact with customers. They were reportedly subject to frequent pressure from customers to operate their aircraft in adverse weather conditions, at excessive gross weights, and from inadequate runways. Company pilots were reportedly not always successful in resisting these pressures, and they sometimes changed their procedures before dealing with customers because they anticipated these customer requests. It was not established whether or not the pilot was subject to pressure from the customers before or during the accident flight.

Analysis

Examination of the wreckage did not reveal any pre-crash malfunctions of the aircraft's
structure, systems, or engines. The shallow angle of the aircraft's impact with terrain, and the speed of the aircraft at impact, are consistent with controlled flight into terrain.

A calculation of the aircraft's weight and balance indicates that its gross weight was within allowable limits. Although the zero fuel weight was slightly over the maximum allowed, this would not have degraded the aircraft's handling or performance characteristics.

The pilot was certified and qualified for the flight, whether flown VFR or IFR, and his flying record indicates that he had recent experience in night VFR operations.

Because the aircraft was not equipped for flight into icing conditions and the area forecast included icing in cloud, the aircraft was not approved for flight into cloud during the accident flight. The aircraft's autopilot was unserviceable and the altimeter required calibration. For these reasons, the aircraft was not approved for flight under IFR, and, in the prevailing weather, was, therefore, not approved for flight into cloud. Although the pilot was qualified to complete the flight under IFR, the aircraft was not equipped for IFR flight under the prevailing conditions.

At the time of departure, the cloud ceiling met the requirements for night VFR flight in the Fort McMurray area. As the flight progressed toward La Loche, the cloud ceiling decreased below the minimum required for commercial air operations. Flight below the cloud left the pilot with reduced terrain clearance and increased the requirement for effective manoeuvring to avoid collision with terrain.

The lighting conditions on departure were likely sufficient to allow the pilot to maintain a visual reference to the ground. As the flight progressed, however, the available lighting and ground reference progressively decreased. The overcast sky, the decreasing sky illumination, and the dark colour of the forested area along the route and in the area of the accident yielded little light with which the pilot could manoeuvre and navigate with reference to the ground. At the low altitude which the pilot flew to maintain clearance from cloud, the lights of La Loche probably provided him with little assistance.

It was not determined whether the pilot would have conducted the flight under IFR had the accident aircraft been appropriately equipped. However, if the aircraft had been so equipped, the pilot would have had the option to commence the flight under IFR, or to revert to IFR en route, when weather and lighting conditions made VFR flight impracticable.

Although the operator's FOM has detailed information on day VFR flight standards, the section on night VFR contains little guidance on night VFR, and the standard it refers to is misleading.

The pilot, who was familiar with the FOM, may have been misled by the lack of information in Section 3.6.1. The requirement for the minimum obstacle clearance height is not contained in the company operations exam. The level of pilot awareness of the requirement within the company indicates that the pilots were not receiving the information from other sources.

It was not established whether the pilot was subject to pressures from the customers of the accident flight to fly in adverse weather. However, customer and self-induced pressures were encountered frequently by company pilots in their dealings with other customers. As well, the occurrence aircraft was already loaded with the passengers' baggage prior to the pilot's return from his previous flight, and a company pilot had recently successfully completed a flight from La Loche. It is not known to what extent the pilot's decision to depart was influenced by one or more of these factors.

The following Engineering Branch report was completed:
LP 166/97 - Instruments Examination

Findings

- The pilot was certified and qualified for the accident flight, whether it was flown VFR or IFR.

- The available information indicates that the pilot's performance was not affected by incapacitation.

- The aircraft records indicated that the aircraft was maintained in accordance with existing regulations.

- The aircraft's gross weight and centre of gravity were within allowable limits at the time of the occurrence.

- Examination of the aircraft's structure, systems, and engines did not reveal any pre-crash malfunctions.

- The aircraft emergency locator transmitter was destroyed in the crash and did not activate.

- The aircraft was not equipped for flight into cloud at the time of the accident.

- The minimum en route altitude allowed by the CARs for the accident flight was 1,000 feet agl.

- The weather at departure from Fort McMurray was within allowable limits for night VFR flight; however, as the flight progressed toward La Loche, the cloud ceiling decreased below allowable limits for a commercial air operator.

- The available lighting and ground reference available en route and at the time of the accident decreased markedly from that prevailing on departure.

- The pilot continued flight into weather and lighting conditions which did not enable him to avoid collision with terrain.

- The operator's FOM contains little guidance to pilots on the subject of night VFR operations.

- Company pilots were subject to customer and self-induced pressures from time to time to complete flights in adverse conditions.

Causes and Contributing Factors

The pilot continued flight into adverse weather and lighting conditions which did not enable him to avoid collision with terrain. Contributing factors to this occurrence were the aircraft's unserviceability for single pilot IFR flight and the lack of guidance to company pilots as to weather limits for night VFR flight.
Safety Action

After the accident, the operator arranged with Transport Canada to obtain, and distribute to company pilots, training information related to night flying and reduced visibility hazards.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 10 September 1998.

Appendix A - Area of the Flight

1. All times are MST (coordinated universal time minus seven hours) unless otherwise noted.


Important Notices
Air 1997

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 Occurrence Report
Rejected Take-Off - Runway Overrun
Ministic Air Ltd.
Beech 1900D C-FYSJ
Island Lake, Manitoba
29 November 1997

Report Number A97C0229

Summary

Ministic Flight 303, a Beech 1900D, serial number UE-233, was departing runway 12 at the Island Lake airport, en route to Winnipeg, Manitoba. The aircraft was carrying a crew of two, and 17 passengers. Take-off acceleration was described as normal. As the aircraft was rotated for take-off, the stall warning horn activated. The take-off was rejected, reverse thrust was selected, and both pilots applied the aircraft's brakes. The aircraft did not stop within the confines of the runway or the stopway area and departed off the end of the prepared surface. The aircraft came to rest straddling a ploughed bank of snow and sustained substantial damage. The engines were shut down, and the passengers and the crew evacuated the aircraft. One minor injury was reported. The occurrence took place during daylight hours, at 1410 central standard time (CST)(1).

Ce rapport est également disponible en français.

Other Factual Information

Both the captain and the first officer were certified and qualified for the flight in accordance with existing regulation. The captain had a total flight time of 5 200 hours, 704 hours of which were on type. The first officer had a total time of 1 250 hours, 200 of which were on type. The captain had received most of his training on the Beech 1900D type at an outside facility which made extensive use of a flight simulator. The first officer had received his type training in-house, most of which was undertaken by a contract instructor. Neither pilot reported receiving instruction on faults related to the stall warning system which could result in a false stall warning.
The flight was a continuation of a series of flights originating at Winnipeg as Ministic Flight 302, with scheduled station stops at St. Theresa Point and Island Lake. The aircraft entered snow conditions at the start of the descent into St. Theresa Point, and visibility was observed to be about one-half mile in snow during the approach. The station stop at St. Theresa Point lasted about 25 minutes, during which time several passengers and some freight items were deplaned, and other passengers embarked. Snow continued to fall during the station stop, and the crew used brooms to remove snow from the aircraft's wings before departure. Snow was falling throughout the flight to Island Lake and the station stop of about 30 minutes at Island Lake. Observers noted some loose snow on the wings as the aircraft taxied from the ramp to the runway. Both crew members reported that this snow was not adhering to the wings, and that it blew off of the wings with the movement of the aircraft after it taxied from the ramp at Island Lake.

The first officer was at the controls during the take-off from Island Lake, and the captain performed the non-flying duties. These duties included monitoring the engine instruments and calling out the reference speeds during the take-off roll. The crew used a cockpit quick-reference chart, with speeds as follows: V1 (take-off decision speed), 103 knots, VR (rotation speed), 106 knots, and, V2 (single engine climb speed), 111 knots. A take-off is not normally rejected after V1 unless the aircraft's ability to fly is in doubt. The chart was produced by another operator and the figures in it were derived from the performance section of the Transport Canada approved aircraft flight manual (AFM). The figures in the quick-reference chart vary for every 1,000 pounds of gross weight and were calculated for an outside air temperature (OAT) of 25 degrees Celsius. For the take-off from Island Lake, the crew selected take-off speeds from the quick reference chart for a take-off weight from 16,001 pounds to 16,950 pounds. The take-off speeds listed in the AFM vary for every five degrees Celsius change in the OAT and every 1,000 pounds of gross weight. For paved, dry runway conditions, the AFM designated take-off speeds for an aircraft at a take-off weight of 16,000 pounds and an outside air temperature of minus five degrees Celsius were: V1, 100 knots, VR, 102 knots, and V2, 108 knots. The aircraft's balanced field length under these conditions is listed as 3,328 feet. The AFM contains a gravel supplement with performance information for aircraft using firm, dry, gravel surfaces. The gravel supplement portions of the AFM list the following take-off speeds for the occurrence aircraft's weight and an outside air temperature of zero degree Celsius: V1, 101 knots, VR, 101 knots, and V2, 108 knots. The balanced field length for these conditions is listed as 3,484 feet.

The aircraft was equipped with both a flight data recorder (FDR) and a cockpit voice recorder (CVR). Both units were removed from the aircraft and their data were analysed. The FDR indicated that, during the start of the take-off roll, both engines were producing rated torque and both propellers were turning at maximum rated rpm. The FDR indicated that the aircraft was rotated at an indicated airspeed of about 106 knots. On hearing the stall warning horn, the first officer suspected that the aircraft may have been over-rotated and lowered the nose. The stall
warning stopped, but recurred when the nose was raised again. The first officer then believed that a malfunction had occurred which would compromise the aircraft's flight capability. He called for a rejected take-off, and the captain concurred. The captain moved the engine power levers to idle and applied reverse thrust. FDR data indicate that engine power reduced to idle about four seconds after the aircraft was rotated. The aircraft's indicated airspeed reached a maximum of 126 knots and then declined sharply. The indicated airspeed was about 40 knots as the aircraft travelled past the end of the runway, and 20 knots as it departed the prepared surface of the stopway. FDR data indicate that the elapsed time to accelerate from 101 knots to 106 knots during the take-off roll was about one second, and a similar time was required for the deceleration through those speeds. The FDR data do not indicate with certainty whether or how far the aircraft lifted from the ground, and witness reports were inconclusive.

When the aircraft was examined after the occurrence, some ice was observed on the engine cowlings and on both wing sections, inboard of the engines; however, no ice or snow was found on the tail surfaces or the wings outboard of the engines. The design of the aircraft incorporates an engine bleed air system, heat exchanger and air cycle machine, much of which is located in the wing roots. When these systems are in operation, they generate heat, which has the effect of warming the skin of the inboard wing sections.

The runway at Island Lake is 4 000 feet long, composed of crushed stone. In addition to the runway length, there is a stopway area of about 300 feet on each end of the runway. The stopway is cleared of snow in winter, and is used by flight crews to turn their aircraft around before take-off and after landing. The area beyond the stopway area of runway 12 is an unprepared surface sloping down toward the lake. On the day of the occurrence, this area contained several banks of hard snow of various heights, and the runway and stopway surfaces were covered with graded, hard-packed snow. About one to two inches of loose snow was observed on the surface of the runway at the time the aircraft taxied for take-off. The runway surface was described as slippery at the time of the occurrence. Loose snow increases tire rolling resistance, delays acceleration, and results in longer take-off runs. Snow-covered or slippery runways provide decreased traction, which results in longer aircraft stopping distances, as compared to bare runways.

The calculated weight of the aircraft at take-off from Island Lake was 16 015 pounds, 935 pounds less than the aircraft's maximum gross take-off weight of 16 950 pounds. Its centre of gravity was within approved limits. The aircraft's maintenance records indicate that it was equipped and maintained in accordance with existing regulations. Transport Canada approved the Beech 1900D aircraft type for operation in Canada under section 704 of the Canadian Air Regulations. Section 704 provides that no person shall conduct a take-off in an aircraft if the weight of the aircraft exceeds the maximum take-off weight specified in the AFM for the pressure altitude and the ambient temperature at the aerodrome where the take-off is to be
made. In the determination of the maximum take-off weight, the required accelerate-stop distance shall not exceed the accelerate-stop distance available, and the required take-off distance shall not exceed the take-off distance available. For the purposes of determining the accelerate-stop distance and take-off distance, the following factors shall be taken into account: the pressure altitude at the aerodrome, the ambient temperature, the runway slope in the direction of take-off, and headwind and tailwind components. The manufacturer was, as a condition of the aircraft type approval, required to determine and supply certain aircraft performance data including the balanced field lengths at various take-off weights, temperatures, and altitudes. The stopping performance of the aircraft for the accelerate-stop distance is calculated with engine power at idle, without the use of reverse thrust.

The James Brake Index (JBI) published in the Canada Flight Supplement contains a table which may be used to adjust calculated landing distances to compensate for slippery braking conditions. JBI correction factors for compacted snow or snow-covered runways range from 80% to 250% higher than hard dry surfaces. Transport Canada did not require the manufacturer to provide data on the effects of soft or wet runways, slippery runways, or runways containing loose snow on the aircraft's accelerate-stop distances or take-off distances. Slippery and snow-covered runways are commonly encountered by flight crews operating in Canada during cold weather. The operator did not have performance charts for use for such conditions, nor were such charts available from the manufacturer.

The Island Lake weather observation at 1400 was as follows: winds 080 degrees true at eight knots, visibility one-half statute mile in snow, an overcast cloud ceiling at 500 feet above ground level, and a temperature of minus four degrees Celsius. The observations at 1450 and 1443 noted visibilities of one mile and two miles in light snow, respectively. As the crew was taxiing the aircraft to the runway for takeoff, they requested updated weather information from the Winnipeg Flight Service Station. They were advised that the current ceiling was 700 feet above ground level, and the visibility was one statute mile. Snow continued to fall throughout the afternoon on the day of the occurrence.

The aircraft's stall warning system consists of a lift transducer vane and a backing plate located on the left wing leading edge, a sensor unit, and several resistors. The vane is able to move up or down within a range of motion afforded by a gap in the backing plate in which it is mounted. Aerodynamic pressure on the lift transducer vane varies with the wing's angle of attack. When an angle of attack approaches that of an imminent stall, the vane changes position, and the sensor unit produces a signal which activates the stall warning horn in the cockpit. Rigging tolerances allow the vane to be in the up, "wing stalled", position or the down, "wing uninstalled" position on the ground. In uninstalled flight, dynamic air pressure holds the vane in the down, or "wing uninstalled" position. The system is disabled on the ground by the operation of the landing gear safety switch, located on the left main landing gear. The system has a prefight test capability through the use
of a switch placarded STALL WARNING TEST on the copilot's left hand subpanel. The stall warning test is incorporated into the "originating" check, which is performed before the first flight of the day, but not at station stops. The stall warning system was tested before the initial flight on the day of the occurrence and found to be serviceable. This switch, when held in the TEST position, bypasses the landing gear safety switch, and, if the system is functional, activates the stall warning horn. The test system does not detect a system malfunction which would generate a false stall warning in flight. The Beech 1900 series stall warning system differs from some other stall warning systems in that the lift transducer vane in the Beech 1900 may be in the "stalled" or "unstalled" position while the aircraft is at rest on the ground. In the Beech 200 system, for example, the vane is normally in the "unstalled" position on the ground.

The stall warning heat is switched on and checked along with other ice protection items as part of the "BEFORE TAKE-OFF (FINAL ITEMS)" check in the Transport Canada approved check list, which was in effect at the time of the occurrence. The stall warning heat is switched off as part of the "AFTER LANDING" check. The crew reported that the stall warning heat was switched on at Island Lake as they taxied the aircraft from the ramp to the runway for take-off. The aircraft taxied away from the ramp about two minutes before the start of the take-off roll. The stall warning system is equipped with anti-icing capability on both the mounting plate and the vane. The heat is controlled by a switch in the ICE PROTECTION group located on the pilot's right subpanel placarded STALL WARN - OFF. Electrical voltage is supplied to the stall warning heat system at 28 volts in the air, and is reduced to 10 volts for ground operation by the operation of the left landing gear safety switch. The manufacturer's information does not quantify the temperatures attained by the system during ground or air operation; such temperatures would depend on ambient temperature, atmospheric moisture, and relative wind. The AFM states that the level of stall warning heat is minimal for ground operation. A STALL HEAT annunciator in the Caution/Advisory panel illuminates if there is insufficient current to heat the vane and the faceplate heaters. No STALL HEAT indication was observed by the crew on the day of the occurrence.

Several hours after the occurrence, the stall warning transducer vane was checked by the crew, and found to be stuck. The ambient air temperature did not rise above freezing from the time of the occurrence until the aircraft was examined the following day by TSB investigators. During that examination, the vane was found to be frozen in the "wing stalled" position. Power was supplied to the stall warning heat system with the landing gear safety switch in the "ground" position. The lift transducer vane and its backing plate gradually became warm to the touch, but remained frozen for several minutes after heat was applied. When the landing gear safety switch was moved to the "flight" position, the temperature of the vane and backing plate increased rapidly, and the vane became free to move. After the stall warning vane was freed, it remained in the "wing stalled" position with the aircraft at rest.
There have been a number of similar occurrences both in Canada and United States where the stall warning horn activated during the take-off sequence, and in some cases after the aircraft had been de-iced.

**Analysis**

During the approach to St. Theresa Point and the flight and approach to Island Lake, the aircraft flew in snow that was heavy enough to reduce visibility to one-half mile. During this time, the gap between the lift transducer vane and the backing plate was exposed to the ambient airflow, and to the snow which was falling during these flights. At the existing ambient temperatures, snow entering the stall warning system would probably have melted on contact, leaving the resulting water in the stall warning system.

The stall warning heat was turned off as part of the after landing checks. After the system was turned off, no heat was provided to the system; thereafter, the ambient airflow over the wing during the taxi from the runway to the ramp, and the ambient temperature, would have had the effect of cooling the stall warning system, allowing the water in the system to freeze during the station stop at Island Lake. The Beech 1900 stall warning system tolerances are such that the lift transducer vanes, in some individual aircraft, may normally be in the "wing stalled" position while in others, the vane may normally be in the "wing unstalled" position with the aircraft at rest. Because the lift transducer vane tolerances in this particular aircraft resulted in a vane position normally in the "wing stalled" position when the aircraft was at rest, the vane would have frozen in that position during the station stop.

The pilots, in accordance with the aircraft checklist, tested the stall warning system on the initial flight of the day, but did not test it after start-up at Island Lake. In any event, the design of the test circuit is such that it would not detect a false warning, and had the pilots tested the system, it would not have helped them avoid the false stall warning after take-off. Although the pilots turned on the stall warning heat during the taxi to the runway, the system did not have sufficient capacity, at its reduced operating voltage, to thaw the frozen lift transducer vane. The vane remained frozen in the "wing stalled" position during take-off.

Although snow was observed on the aircraft's wings while the aircraft was on the ramp at Island Lake, the snow probably blew off before or during the take-off roll. Most of the snow observed after the occurrence on the inboard wing sections likely resulted from the warming effect of the aircraft's engine and systems, combined with the snow which fell after the occurrence. The aircraft's speed, gross weight, relatively clean wings, and configuration indicate that the wings were producing lift and were not stalled at take-off.

During the take-off roll, when the first officer rotated the aircraft and weight came off of the landing gear, the landing gear safety switch closed, which completed the stall warning circuit and generated an inappropriate stall warning signal. Because the first officer believed that the aircraft might not be capable of flight, he called for a reject, even
though the airspeed was beyond V1, and the captain concurred.

The information about the other occurrences, where the stall warning horn activated during the take-off sequence, does not appear to have been disseminated to other Beech 1900 operators.

A number of factors present during the occurrence changed the aircraft's accelerate-stop performance from that listed in the AFM:

- The quick-reference speeds for V1 of 103 knots, and VR of 106 knots used by the crew, were slightly higher than those (101 knots and 101 knots respectively) listed in the more-detailed reference in the AFM;

- Because of the time required for recognition, decision, and reaction, engine power was reduced four seconds after rotation, and the aircraft reached a speed of 126 knots before starting to decelerate;

- The snow-covered, slippery condition of the occurrence runway differed from the bare, dry surfaces on which the AFM data is based. The snow on the runway increased both the aircraft's acceleration distance by increasing the rolling resistance, and increased the stopping distance by decreasing tire traction, thereby increasing the accelerate-stop distance of the aircraft by an undetermined amount; and

- Partially mitigating the effects of the factors listed above, the crew used reverse thrust on both engines.

Although Transport Canada required the manufacturer to provide performance charts containing correction factors for density-altitude, temperature, runway gradient, and wind conditions, the manufacturer was not required to provide charts for corrections to the accelerate-stop or take-off distances resulting from soft or wet runways, slippery runways, or runways containing loose snow. Because performance data were not available, the crew was not able to determine how much snow on the runway was acceptable for continued operation of the aircraft, or to what extent such snow and a slippery runway would affect the take-off and rejected take-off performance of the aircraft.

The following TSB Engineering Branch Report was completed:

LP 183/97 Flight Recorder Report.

Findings

- Maintenance records indicate that the aircraft was equipped and maintained in accordance with existing regulations.

- Both the captain and the first officer were certified and qualified for the flight in accordance with existing regulation.
- The aircraft's weight and centre of gravity were within allowable limits for the departure from Island Lake.

- The crew tested the stall warning system on the first flight of the day in accordance with the aircraft checklist and found it to be serviceable.

- The Beech 1900 stall warning test function does not detect a condition in the stall warning system that will lead to a false stall warning on take-off.

- Neither pilot received instruction on faults related to the stall warning system which could result in a false stall warning.

- The rigging of the lift transducer vane of the Beech 1900 differs from that of some other aircraft types in that the vane may be in the "stalled" or "unstalled" position when the aircraft is at rest.

- The aircraft flew in snow which was heavy enough to reduce visibility to one-half mile during the approach to St. Theresa Point and during the subsequent flight to Island Lake.

- The moisture in the stall warning system froze the lift transducer vane in the "stalled" position during the station stop at Island Lake.

- The reduced heat provided to the stall warning system during the short taxi time was not sufficient to melt the ice after the stall warning heat was turned on during the "Before Take-off" check.

- The aircraft's engines were developing normal rated power at take-off, and both propellers were turning at maximum rated rpm.

- The aircraft's stall warning system activated as the aircraft was rotated at 106 knots.

- The pilots were not aware of previous occurrences of false stall warnings in the Beech 1900 aircraft type.

- The pilots rejected the take-off about four seconds after rotation and reached a maximum speed of 126 knots.

- The runway was snow covered and slippery at the time of the occurrence.

- There were no performance data available to the pilots to determine the aircraft's accelerate-stop distance under snowy and slippery runway conditions.
- The pilots' use of the cockpit quick reference take-off speed chart lead to slightly increased aircraft's accelerate-stop distance.

- The higher-than-V1 speed from which engine power was reduced, together with the snow-covered runway conditions, increased the aircraft's accelerate-stop distance.

**Causes and Contributing Factors**

The stall warning activated at take-off because the lift transducer vane had frozen in the "stalled" position, and a rejected take-off was initiated at a speed and position from which the aircraft could not be stopped within the cleared runway and stopway surfaces remaining. Contributing to the occurrence were insufficient heat to melt the frozen stall warning system and the lack of performance data for the prevailing runway conditions.

**Safety Action**

During training, neither pilot had received instruction on the differences in the design of the Beech 1900 stall warning system from that of other aircraft types. Neither pilot was aware that such differences could lead to a false stall warning on take-off in the event of a malfunction of the system, as it did in this occurrence. Ministic Air Ltd. has added a segment to its initial and recurrent pilot training explaining the design of this system and the effects of some system malfunctions. In addition, the company standard operating procedures will be changed to include this information.

The approved aircraft flight manual requires the pilots to complete a pre-flight inspection of various interior and exterior components of the aircraft before engine start. Some of these items are required to be checked before the first flight of the day and need not be checked before the subsequent flights undertaken that day. Some items, marked "+", must be checked before every flight. Item number 14 on the "Preflight Inspection, Left Wing and Nacelle" check is "Stall Warning Vane ---- CHECK FOR FREEDOM OF MOVEMENT". After the occurrence, the manufacturer amended the checklist by designating this as an item to be checked before every flight. Because of the rigging of the stall warning vane, its freedom of movement cannot be checked from inside the cockpit. The change was made in order to ensure that pilots would be made aware, before any flight, of a condition which would render the vane unserviceable.

At the time of the occurrence, item number 5 on the "BEFORE TAKE-OFF (FINAL ITEMS)" check was "Stall Warn Heat ---- ON." The manufacturer amended the checklist in December, 1997, and moved this item to the "BEFORE TAXI!" check, which is completed after engine start and before the "BEFORE TAKE-OFF" check. The change was made in order to allow the stall warning heat to operate for a longer period of time on the ground before flight so as to ensure that the system would be functional after take-off.
No recurrences of false stall warnings were reported to the manufacturer during the first winter operating season after the date of these changes. However, the stall warning heat system is affected by many variables, including ambient temperature, humidity, precipitation, wind, stage length, taxi distance, and ground turn-around time. The situation will continue to be monitored by the TSB.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 16 November 1998.

1. All times are CST (Coordinated Universal Time minus six hours) unless otherwise noted.
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 Occurrence Report
Collision with Terrain
Sowind Air Limited
Embraer EMB-110P1 Bandeirante C-GVRO
Little Grand Rapids, Manitoba
09 December 1997

Report Number A97C0236

Synopsis

The Sowind Air Ltd. Embraer EMB-110P1 Bandeirante aircraft departed the operator’s base at St. Andrews, Manitoba, with a crew of 2 and 15 passengers, on a 40-minute, scheduled flight to Little Grand Rapids, Manitoba. The aircraft arrived at Little Grand Rapids, and the crew flew an instrument approach to the airport and executed a missed approach because the required visual reference was not established. A second instrument approach was attempted. Ground-based witnesses observed the aircraft very low over the lake to the south of the airport and to the east of the normal approach path. Passengers in the aircraft also reported being very low over the lake and to the east of the normal approach path. The passengers described an increase in engine power followed by a rapid series of steep banking manoeuvres after the aircraft crossed the shoreline to the southeast of the airport. During the manoeuvres, the aircraft descended into the trees and crashed approximately 400 feet south and 1 600 feet east of the approach to runway 36 at Little Grand Rapids. The captain and three passengers were fatally injured, and the first officer and the remaining 12 passengers were seriously injured.

Other Factual Information

1.0 Factual Information

1.1 History of the Flight
1.2 Injuries to Persons
1.3 Damage to Aircraft
1.4 Other Damage
1.5 Personnel Information
1.5.1 General
1.5.2 The Captain
1.5.2.1 General
1.5.2.2 Flying History
1.5.3 The First Officer
1.5.3.1 General
1.5.3.2 Flying History
1.6 Aircraft Information
1.6.1 Aircraft Data
1.6.2 Aircraft Description
1.6.3 Weight and Balance Information
1.6.4 Equipped Operating Weight
1.6.5 Aircraft Seating Configuration and Loading Graphs
1.6.6 Cancelled Morning Flight Load Calculations
1.6.7 Occurrence Flight Load Calculations
1.6.8 Aircraft Overload
1.6.9 Aircraft Approach and Stall Speeds
1.6.10 Ground Proximity Warning System
1.7 Meteorological Information
1.8 Aids to Navigation
1.9 Communications
1.10 Aerodrome Information
1.11 Flight Recorders
1.12 Wreckage and Impact Information
1.12.1 General
1.12.2 Landing Gear
1.12.3 Flaps
1.12.4 Flight Control Systems
1.12.5 Engine Examination
1.12.6 Auto-feather System
1.12.7 Propeller Examination
1.12.8 Instrument Examination
1.12.9 Global Positioning System
1.12.10 Fuel Samples
1.13 Medical Information
1.14 Fire
1.15 Survival Aspects
1.15.1 Aircraft
1.15.2 Emergency Locator Transmitter
1.16 Tests and Research
1.17 Organizational and Management Information
1.17.1 General
1.17.2 Senior Management
1.17.3 Flight Operations
1.17.4 Maintenance Department
1.17.5 Transport Canada Safety Oversight
1.18 Additional Information
1.18.1 Controlled Flight into Terrain
1.18.2 False Climb or Somatogravic Illusion
1.18.3 Carbon Monoxide
1.18.4 Aeromedical Factors
1.18.5 Sowind Air Ltd. Approach and Landing Procedures
1.18.6 Operations in Marginal Weather
1.18.7 Commuter VFR Flight Obstacle Clearance Requirements

2.0 Analysis

2.1 General
2.2 The Weather in the Vicinity of Little Grand Rapids
2.3 Aircraft Contamination
2.4 Weight and Balance
2.5 Controlled Flight into Terrain--Flight Crew Performance
2.5.1 Decision Making
2.5.2 Crew Resource Management Training
2.5.3 Somatogravic Illusion
2.6 Ground Proximity Warning
2.7 Cockpit Voice Recorder
2.8 Transport Canada Monitoring
2.8.1 Transition to Commuter Operations
2.8.2 Weight and Balance Monitoring Policy
2.9 Company Management
2.10 Global Positioning System
2.11 Emergency Locator Transmitter
2.12 Operations in Marginal Weather
2.13 Summary

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors
3.2 Other Findings
4.0 Safety Action

4.1 Action Taken
4.1.1 Transport Canada Post-Occurrence Audit
4.1.2 Global Positioning System
4.1.3 Operations in Marginal Weather
4.2 Safety Concern

5.0 Appendices

Appendix A - Approach Outlines
Appendix B - Weight and Balance Estimates for the Flight
Appendix C - Weight and Balance Discrepancies
Appendix D - List of Supporting Reports
Appendix E - Glossary

1.0 Factual Information

1.1 History of the Flight

The Sowind Air Ltd. Embraer EMB-110P1 Bandeirante aircraft, Flight 301, departed St. Andrews, Manitoba, at 1415 central standard time on a 40-minute, scheduled flight to Little Grand Rapids, Manitoba. Onboard the aircraft were a crew of 2 and 15 passengers. The flight was pilot self-dispatched and departed under visual flight rules (VFR) in controlled airspace. When the aircraft approached Little Grand Rapids, the crew received the unofficial airport weather report by radio from the airport manager (APM). The weather was reported as a ceiling of 200 feet above ground level (agl) and a visibility of one statute mile and the crew flew an instrument approach. When the aircraft was overhead the airfield, the crew asked the APM if the aircraft could be seen. The APM responded negatively and the crew initiated a missed approach advising that they had not acquired the airport visually.

After the aircraft had climbed back above the cloud layer, a second Sowind Air Ltd. aircraft, a PA31-350 Navajo, Flight 318, arrived in the vicinity of Little Grand Rapids, operating under VFR. The Navajo pilot reported that he flew over the airport from the southwest at a height of about 300 feet agl, turned, and made a successful landing on runway 18. He then advised the Bandeirante crew by radio that the visibility on final for runway 18 was two miles and that he was on the ground. The Navajo was clearly seen, by witnesses, over the lake to the south of the runway. The approach flown by the Navajo was described as west of the normal approach path to runway 36, but conforming to about the altitude usually observed. The Navajo was observed flying over the runway at low level before turning for an approach to runway 18. One witness described the Navajo as appearing as a vague outline; another observer stated that the Navajo appeared to "pop out" over the runway.

Based on the information gathered during the investigation, including that from witnesses and survivors, the following scenario was derived. The Bandeirante crew then began a second approach from above the cloud layer. The aircraft approached from the south over the community of Little Grand Rapids, to the east of the flight path of the Navajo, and crossed the lake at low level. The aircraft was at about half the height flown by the Navajo or about 150 feet above the lake surface. When the aircraft approached the shoreline to the southeast of the airport, the engine power was advanced. The aircraft then banked quickly left and then right and disappeared from view in fog as it descended. The track followed by the aircraft was east of the normal approach path and at low level. Power was applied just before the aircraft banked rapidly to the left, followed by a nearly immediate right bank and impact with the terrain. The aircraft descended into the trees in a shallow left bank approximately 400 feet south and 1 600 feet to the east of the approach to runway 36. During the banking manoeuvres, the aircraft passed in proximity to an abandoned, 93-foot fire tower. The aircraft crashed at 1526, in daylight hours, at latitude 5202' N, longitude 09553' W, at an elevation of 1 050 feet above sea level (asl).

1.2 Injuries to Persons
<table>
<thead>
<tr>
<th></th>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Serious</td>
<td>1</td>
<td>12</td>
<td>-</td>
<td>13</td>
</tr>
<tr>
<td>Minor/None</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>15</td>
<td>-</td>
<td>17</td>
</tr>
</tbody>
</table>

The captain and three passengers were fatally injured. The first officer and the other 12 passengers suffered varying degrees of serious injuries. The first officer's injuries were such that he was unable to provide any statement to the Board.

1.3 Damage to Aircraft

The aircraft was destroyed by the impact forces.

1.4 Other Damage

There were trees damaged, and the fuel that was on board the aircraft spilled onto the ground.

1.5 Personnel Information

1.5.1 General

<table>
<thead>
<tr>
<th></th>
<th>Captain</th>
<th>First Officer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>62</td>
<td>30</td>
</tr>
<tr>
<td>Pilot Licence</td>
<td>Airline Transport</td>
<td>Commercial</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
<td>01 June 1998</td>
<td>01 March 1998</td>
</tr>
<tr>
<td>Total Flying Hours</td>
<td>15 000</td>
<td>700</td>
</tr>
<tr>
<td>Hours on Type</td>
<td>114</td>
<td>367</td>
</tr>
<tr>
<td>Hours Last 90 Days</td>
<td>73</td>
<td>135</td>
</tr>
<tr>
<td>Hours on Type Last 90 Days</td>
<td>73</td>
<td>135</td>
</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Hours Off Duty Prior to Work Period</td>
<td>14</td>
<td>18</td>
</tr>
</tbody>
</table>

1.5.2 The Captain

1.5.2.1 General

The captain had successfully completed a pilot proficiency check (PPC) and instrument flight check (IFC) on the Bandeirante on 03 February 1997, and held a Group 1 instrument rating. The captain's medical certificate was current, with a requirement that glasses be available.

The captain began his employment with Sowind Air Ltd. in February 1997 and left the company in April 1997. He flew the Curtis Wright C-46 for another company and then returned to Sowind Air Ltd. in October 1997. At the time of the occurrence, the captain was the chief pilot for Sowind Air Ltd. He was appointed to that position on 03 December 1997 and was responsible for standard operating procedures, training programs, operational suitability of aerodromes and routes, and the supervision of flight crews.

Information revealed conflicts between the captain and other company Bandeirante pilots, to the extent that several did not like to fly with him. The occurrence first officer had on one occasion formally expressed this dislike; however, there was some information that indicated that the first officer had adjusted and accepted the captain's methods. The conflicts surfaced because of the captain's preference to fly VFR rather than instrument flight rules (IFR) and his tendency to continue.
VFR flight in marginal weather.

1.5.2.2 Flying History

The captain's records indicate that he had experienced no difficulty within the last five years with VFR flying skills on the Curtis Wright C-46 or the initial PPC and IFC on the Bandeirante. The Transport Canada (TC) inspector noted on the test report for the Bandeirante PPC, "Well flown initial PPC." Similar remarks were contained in other recent PPCs. The only difficulties that he had had with IFR flying skills within the last five years were noted on two IFC rides. On an IFC ride in February 1996, on the Curtis Wright C-46, the inspector marked a precision approach as satisfactory with briefing because of glide slope and localizer deviations. Similarly, on a PPC/IFC for the DC3 in February 1996, the inspector marked a holding as satisfactory with briefing because of an error in tracking to the fix.

The captain's records indicate that he had been involved in two aviation occurrences in the last 10 years that had been investigated by the TSB. Occurrence A90C0037 involved the near loss of control of an HS-748 after full flap selection on approach. One of the findings of the report was that the captain had not calculated the centre of gravity of the aircraft before departure, and the cause was as follows: "A centre of gravity beyond the aft limit combined with the application of full flaps resulted in an uncontrollable nose-up pitching moment and a near loss of control during the initial landing attempt." Occurrence A93C0113 also involved an HS-748. It was determined that the cause of this accident was, "The pilot continued with an unstabilized approach and landed with insufficient runway remaining to stop the aircraft within the confines of the published runway length." One of the findings of the report was that, "The aircraft crossed the threshold of the runway at an airspeed of approximately 130 knots. The maximum threshold speed for an aircraft weight of 42,000 pounds is 110 knots." The captain's records beyond 10 years indicate some variability of performance. He failed two IFCs, in June 1986 and April 1985. He failed one PPC in May 1988. Several test reports had adverse comments with respect to instrument procedures and others had comments such as "A smooth and experienced captain."

1.5.3 The First Officer

1.5.3.1 General

Company pilots described the first officer as requiring extra assistance on occasion. For example, he had experienced difficulty initially understanding and using the global positioning system (GPS). He was reportedly one of several pilots who programmed the runway thresholds into the GPS as waypoints and used these waypoints during approaches in both IFR and VFR conditions. He was described as an individual who spoke up if he believed flying safety was compromised.

1.5.3.2 Flying History

The first officer began flight training in 1993 to secure a commercial licence. He passed a commercial flight test in March 1996, obtained an instrument rating in May 1996, and a flying instructor rating in December 1996. He was hired by Sowind Air Ltd. in the spring of 1997. After completing company training, he failed his initial PPC/IFC on the Bandeirante in April 1997, and his instrument rating was suspended. He failed the second PPC/IFC attempt on 02 May 1997. On May 15 he passed the third attempt. The first officer had a current medical certificate and had completed a pilot decision-making course conducted by TC on 04 October 1997.

1.6 Aircraft Information

1.6.1 Aircraft Data

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Embraer (Empresa Brasileira de Aeronautica)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and model</td>
<td>EMB-110P1</td>
</tr>
<tr>
<td>Year of manufacture</td>
<td>1980</td>
</tr>
</tbody>
</table>
1.6.2 Aircraft Description

The Embraer Bandeirante is a low-wing, twin-turboprop, non-pressurized monoplane with an all-metal stressed skin structure, cantilever wings and empennage, and a semi-monocoque structural fuselage. The landing gear is a single wheel, hydraulically operated, retractable tricycle type. The flight controls are operated by a cable and pulley system that is connected to bell cranks and push/pull rods in the wings and tail. The aircraft is equipped with two over-wing emergency exits, a large rear hydraulically operated cargo door, a forward passenger door on the left side of the fuselage, and a forward emergency exit crew door on the right side of the fuselage. The aircraft is equipped with pneumatically operated leading edge de-icer boots, electrically operated propeller de-icer boots, electric blankets for the engine air inlets, an electrically heated centre windshield with wiper blades, and an engine bleed air defrost system. The aircraft is type-approved to operate in Canada and is designed to carry 19 passengers and 2 crew members.

The occurrence aircraft was imported from the United States in July 1996, and underwent extensive inspection and refurbishment before the issuance of a Canadian Certificate of Airworthiness on 09 December 1996. The aircraft was flown approximately 1 150 hours during its one year of operation with the company. The most recent major work performed on the aircraft was a hot section inspection of both engines, completed on 01 December 1997, eight days before the accident. At the time of the accident, there were no recorded deferred maintenance items or unserviceabilities with the aircraft. The aircraft was being maintained on a progressive inspection program with inspection checks due every 75 hours. The last inspection of the aircraft was an A1 & A2 check conducted on 07 November 1997 at an airframe time of 13 674.4 hours. The aircraft was due for a major C12 or 1200-hour inspection in approximately 50 hours' time.

1.6.3 Weight and Balance Information

The aircraft is approved to operate at a maximum take-off weight of 12 500 pounds, with a maximum landing weight of 12 015 pounds. The aircraft's maximum ramp weight, accounting for fuel burn prior to take-off, is 12 566 pounds. At weights above 8 818 pounds, the aircraft's C of G limits are between 255.5 inches and 272.0 inches aft of the datum or 9.5 per cent to 31 per cent mean aerodynamic chord (MAC). At weights below 8 818 pounds, the C of G limits are between 251.3 inches and 272.0 inches aft of the datum or 4 per cent to 31 per cent MAC with a straight line variation between the points.

With the extensive refurbishment of the aircraft during the certificate of airworthiness approval process, which included new upholstery and paint, the company decided to reweigh the aircraft. The aircraft was weighed on 20 November 1996 by Sowind Air Ltd. The aircraft was weighed in the cargo configuration with full hydraulic system fluid and residual fuel and oil. A new weight and balance report was produced, which was submitted to TC along with a revised equipment list.

The weight and balance report was prepared by and signed by the maintenance coordinator of Sowind Air Ltd. The maintenance coordinator did not hold the appropriate endorsement on his licence for the aircraft type and, therefore, did not have the authority to sign the weight and balance report. The weight and balance report contained numerous errors, including incorrect scale weights, incorrect moment calculations, and incorrect empty weight C of G calculations. These are included in the discrepancies listed in Appendix C. The equipment list had not been fully updated and several
items were shown as being installed on the aeroplane, when in fact the items had been removed before the weighing of the aircraft. As well, several items, such as a KR87 ADF installation, a new and lighter aircraft battery, the survival gear, and cargo net installation were not added to the equipment list to show that they had been installed on the aircraft.

1.6.4 Equipped Operating Weight

The equipped operating weight (EOW) is the weight of the aircraft ready for flight, including crew, but excluding fuel, passengers, and baggage. The company computed an EOW of 7 971 pounds. To derive this calculation, the company took the empty weight of the aircraft of 7 607 pounds and added two crew, using a summer weight of 182 pounds per crew member. No allowance was made for the weights of unusable fuel, engine oil, crew baggage, aircraft flight manuals, survival gear, the cargo net and strap installation, or the seasonal allowance for the winter weights of the flight crew; the sum of these weights was approximately 200 pounds. This additional weight was not included in the weight calculations for the aircraft.

1.6.5 Aircraft Seating Configuration and Loading Graphs

The aircraft was originally configured by the operator to carry 15 passengers. The seats were spaced to provide maximum leg room and comfort for the passengers, and the company produced a sample weight and balance loading graph using the revised 15-passenger seat location. However, the C of G location on the loading graph was in error as a result of the mistakes made in the basic weight and balance document.

At some point during the year that the aircraft had been operated by the company, the aircraft seating configuration was changed to provide seating for 18 passengers. The 15 seats were placed closer together to allow for the placement of an additional row of 3 seats. The last row of seats was removed or installed depending on load requirements. When removed, the area was used for cargo. No weight and balance adjustments were made by the company for the new seating or cargo configuration, nor could the company provide sample weight and balance loading graphs to cover the full range of aircraft loading possibilities.

1.6.6 Cancelled Morning Flight Load Calculations

On the morning of the occurrence, the aircraft had been scheduled to fly to Little Grand Rapids with a load consisting of eight passengers and 1 166 pounds of freight. Because the passenger load was less than nine passengers, single pilot operation was authorized, and the occurrence captain was scheduled to fly the aircraft. The freight consisted of 1 144 pounds of food goods destined for Little Grand Rapids and 22 pounds of freight destined for Paungassi, Manitoba. The freight was loaded onto the aircraft by the company operations manager and the occurrence aircraft captain. The occurrence aircraft captain fuelled the aircraft and entered into the fuel log an upload of 450 litres of Jet-B aviation fuel. The total fuel load on the flight load manifest was recorded as 1 400 pounds. The all-up weight (AUV) on the flight load manifest was estimated at 12 477 pounds. The front office manager arranged for the aircraft load for the morning flight.

The flight was put on hold because of poor weather in the Little Grand Rapids area, and the company decided to cancel the flight and wait for an improvement in the weather for the afternoon flight. Some of the passengers decided not to wait for the afternoon flight, and the company shipping manager drove those passengers and their luggage into Winnipeg. When the shipping manager returned, the afternoon flight had departed.

1.6.7 Occurrence Flight Load Calculations

The company was expecting a higher passenger load for the afternoon flight and a second pilot had been called in to act as first officer on the Bandeirante. A customer support clerk arrived for her shift after the morning flight had been cancelled and arranged the aircraft load for the afternoon flight. The front office manager was away from the office when the customer support clerk arranged for the load, and the clerk did not know that the aircraft had already been loaded with cargo for the morning.
flight. The customer support clerk booked 15 passengers onto the flight and weighed their baggage at 295 pounds.

In the early afternoon, reports of an improvement in the weather were received from company staff at Little Grand Rapids and all flights were dispatched. The operations manager indicated to the pilot of the Bandeirante that he and his first officer would have to unload the freight from the aircraft by themselves, as he was busy with his own flight and the shipping manager was away. The customer support clerk gave the pilot the passenger load and baggage information, and the pilot asked if there was any room for additional cargo. The pilot indicated that he now had a fuel load of 1 600 pounds\(^{(5)}\) and the clerk forecast the aircraft's total weight at 12 352 pounds. The pilot indicated that he would load an additional 150 pounds of cargo. The flight load manifest was amended to read an AUW of 12 500 pounds.\(^{(6)}\)

### 1.6.8 Aircraft Overload

Calculations of the weight and balance for the occurrence flight are contained in Appendix B. The weight of the aircraft was calculated to have been between 13 230 and 13 830 pounds, exceeding the maximum take-off weight limit of 12 500 pounds by 730 pounds to 1 330 pounds. At impact, the aircraft was 495 to 1 095 pounds heavier than its maximum landing weight.

The estimate of 730 pounds overweight is based on the following: 200 pounds of unrecorded aircraft equipment, 42 pounds of unrecorded passenger weight, a flight load manifest calculation error of 2 pounds, 64 pounds of extra baggage located at the accident site, and 424 pounds of extra cargo (from the cancelled early morning flight) that was located at the accident site. The estimate of 1 330 pounds overweight is based on the preceding 730 pounds plus an additional 200 pounds of cargo from the early morning flight that could not be accounted for by the company or located at the occurrence site, and 400 pounds of extra fuel based on fuel quantity gauge readings derived after the occurrence.

### 1.6.9 Aircraft Approach and Stall Speeds

Figure 5-4 in the approved flight manual presents the stall speeds as a function of gear and flap configuration, and aeroplane weight and bank angle. Interpolation of the table gives an increase in the stall speed of from 2 to 3 knots indicated airspeed (KIAS) for a weight increase of 500 pounds for all configurations and bank angles. There are no data available for weights in excess of 12 500 pounds. At 12 500 pounds, the maximum take-off weight, and configured with landing gear down and flaps set at 25 per cent, the stall speeds are as shown in Figure 1.

<table>
<thead>
<tr>
<th>Degrees of bank</th>
<th>Stall (KIAS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>85</td>
</tr>
<tr>
<td>30</td>
<td>91</td>
</tr>
<tr>
<td>45</td>
<td>101</td>
</tr>
<tr>
<td>60</td>
<td>121</td>
</tr>
</tbody>
</table>

Figure 1 - Stall speeds at 12 500 pounds

The flight profile chart for non-precision approaches in the Sowind Air Ltd. Standard Operating Procedure (SOP) manual gives a non-precision approach speed of 120 KIAS for Sowind Air Ltd. Flight 301's aircraft configuration and position on the approach. Figure 5-26 in the approved flight manual gives a final approach speed of 112 KIAS for an aircraft weight of 12 500 pounds with flaps set at 25 per cent. The approved flight manual indicates that both the maximum gear-lowering speed and maximum gear-extended speed are 145 knots.

### 1.6.10 Ground Proximity Warning System

A ground proximity warning system (GPWS) is designed to issue visual and aural warnings to the flight crew when their aircraft is too close to terrain or when the aircraft's terrain closure rate, rate of descent, or glideslope deviation becomes excessive. The warnings are based on GPWS internal
logic, radar altimeter information, and the aircraft's configuration. GPWS has prevented many accidents where, until the warning sounded, the pilots had been unaware that the aircraft was in danger because of proximity to the ground or water. The occurrence aircraft was not equipped with a GPWS and none was required by the regulations.

1.7 Meteorological Information

South and central Manitoba had been under a stagnant flow and weather pattern for several days before the accident as a quasi-stationary high-pressure ridge dominated the province. The surface and low-level wind was weak and variable. The boundary layer of the atmosphere had been nearly saturated for several days with very few breaks in an extensive stratus cloud deck. On the morning of the accident, the lower level of the atmosphere consisted of an isothermal temperature layer with an inversion above. The airmass was nearly saturated throughout the isothermal layer. These elements combined to produce widespread areas of low cloud, fog patches, and patchy freezing drizzle. Typically, ceilings and visibilities were at their lowest at sunrise each day with marginal improvement through the afternoons.

Between Winnipeg and Little Grand Rapids, official Environment Canada weather observations of ceiling, visibility, and precipitation (including icing) are available from Winnipeg and Berens River, about 75 nautical miles from Little Grand Rapids. Visibility and precipitation reports are also available from Gimli, about 115 nautical miles southwest of Little Grand Rapids.

At the time of the aircraft's departure from the St. Andrews airport, the Winnipeg weather was reported as: ceiling partially obscured, a scattered cloud layer at 1 000 feet agl, an estimated ceiling of 2 500 feet agl overcast, and visibility three statute miles in light snow. At the time of the flight, the automated weather observation station at Gimli reported visibilities above nine statute miles with light easterly winds. The Berens River reports during the time period of the flight gave ceilings of 800 feet agl broken, 1 500 feet agl overcast with visibility of 15 statute miles in light snow.

Unofficial weather observations are available three times daily, at 0800, 1000, and 1500, from Little Grand Rapids and Bloodvein River, about 65 nautical miles west of Little Grand Rapids. Observations at these two sites are made by airport personnel employed by the Province of Manitoba and are available in the form of a special bulletin. Typically, the unofficial reports contain an estimate of ceiling height, visibility, and precipitation.

At 1500, the Bloodvein reported weather was a ceiling at 1 000 feet agl, with a visibility of three statute miles. The Little Grand Rapids reported weather was a ceiling of 200 feet agl with a visibility of one statute mile in fog.

Little Grand Rapids is in the extreme southern portion of the FACN32 forecast area, and just north of the region covered by the FACN31 forecast area. The area forecasts valid at the time of the accident were issued at 1130. Both forecasts indicated that a ridge of high pressure would lie east of the flight track giving a light variable flow to southern Manitoba. The airmass was forecast to be stable with extensive low-level moisture. En route, the FACN31 forecast called for general ceilings at 2 000 feet asl with tops at 4 000 feet asl. In addition, frequent stratus ceilings, between 400 and 1 200 feet agl, and isolated visibilities between one and five statute miles in snow, freezing drizzle and fog, were forecast; these lower conditions were expected to be more common over higher terrain. Moderate mixed icing was forecast in freezing drizzle with light rime icing elsewhere. The FACN32 forecast, which would form the basis for the terminal weather forecast at Little Grand Rapids, called for slightly deeper cloud (tops at 5 000 feet asl) with a few stratus ceilings to 500 feet agl and visibilities to one statute mile in freezing drizzle and fog.

In general, the area forecasts were representative of the conditions reported. However, at Little Grand Rapids, the cloud ceiling reported by the observer was lower than the lowest forecast in the FACN32 forecast. This observation was made several hours after the release of the forecast; the lowest ceilings reported up to that point were well within the range of the forecast. Visibility observations were within the range of the forecast at the time of the accident. Additionally, the FACN32 forecast was more pessimistic concerning the extent of cloud ceilings in the area west of the ridge: many stations reported clear skies while the forecast called for broken to overcast
conditions.

Pilot reports of the weather at the time of the accident were available from two sources, a local pilot who had taken off and returned because of weather about 50 minutes before the crash, and the pilot of the Sowind Air Ltd. Navajo who landed about 10 minutes before the accident. The local pilot reported that the ceiling was indefinite and varying between 100 and 200 feet agl, and that the visibility was one statute mile with fog down to the trees to the east of the runway and down to the water over the river immediately west of the runway. He reported his observations to the APM who, in conjunction with her own observation of the weather, reported the unofficial weather as 200 feet agl and one mile visibility. The Navajo pilot reported that he had one-mile visibility approaching from the south over the lake with a ceiling at 300 feet agl. He found that the visibility was two miles after he turned final for runway 18 to the northeast. He stated that the cloud base was ragged and that there had been patchy fog in the vicinity of his turn to runway 18.

During the day of the flight, the company president telephoned a relative in Little Grand Rapids for weather information. The information received indicated better ceilings and visibilities than those reported from the airport because the relative was located in the local community, further from the open water. Based on this weather information, the company president had his personal aircraft readied for a flight to Little Grand Rapids.

1.8 Aids to Navigation

A non-directional beacon (NDB), identifier 4B, is located on the Little Grand Rapids airport property, north of the centre point of the runway, and serves as an aid for a cloud-breaking procedure.

Sowind Air Ltd. has authorization from TC to use the NDB A approach at Little Grand Rapids. The chart is labelled "Company Use Only," and is not for public use without TC approval. The minimum descent height for the circling approach is 1 560 feet asl, 555 feet above the airport reference elevation. The procedure turn is flown to the southeast of the airport at a minimum altitude of 2 500 feet asl.

1.9 Communications

Communications between Sowind Air Ltd. Flight 301 and air traffic services were normal throughout the flight. The Sowind Air Ltd. Flight 301 transponder code of 1200 was recorded by the radar system until the flight left radar coverage about 55 nautical miles northeast of St. Andrews. On arrival in the area of Little Grand Rapids, Sowind Air Ltd. Flight 301 communicated with the APM using the aerodrome traffic frequency, and with the other company aircraft on the company frequency. With the exception of the radio transmissions between Sowind Air Ltd. Flight 301 and St. Andrews Tower and Winnipeg Terminal, no other radio transmissions were recorded.

1.10 Aerodrome Information

The aerodrome serving the community of Little Grand Rapids, a community of about 900 people, is a certified airport operated and maintained by the Government of Manitoba. The airport is identified as CZGR, and the airport reference elevation is 1 005 feet asl. It has one runway, 18/36, which is gravel-surfaced, 2 800 feet long and 75 feet wide.

Low-intensity runway threshold and end lights are available for both runways, and can be activated by aircraft radio control of aerodrome lighting (ARCAL). The lights are activated for 15 minutes by keying a microphone five times in five seconds on frequency 122.8 megahertz (MHz). There was no information to indicate whether the lights had been activated by the crew of the occurrence aircraft.

Runway 36 heads away from the main community and terminates at the shore of a rapids, which is open year round. Runway 18 heads towards a lake and has a 0.7 per cent slope up, terminating in a sharp drop-off to the lake shore. A river flows immediately to the north and west of the runway, and is also open year round. The terrain to the east of the airport is higher, heavily forested, and is about 70 feet above the surface of the lake. There is an abandoned, unpainted, and unlighted fire tower, about 93 feet in height, approximately 1 100 feet to the east of the threshold of runway 36. Trees in the area are about 50 to 70 feet in height.
1.11 Flight Recorders

The aircraft had been equipped with a Loral Fairchild cockpit voice recorder (CVR) before its importation from the United States. While in the United States, the aircraft had been taken out of service and the voice recorder was removed. The voice recorder control panel was removed during the importation of the aircraft; however, the mounting tray and wiring installation remained in the aircraft.

The aircraft was not equipped with a flight data recorder (FDR) nor was one required by the regulations.

1.12 Wreckage and Impact Information

1.12.1 General

The aircraft struck the tops of 40- to 50-foot trees in a near wings-level, slightly nose-high attitude, on a heading of 358 degrees magnetic. The aircraft's ventral fin and left elevator balance weight were torn off. The aircraft's left wing then struck trees tearing off six feet of the outboard section of the wing and aileron. The aircraft entered a roll to the left, arcing to a final heading of 344 degrees magnetic and began a 30-degree angle descent to the ground. The aircraft struck the ground in a steep left-wing-low, nose-down attitude and cartwheeled over the left wing, coming to rest upright and pointing back towards the initial impact point. The aircraft travelled approximately 435 feet from the initial tree contact to its final resting point. The aircraft was covered in trees that were torn down during the accident sequence, and the only portion of wreckage that was visible from the air was the aft fuselage structure. Until the arrival of the investigation team, the temperature remained below freezing and the aircraft was under both cloud cover and tree canopy.

The forward portion of the aircraft, including the cockpit and first two rows of passenger seats, up to the leading edge of the wings, was destroyed by impact forces. The main cabin structure, aft of the leading edge of the wings, remained largely intact, and the cargo in the aft cabin area remained secure beneath the cargo net. The horizontal stabilizer was torn from its mounting structure. The left engine and propeller were torn from their mounts and thrown backwards onto the left wing. The right engine remained within its mounts; however, the propeller separated at the reduction gear box and spun into the cockpit structure.

1.12.2 Landing Gear

Witnesses on the ground reported that the landing gear appeared to be extended before the accident. An examination of the wreckage found that the nose gear was broken and pushed forward; the right gear was partially folded underneath the wing, and the left gear was down and locked in position. The landing gear selector handle was bent and in the UP position; however, it could not be determined if it had been driven up during the impact. The emergency gear selector was found in the normal position. An examination of the landing gear indicator lamps by the TSB Engineering Branch Laboratory (LP 193/97) showed that the green "gear down" bulbs were not illuminated at the time of impact; however, the red "gear in transit" bulb exhibited deformation considered consistent with an illuminated or hot filament when shocked.

1.12.3 Flaps

The flap handle has three positions: UP, TO (take-off or approach), and DOWN. The flap handle was found to be bent and in the UP position; however, it could not be determined if it had been driven to the UP position during impact. The extension of the left and right flap actuators was measured and found to be symmetrical, with an approximate 11.25- to 11.35-inch extension. A flap actuator extension of 11.42 inches corresponds to a flap setting of 10 degrees, or 25 per cent, the TO position (approach flap).

1.12.4 Flight Control Systems
The elevator, rudder, and aileron are equipped with a trim system with manually operated cockpit controls that have a selection range from 1 to 6 on either side of a 0, or neutral, position. The elevator trim indicator was found at the top of the green range or at the 1 indicator position (towards nose UP). The rudder trim indicator was found between the 0 and 1 nose-right position and the aileron trim indicator was found between the 0 and 1 right-wing-low position. All trim positions were indicative of a neutrally trimmed aircraft.

The flight control cable routing, integrity, and security through the wings, cabin, and tail sections were examined by the TSB Engineering Branch, and no faults in these systems were found.

1.12.5 Engine Examination

The engines (Pratt & Whitney PT6A-34) were removed from the occurrence site and taken to the manufacturer's service investigation facility at Saint-Hubert, Quebec, for examination under the control of the TSB. The results of the investigation are contained within a teardown and examination report prepared by Pratt & Whitney Canada for the TSB. The engine examination revealed no mechanical, manufacturing, assembly, or maintenance-related anomalies that would have affected engine operation. The report concluded that, based on impact-related damage, both engines were likely operating in a mid- to high-power range at impact.

1.12.6 Auto-feather System

The two green auto-feather armed lights were examined by TSB Engineering Branch personnel and were considered to be ON at impact. The company E110 SOP manual, Approach & Landing Procedures Section states: "If icing is anticipated, turn on the anti-ice. Arm the auto-feather, and turn off the prop sync."

1.12.7 Propeller Examination

The propellers (Hartzell HC-B3TN-3C/3D) were removed from the occurrence site and taken to manufacturer's service investigation facility in Piqua, Ohio, for examination under the control of the TSB. The results of the investigation are contained within a teardown report prepared by Hartzell Propellers for the TSB. The propeller examination revealed no mechanical, manufacturing, assembly, or maintenance-related anomalies that would have affected propeller operation. The report concluded that both propellers were in a thrusting mode of operation (normal governing range) and absorbing a similar amount of engine power at impact.

1.12.8 Instrument Examination

An examination of the instruments at the site revealed that both the captain's and first officer's altimeters had been set to 30.05 (the setting that was passed to the crew by the APM at Little Grand Rapids). The aircraft clock had stopped at 1526, the aircraft radios were set to 122.8 MHz (UNICOM frequency) and 130.07 MHz (company frequency), and the windshield defog switch was in the ON position. The airspeed indicators, fuel flow gauges, and fuel quantity gauges were sent to the TSB Engineering Branch Laboratory for examination (LP 193/97).

The TSB Engineering Branch found that both airspeed indicators displayed internal damage. Both instruments indicate the speed at impact to have been in the 138- to 153-knot range.

The left engine fuel flow indicator pointer was indicating a minimum of 325 pounds per hour at impact (the maximum gauge reading is 500 pounds per hour). The right fuel flow indicator provided no information. The left and right fuel quantity gauges displayed needle imprints at 640 pounds and 380 pounds respectively. The gauges return to zero by an internal spring when power is removed; therefore, the fuel quantity readings were considered minimum readings at the time of impact. The fuel quantity gauge range is from zero to 1 650 pounds.

1.12.9 Global Positioning System
The GPS, a II Morrow Classic, model 820, was removed from the occurrence site and forwarded to the manufacturer's facility in Salem, Oregon, for data retrieval. A representative of the U.S. Federal Aviation Administration (LP 193/97) was present at the request of the TSB. The system software version was current and appropriate, the manual altitude setting was 700 feet, and there was no active flight plan inserted. The last recorded waypoint was latitude 5202'73" N, longitude 09527'93" W and identified as CZGR. The last recorded aircraft position was latitude 5202'34" N, longitude 09527'58" W, with a magnetic bearing and distance to the last recorded waypoint of 333 degrees at 0.4 nautical mile. The last recorded waypoint corresponded to the ramp (mid-runway location) at the Little Grand Rapids airport. The last recorded aircraft position corresponded to the position of the crash site.

A check with the operator found that the original GPS, a II Morrow Classic, had been replaced with a more advanced Apollo GX55. The GX55 was then removed from the aircraft due to a card incompatibility and temporarily replaced with a II Morrow Classic (the occurrence GPS) from another company aircraft (a float-equipped DHC-2 Beaver). The mounting tray installation and aircraft antennae systems for both styles of GPS were compatible. Neither GPS had been coupled to the aircraft's navigational equipment.

The II Morrow Classic GPS installation did not meet the requirements of the technical standard order for IFR GPS receivers (technical standard order C-129); therefore, the GPS was not approved for use as primary IFR flight guidance.

The Beaver aircraft had been operating at the company float base at Little Grand Rapids, which is across the lake from the airport, near the community. The coordinates of the float base had been entered into the GPS under the identifier ZGR. The Bandeirante aircraft passed near the float base on its final approach to the airport; however, it was not established if the crew had been using float base coordinates as a point of reference because the second-last selected waypoint is not stored information.

1.12.10 Fuel Samples

A fuel sample was secured from the company's fuelling facility at the St. Andrews airport. The fuel was identified as Jet-B. A visual examination showed it to be clean and bright, and free of contaminants. The company's fuel cache of Jet-B at Little Grand Rapids had been run dry before the accident and was not being used. The pilot of the aircraft was aware of this.

During impact with the trees, the fuel tanks were ruptured and fuel was dispersed along the wreckage trail. Very little fuel was found in the damaged fuel tanks.

1.13 Medical Information

An autopsy and toxicological tests were conducted on the captain. The toxicological tests indicated the presence of the non-prescription drug, diphenhydramine, in some body fluids but not in the blood sample. The testing found that the captain's blood had a four per cent saturation level of carbon monoxide. The captain was reported to have been a non-smoker. The source of the carbon monoxide was not determined. However, second-hand smoke could account for a four per cent saturation level. Diphenhydramine is a drug with sedative, antihistamine, and antiemetic effects. It is commonly used to treat motion sickness and can be found in non-prescription cold or flu medicine. The absence of the drug in the captain's blood stream likely indicates that the drug was nearly eliminated from his body before the time of the accident. There was no indication of any other pre-existing conditions that could have affected the captain's performance.

1.14 Fire

A small post-crash fire started in the area of the left engine. Passengers quickly extinguished the fire with snow.

1.15 Survival Aspects
1.15.1 Aircraft

The fatalities and the most serious injuries occurred to the occupants in the cockpit and the first two passenger rows. The extensive damage to the front of the aircraft destroyed the liveable space surrounding the occupants. The passengers in the remaining rows suffered varying degrees of somewhat less serious injuries, as the cabin structure remained intact.

The two forward doors were destroyed and blocked by debris. The passengers in the rear rows were able to open the over-wing, emergency exit doors and egress through them. Several of the passengers were trapped amid the debris and rescue workers had to move portions of the forward cockpit structure to extract them.

The survival gear was stored in the back of the aircraft and was easily accessible after the crash. The first-aid kit, however, was located in the front of the aircraft and was buried within the crushed structure. In this occurrence, neither kit was necessary because of the prompt emergency response; however, the inaccessibility of the first-aid kit would have made it difficult for the survivors to treat the injuries.

The Little Grand Rapids airport is equipped with a fire truck, which was driven onto the frozen lake surface and to the shoreline near the crash site. The fire truck responded within minutes of the accident but was not needed because the small post-crash fire had been extinguished. First at the crash site were residents, who arrived on snowmobiles and helped to organize rescue operations and to stabilize the survivors, who were then transported via snowmobile and sled to the nursing station across the lake at the community of Little Grand Rapids. Three of the more seriously injured were flown to Winnipeg on the company's Navajo that had landed minutes before the accident. Military rescue operations were hampered by poor weather conditions and the remaining passengers could not be transported to Winnipeg until the following day.

1.15.2 Emergency Locator Transmitter

The emergency locator transmitter (ELT) was identified as a Dorne & Margolin, serial number 32527, which had been re-certified with a new battery on 07 November 1997. The ELT was found in the ARMED position and had activated upon impact. A military search and rescue aircraft picked up an ELT signal in the area of the crash site; however, the signal was very weak.

An examination of the ELT at the occurrence site found that the antenna cable had pulled out of the aerial at the connector fitting. The antenna cable was found to be looped together and wrapped tightly with "Ty-Rap," effectively taking slack out of the cable. During the impact sequence, there was sufficient movement and flexing in the fuselage structure to cause the antenna cable to be pulled out of the connector fitting.

1.16 Tests and Research

Not applicable.

1.17 Organizational and Management Information

1.17.1 General

At the time of the accident, Sowind Air Ltd. operated a fleet of eight aircraft, which included three Piper Navajos, two Cessna 185s, one DHC-2 Beaver, one DHC-3 Otter, and the Bandeirante. The company had been formed in 1992 to provide scheduled and charter service between northern communities and St. Andrews. In 1996, the company acquired the Bandeirante. With the implementation of the Canadian Aviation Regulations (CARs), the smaller aircraft were operated under part 703, Air Taxi Operations, and the Bandeirante was operated under part 704, Commuter Operations.

1.17.2 Senior Management
At the time of the accident, Sowind Air Ltd. was a privately owned company with three directors including the president. Reporting to the president were an operations manager, a chief pilot, and a maintenance coordinator. The president indicated that he was primarily responsible for the financial and other non-flying aspects of the company. The operations manager was responsible for the day-to-day flying operations and the chief pilot was responsible for the training of pilots and the procedures used by them. The president retained control of the hiring practices of the company. The president indicated that he had started the company to provide a higher standard of service to the northern communities served by the company.

The operations manager had been with the company since it started. He indicated that he considered his duties to include the general supervision of flight dispatching and flying administration, such as flight times and log books. A self-dispatch system was in place for all flights, and because the operations manager flew as a line pilot, he was not always present to supervise the aircraft loads and weather accepted by pilots. The pilots dealt directly with the passenger clerks and freight handlers as a matter of routine.

The chief pilot, who was the occurrence captain, had been chief pilot for seven days at the time of the accident. The previous chief pilot had been with the company since its inception and had been responsible for the training of pilots and the establishment of procedures during the introduction of the Bandeirante and the start-up of commuter operations.

1.17.3 Flight Operations

In general, the pilots did not believe there was management pressure to fly in marginal weather. However, there was a belief that there was little concern for accurate weighing of cargo and passenger baggage. Specific examples of inaccurate weight and balance control were discussed with investigators. The previous chief pilot indicated that sample weight and balance calculations had been made to assist pilots; however, no sample calculations were found. It was determined that pilots used the GPS to assist in approaches in IFR conditions and that some pilots engaged in the practice of entering runway thresholds as waypoints for the conduct of approaches.

1.17.4 Maintenance Department

In 1993, Sowind Air Ltd. established an approved maintenance organization (AMO 7693) to maintain fixed-wing, piston aircraft. The company employed two licenced engineers and two apprentice engineers. Neither the company’s AMO nor the company’s maintenance staff were certified to maintain the Bandeirante, and the maintenance of the aircraft was contracted to Northeastern Aircraft Sales & Service, which held the appropriate qualifications. The company subsequently produced a new maintenance control manual (MCM) as required by CAR 726.08. The MCM was approved by TC on 14 November 1997. The MCM indicated that an approved maintenance agreement was in effect with Northeastern Aircraft Sales & Service for maintenance of the Bandeirante.

There were maintenance concerns that pilots had moved equipment from aircraft to aircraft without coordination with the maintenance department.

1.17.5 Transport Canada Safety Oversight

Air carrier audits were conducted on Sowind Air Ltd. in September 1993 and 1994 by TC. These audits identified a small number of non-conforming items, all of which were corrected to TC’s satisfaction. Similarly, TC maintenance audits, conducted in May 1994 and December 1995, identified maintenance non-conformances that were subsequently corrected. A post-occurrence audit of Sowind Air Ltd. was conducted from 12 to 14 January 1998 by TC, with 32 non-conformances identified. The audit found that the operations manager was not fulfilling the responsibilities of the position. There were several non-conformances with respect to training. These non-conformances indicated that no company pilots, including both occurrence pilots, had received required training in the use of onboard survival or emergency equipment. Additionally, the captain had not undertaken required training to operate the aircraft from either pilot seat. The audit also
revealed that, in the months of September and December before the occurrence, the maximum take-off weight of the occurrence aircraft had been exceeded on seven flights.

TC inspectors had a good working relationship with Sowind Air Ltd. personnel; problems were dealt with positively, and TC inspectors did not feel there were significant problems in the company. The TC Manual of Regulatory Audits specifies that an initial certification audit will normally be conducted approximately six months after the certification date. Because Sowind Air Ltd. had been certified to use the Bandeirante in commuter operations in the fall of 1996, an initial certification audit should have been conducted in the summer of 1997, before the occurrence. TC officials explained that audits were suspended for approximately one year following the introduction of the new CARs in October 1996. This was done to allow both the industry and TC to adjust to the new regulations and to accommodate the heavy workload related to implementation of the new regulatory philosophy and process in TC.

TC uses an activity reporting and standards system (ARASS) to assist management in analysing operational workload and resource requirements. The ARASS is composed of discretionary and non-discretionary tasks. The review of initial weight and balance reports is deemed a discretionary task dependent on the workload of the assigned inspector. At one time, TC attempted to review all weight and balance reports submitted by operators, but found the workload prohibitive. The weight and balance report for the Bandeirante was received by TC and placed in the aircraft's file. The information contained within the reports was not reviewed.

1.18 Additional Information

1.18.1 Controlled Flight into Terrain

Controlled flight into terrain (CFIT) accidents are those accidents in which an aircraft, capable of being controlled and under the control of the crew, is flown into the ground, water, or obstacles with no prior awareness on the part of the crew of the impending disaster.

1.18.2 False Climb or 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 powerful disorientation. In the case of an aircraft that is accelerating during a missed approach, 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, which is usually the case in a missed approach, 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. If the aircraft is being flown in proximity to the ground, ground contact can occur before the pilot can assimilate information from the aircraft's instruments, overcome the powerful illusion, and take corrective action.

1.18.3 Carbon Monoxide

Levels of carbon monoxide saturation of less than 10 per cent are not considered to have a major effect on performance, although such a level would have a greater effect on non-smokers than on smokers. Cigarette smokers, for example, may routinely have saturation levels of 6 to 8 per cent. Carbon monoxide saturation levels can also be increased in non-smokers where an individual is exposed to second-hand smoke in an enclosed area. When saturation levels exceed 10 per cent, headache and shortness of breath can occur.

1.18.4 Aeromedical Factors

The Aeronautical Information Publication (AIP) refers to self-medication in sections Air 3-1 and 3-12. In section Air 3-1, the AIP states that, while flying an aircraft, a pilot must have no condition that
impairs alertness, reaction time, or decision-making ability. Individual pilots must make the decision whether they are fit to fly based on common sense and training. Section Air 3-12 states that self-medication, or taking medicine in any form immediately before or while flying, can be hazardous. The section explains that certain drugs, the most common being antihistamines, have been associated with aircraft accidents in the past and may seriously impair the judgement and coordination needed by a pilot.

1.18.5 Sowind Air Ltd. Approach and Landing Procedures

Sowind Air Ltd. SOPs specify that the pilot-flying will brief the approach applicable to the runway of intended landing. The applicable instrument approach plate will be available and visible to both the pilot-flying and the pilot-not-flying throughout the approach to landing. The approach plates found in the wreckage, including the plate for Little Grand Rapids, were in a three-ring binder and not in the approach plate holder. The three-ring binder was found under the captain's seat.

1.18.6 Operations in Marginal Weather

The aircraft was observed operating at low level, at an altitude of 150 feet agl, in ceilings of 100 to 200 feet agl and visibility of one to two miles. In two earlier safety recommendations (A96-11 and A96-12), the TSB recommended that the Department of Transport raise commercial operators' awareness of the inherent risks associated with operations in marginal weather, and require pilots involved in air taxi and commuter operations to receive specialized training in making prudent decisions under deteriorating operational conditions.

1.18.7 Commuter VFR Flight Obstacle Clearance Requirements

CARs, part 704, governs commuter operations. CAR 704.23 restricts commuter aircraft in day VFR operations to a minimum of 500 feet agl and not less than 500 feet horizontally from any obstacle.

2.0 Analysis

2.1 General

There was nothing found in the examination of the wreckage or in the detailed examination of individual components to suggest that the aircraft had experienced a structural failure, flight control malfunction, or loss of engine power that would have caused the observed approach and manoeuvring. Consequently, the analysis will be primarily concerned with the local weather, the possibility of aircraft contamination, the aircraft's weight and balance, CFIT, the crew's decision making and actions, and management.

2.2 The Weather in the Vicinity of Little Grand Rapids

Because there is no official weather observer or automated weather station at Little Grand Rapids, the available local weather information is that which has been reported by pilots. The estimated local ceilings and visibilities, as reported by two pilots, were generally lower than the official area forecasts because of the influence of the open, rapidly flowing water close to the airport. One report estimated the ceiling as indefinite from 100 to 200 feet agl with a visibility of one statute mile. The other report estimated the ceiling as 300 feet agl with a visibility, when landing on runway 18, of two statute miles. Both of these ceiling estimates were below the minimum descent altitude (MDA) for the NDB A approach and below the minimum altitude for commuter operations. Of more significance was the report that the fog from the open water had drifted to the east of the airport and extended to tree-top level. Thus, Sowind Air Ltd. Flight 301, while flying below the cloud layer to the east of the track below the MDA, was flying directly towards a fog bank extending from the white, frost-covered tree tops to the cloud layer. In the area of the fog, the ceiling and visibility were much lower than over the runway, and the frost-covered trees blended into the fog layer, virtually eliminating all outside visual reference for the crew of Sowind Air Ltd. Flight 301.

2.3 Aircraft Contamination
Because moderate mixed icing was forecast in freezing drizzle, with light rime icing elsewhere, it is possible that the aircraft's flying surfaces were being contaminated. The reports of witnesses indicated that there was no freezing drizzle in the area of Little Grand Rapids during the period of the flight from Winnipeg. The icing on the wing of the aircraft reported by one passenger was white and was not flowing back from the leading edge. The ice on the windscreen reported by another passenger was described as similar to frost patches. Both of these reports are consistent with the presence of rime ice. The pilot who examined the aircraft a few hours after the crash found only a trace of rime ice on the vertical fin of the aircraft. There were no signs of either clear or rime ice found by investigators on the day following the accident, although the temperature had remained below freezing and the aircraft was under both cloud cover and tree canopy. Consequently, it is likely that only small amounts of light rime ice formed on the aircraft before the occurrence.

The ice was observed on the windscreen, so the crew would have known that ice was present and would have had the opportunity to deal with it. Because little ice was found immediately after the accident, it is concluded that the crew took appropriate action, and aircraft contamination was being reduced by the aircraft's systems to the extent possible. However, even small amounts of rime ice would cause a small increase in stall speed, and any residual contamination on the aircraft windscreen would have reduced the crew's ability to see the terrain. Because all trims were found in a neutral position, it is unlikely that any trace amounts of ice were reducing control effectiveness.

### 2.4 Weight and Balance

Although the weight of the aircraft at impact could not be determined with precision, it was determined to be 495 pounds to 1 095 pounds greater than its maximum allowable landing weight, and 10 pounds to 610 pounds greater than its maximum allowable take-off weight. Using the stall speeds presented in the approved flight manual for 12 500 pounds (and a factor of about three knots' increase for each additional 500 pounds), Figure 2 presents an approximation of the stall speeds of the aircraft weighing 500 pounds more than the maximum take-off weight at various bank angles.

<table>
<thead>
<tr>
<th>Degrees of bank</th>
<th>Stall (KIAS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>88</td>
</tr>
<tr>
<td>30</td>
<td>94</td>
</tr>
<tr>
<td>45</td>
<td>104</td>
</tr>
<tr>
<td>60</td>
<td>124</td>
</tr>
</tbody>
</table>

![Figure 2 - Stall speeds at 13 000 pounds](Image)

While the airspeed at which the aircraft was flown is not known, the flight should have been operating at 120 KIAS based on the Sowind Air Ltd. SOPs, and the TSB Engineering Branch determined that the indicated airspeed at impact was between 138 and 153 KIAS. Therefore, the airspeed of the aircraft during the approach was probably in the range of 120 to 153 knots. Using the above chart, it can be seen that the crew would have to have entered a sustained bank of more than 45 degrees to stall the aircraft at the low end of this speed range. While the passengers described the bank applied immediately before the crash as extremely steep, in the absence of FDR information, the bank angle achieved was not determined. While it is unlikely that the captain would have initiated a bank of more than 30 degrees at low speed and at low level, a bank angle greater than 30 degrees cannot be discounted. However, even at an aggressive bank angle of 45 degrees, the approximate stall speed is 104 KIAS, leaving a 16-knot margin for an increase in stall speed because of residual rime ice. Thus, a stall caused by a combination of weight, bank angle, and contamination is not considered likely.

### 2.5 Controlled Flight into Terrain--Flight Crew Performance

#### 2.5.1 Decision Making

The captain attempted a second approach after communicating with the pilot of the Navajo, Sowind Air Ltd. Flight 318. It is reasonable to conclude that the information provided by the Navajo pilot influenced the captain's decision to attempt a second approach and subsequent actions on approach. Because the captain had a reputation for "pushing the weather," the knowledge that a company aircraft had just landed was likely a factor in his decision to descend below the MDA and
the minimum altitude for commuter operations and attempt a visual approach in marginal conditions.

Because passengers were able to discern that the aircraft was well east of the normal track, the crew members, who were very familiar with the area, should also have known that the aircraft was out of position for an approach to land. The reason that the aircraft was flown to the east of the normal approach was not determined.

The presence of diphenhydramine likely indicates that the captain was recovering from a cold or the flu. The toxicology results confirmed that the drug was nearly eliminated from his body at the time of the accident. The residual effects of the illness or the diphenhydramine, combined with the elevated level of carbon monoxide (for a non-smoker), could have reduced the captain's decision-making ability and level of alertness and delayed his reaction as a dangerous situation developed. However, there was no other information directly supporting this possibility.

2.5.2 Crew Resource Management Training

Records indicate that the first officer had completed a TC pilot decision-making course and that he had previously objected to unsafe practices and procedures; there was no information recovered regarding his actions during the occurrence flight.

2.5.3 Somatogravic Illusion

Information from eyewitnesses placed the aircraft at about 150 feet above the lake surface, well to the right of the normal approach path, at about one and a half miles from the airport. The aircraft was thus about the height of the top of the fire tower, which was about 163 feet above the lake surface. Because the aircraft was flying to the right of the normal approach path, the fire tower was between the flight path and the runway. Eyewitnesses indicated that, as the aircraft approached the shoreline, the engine power was advanced and the aircraft banked to the left and then immediately banked to the right before descending into the terrain. It is possible that the crew observed the fog to the east of the airfield, initiated an overshoot, and turned to the left to remain clear of the fog. Witness statements that the power was advanced, and the illumination of the "landing gear in transit" light, support this interpretation. After the bank to the left was applied, it is possible that the fire tower was observed and the captain immediately banked right to avert a collision. In that case, the aircraft would have turned back towards (or entered) the fog bank, and the crew would have had to transition immediately to instrument flying techniques and initiate a climb. Because the aircraft was not equipped with a CVR, the decisions taken by the crew cannot be known with certainty. However, it is possible that the application of power induced a somatogravic illusion in the crew members, leading them to believe that they were in a climb rather than a descent. In such a situation, the captain would have flown the aircraft into the terrain, believing that he was climbing up through the cloud layer.

2.6 Ground Proximity Warning

A GPWS, if installed and operable, would have provided appropriate warnings and cues to the crew members of their proximity to the terrain. However, since the crew members were flying below authorized altitudes, it is unlikely that they would have responded to GPWS advisories.

2.7 Cockpit Voice Recorder

A CVR, if installed, would have provided valuable information in the determination of what took place in the minutes preceding the accident; TC had granted an exemption until 01 August 1998 for operators to comply with the requirement of CAR 605.33 (2) that a CVR be installed in this particular type of aircraft.

2.8 Transport Canada Monitoring

2.8.1 Transition to Commuter Operations

The audit history of Sowind Air Ltd. and the positive relationship that existed between the company
and TC inspectors did not indicate to TC any need for special attention during the introduction of the Bandeirante. Further, because TC policy suspended audits during the introduction of the CARs, the initial certification audit was not accomplished. Because TC inspectors believed that Sowind Air Ltd. was conforming to the aviation regulations and standards, there was no reason to override the audit suspension policy and audit the company. However, the significant number of audit findings, made during the post-occurrence audit, indicates that the company had difficulty with the transition from an air taxi operator to a commuter operator. Given that TC officials were of the opinion that the company had been well-managed and could cope with the transition, it is likely that the transition difficulties faced by the company were underestimated by TC.

### 2.8.2 Weight and Balance Monitoring Policy

TC's weight and balance policy allowed the basic weight and balance calculations of a commuter type aircraft to be accepted without any review for accuracy. A significant number of discrepancies developed (see Appendix C) and were not detected or resolved. Consequently, the occurrence aircraft, C-GVRO, was operated for approximately one year, and over a wide range of loads, without accurate weight and balance calculations.

### 2.9 Company Management

Company management, as assessed by TC audits and inspections, had been deemed satisfactory before the introduction of the Bandeirante. As revealed by the post-occurrence TC audit, the management of the company had not dealt effectively with the introduction of the Bandeirante. While the president stated that the policy was to provide a higher standard of service, and that the company's first concern was safety, safety was compromised in three areas of management responsibility: training and standards, operations, and maintenance.

The investigation revealed that the chief pilot's operational control diminished during the introduction of the Bandeirante. Over time, the weighing of cargo and passenger baggage became less effective, and GPS was used routinely on approaches in IFR conditions contrary to the provisions of the CARs. The operations manager exercised little influence in the commuter operations, primarily flying in the air taxi operation and providing little supervision.

### 2.10 Global Positioning System

The use of the GPS during the occurrence approaches was not confirmed. However, the GPS was selected to a waypoint that corresponded to the mid-point of the airport, and the GPS would have provided both track guidance and distance to the airport. Because the crew members descended through the cloud layer to an altitude that was some 400 feet below the MDA, it is likely that they were utilizing the distance to the airport provided by the GPS as a means to descend to establish visual contact with terrain. Other company pilots indicated that the GPS was used in this manner on other occasions.

The TSB has made a safety recommendation (A95-07) to expedite the implementation of approved GPS standards and procedures for use in Canadian airspace. The TSB has also recommended (A95-08) that TC initiate a national safety awareness program addressing the operating limitations and safe use of GPS in remote operations.

### 2.11 Emergency LOCator Transmitter

The separation of the ELT antenna and consequent reduction in ELT signal strength had no effect on the outcome of the occurrence because ground rescue parties knew the position of the aircraft. However, the absence of a strong ELT signal would have delayed search and rescue response if the aircraft wreckage had been located a greater distance from the local community.

### 2.12 Operations in Marginal Weather

In 1996, the TSB brought safety recommendation A96-11 to the attention of the Minister of Transport, as the Board believed that there was inadequate understanding throughout the aviation
community of the risks and consequences of operating in marginal weather conditions. The recommendation was for the Department of Transport to develop and implement a targeted national promotion campaign to raise commercial operators’ awareness of the risks associated with flight operations in marginal weather. TC, in its response, stated that it would undertake new initiatives in response to recommendations from the Safety of Air Taxi Operations (SATOPS) Task Force and consideration of a targeted national promotion campaign would be done at that time.

The Board also believed that, given the natural human limitations in interpreting distances in conditions of marginal visibility, the natural human tendencies in complex decision making in the presence of changing and ambiguous cues, and the CFIT accident record involving small commercial operators, further counter-measures were required to facilitate safe crew decision making. To that end, the Board recommended that the Department of Transport require that pilots involved in air taxi and commuter operations receive specialized training, including skills development, in making prudent decisions under deteriorating operational conditions (A96-12). TC, in its response, stated that it would task the Canadian Aviation Regulation Advisory Council (CARAC) to study and develop whatever additional specialized training may be required so that pilots involved in air taxi and commuter operations are fully capable of making prudent decisions under deteriorating operational conditions.

The SATOPS Report, finalized on 28 May 1998, addresses the issue of flight operations in reduced visibility. It concludes that "pilots are still pushing the weather," and recommends that a one-time attendance of the pilot decision-making course may not be sufficient for reduced visibility operations.

2.13 Summary

The company did not make the transition well from air taxi operations to commuter operations, and did not handle the introduction of the Bandeirante safely. TC’s policies reduced monitoring in critical areas, and the transition problems the company was experiencing were not identified. The occurrence flight was dispatched overweight into marginal weather with a captain known to continue in marginal weather. After completing a missed approach, the captain began a second approach after receiving weather information from a company aircraft that had landed. The occurrence aircraft was observed at low level, below the MDA and the minimum en route altitude for commuter operations, to the east of the approach path and heading for the fog-covered terrain. Witness observations support the possibility that the crew initiated an overshoot in the vicinity of a fire tower and then manoeuvred to avoid the tower. Conditions were conducive to somatogravic illusion in whiteout conditions. It is likely that the captain flew the aircraft into the terrain under the illusion that the aircraft was climbing.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. At the time of the occurrence, the base of the cloud at Little Grand Rapids was between 100 and 300 feet agl, with fog to the east of the airport, and the visibility was one to two miles.

2. The aircraft was flown in marginal weather at low level, below the minimum en route altitude for commuter operations and below the MDA for the NDB A approach at Little Grand Rapids. The MDA for the approach was 1 560 feet asl, 555 feet above the airport elevation.

3. While the aircraft was being manoeuvred at very low level in marginal weather, it descended after an abrupt turn, and flew, in controlled flight, into the terrain.

3.2 Other Findings

1. At both take-off and landing, the aircraft was about 1 000 pounds heavier than the relevant maximum allowable weight.

2. The GPS installed in C-GVRO was not approved as a primary navigational aid. The available information indicates that the flight crew used the GPS as a primary navigational aid during the last approach to Little Grand Rapids.

3. The aircraft was not equipped with a GPWS, nor was it required to be by regulation.

4. The weight and balance report that was submitted to Transport Canada, required for the importation of C-GVRO, contained numerous discrepancies; the report was not reviewed for accuracy by Transport Canada.

5. The emergency locator transmitter (ELT) produced a very weak signal because the antenna cable had been installed with little slack, and it pulled out of the antenna fitting during impact.

6. It could not be determined whether the presence of carbon monoxide and diphenhydramine in the captain's body affected his decision making and level of alertness.

7. The company, which had been an air taxi operator, did not effectively manage either the addition of the more complex commuter operations or the introduction of the larger Bandeirante aircraft.

8. The difficulty that the company had in the transition to commuter operations and in the introduction of the Bandeirante aircraft was underestimated by Transport Canada.

9. There were inadequacies in TC's oversight, whereby the post-certification audit of the company was not conducted, thus eliminating an important mechanism by which TC could have found, and addressed, the inadequate safety management practices, non-conformance with pilot training requirements, and related operating irregularities.

10. The pilots had passed their flying proficiency and medical tests, but they had not completed elements of pilot training requirements with respect to servicing and operational control and right seat conversion as prescribed by TC. Also, no company pilot had received required training in the use of onboard survival or emergency equipment.

11. There was no indication found of any pre-impact failure or malfunction of the airframe, flight controls, or engines.

12. The aircraft was not equipped with either a CVR or an FDR; TC had given the company an exemption to operate without a CVR until 01 August 1998, and the aircraft was not required to be equipped with an FDR.

13. The absence of recorders on this aircraft, which was configured to carry 20 people, left many of the otherwise ascertainable facts associated with the accident unknown and reduced the opportunity of uncovering risks to safety associated with the flight.

14. Conditions were conducive to the pilot experiencing a false sensation that the aircraft was climbing (somatogravic illusion) after increasing the engine power, and he may have been manoeuvring to avoid an abandoned fire tower.

4.0 Safety Action

4.1 Action Taken

4.1.1 Transport Canada Post-Occurrence Audit

In January 1998, TC conducted a post-occurrence audit of Sowind Air Ltd. The findings of this inspection, primarily with respect to training shortcomings, and the lack of qualified management personnel resulted in the voluntary suspension of the company's air operator certificate. The company's subsequent response to the identified shortcomings resulted in the reinstatement of the air operator certificate.

4.1.2 Global Positioning System

The NAV CANADA SAT NAV office is working in cooperation with TC and the U.S. Federal Aviation
Administration to implement a phased approach to the full realization of GPS for all phases of flight in Canada. In the SATOPS Report, it is recommended that TC continue to publish articles in the Aviation Safety Letter and Aviation Safety Vortex newsletters about the safe, proper use of GPS and the hazards associated with its misuse. TC has issued Special Aviation Notices, Aeronautical Information Circulars, made entries in the Aeronautical Information Publication (AIP) and has published articles in the Aviation Safety Letter and Aviation Safety Vortex newsletters that address the operating limitations and safe use of GPS.

4.1.3 Operations in Marginal Weather

Subsequent to the TSB safety recommendation (A96-11) to raise commercial operators' awareness of the risks associated with flight operations in marginal VFR flight conditions, many of TC's national aviation safety promotional efforts, safety awareness programs and regional education programs have focused on the respect of weather.

The TSB also recommended (A96-12) that pilots involved in air taxi and commuter operations receive specialized training in making prudent decisions under deteriorating operational conditions. Pilot decision making (PDM) has been addressed in the SATOPS Report, which recommends that TC review the Commercial Air Service Standard authorizing operations in reduced visibility (provided the pilot has taken a PDM course), to determine if one-time attendance at the PDM course is sufficient. As a result, TC is preparing a Notice of Proposed Amendment that will require annual PDM training for companies that hold the Operations Specification for operations in reduced visibility; this will apply to operators subjected to CARs 702, 703, and 704 (helicopters only).

A combined TC and industry study group is reviewing the safety data and issues surrounding approaches in poor weather. Regulatory recommendations concerning approach bans in the form of a Notice of Proposed Amendment (NPA) are to be submitted to the General Operating and Flight Rules Technical Committee of TC in December 1999.

4.2 Safety Concern

The Board is concerned about the frequency of accidents involving airworthy aircraft and fit pilots conducting instrument approaches during conditions of low visibility and/or low ceilings. The TSB is currently analysing 19 such accidents that have occurred in Canada from 1994 to the present. The most recent of these was a fatal accident involving a Beech 1900D aircraft at the Sept-Îles airport in Quebec. The pilots flew the aircraft well below the minimum descent altitude for the published NDB approach. Further work is in progress to determine the nature and extent of any safety deficiencies evidenced by these accidents.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Jonathan Seymour, Charles Simpson, W.A. Tadros and Henry Wright authorized the release of this report on 02 December 1999.

Appendix A - Approach Outlines
### Appendix B - Weight and Balance Estimates for the Flight

Sowind Air Ltd. Embraer EMB-110P1 Bandeirante, C-GVRO, Serial No. 110-285

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lb)</th>
<th>Arm</th>
<th>Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic aircraft (corrected)</td>
<td>7607</td>
<td>258.9</td>
<td>1969872.6</td>
</tr>
<tr>
<td>Unusable fuel (28 litres)</td>
<td>48.5</td>
<td>285.8</td>
<td>13861.3</td>
</tr>
<tr>
<td>Engine oil (17 litres)</td>
<td>35.5</td>
<td>226.4</td>
<td>8037.2</td>
</tr>
<tr>
<td>Crew baggage</td>
<td>10</td>
<td>129.9</td>
<td>1299</td>
</tr>
<tr>
<td>Flight manuals</td>
<td>12</td>
<td>129.9</td>
<td>1558</td>
</tr>
</tbody>
</table>

Survival gear 40 435.5 17420
Cargo net and straps 40 361.5 14460
Crew (winter weights) 376 115 43240

**Equipped operating weight (without seats)** 8169 2069748.1

<table>
<thead>
<tr>
<th>Description</th>
<th>Fuel</th>
<th>Cargo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passengers and seats 1, 2 and 3</td>
<td>a)</td>
<td></td>
<td>176.8</td>
</tr>
<tr>
<td>Passengers and seats 4, 5 and 6</td>
<td>430.5</td>
<td></td>
<td>207.5</td>
</tr>
<tr>
<td>Passengers and seats 7, 8 and 9</td>
<td>513.5</td>
<td></td>
<td>238.6</td>
</tr>
<tr>
<td>Passengers and seats 10, 11 and 12</td>
<td>513.5</td>
<td></td>
<td>269.7</td>
</tr>
<tr>
<td>Passengers and seats 13, 14 and 15</td>
<td>607.5</td>
<td></td>
<td>301.7</td>
</tr>
<tr>
<td>Passenger baggage</td>
<td>359.0</td>
<td></td>
<td>361.5</td>
</tr>
<tr>
<td>Cargo (groceries)</td>
<td>574.0</td>
<td></td>
<td>361.5</td>
</tr>
<tr>
<td>Fuel (on manifest)</td>
<td>1600</td>
<td></td>
<td>283.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Fuel</th>
<th>Cargo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total weight at take-off (C of G position)</strong></td>
<td>13 230.0</td>
<td>263.4 (19.7% MAC)</td>
<td>3484153.9</td>
</tr>
<tr>
<td>Fuel used prior to impact</td>
<td>-720.0</td>
<td>283.5</td>
<td>-204120</td>
</tr>
<tr>
<td><strong>Total weight at impact (C of G position)</strong></td>
<td>12 510.0</td>
<td>262.2 (18.2% MAC)</td>
<td>3280033.9</td>
</tr>
<tr>
<td>Cargo (unaccounted for)</td>
<td>200.0</td>
<td>361.5</td>
<td>72300</td>
</tr>
<tr>
<td>Fuel not shown on manifest</td>
<td>400.0</td>
<td>283.5</td>
<td>113400</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Fuel</th>
<th>Cargo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revised weight at take-off (C of G position)</strong></td>
<td>13 830.0</td>
<td>265.3 (22.3% MAC)</td>
<td>3669853.9</td>
</tr>
<tr>
<td><strong>Revised weight at impact (C of G position)</strong></td>
<td>13 110.0</td>
<td>264.4 (21.0% MAC)</td>
<td>3465733.9</td>
</tr>
</tbody>
</table>

C of G limits: Maximum take-off weight: 12 500 lb
255.5 inches to 272.0 inches aft of the Maximum ramp weight: 12 566 lb
datum at 12 500 lb, or 9.5% to 31% MAC Maximum landing weight: 12 015 lb

**Notes on weight and balance estimates:**

a) The passenger weights are standard winter weights of 188 pounds for an adult male,
141 pounds for an adult female, and 75 pounds for a child. These passenger and seat weights include seat weights of 43.5 pounds per row.
b) The baggage as weighed at the accident site. The flight manifest indicated a baggage weight of 295 pounds.
c) The cargo as weighed at the accident site. The flight manifest indicated a cargo weight of 150 pounds.
d) The fuel burn was based on 650 pounds per hour.
e) The weight of cargo from the earlier, cancelled flight that could not be accounted for by the company or by investigators at the occurrence site.
f) The total fuel at take-off was computed by adding the fuel burn to the fuel quantity gauge reading at impact.

**Appendix C - Weight and Balance Discrepancies**

*Discrepancies noted in the Basic Aircraft Weight and Balance Report and Equipment Check List, dated 20 November 1996, and prepared during the re-weigh:*

The basic equipment check list was not updated as to items installed at the time of the "re-weigh."
Items such as the portable toilet and divider panel were still being shown as installed.

The weight and balance report datum location was incorrect, i.e. 306.8 inches from rear jack point, not from the main wheel axle, as stated.

The weight and balance report weighing diagram was incorrect; it should have been the jack point diagram Fig. 6.2, not 6.3, as provided.

The moment calculation for the nose wheel weight was incorrect on the weight and balance report. The moment calculation should have been 1080 x 99.3 = 107.2 (lb x in/1000), not 10.7, as stated.

The total moment and arm calculations on the weight and balance report were affected by the incorrect nose wheel moment calculation. The C of G location should have been 277.9 inches aft of datum at 37.9% MAC instead of 255.2 inches aft of datum at 9.1% MAC.

The scale figures, taken during the re-weigh, were incorrectly transcribed onto the weight and balance form, making the subsequent weight and balance calculations meaningless.

Discrepancies noted in the Operational Weight and Balance Report, prepared after the re-weigh:

The weights and moment arms of the passenger seats were not the same as the ones reported on the basic equipment check list.

The total engine oil (36.5 pounds) was not included in the equipped operating weight (EOW).

The unusable fuel (48.5 pounds) was not included in the EOW.

The survival gear (40 pounds) was not included in the EOW.

The aircraft documents (12 pounds) were not included in the EOW.

No allowance was made for crew baggage in the EOW.

The crew winter weights (14 pounds total) had not been converted as per SOP 2.5.7.

The cargo net and "herc" straps (41 pounds) were not included in the EOW.

No moment arm measurement was provided for the 6th row seat installation.

No conversion formula was provided on the balance sheets to calculate % MAC.

Discrepancies noted in the Flight Load Manifest dated 09 December 1997, completed before the flight:

The AUW was incorrectly calculated as 12 500 lb.

The baggage and freight at the occurrence site weighed 933 pounds. On the manifest, the baggage and freight was reported as 445 pounds, a difference of 488 pounds.

Less fuel was shown on the flight manifest than was indicated on the fuel gauges at the occurrence site (400 pounds less).

Standard passenger weights were used; however, at least two of the passengers weighed nearly double the standard weight (300+ and 255 pounds).

Other weight and balance discrepancies noted:

The locations of the passenger seats were not the same as the ones reported by the company on a sample loading graph.

No weight and balance form was found for the occurrence flight, nor could the company produce a
sample form for a similarly loaded aircraft.

No sample weight and balance forms could be found for the full range of aircraft operations.

The company was not computing the individual moment arms of the separate aircraft compartments when cargo spanned more than one compartment. On the occurrence flight, cargo was placed in three compartments, but one moment arm (an incorrect one) was shown on the sample loading graph.

Appendix D - List of Supporting Reports

The following TSB Engineering Branch Report was completed:

LP 193/97 - Instrument Examination - C-GVRO

This report is available from the Transportation Safety Board of Canada upon request.

Appendix E - Glossary

agl above ground level
AIP Aeronautical Information Publication
AMO approved maintenance organization
APM airport manager
ARASS activity reporting and standards system
ARCAL aircraft radio control of aerodrome lighting
asl above sea level
ATPL airline transport pilot licence
AUW all-up weight
CAR Canadian Aviation Regulations
CARAC Canadian Aviation Regulation Advisory Council
CFIT controlled flight into terrain
C of G centre of gravity
CVR cockpit voice recorder
ELT emergency locator transmitter
EOW equipped operating weight
FDR flight data recorder
GPS global positioning system
GPWS ground proximity warning system
IFC instrument flight check
IFR instrument flight rules
KIAS knots indicated airspeed
lb pound(s)
MAC mean aerodynamic chord
MCM maintenance control manual
MDA minimum descent altitude
MHz megahertz
N north
NDB non-directional beacon
NPA Notice of Proposed Amendment
PDM pilot decision making
PPC pilot proficiency check
SATOPS Safety of Air Taxi Operations
SOP standard operating procedure
TC Transport Canada
TO take-off
TSB Transportation Safety Board of Canada
UNICOM a private advisory radio station located at an uncontrolled aerodrome
U.S. United States of America
VFR visual flight rules
W west
' minute(s)
" second(s)
degree(s)

1. All times are central standard time (coordinated universal time minus six hours) unless otherwise stated.

2. See Appendix E - Glossary for all abbreviations and acronyms.

3. Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

4. See Appendix A - Approach Outlines.

5. No record of a fuel upload could be found.

6. See Appendix B for a weight and balance calculation for the occurrence flight.

Updated: 2002-10-06
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
Uncontained Engine Failure
Canadian Airlines International
Boeing 767-375ER C-FTCA
Beijing, China
06 September 1997

Report Number A97F0059

Synopsis

The scheduled passenger flight, CP30, was operating from Beijing to Vancouver, British Columbia, on 06 September 1997. Shortly after the commencement of the takeoff roll, at about 20 knots, there was a loud explosion and the aircraft yawed sharply to the left. The take-off was rejected, and there was a fire warning on the left engine. The augmenting pilot visually confirmed a fire in the left engine, as the captain and operating first officer carried out the emergency procedures to deal with the fire indication. After use of the second fire bottle, the fire warning ceased, and there was visual confirmation that the fire had been extinguished. The passengers deplaned using the normal exits after the aircraft was towed to the terminal.

The Board determined that an uncontained failure of the third stage of the 3-9 high-pressure compressor spool was due to the presence of an oxygen-rich segregate produced in the batch of titanium used to construct the 3-5 stages of the spool. The segregate caused locally degraded resistance to fatigue crack initiation in the dove-tail slot bottom, an area of the spool that is subject to some of the higher design hoop stresses. Contributing to the occurrence were the quality control decisions made at the time of manufacture of the titanium, the inability of existing in-service inspection techniques to detect crack zones, and the intolerance of the spool design for slightly degraded material.

Ce rapport est également disponible en français.

Table of Contents

1.0 Factual Information
   1.1 History of the Flight
   1.2 Injuries to Persons
   1.3 Damage to Aircraft
   1.4 Other Damage
   1.5 Personnel Information
   1.6 Aircraft Information
   1.6.1 Description of Engine
1.6.2 Number 1 Engine History
1.7 Meteorological Information
1.8 Aids to Navigation
1.9 Communications
1.10 Aerodrome Information
1.11 Flight Recorders
1.12 Wreckage and Impact Information
1.13 Medical Information
1.14 Fire
1.15 Survival Aspects
1.16 Tests and Research
1.16.1 Introduction
1.16.2 Titanium 6242
1.16.3 Titanium Manufacturing
1.16.4 Fracture Examination
1.16.5 Dwell Time Fatigue
1.16.6 Melt Irregularity
1.16.7 Test for Fluorescent Penetrant Residue on the Fracture Surface
1.16.8 Non-destructive Inspection (NDI) of Remainder of 3-9 High-pressure Compressor (HPC) Spool
1.16.9 NDI of Sister Spools
1.16.10 Forger Test Rings
1.16.11 Eddy Current Test
1.17 Organizational and Management Information
1.18 Additional Information
1.18.1 Manufacturing Process of the CF6-80C2 HPC Spool
1.18.2 Quality Assurance Tests During Manufacture
1.18.3 Stress Levels
1.18.4 Spool In-service Inspections
1.18.5 Recent Airworthiness Directive History of CF6 Engine HPCs

2.0 Analysis

2.1 Introduction
2.2 Failure of the Third Stage of the HPC Spool
2.3 Oxygen-rich Segregation
2.4 Detection of Flaws
2.5 Crew Action

3.0 Conclusions

3.1 Findings
3.2 Causes

4.0 Safety Action

4.1 Action Taken
4.1.1 Removal of Sister Spools from Service
4.1.2 Process Changes
4.1.3 Melt Records Reviewed
4.1.4 Action by the State of Manufacture

5.0 Appendices

Appendix A - Flight Data Recorder Plot
Appendix B1 - Manufacturing of Titanium
Appendix B2 - Manufacturing of Titanium
Appendix C - List of Supporting Reports
Appendix D - Glossary

List of Figures
1.0 Factual Information

1.1 History of the Flight

The scheduled passenger flight, CP30, was operating from Beijing to Vancouver, British Columbia, on 06 September 1997. The augmented crew had flown the aircraft into Beijing on the previous day and indicated that the inbound flight and departure start-up were normal. Shortly after the commencement of the take-off roll, at about 20 knots, as the engines were close to 40-degree Celsius rated take-off thrust, there was a loud explosion and then the aircraft vibrated and yawed sharply to the left. The take-off was rejected immediately, and within a few seconds there was a fire warning on the left engine. The augmenting first officer, who had been sitting in the cockpit jump seat, quickly went to the aircraft cabin and visually confirmed that there was a fire in the left engine. Meanwhile, the captain and the operating first officer carried out the emergency procedures to deal with the fire indication. After use of the second fire bottle, the fire warning ceased, and there was visual confirmation by the augmenting first officer that the fire had been extinguished. The emergency response services personnel confirmed that the fire was extinguished. The passengers deplaned using the normal exits after the aircraft was towed to the terminal. After the aircraft was shut down, it was noted that parts from the high-pressure compressor (HPC) had detached from the engine.

1.2 Injuries to Persons


<table>
<thead>
<tr>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>199</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

1.3 Damage to Aircraft

Approximately 30 kilograms of rotating hardware from the left engine HPC and the compressor case was found on the ground near the aircraft. Debris had penetrated the left-engine casings, inboard reverser, and the translating cowl. A 1.5-inch long puncture was found in the fuselage adjacent to the left-wing root, just forward of Station 720, but no engine debris penetrated the passenger cabin. The left-hand high-speed (inboard) aileron had three punctures in the lower skin.

Inspection of the engine by maintenance personnel in Beijing established that the third stage had broken away from the HPC spool. Several pneumatic and electrical components on the outside of the engine had been damaged by material exiting the engine and by fire. An engine teardown conducted at the Motoren- und Turbinen-Union (MTU) facility in Hannover, Germany, revealed that there was some damage to the internal rotating structure of the engine.
The engine’s inlet gearbox bearing was fractured, causing a disconnect of the engine accessory drive, which includes the main engine fuel pump. Rub marks from the fan blades were observed in lower portions of the abradable fan shroud, the result of a period of unbalanced operation as the engine was failing.
1.4 Other Damage

None

1.5 Personnel Information

<table>
<thead>
<tr>
<th>Captain</th>
<th>First Officer (PF)</th>
<th>Augmentee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>58</td>
<td>47</td>
</tr>
<tr>
<td>Pilot licence</td>
<td>ATPL</td>
<td>ATPL</td>
</tr>
<tr>
<td>Medical expiry date</td>
<td>01 December 1997</td>
<td>01 February 1998</td>
</tr>
<tr>
<td>Total flying hours</td>
<td>20,000</td>
<td>13,500</td>
</tr>
<tr>
<td>Hours on type</td>
<td>1,400</td>
<td>3,500</td>
</tr>
<tr>
<td>Hours last 90 days</td>
<td>195</td>
<td>212</td>
</tr>
<tr>
<td>Hours on type last 90 days</td>
<td>195</td>
<td>212</td>
</tr>
<tr>
<td>Hours on duty prior to occurrence</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Hours off duty prior to work period</td>
<td>22</td>
<td>22</td>
</tr>
</tbody>
</table>

Because of the scheduled length of the flight, the crew consisted of a captain and two first officers. The first officer occupying the right pilot seat was the pilot flying (PF) for the take-off. The other first officer (referred to as the augmentee) was occupying the cockpit jump seat for the take-off, in accordance with Canadian Airlines International (CAI) procedures.

There are no specific assigned duties for the augmenting pilot during the emergency response to an engine fire during take-off.

The same crew had flown the aircraft from Vancouver to Beijing on the day before the occurrence. The crew had been given about 22 hours of rest, and each crew member had not worked in the 72-hour period prior to the flight from Vancouver. All crew members indicated they had adequate rest prior to the departure from Beijing.

1.6 Aircraft Information

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Boeing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and model</td>
<td>767-375ER</td>
</tr>
<tr>
<td>Year of manufacture</td>
<td>1989</td>
</tr>
<tr>
<td>Serial number</td>
<td>24307</td>
</tr>
<tr>
<td>Certificate of airworthiness</td>
<td>Valid</td>
</tr>
<tr>
<td>Total airframe time</td>
<td>35,672 hours</td>
</tr>
<tr>
<td>Engine type (number of)</td>
<td>General Electric CF6-80C2B6F (2)</td>
</tr>
<tr>
<td>Maximum allowable take-off weight</td>
<td>407,000 pounds</td>
</tr>
<tr>
<td>Recommended fuel type</td>
<td>Jet A1</td>
</tr>
<tr>
<td>Fuel type used</td>
<td>Jet A1</td>
</tr>
</tbody>
</table>

1.6.1 Description of Engine

The CF6-80C2B6F engine is a high-thrust variant of the General Electric (GE) CF6 high-bypass series of engines. The take-off thrust of the engine is 60,030 pounds at 30 degrees Celsius. The engine has two rotating sections: the fan section (N1), driven by the low-
pressure turbine (LPT); and the high-pressure compressor (N2), driven by the high-pressure turbine (HPT). The HPC has 14 stages of compression and consists of several attached units, one of which is the 3-9 spool section. The blades of the 3-9 stages of the HPC fit into slots known as dove-tail slots, as shown in Figure 3.

![Figure 3 - Schematic of the CF6-80 engine](image)

The engine was certified in November 1987.

### 1.6.2 Number 1 Engine History

The number 1 (left) engine, serial number 702-386, was manufactured in 1989. This engine had undergone an overhaul from November 1994 to January 1995 as a result of suspected damage due to the possible ingestion of shredded tire material. The overhaul was conducted at Aviall Caledonian Engine Services (now known as GE Caledonian) in Prestwick, Scotland. At the time of the unscheduled overhaul, the engine had accumulated 14,585 hours and 2,758 cycles.

During the overhaul, some fan damage was noted; however, the engine core (which includes the HPC) had limited damage, indicating that the bulk of any debris had passed through the fan bypass and not the engine core. The HPC was fully disassembled during the overhaul. A number of HPC blades from the second, eighth, and ninth stages were rejected for airfoil damage outside of repairable limits.

As part of the overhaul procedure, the HPC spool (3-9 spool portion of the HPC, serial number VOL09752) was subjected to non-destructive inspection (NDI) in accordance with maintenance procedures in place at the time. Fluorescent penetrant inspection (FPI)\(^1\) and ultrasonic\(^2\) NDI, in accordance with GE Service Bulletin SB72-418 - Revision 3, were carried out. During the ultrasonic inspection, a maximum value of 23 per cent of full scale was noted in the stage-3 section at the 45-degree clockwise shear-wave inspection, but this indication did not exceed the "further evaluation" threshold of 30 per cent (multi-pass reject threshold was 40 per cent) and did not produce a similar value on the counter-clockwise inspection. As a result, the spool was deemed to be acceptable. The 23 per cent indication was the highest value recorded during inspection of all the 3-9 stages. In reviewing the ultrasonic inspection records after the occurrence, the engine manufacturer indicated that it believes that the 23 per cent reading was the result of "noise" (or an indication of structure or grain boundaries) and not a true indication of a crack in the third stage of the HPC spool.

At the time of the overhaul, eddy current inspection\(^3\) of the 3-9 stages of the HPC was not
required by maintenance practices.

The engine underwent a test run at the end of the overhaul, and all its parameters were in the normal range. The engine was returned to service following the overhaul and had a total of 25,653 hours and 4,744 cycles at the time of the uncontained failure (11,068 hours and 1,986 cycles since overhaul). The approved service life of the HPC spool is 15,000 cycles.

The last compressor boroscope inspection was conducted on 09 May 1997 with the only finding being one first-stage HPC blade with a bent tip, which was within limits in accordance with the Transport Canada-approved CAI Maintenance Manual. All other blades had no defects noted. The engine also had an inspection of the 3-5 stage HPC blades carried out on 26 May 1997 with no findings noted. After the occurrence, CAI reviewed the trend data for engine 702-386 to assess if there were any indications of an impending failure and determined that there were no changes of engine parameters warning of impending problems.

1.7 Meteorological Information

The weather near the time of the occurrence was: light winds from 090 degrees true, visibility 6,000 metres, scattered clouds, temperature 27 degrees Celsius, altimeter setting 1,010 millibars.

1.8 Aids to Navigation

Not applicable

1.9 Communications

The crew noted that on occasion there had been communication problems with the Beijing control tower due to language difficulties, but no problems were noted during the occurrence. The crew of another aircraft operated by a Chinese company attempted to pass information to the crew of CP30 related to some observations of the situation, but was unable to communicate the message because of language problems.

1.10 Aerodrome Information

Beijing Capital Airport (ZBAA) is equipped with two runways. The flight used runway 18L, which has a length of 12,467 feet and a width of 197 feet. The airport elevation is 118 feet above sea level (asl).

1.11 Flight Recorders

The aircraft was equipped with an Allied Signal digital universal flight data recorder (UFDR), model 980-4100-AXUN, and a Loral cockpit voice recorder (CVR), model 93-A100-82. The recorders were delivered to the TSB Engineering Branch for analysis.

The 30-minute CVR was played back, but it was determined that the occurrence take-off was overwritten because the CVR circuit breakers were not pulled. As a result, no useful information pertaining to the occurrence was obtained from the CVR.

As per established procedure, an attempt was made to play back the UFDR at high speed to produce a copy tape without removing the UFDR tape. This effort was unsuccessful, likely because the initial high-speed playback had caused coning and misalignment of the tape, which resulted in the tape seizing during playback. The recorder is designed for fast playback, but if the tape is near the end of its service life, it is not uncommon for this type of problem to occur. The UFDR tape was subsequently removed from the unit and played back
on standard eight-track, open-reel playback equipment. In spite of the damage to the tape, the occurrence data were recovered, as were data from the previous flight. A plot of the UFDR data can be found in Appendix A.

Analysis of the UFDR showed that, at a point approximately six seconds into the take-off roll, the UFDR signal lost synchronization for a period estimated to have been as long as four seconds. It was determined that the failure of the left engine occurred at this point. The loss of synchronization was probably the result of a voltage transient related to the engine-driven electrical system at the moment of the engine failure.

At the time of the engine failure, the rotor speeds of both engines were nearly equal and had reached estimated values of 100 per cent N1 and 107 per cent N2. The recorded value of left-engine exhaust gas temperature (EGT), 0.4 seconds prior to the engine failure, was approximately 730 degrees Celsius, about 25 degrees above the interpolated temperature value of the right engine. Following the synchronization loss, the left-engine failure was further indicated by rapidly decreasing left-engine rotor speeds and a rapid four-degree heading change towards the side of the failed left engine. The maximum recorded left and right EGTs after the left engine had failed were approximately 850 degrees and 790 degrees Celsius, respectively.

Within 1 ½ seconds of the engine failure, the right engine was throttled back (from 104 per cent N1, possibly higher) and, about one second later, the brakes were applied. Approximately five seconds after the engine failure, as the aircraft slowed to a stop, the left-engine fire discrete indicated fire in the left engine for about 10 seconds. A few seconds later, the fire discrete indication occurred once again for about another 10 seconds.

1.12 Wreckage and Impact Information

Not applicable

1.13 Medical Information

Not applicable

1.14 Fire

The fire damage was limited to the left side of the engine. It was determined, during the engine teardown conducted in Hannover, that the source of the fire was a fuel-servo line used to actuate the LPT active clearance control valve. Debris leaving the compressor punctured the fuel-servo line and sprayed fuel, which then ignited (see Figure 4).
1.15 Survival Aspects

Not applicable

1.16 Tests and Research

1.16.1 Introduction

Research was conducted into the properties of titanium and the methods employed to produce the titanium 6242 (Ti 6242) alloy used in the CF6-80C2B6F engine HPC spool. Specific tests were performed on the material recovered at the site of the occurrence to study the reasons for the material fracture. Some research into the properties of Ti 6242 was also conducted.

1.16.2 Titanium 6242

The material used in 3-9 HPC is Ti 6242, so called because of the percentages of alloying elements used.\(^{(4)}\) According to the engine manufacturer, one reason Ti 6242 was chosen as the material for the HPC spool was because of the alloy's creep-resistant properties.

Titanium exists in two major crystalline forms, alpha and beta. Alpha titanium consists of an hexagonal close-packed crystal structure, whereas beta titanium has a body-centred cubic crystal structure. An important characteristic of titanium is reversible transformation (or allotropy) of its crystal from alpha to beta structure. The allotropic behaviour of titanium depends on the type and amount of alloy content, and allows for variations in microstructure and diverse strengthening opportunities. The microstructure and mechanical properties of titanium vary, depending on the methods of thermal-mechanical processing (shaping and forging). The addition of alloying elements causes changes in the temperature at which alpha crystals change to beta crystals (beta transus). Ti 6242 is considered to be an alpha
and beta alloy, with approximately equal amounts of alpha and beta phases.

There are allowable limits in the amount of other elements in Ti 6242. The GE specified permissible limit of oxygen content is 0.15 per cent.

According to information provided by the engine manufacturer, the average yield strength for Ti 6242 disk forging at 80 degrees Fahrenheit is about 127,000 pounds per square inch (psi); the minimum yield strength ("95 per cent confidence of 95 per cent exceedence") is given as 108,000 psi. At 900 degrees Fahrenheit, the average yield strength is about 77,000 psi, with a minimum value of about 58,000 psi.

1.16.3 Titanium Manufacturing

GE has used several suppliers of titanium for its production of engines. The titanium for the 3-5 portion of the 3-9 HPC spool was produced by RMI Titanium Company (RMI) of Niles, Ohio. The investigation team, comprising persons from the TSB, the Federal Aviation Administration (FAA), the National Transportation Safety Board (NTSB), and GE, travelled to the RMI facility to review the process for manufacturing titanium and to review the melt records related to the titanium used in the occurrence HPC spool.

The process employed to produce the titanium has evolved over many years. At the time of manufacture of the event spool (1989), a triple-melt vacuum process was used.

The first steps of titanium manufacturing (Appendix B) are the mixing of pure titanium sponge with the powdering alloying material. This mixture is compressed into large brick-like blocks, and these sponge blocks are joined by straps, using inert gas welding, to make an electrode. Spacer bars are used to attach the electrode to a header assembly. The electrode is melted using high-current electricity in a water-cooled copper crucible, under vacuum conditions. Some hanger spacer-bar melt-in is normal, and therefore the spacer-bar material and the straps are required to be of rotor quality if the titanium to be produced is to be rotor quality.

For the second melt, three 24-inch diameter ingots produced by primary melts are welded together and this electrode is melted to form a 30-inch diameter ingot. No header material is melted into the second-melt ingot. The 30-inch ingot is inverted and becomes the electrode for the third melt. Appendix B shows the electrode in the pre-melted state. The final product is a 36-inch ingot. Other diameter ingots have also been produced.

The ingots produced following the third melt are machined, heated, then shaped into billets of various diameters (billet cogging), and then cut to various lengths and machined to final finish.

The specified process vacuum has evolved over the years. At the time of manufacture of the event spool, AMS 2380 (Aerospace Material Specifications) allowed for maximum steady-state pressure of 1,000 microns with “occasional momentary peaks” to 6,000 microns. The definition of a momentary peak is:

A temporary surge of pressure which recovers to original pressure level within:

A) 120 seconds in the first stage melt
B) 120 seconds in the second stage melt of a triple melt
C) 90 seconds in the second stage of a double melt
D) 90 seconds in the third stage of a triple melt.

At the time of the manufacture of the event-spool titanium, RMI also used a maximum steady-state pressure of 1,000 microns during the intermediate melt of the triple-melt.
process. The current specification used by RMI, which is based on the most stringent requirement of its various customers, is a maximum steady-state pressure of 200 microns with allowable excursions to 400 microns during the intermediate and final melts. Recovery to the steady-state pressure following any allowable excursion is to be within 60 seconds.

The RMI specification M-312P, as revised on 18 September 1989, included the following information in section 4.1:

Should a water leak occur during the melting of a cast electrode, the affected areas shall be ground, sampled and analyzed for oxygen and nitrogen. The material shall be considered acceptable if the chemical analysis of the water leak area after grinding indicates absence of contamination. Any water leak during the final melt cycle shall reject the material for premium applications. A water leak will be assumed if the electrode or ingot exhibits a discolored area and there was an increase in pressure during the melt cycle.

1.16.4 Fracture Examination

The TSB Engineering Branch examined the fractured third stage of the HPC and some associated hardware in attempts to isolate the cause of the spool separation (LP144/97). The three segments of the stage-three disk, fragments of the forward flange, numerous blades and vanes, pieces of compressor case and other engine hardware were studied. Preliminary examination at Beijing and at the operator's facility in Vancouver indicated that the third-stage HPC disk broke as a result of fatigue or some other progressive cracking mechanism.

A detailed examination of the physical evidence was undertaken by the TSB Engineering Branch, with representatives of Transport Canada, the NTSB and GE in attendance. By the shape of the three spool segments and through examination of each spool fracture, it was verified that one of the fractures was a progressive type (Figures 5 and 6) and was the lead event in the failure sequence. The remaining two fractures were consistent with a sudden overload condition. The fatigue fracture was examined in detail.
One mating half of the fatigue fracture was mechanically damaged but, after cleaning, was usable for preliminary examination of fractographic features. The cleaning removed aluminium debris smeared onto the fracture surface. Preliminary scanning-electron microscope (SEM) examination revealed faceted fracture topography interspersed with patches of fatigue striations (shown in Figure 6). The fatigue crack area covered an oval region extending from the slot bottom nearly through the thickness of the hub. The approximate size of the fatigue crack was 14 millimetres (mm) deep and 21 mm across or about 45 per cent of the third-stage cross-section.

The exact origin of the fatigue was not determined, but it was estimated to be subsurface, in the vicinity of the slot bottom, near the point of radius transition. The transition radii of the occurrence part were found to comply with engineering drawing requirements.

An attempt was made to count the number of striations in the fatigue area, but this was very difficult because the striations were irregular in shape, ran in many directions, and were interspersed with faceted areas. One estimate of the number of striations was about 800.

It was not possible to estimate the time (cycles) of the crack propagation based on a striation count. The engine manufacturer indicated that faceted-type failures were typical of
fatigue in Ti 6242. However, the NTSB in its investigation of another fatigue failure due to a "hard alpha" inclusion\(^\text{(5)}\) noted that the fatigue zone had a typical striated pattern. The manufacturer also indicated that propagation rates were accelerated within the segregate.

The microstructure of the titanium alloy near the fracture was also examined. To that end, slices parallel to the principal fatigue fracture surfaces (about 6 mm from the fracture) were removed and studied. The surface preparation consisted of grinding, polishing and etching the full cross-section. The etching showed that a microstructural anomaly existed on both sides of the fracture. The anomaly appears as a dark, diffused band approximately 2 mm wide, arcing rearward from the front of the third stage, almost touching but not intercepting the slot bottom in the vicinity of the rear transition radius, and finally exiting slightly below the rear face edge (as seen in Figure 7). Examination of the microstructure anomaly band at higher magnification revealed enlarged alpha grains as well as a higher proportion of the alpha phase within the band.

Additional slices parallel to the principal fracture were made to determine the extent of the anomalous band. It was established that the band faded to just an edge effect 14 mm behind one fracture surface and was completely gone 30 mm away. On the other side of the fracture, the band was still present in full width and breadth 45 mm away from the fracture surface.

Hardness and microhardness readings were taken in the band, across the band and in the normal material (matrix) away from the band. It was found that there was a moderate increase in hardness in the band compared to the matrix. The actual values ranged from 38 to 43 Rockwell C hardness (HRC) for the band and averaged 34 HRC for the matrix.

Sample slices containing the microstructure anomaly band were examined at the GE facility, using electron-microprobe equipment. The alpha grains within the band exhibited moderately elevated oxygen content, ranging from 0.1 to 0.4 per cent, with one peak value of 0.8 per cent. There were also minor variations in the content of the alpha stabilizing elements. There was no indication of increased levels of nitrogen in the band. Further tests were conducted by the University of British Columbia using energy-dispersive spectroscopy and wave-length dispersive spectrography; these tests confirmed the oxygen levels in the anomaly band. The various examinations of the material established that the anomalous band is an oxygen-enriched inclusion, although more diffuse than concentrated inclusions usually classified as "hard alpha" inclusions.

### 1.16.5 Dwell Time Fatigue

Dwell time fatigue (DTF) is defined by GE as:

> Fatigue phenomenon in which sustained loads at low temperature result in a flat faceted, subsurface initiation site and lower fatigue life than predicted from continuously cycled fatigue tests.
According to the engine manufacturer, materials that are susceptible to DTF are those with aligned alpha "colonies" (Figure 8). This aligned structure causes reduced resistance to stress and allows for the initiation of cracks.

Tests were conducted at the manufacturer's laboratory to assess the microstructure orientation of the anomaly band and the matrix portion of the third-stage spool pieces. It was determined that the alpha volume fraction in the band was about 70 per cent, as compared to 50 per cent in the matrix. The tests indicated that the alpha colony structures in both areas were similar. Qualitatively, the alpha colonies in the anomaly band appeared larger and less randomized than in the matrix portion. According to the engine manufacturer, the orientation tests indicated that because of the low alpha volume and the randomized grain structure, the matrix material had low susceptibility to DTF associated with other failure events. GE also indicated that the high alpha fraction and the influence of elevated oxygen content in the anomalous band "could be conducive to dwell time fatigue type initiation, however the elevated oxygen levels could also have resulted in more traditional initiation mechanisms."

1.16.6 Melt Irregularity

Research into the records for the melt that produced the Ti 6242 (RMI heat number 981897) that was used to manufacture the 3-5 section of the event spool revealed some irregularities during the first and second melts. During the first melt, some titanium of unknown pedigree was used for the spacer-bar hanger material. It is believed that the material was of rotor quality, but there were no documents certifying its quality. As per the normal process, some of the spacer-bar material was melted into the ingot. The use of uncertified titanium may have allowed the introduction of impurities into the ingot.

During the second melt, an unusual partial vacuum loss was experienced. The vacuum deviation peaked at approximately 950 microns and gradually returned to the steady-state vacuum of about 100 microns. The vacuum returned to less than 200 microns in about 30 minutes after the start of excursion. According to RMI, this type of pressure excursion was likely due to an electrode shift, causing a crucible water leak during the intermediate (second) melt. Water leaks can lead to the infusion of oxygen into the melt.

It was recognized that the melt had irregularities, and there were discussions between the titanium manufacturer and the engine manufacturer as to whether the titanium produced by the melt was acceptable or should have been downgraded to non-rotor material. The engine manufacturer accepted the material because the melt specifications had not been exceeded. Apparently, there was a considerable demand for titanium at the time the melt was produced.
After reviewing the melt records, RMI provided an estimate of where in the ingot any material affected by a water leak or the spacer-bar melt-in may have pooled. These diagrams, included in Appendix B, show the estimated position of the two suspect materials prior to the intermediate melt and the estimated position of the material after the intermediate melt. For the final melt, the intermediate cast was inverted before re-melting, and the material affected by a water leak and spacer-bar melt-in would have melted down into the final ingot. It was not possible to predict where the affected material would be in the final ingot, and it now has to be assumed that the entire ingot was suspect.

The records provided by the engine manufacturer revealed that there had been two HPC disk separations that involved the presence of oxygen-rich material. These two HPCs were produced from ingots produced by RMI in 1972. RMI retrieved the records for these melts and provided the information to the investigation team. These two heats had minor pressure excursions, well within specification limits, during the primary melts. One of the two heats had a minor pressure excursion of less than 600 microns for less than two minutes. Because of several production changes from the 1972 time frame, it was not possible to draw any conclusions about any relation of vacuum changes to the presence of oxygen-rich material that led to the disk separations.

The study of its melt records also showed that RMI had produced three other heats where there had been unusual pressure excursions and the material had been accepted as rotor quality by another manufacturer. It was determined that these excursions were of shorter duration but had higher peak excursions. These excursions met the heat specifications in place at the time of manufacture.

### 1.16.7 Test for Fluorescent Penetrant Residue on the Fracture Surface

Research was conducted in an attempt to determine if there were surface-breaking cracks present at the time of the last engine inspection in 1994 (at 2,785 cycles). X-ray photoelectron spectroscopy (XPS), which is a non-destructive technique used to determine the concentration and forms of elements at or near a fracture surface, was used in attempts to detect the presence of residue from FPI testing. The presence of such residue could indicate that FPI solution was able to get into a crack, and thus the crack would have been surface-breaking at the time of the last inspection, when FPI methods were used.

In preparation for the XPS testing, a reference sample made from Ti 6242 alloy was prepared. This sample using Ti 6242 was pre-cracked, and the same type of FPI solution (ZL-37 Zyglo) was applied to the sample. The sample was maintained at a temperature similar to the in-service temperature of the dove-tail in the third stage of the spool (about 150 degrees Fahrenheit) for one week; the sample was then fractured. The XPS method was able to detect the presence of FPI residue on the sample.

Next, the fracture surface of the third stage of the HPC spool was examined using XPS. Because of the presence of foreign organic material on the fracture surface, the presence of FPI residue could not be confirmed. Some of the material identified included substances similar to those produced by the application of fire-extinguishing agents. The tests for FPI residue on the HPC spool fracture were inconclusive.

### 1.16.8 Non-destructive Inspection (NDI) of Remainder of 3-9 High-pressure Compressor (HPC) Spool

The remnant of the event 3-9 HPC spool was inspected using ultrasonic, eddy current and blue-etch anodizing (BEA) NDI. A complete immersion ultrasonic inspection of all the bore features was conducted with "no relevant indications" detected. A complete eddy current inspection of the bore revealed numerous surface indications that were assessed as damage resulting from the failure of the spool. Immersion ultrasonic and eddy current inspection of the forward webs, and the forward web-to-bore transition radii of stages 6, 7, 8 and 9, did not show any "relevant indications". The front and aft faces of the fourth-stage bore showed evidence of segregated material similar to that found in the region of the fracture (Figures 9 and 10). The position of the segregate was such that BEA of the finish-machined spool would have revealed its presence. Eddy current NDI conducted by the engine manufacturer was not able to detect the segregated material.

The event spool did not undergo BEA NDI at the time of manufacture. The process of BEA NDI of the finished spools did not begin until 1991.

1.16.9 NDI of Sister Spools
In order to determine the presence of any other oxygen-rich titanium from the melt that produced the event spool, the spools produced from material adjacent to that used for the event spool were inspected using ultrasonic, eddy current and BEA NDI. No indications of oxygen-rich segregates were noted, and no relevant ultrasonic or eddy current indications were observed.

1.16.10 Forger Test Rings

When forgings are made for production of the CF6 HPC spool, the forger cuts a test ring from the forging. These test rings are intended to be available for future reference or testing. The investigation team requested that the test rings from the event-spool forging and several other forgings from adjacent sections of the production billet be sent to GE for BEA NDI. The forging company was not able to comply with the request because these test rings had been inadvertently scrapped in 1991. The forger did provide some other test rings that came from the same ingot but were from locations away from the material used to make the event spool.

The BEA NDI of available test rings did not reveal the presence of any oxygen-rich segregate areas.

1.16.11 Eddy Current Test

Two sections cut from the third stage of the HPC were sent to the Transport Canada maintenance facility at the Ottawa airport for eddy current testing. One third-stage piece contained the band of alpha-rich oxygen-rich material. The other piece did not have this band. Without etching, it was not possible to detect the presence of the band. Experimentation with eddy current inspection equipment showed that the flaw in the material was detectable on a flat and polished surface. However, the eddy current assessment along the forward and rear faces of the disk was unsuccessful with the available probes because of geometric edges. The eddy current specialist at Transport Canada Aircraft Services was of the opinion that suitable probes and procedures could be developed to detect a microstructure flaw such as the one found in the event spool.

1.17 Organizational and Management Information

Not applicable

1.18 Additional Information

1.18.1 Manufacturing Process of the CF6-80C2 HPC Spool

The 3-5 portion of the event spool was forged by Schlosser Forging Company from a section of billet B1B. The 6-9 portion of the spool was forged by another forging company, using titanium from another supplier. The two sections were rough-machined and inertia-welded by GE. The 3-9 rough-machined HPC spool was machined to its finished state by Volvo Aero Corporation in Sweden.

Originally the 3-9 HPC spools for the CF6 engine were forged from a single 16-inch diameter billet. GE then switched to a single 13-inch diameter billet for the 3-9 stages. During the same period a few hundred HPC spools were made from two billets (12-inch and 13-inch). A two-piece process using a 9-inch and 10-inch diameter billet was begun in 1988, and this was the method used to manufacture the event spool. Since 1995, the 3-9 HPC spools have been made from two 8-inch diameter billets. The changes in manufacturing methods were intended by GE to allow for improved inspection for hard alpha during
manufacture. Because of the greater forge work, the smaller billet reportedly also produces better microstructure, which is intended to reduce the potential for DTF.

1.18.2 Quality Assurance Tests During Manufacture

A total of seven billets were made from the melt (heat number 981897) that produced the material for the occurrence HPC. The billet test report for heat 981897 showed that three of the billets had some sections removed for a variety of reasons, including material segregation, grain size variation and high hydrogen. The three billets also had test pieces (macro-slices) cut from their ends. The billet that was used to manufacture the 3-5 HPC spool (billet B1B) was shipped to the forger with no extra trimming, and no macro-slice section was cut from the B1B billet.

RMI, while shipping the billets to Schlosser Forge Company, provided test reports on the material being shipped. Two of the billets from the melt with the irregularities were tested and found to have oxygen content within the specification limit (measured at 0.14 per cent). Room temperature yield strength (0.2 per cent offset) in the two billets averaged 139,000 psi; the yield strength at 900 degrees Fahrenheit was about 85,000 psi.

Inspection improvements have been implemented by GE to reduce the problem of hard alpha inclusions in titanium. The ultrasonic reject criteria have been reduced from 6/64 inch, flat bottom hole (FBH) to the current 2/64 inch FBH with multi-zone coverage. Beginning in 1991, BEA was used to inspect billet slices and finished machined spools.

1.18.3 Stress Levels

The engine manufacturer provided stress data for various sections of the 3-9 HPC spool. The maximum hoop stress in the area of fatigue initiation is in the range of 65,000 to 70,000 psi. This area is the portion of the third stage of the HPC spool that has the highest hoop stresses. These stress levels are comparable to the highest stress levels in the bores of the sixth to ninth stages of the spool.

According to GE, the area of the third-stage slot bottom of the HPC operates at about 280 degrees Fahrenheit during take-off. According to information provided by GE, the average yield strength for Ti 6242 at this temperature is about 104,000 psi and the minimum yield strength is about 91,000 psi. The maximum operating stress of the third-stage slot bottom is about 75 per cent of the minimum yield strength of Ti 6242. During the research into stresses in the HPC spool, it was noted that on some models of the CF6 engine the maximum operating stress, locally in stress concentration areas, was greater than 100 per cent of the material yield.

1.18.4 Spool In-service Inspections

Inspections of the CF6 HPC have evolved in response to in-service failures and predicted potential areas of initiation of fatigue cracking. At the time of the overhaul at Aviall Caledonian Engine Services in 1994-95, the occurrence engine HPC spool was inspected using ultrasonic NDI and FPI NDI methods. These methods did not ensure 100 per cent coverage of the spool's material. According to the engine manufacturer, even with the addition of eddy current inspection (SPM 70-32-10), which was not a standard practice at the time of the 1994-95 overhaul, "blind spots" exist near the surface, where flaws could remain undetected. One of these "blind spots" is in the area of the third stage of the spool in which the band of oxygen-rich material and the fatigue origin were located.

1.18.5 Recent Airworthiness Directive History of CF6 Engine HPCs
The NTSB, on 25 August 1995, issued Safety Recommendation A-95-85 to the FAA. This recommendation urged the FAA to amend Airworthiness Directive (AD) 95-03-01, which applied to CF6-50, CF6-80A and CF6-80C2 engines, to require repeated inspections of all of the 3-9 HPC spools, except for the two-piece spools that had not been solution heat-treated after welding. The NTSB indicated that the maximum interval between inspections should be "appropriately less than the 4,000 cycles" specified in the AD. The FAA responded by issuing AD 95-23-03, which reduced the repetitive inspection cycle for spools made from one-piece 16-inch diameter billets and for some spools made from one-piece 13-inch diameter billets. The FAA did not require an inspection interval for spools from the CF6-80A engines made from 13-inch diameter billets or for any spools made from two-piece forgings.

On 03 December 1996, the NTSB indicated, by letter, that AD 95-23-03 did not satisfy the intent of Safety Recommendation A-95-85, and the recommendation was classified "Closed - Unacceptable Response."

2.0 Analysis

2.1 Introduction

The failure of the third stage of the 3-9 HPC spool was the cause of the uncontained failure of the left engine of flight CP30 during take-off at Beijing. The failure had the potential of causing injuries to the occupants of the aircraft because of the high-speed flying debris from the rotating hardware and because of the engine fire. The analysis discusses the failure mode and the material characteristics that led to the failure, and the manufacturing processes and in-service inspections that were unable to prevent the occurrence. The crew's response to the emergency will also be addressed.

2.2 Failure of the Third Stage of the HPC Spool

The fatigue fracture of the HPC spool initiated in the third stage near the dove-tail slot bottom. The exact origin of the cracking was not determined, but it was subsurface in the vicinity of the change of machining radii toward the aft end of the slot bottom. This is an area subject to relatively high stresses, of the order of 75 per cent of minimum yield strength for the Ti 6242 alloy used in the spool. The failure of the third stage of the HPC spool caused the uncontained failure of the engine, followed by the secondary damage and the ensuing fire.

Engineering tests performed on the failed third stage showed that the fracture surface was faceted with interspersed areas of classical striations. At the time of the failure about 45 per cent of the third-stage cross-section had been pre-cracked. The remainder of the material failed suddenly in overload as take-off thrust was applied to the engine.

The manufacturer was not able to provide an estimate of the propagation rates of the fatigue crack for the Ti 6242 in the event spool but indicated that propagation within the segregate area appeared to be accelerated. The manufacturer also indicated that the faceted type of failure is typical for progressive failures of that alloy. The time at which the crack first initiated or the exact number of cycles from initiation to failure were not determined because of the multi-directional nature of the striations that were present and the interspersing of faceted areas. What is known is that the part failed at 4,744 cycles since new, considerably before its approved service life of 15,000 cycles, and that the cracking originated near the aft transition radius of the dove-tail slot bottom.

Tests were performed to determine if the failure was due to DTF. Ti 6242 is vulnerable to
DTF failures when its crystal structure contains aligned alpha grain colonies. According to the definition provided by the engine manufacturer, the fatigue failure is consistent with all the elements of DTF. Tests conducted at the engine manufacturer's laboratories led GE to the conclusion that the alpha-rich, oxygen-rich area of the third stage of the spool could be conducive to DTF initiation; however, the elevated oxygen levels could also have resulted in more traditional initiation mechanisms.

The presence of the oxygen-rich segregate material in an area subject to relatively high stresses was a primary cause of the early failure of the third stage of the HPC. The ingestion event that led to the unscheduled overhaul of the engine in 1994-95 was not a factor in the occurrence.

2.3 Oxygen-rich Segregation

There were irregularities during the production of the ingot that was used as the material to fabricate the 3-5 portion of the 3-9 HPC spool. Normally only rotor-quality material is used for first-melt hanger straps and spacer bars for heats intended for rotor-quality applications. Documentation is provided to identify the material as suitable. In the case of the first melt for the titanium used in the event spool, the quality of the material was not known, and thus the melt-in of the hanger strap / spacer bar material had the potential of introducing material into the melt that had unwanted impurities, such as oxygen. However, the titanium manufacturer believes that the material was, in fact, of rotor quality. Nonetheless, there is a slight possibility that the hanger strap / spacer bar melt-in was a potential source of the oxygen in the material.

There was another anomaly noted from the records of the heat number 981897. During the intermediate (second) melt of the triple-melt process, there was a pressure excursion to about 950 microns, up from the steady-state value of about 100 microns. This excursion was likely due to an electrode shift leading to a water leak in the crucible. The vacuum deviation quickly went to its peak value and then gradually returned to the previous steady-state value of 100 microns. The vacuum moved below 200 microns in about 30 minutes. In 1989, the time of manufacture of the spool material, the maximum allowable steady-state vacuum during the intermediate melt was 1,000 microns with an allowable maximum excursion to 6,000 microns for a maximum time of two minutes. The pressure excursion did not exceed the specifications in place at the time of the heat's production.

RMI's current practice for intermediate and final melts of heats produced today limits the maximum allowable steady-state to 200 microns with a maximum excursion to 400 microns for a period of one minute or less. Production of heat number 981897 complied with the current specification with regard to steady-state vacuum but would have been rejected today on the basis of the vacuum deviation to 950 microns.

Study of the melt records of the titanium manufacturer showed that over a five-year period, from 1987 to 1991, there were three rotor-quality melts with pressure excursions that met the specifications of the time but would have exceeded the present RMI specifications. None of these three had excursions with as long a time above the steady-state vacuum, but the maximum excursions were greater. At the time of the production of heat number 981897, the titanium manufacturer and the engine manufacturer discussed the melt irregularity but decided that the material could be used because it had met specifications. Armed with the knowledge that the material produced by heat number 981897 contained oxygen-rich zones, as evidenced by the failure and the subsequent material analysis, it can now be concluded that the decision to use the material was a factor in the occurrence. However, manufacturing improvements are based on in-service experience, and the decisions that were made at the time, regarding the use of the material, do not seem to have been unreasonable.
At the time of the manufacture of the titanium, there were procedures in place to conduct tests on the ingot if a water leak occurred. There is no record or indication that any special procedures were followed to test for oxygen-rich areas. The normal test samples taken from the ingot and billets have a randomness that allows the segregated areas to be missed. Most of the material likely had normal alloy chemical composition (oxygen reading of 0.124 per cent), and samples taken from these areas would not show high levels of oxygen, as was the case of the actual sample results. The material property tests would also have been subject to the chance of obtaining test samples that happened to contain the oxygen-rich segregate. These material property tests showed normal results and likely contained only normal alloy material.

2.4 Detection of Flaws

There were several NDI tests performed on the billets prior to their leaving the manufacturing facility, including complete ultrasonic coverage. These tests, however, are not capable of detecting altered microstructure such as was found in the failed third-stage HPC spool. Typically, material with very hard inclusions, such as those produced by nitrogen or oxygen "nuggets" (HRC about 60), will cause the material to crack during billet conversion or spool forging. It is the cracking that is most easily detected by ultrasonic NDI. The value of hardness for the segregate band was higher than it was for the matrix material, but apparently the hardness was not high enough to produce cracking during the manufacturing of the spool.

Eddy current NDI methods were not conducted on the material at the time of manufacture. However, the manufacturer indicated that present eddy current NDI methods likely would not have detected the unusual alloy composition.

BEA is capable of detecting the oxygen-rich microstructure, but at the time of manufacture the finished parts did not undergo such tests. Based on the location of the oxygen-rich segregate, which was surface-breaking in some areas of the HPC spool, BEA of the machined part would have revealed the presence of the oxygen-rich microstructure and would likely have caused the spool to have been rejected. BEA NDI has been part of the manufacturing process for HPC spools since 1991.

Inspection of the 3-9 HPC spool by Aviall during overhaul in 1994-95 did not cause the part to be removed from service. The NDI performed on the spool was done in accordance with approved procedures in place at the time of the overhaul. It is now known that ultrasonic NDI methods are unable to detect flaws in certain areas of the spool. These so-called blind spots are located in several areas, including the area where the fatigue crack originated. It is possible that the one 23 per cent reading noted in the third stage was a hint of a possible defect, but the reading was below that required for either rejection or for further inspection. According to the manufacturer, the reading could also have been an indication of structure or grain boundary in the material.

Based on the fatigue fracture characteristics, it is unlikely that the fatigue crack, if it existed, was surface-breaking at the time of the overhaul. Thus, FPI NDI methods would not have been able to detect the material flaw. There were no indications of FPI dye residue found on the fracture surface, but these tests were inconclusive due to the presence of surface contaminants.

The failure of the HPC spool appears to validate the concern expressed in NTSB Safety Recommendation A-95-85 regarding inspection cycles. The crack initiation times and propagation rates are unpredictable and may have been less than 4,000 cycles. The spool design stresses and inspection limitations leave the part vulnerable to failure in the presence of small material defects in the areas subject to high stresses.
2.5 Crew Action

The flight crew and cabin crew reacted quickly to the uncontained engine failure. All actions appear to have been appropriately carried out in a coordinated way. Even though there are no specific, assigned tasks for the augmenting first officer during the emergency response to an engine fire, the initiative of the augmenting first officer in hurrying back to visually check the left engine greatly aided the crew in their response to the failure and provided vital communication to the captain for his decision making. The cabin crew also worked quickly to reassure the passengers and reduce any panic. The net result of the crew resource-management skills was the avoidance of a passenger evacuation, with its potential for passenger and crew injury.

The rapid response of the Beijing Capital emergency response services also assisted the crew in avoiding a passenger evacuation.

3.0 Conclusions

3.1 Findings

- The third stage of the high-pressure compressor (HPC) spool failed, at high power, as a result of fatigue that initiated in the vicinity of the spool's blade dove-tail slot bottom.

- The Ti 6242 used to manufacture the engine's 3-9 HPC spool contained an oxygen-rich (alpha-rich) segregate, which locally degraded its resistance to fatigue.

- The oxygen-rich segregate was located in the dove-tail slot bottom, an area subject to relatively high stresses.

- The oxygen-rich segregate was produced during the triple-melt manufacturing process, likely as a result of a pressure excursion during the intermediate (second) melt.

- The pressure excursion, although unusual, did not exceed the manufacturing specifications at the time of manufacture in 1989.

- As the melt met GE specifications, it was not downgraded from rotor quality.

- At the time that the HPC spool was manufactured, the oxygen-rich segregate was not detectable using in-production and in-service ultrasonic non-destructive inspection (NDI).

- The segregate would likely have been detected by blue-etch anodizing (BEA) or a similar process, but BEA was not performed on finish-machined HPCs at the time of manufacture in 1989.

- The investigation was not able to determine if there was a crack in the third stage of the HPC at the time of last inspection. If it did exist, it may have been subsurface and therefore not detectable by fluorescent penetrant inspection (FPI) techniques.

- There was an unusual result in the third stage of the HPC during ultrasonic testing at the last engine overhaul, but in accordance with the approved inspection procedures the part was assessed as acceptable.

- Because of its properties, ultrasonic NDI cannot detect cracking in certain zones just below the surface, and one of those zones was in the area of the initiation of the fatigue crack.

- Eddy current NDI methods have the potential to detect subsurface cracks in the area of the failure initiation, but such inspections were not part of the HPC inspection.
requirements at the time of the last overhaul.

- The crew resource-management skills and teamwork avoided an emergency evacuation following the engine failure and fire, thus preventing potential injuries to those on board the aircraft.

3.2 Causes

An uncontained failure of the third stage of the 3-9 HPC spool was due to the presence of an oxygen-rich segregate produced in the batch of titanium used to construct the 3-5 stages of the spool. The segregate caused locally degraded resistance to fatigue crack initiation in the dove-tail slot bottom, an area of the spool that is subject to some of the higher design hoop stresses. Contributing to the occurrence were the quality control decisions made at the time of manufacture of the titanium, the inability of existing in-service inspection techniques to detect crack zones, and the intolerance of the spool design for slightly degraded material.

4.0 Safety Action

4.1 Action Taken

4.1.1 Removal of Sister Spools from Service

General Electric Aircraft Engines (GEAE) determined, through its records and by communicating with operators, which companies were operating CF6 engines with 3-9 HPC spools that were manufactured with the Ti 6242 from the same heat as the event spool. A total of 21 other spools were produced from the same heat. Some airlines removed those engines from service voluntarily and others kept engines already off wing in their maintenance facilities. The FAA, after coordinating with GEAE, issued AD 97-22-14 on 31 October 1997, which required that all 21 spools be removed from service within 30 days. All 21 spools were removed from service within the allotted time.

4.1.2 Process Changes

Over the years there have been several titanium manufacturing process changes designed to provide better material, resulting in safer operation. The specification for vacuum during titanium manufacture has been reduced, and the allowable maximum deviation and deviation time period have also been reduced. These changes have reduced the likelihood of the production of the type of oxygen-rich, alpha-rich microstructure found near the origin of the fatigue area of the event spool.

The introduction, in 1991, of BEA inspection of the finished spools increases the chances of detecting microstructure anomalies that may be present in the material.

4.1.3 Melt Records Reviewed

RMI reviewed its records of melts made between 1987 and 1991. (After 1991, changes in the production of the HPC spool ring introduced BEA NDI methods to detect segregated areas.) It was noted that in this five-year period there were three other premium-grade ingots produced that had encountered pressure excursions during their manufacture but had remained as rotor-quality material. The pressure variations for these heats were shorter in duration than for the melt used to make the event spool, but the peak pressures were greater. These melts had been used to produce material for helicopter rotor hubs. Although the heats met the specifications of the time, RMI informed the helicopter manufacturer of the melt records. The helicopter manufacturer indicated that it would assess the information to
see if its products had been affected.

4.1.4 Action by the State of Manufacture

The NTSB, based on the accident/incident and inspection record of the CF6 series of engines and also based on information gathered during this investigation, made several recommendations. On 06 March 1998, the NTSB recommended that the FAA:

Require General Electric Aircraft Engines to develop and implement improved inspection techniques that will provide 100 percent inspection coverage of high-stress areas of the CF6-50 and -80 series high-pressure compressor stage 3-9 spool and that will provide the maximum coverage possible of other areas. (A-98-27)

Review the prescribed nondestructive inspection techniques for all turbine engine multistage compressor spools to ensure 100 percent inspection coverage of high-stress areas and maximum coverage possible for all other areas and, if necessary, require engine manufacturers to develop and implement improved inspection techniques. (A-98-28)

Review General Electric Aircraft Engines' Ti 6242 titanium alloy suppliers' melting records and identify any vacuum excursions or other process deviations that exceed current specifications or that may otherwise cause an inclusion or abnormal microstructure. Based on the results of this review, issue an airworthiness directive to require removal from service and/or inspections of the components manufactured from these melts. (A-98-29)

Conduct a critical design review of the CF6-50 and -80 series high-pressure compressor stage 3-9 spools to assess the overall safety and soundness of the part. The review should, at a minimum, evaluate the following:

- the adequacy of current and past manufacturing processes, including the ability of current and previous melt specifications and post-weld procedures to protect against the creation of microstructure abnormalities; (A-98-30)

- the propriety of using Ti-6242 titanium alloy, including the possible susceptibility of this alloy to the development of aberrant or undesirable crystallographic arrangements of alpha phase and a resulting vulnerability to rapid cracking; (A-98-31) and

- the adequacy of the stress margins for the spool in the presence of an aberrant or undesirable microstructure. (A-98-32)

Revise Airworthiness Directive 95-23-03, applicable to General Electric Aircraft Engines CF6-50, -80A, and -80C2 model engines, to include the -80E model engines, and to require repeated inspections of all high-pressure compressor rotor stage 3-9 spools at maximum intervals appropriately less than 4,000 cycles. (A-98-33)

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard and members Jonathan Seymour, Charles Simpson, W.A. Tadros and Henry Wright, authorized the release of this report on 10 December 1999.

Appendix A - Flight Data Recorder Plot
Appendix B1 - Manufacturing of Titanium
Electrodes for Heat Number 981897

Appendix B2 - Manufacturing of Titanium
Appendix C - List of Supporting Reports

The following TSB Engineering Branch reports were completed:

LP 144/97 - HP Compressor Failure
LP 145/97 - Flight Recorder Analysis

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

Appendix D - Glossary

AD Airworthiness Directive
AMS Aerospace Material Specifications
asl above sea level
ATPL Airline Transport Pilot Licence
BEA blue-etch anodizing
C Celsius
CAI Canadian Airlines International
CVR cockpit voice recorder
Deg. degree
DTF dwell time fatigue
EGT exhaust gas temperature
Eng engine
FAA Federal Aviation Administration
FBH flat bottom hole
FDR flight data recorder
FPI fluorescent penetrant inspection
g G load factor
GE General Electric
GEAE General Electric Aircraft Engines
Hdg heading
HRC Rockwell C hardness
HPC high-pressure compressor
HPT high-pressure turbine
L left
lb. pound
LPT low-pressure turbine
mm millimetre
MTU Motoren- und Turbinen-Union
N1 fan speed
N2 engine core speed
NDI non-destructive inspection
NTSB National Transportation Safety Board
PF pilot flying
pph pounds per hour
psi pounds per square inch
R right
RMI RMI Titanium Company
rpm revolutions per minute
sec second
1. During the FPI process, a dye is applied to surfaces of the parts. The dye penetrates any cracks and leaves a surface indication that is detectable with fluorescent light.

2. Ultrasonic inspection is a non-destructive method in which beams of high-frequency sound waves are transmitted into material to detect subsurface flaws in the material.

3. Eddy current inspections measure fluctuations in an alternating magnetic field around a part. This method uses a transducer carrying an alternating current and is used to locate surface and near-surface defects.

4. Titanium 6242 contains approximately 6 per cent aluminium, 2 per cent tin, 4 per cent zirconium and 2 per cent molybdenum.

5. EgyptAir Airbus A300-B4 at Cairo, 10 April 1995 (NTSB file DCA95-W-A030)
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.

Risk of Collision between
Avionair Inc.
Swearingen Aviation Metro II C-GBXX and
Air Canada
Canadair Ltd. CL-600 Regional Jet C-FSKI
Ottawa/MacDonald-Cartier International Airport
12 March 1997

Report Number A97H0002

Synopsis

At approximately 0751 eastern standard time, Air Canada Flight 330 was cleared to position on runway 25 at the Ottawa/MacDonald-Cartier Airport. Immediately thereafter, the airport controller on duty was relieved by another controller. Approximately five minutes later, Avionair Inc. Flight 403, conducting an instrument approach to runway 25, was cleared to land while the Air Canada flight was still holding in position on the runway. While descending through 200 feet above ground, the Avionair flight crew saw the Air Canada aircraft on the threshold. The Avionair flight crew initiated a missed approach and landed uneventfully at 0818.

The Board determined that a risk of collision occurred as the result of an ineffective controller handover procedure. Contributing to this occurrence were the following: no method other than memory was used to ensure the completeness of the handover briefing; the relieving controller did not adequately monitor incoming communications; the location of the airport surface detection equipment monitor was inadequate for airport controller use; there was no standard method by which controllers kept track of uncompleted critical actions; there were deficiencies in the management and supervision of the unit; and NAV CANADA audit procedures of the unit were inadequate.

Ce rapport est également disponible en français.

Table of contents

1.0 Factual Information
   1.1 History of the Flight
   1.2 Injuries
   1.3 Damage to Aircraft
1.3 Damage to Aircraft
1.4 Other Damage
1.5 Personnel Information
1.5.1 Flight Crew
1.5.2 Air Traffic Controllers
1.5.2.1 Relieved Airport Controller
1.5.2.2 Relieving Airport Controller
1.5.3 VFR Controller Training Requirements
1.6 Aircraft Information
1.7 Meteorological Information
1.8 Aids to Navigation
1.9 Communications
1.9.1 General
1.9.2 Regulations Concerning the Use of Both Official Languages
1.10 Aerodrome Information
1.10.1 General
1.10.2 ATC Tower
1.10.3 ATC Tower Personnel Manning
1.11 Flight Recorders
1.12 Wreckage and Impact Information
1.13 Medical Information
1.14 Fire
1.15 Survival Aspects
1.16 Tests and Research
1.17 Unit Equipment and Procedures
1.17.1 Airfield Surface Detection Equipment (ASDE)
1.17.1.1 General
1.17.1.2 ASDE Monitor Location
1.17.1.3 MANOPS Directives and Procedures Pertaining to ASDE
1.17.1.4 ATSAMM Directives Pertaining to the ASDE
1.17.1.5 Action by the Controller
1.17.1.6 Past Safety Action Regarding Control Tower Layouts
1.17.2 Unit Procedures
1.17.2.1 Transfer of Position Responsibility Procedures
1.17.2.2 Use of a Transfer of Position Responsibility Checklist
1.17.2.3 Handover Procedure
1.17.2.4 Use of Headsets by Controllers During Transfer of Position
1.17.2.5 Flight Progress Strips
1.18 Organizational and Management Information
1.18.1 TC's ATS Standards Division Audit and Inspection Responsibilities
1.18.2 Unit Management Supervision and Turnover
1.18.3 NAV CANADA's ATS Audit Organisation and Evaluations
1.18.4 Ottawa ATS Routine Evaluations
1.18.5 Past Safety Action

2.0 Analysis

2.1 General
2.2 Handover Coordination
2.2.1 Pre-relief Procedures
2.2.2 Post-relief Procedures
2.2.3 Controller Decision Making
2.3 Transfer Procedures
2.3.1 Use of the Transfer of Position Responsibility Checklist
2.3.2 Communications Monitoring
2.3.3 Flight Progress Strip Marking
2.4 Location of the ASDE Monitor
2.5 Language of Communications
2.6 Unit Management
2.7 NAV CANADA Audit Procedures and Tracking
3.0 Conclusions
   3.1 Findings
   3.2 Causes

4.0 Safety Action
   4.1 Action Taken
     4.1.1 ASDE Location
     4.1.2 Transfer of Position Responsibility Checklist
     4.1.3 Follow-up to Items of Consequence
     4.1.4 Use of Checklists During Unit Evaluations
     4.1.5 Unit Management's Implementation of ATSAMM Directives and Guidelines
     4.1.6 Annual Knowledge Verification Test Requirements
     4.1.7 Implementation of Ergonomic Presentation of Equipment in Tower Cabs
     4.1.8 Frequency of Unit Evaluations
     4.2 Action Required
     4.2.1 Control Tower Performance Aid
   4.3 Safety Concerns
     4.3.1 Unit Guidelines, Rules and Directives

Appendices
   Appendix A - List of Supporting Reports
   Appendix B - Glossary

Figures
   Figure 1 - Ottawa/MacDonald-Cartier International Airport

1.0 Factual Information

1.1 History of the Flight

Air Canada Flight 330 (ACA330), a passenger flight with 2 flight crew, 1 cabin crew and 12 passengers on board was scheduled to depart Ottawa for Washington, DC, at 0700 eastern standard time (EST), but was delayed because the aircraft needed to be de-iced.(1),(2) At 0749:08, the crew of ACA330 advised Ottawa Tower that they were holding short of runway 25, and that they would be ready for takeoff in a few minutes. At 0751, the crew informed Ottawa tower that they were now ready for takeoff, and the airport controller cleared the aircraft to position on runway 25. Runways 25 and 32 were in use for landing aircraft, and all departing commercial aircraft were taking off on runway 25. An airport controller handover, commonly called "transfer of position responsibility," was effected between 0751:46 and 0752:05. The out-going controller did not advise the relieving controller that ACA330 was in position on runway 25.

At approximately 0754:36, Avionair Flight 403 (ANU403), a cargo flight on a direct flight from Mirabel, Quebec, to Ottawa, was handed over to tower from the approach terminal controller. The flight advised the airport controller that it was inbound to runway 25 on a localizer back course (LOC BC) approach. At 0755:38, the controller cleared ANU403 to land on runway 25, and ANU403 acknowledged the clearance. Radio communications with ANU403 were in French.
During the approach the crew of ANU403 levelled off at the minimum descent altitude of 800 feet above sea level (asl), 427 feet above ground level (agl). Because of the low visibility, the crew did not see the runway environment until they were approximately one mile from the threshold, where they resumed the descent. As the aircraft descended through approximately 200 feet agl, the crew noticed that there was an aircraft on the threshold of runway 25. ANU403 advised the controller and began a go-around procedure. The crew completed a second approach and landed uneventfully on runway 25.

1.2 Injuries

There were no injuries as a result of this occurrence.

1.3 Damage to Aircraft

There was no damage to either aircraft.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

1.5.1 Flight Crew

The respective companies indicated that the flight crews of both aircraft were certified and qualified for their respective flights in accordance with existing regulations.

1.5.2 Air Traffic Controllers

<table>
<thead>
<tr>
<th>Airport Controller Position</th>
<th>Controller Being Relieved</th>
<th>Relieving Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>30</td>
<td>48</td>
</tr>
<tr>
<td>Licence</td>
<td>VFR(3)</td>
<td>VFR</td>
</tr>
<tr>
<td>Medical expiry date</td>
<td>1 August 1997</td>
<td>9 December 1997</td>
</tr>
<tr>
<td>Experience</td>
<td>10 months</td>
<td>16 years</td>
</tr>
<tr>
<td>- as a Controller</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>- as an IFR Controller(4)</td>
<td>10 months</td>
<td>14 years</td>
</tr>
<tr>
<td>- in present unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hours on duty prior to occurrence</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Hours off duty prior to work period</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

1.5.2.1 Relieved Airport Controller
The relieved controller qualified as a VFR Ottawa airport controller on 24 May 1996. He was subsequently involved in two operating irregularities, which prompted management to provide him with additional training. He re-qualified on 17 October 1996. He stated that he was well rested, under no abnormal stresses, and in good health at the time of occurrence. Records show that his performance was satisfactory following his re-qualification.

1.5.2.2 Relieving Airport Controller

The relieving controller had 16 years’ experience in tower operations. He stated that he was in good health, properly rested, and under no undue stress at the time. He was the tower supervisor at the time of the occurrence. He was also the unit training officer, and in this capacity he was responsible for conducting the tower familiarization course for each new trainee posted to the establishment.

1.5.3 VFR Controller Training Requirements

The tower familiarization course consists of a few days in a classroom, and includes discussion of the material that is on the knowledge verification test (KVT). The Air Traffic Control (ATC) Manual of Operations (MANOPS), Article 119.3, specifies that each air traffic services (ATS) employee who is required to perform operational duties is required to complete the KVT at least once annually. Further, the Air Traffic Services Administrative and Management Manual (ATSAMM), Article 251.8, directs that unit managers ensure that operational personnel under their control demonstrate that they meet the unit operational knowledge requirement by successfully completing the applicable KVT for their operational positions "at least once annually." Annex "C" to that order specifies that failure to achieve a pass mark will normally require removal from operational duties.

The relieving controller stated that he had not completed the KVT for the last three years or more, because during this time period he had been the unit training officer. There were no recent KVT result records found in his file, and there was no unit directive or order found that exempted unit training officers from the requirement to write the KVT. Queries with two other ATS units confirmed that all their operational controllers, including designated instructors and unit training officers, write the KVT.

1.6 Aircraft Information

ACA330 flight was a Canadair Ltd. CL-600 Regional Jet, serial number 7068, registered as C-FSKI. ANU403 flight was a Swearingen Aviation SA-226TC Metro II, serial number TC293 registered as C-GBXX. The respective crews reported that, at the time of the occurrence, there were no aircraft system anomalies that could have affected this occurrence.

1.7 Meteorological Information

The aerodrome forecast (TAF) for the period 0700 to 1000 called for the following: temporarily, ½ statute mile prevailing visibility in light snow, and a vertical visibility of 1,200 feet. No significant meteorological reports(SIGMETs) were reported for the area, although a series of special weather reports (SPECI)
were issued at 0724, 0750, 0754, and 0805. Special weather reports issued at such close intervals normally indicate rapidly changing ceiling and/or visibility conditions.

The tower received a pilot report (PIREP) at 0750 from a landing aircraft indicating that the threshold of runway 25 was visible from approximately one mile back. The 0754 SPECI issued four minutes before the occurrence reported ¾ mile prevailing visibility in light snow showers, with a reported vertical visibility of 1,200 feet. By 0805, the snow shower had passed, and that SPECI reported a prevailing visibility of 10 miles.

1.8 Aids to Navigation

There were no reported problems with the aids to navigation within the terminal control area (TCA) for the time of the occurrence, and all of the approach aids to runways 25 and 32 were serviceable.

1.9 Communications

1.9.1 General

There were no communications equipment discrepancies noted or reported that would have contributed to the occurrence, and neither aircraft experienced communications malfunctions or difficulties.

From the time of the transfer of position responsibility until the incident occurred, five aircraft were on the tower frequency. At the time of the occurrence, two had landed, CDN901 and KNX9910, and were on the ground control frequency, and three were on the tower frequency, ANU403, ACA330, and C-GBAF, a light aircraft on the north field.

1.9.2 Regulations Concerning the Use of Both Official Languages

The Ottawa tower is a bilingual unit, required to communicate only in the language initially chosen by the aircraft (MANOPS 754.1), unless:

1. a specific request is received from the aircraft to change to the other language; or,

2. it is considered necessary for safety of flight. A MANOPS note adds that safety of flight may be considered in jeopardy if communications appear to be misunderstood.

Bilingual service is provided as required from all operating positions in the tower. Controllers are required to mark the strip appropriately with a highlighting marker to indicate that the flight has chosen to use French. The strip for ANU403 was appropriately marked, and on handover from approach control, the airport controller communicated with that aircraft in French. The flight crew of ANU403 were bilingual; the flight crew of ACA330 were unilingual English.

The controller spoke French when he cleared ANU403 to land on runway 25, and the crew of ACA330, on the same frequency, did not understand that communication. Approximately 10 seconds later, the controller asked ACA330 "you're with me and ready, confirm?" ACA330 replied "Yeah, Air Canada three-
thirty is in position, ready to go, 25." The controller acknowledged this call and advised ACA330 that there would be a short delay for their departure, as he had another aircraft to land first. The crew of ACA330 assumed that the aircraft referred to was landing on runway 32. The crew of ANU403 did not react to these transmissions by ACA330 and the controller.

A TSB survey of the three major ATS units in Quebec was conducted to ascertain whether bilingual service in air-ground-air communications was a factor in any operating irregularities that occurred in that province over the last two years. The survey consisted of a verification of the results of fact-finding boards (FFBs) and operating irregularities reports on file. There was nothing found to indicate that language was a causal factor in any incidents. Therefore, it was concluded that, for the time period covered by the survey, the bilingual issue was seldom, if ever, a factor in air proximity events.

1.10 Aerodrome Information

1.10.1 General

The Ottawa/MacDonald-Cartier International Airport has two main runways, used primarily by commercial carriers, and two secondary runways at the
northwest end of the field, used mainly by small aircraft and the resident flying schools. The orientation and length of the major runways are depicted on the accompanying diagram. The distance from the tower to the threshold of runway 25 is approximately 8,100 feet. A visibility of 3/4 mile prevents the airport controller from seeing the threshold and first half of runway 25, as depicted by the shadowed area.

The runways and taxiways were generally covered by a light coat of snow because of a local snow shower at the time of occurrence. The snow blended the airfield surface with that of the surrounding area. Moreover, the upper surface of the Regional Jet was painted white, and the flight crew of ANU403 reported that the white aircraft on the snow-covered threshold was difficult to discern.

1.10.2 ATC Tower

The ATC tower, operated by NAV CANADA, was erected in 1990 and operations began in December of that year. The tower structure and cab are located to the west of the intersection of the two main runways. This location provides a good view of the approaches to runways 25 and 32, weather permitting, and a fair to good view, because of the distance and background, of the north field.

1.10.3 ATC Tower Personnel Manning

The Ottawa tower manning is established for five operating positions: operational support specialist (OSS); clearance delivery; ground control; airport control; and, supervisor. The supervisor is responsible for the safe operation of the shift and replaces any of the four other positions as the need arises, such as during breaks, provided the current and anticipated workload permits. No provision is made to back-up the supervisor when he is required to fill any of the positions during a vacancy, nor is there a procedural requirement to do so. All of the positions can be interchanged during a shift except that of the OSS, as this position is not filled by a qualified controller; however, qualified controllers can fill the OSS position. During light activity periods, two positions can be combined, allowing the supervisor to fulfil his primary supervisory function without having to work a control position. Traffic volume and complexity were respectively assessed as being light and moderate at the time of the occurrence. No positions were combined at the time, therefore the supervisor was required to occupy the airport controller position when the latter went on a break.

1.11 Flight Recorders

Data from the flight recorders were not retrieved because the information was not required for the conduct of this investigation.

1.12 Wreckage and Impact Information

There was no wreckage.

1.13 Medical Information
The medical records for the two ATS specialists were up to date, and indicated that both were in good health at the time of their examinations. Medical records for the flight crew were not verified.

1.14 Fire

There was no fire.

1.15 Survival Aspects

Not applicable.

1.16 Tests and Research

None were conducted.

1.17 Unit Equipment and Procedures

1.17.1 Airfield Surface Detection Equipment (ASDE)

1.17.1.1 General

The Ottawa airport is equipped with an ASDE radar system, which was reportedly functioning properly at the time of the occurrence. The ASDE is specifically designed to detect aircraft and vehicular traffic on the surface of an airport, and to present this image in the control tower, via one or more monitors. The ASDE is designed to detect a target as small as a passenger car anywhere on the displayed surface, and controllers reported that the ASDE monitor accurately reflected airfield traffic at all times. The primary purpose of the ASDE is to augment visual observation by tower personnel of aircraft and/or vehicular movements on runways and taxiways, especially during times of reduced visibility and at night. The radar antenna and its associated rotating structure for the ASDE are mounted on top of the tower cab.

1.17.1.2 ASDE Monitor Location

During the construction of the tower, it was realized that one of the three posts used to support the roof structure of the tower cab obstructed the Airport controller's ability to observe the intersection of the two main runways. As it was no longer possible to move the offending post, the Airport controller's position was shifted approximately eight feet to the right in order to alleviate the situation and to provide optimum visibility. At the time of the occurrence, ASDE information was displayed in the cab on a single monitor, located near the ground controller. A second ASDE monitor was in storage. Because of his distance from the monitor, the airport controller could not easily view the ASDE information.

Reportedly, airport controllers had complained on a number of occasions about the poor positioning of the ASDE monitor. Unit management had also, on a number of occasions, verbally requested that maintenance personnel install the second monitor next to the airport controller's position as a matter of priority.

1.17.1.3 MANOPS Directives and Procedures Pertaining to ASDE
MANOPS 307.1 states that controllers are to use the ASDE to augment visual observation of the manoeuvring areas under the following conditions:

1. at night;

2. when visibility, for any reason, is less than the most distant point of the manoeuvring area; and,

3. at any other time when, in the opinion of the controller, an operational advantage will be gained.

MANOPS 30 7.2 further states that the controller may use ASDE derived information to:

1. determine that a runway or taxiway is clear of aircraft, vehicles or obstructions prior to a landing or a take-off;

2. confirm the location of aircraft and vehicles on the displayed airport manoeuvring area;

3. provide directional instruction to pilots and vehicle operators on the displayed manoeuvring area when requested by them, or when deemed necessary by the controller;

4. confirm compliance with control instructions to aircraft or vehicles operating on the displayed manoeuvring area; and,

5. provide directional instruction to crash, fire and rescue vehicles manoeuvring on any displayed area, as necessary.

1.17.1.4 ATSAMM Directives Pertaining to the ASDE

ATSAMM Article 213.3 states that the unit manager shall develop local procedures to enable airport controllers to determine that the runway is clear whenever operating during restricted visibility or at night. Article 214.1 states that the unit manager shall develop local procedures incorporating the direction provided in 213.3 and specify any additional restrictions or operational limitations applicable at their respective sites; there were no such amplifying procedures found in the unit's operations manuals.

1.17.1.5 Action by the Controller

After assuming the airport control position, the relieving controller glanced at the ASDE and saw a radar return on the taxiway adjacent to the threshold of runway 25, where he expected AC330 to be. This radar return was in fact a DC-9 waiting for departure. The controller did not leave his position to obtain a better view of the ASDE monitor and never saw the radar return for ACA330 on the threshold.

1.17.1.6 Past Safety Action Regarding Control Tower Layouts

In its March 1990 special investigation report into Air Traffic Control Services in Canada, the Canadian Aviation Safety Board (CASB) concluded that "the
current lack of integration of information required airport controllers to monitor several displays and information sources to make critical decisions." It was noted in one Transport Canada Fact Finding Board (FFB) report that the controller had to move 15 feet from his work station to visually check the ASDE display. In view of the inefficiencies in the layout of airport controller’s information displays, the CASB recommended that:

The Department of Transport accelerate the improvement of control tower layouts with a view to implementing an ergonomically efficient configuration.

(CASB 90-07)

The Minister of Transport responded by stating that implementation was ongoing. Transport Canada Publication TP210, Control Tower Site and Design Standards, had been updated and would be re-issued by December 1990. Through the Transportation Development Centre, the Department of Transport would determine how technology and ergonomics could best be applied and integrated in control tower workstations, and that a study was underway to determine the optimum presentation of radar information in control towers. Transport Canada Publication TP210 was re-issued one year later than planned. At the time of the occurrence, the TSB was not aware of any changes to ergonomic presentations as a result of the Transportation Development Centre study.

1.17.2 Unit Procedures

1.17.2.1 Transfer of Position Responsibility Procedures

MANOPS 113.2 directs that the relieving controller perform the following actions during the pre-relief monitoring process:

- observe operational situations and equipment;
- listen to communications;
- observe current and pending aircraft and vehicular traffic;
- verify the position relief checklist;
- correlate information; and
- indicate to the controller being relieved that the position has been previewed and you are ready to begin the verbal briefing.

After the briefing, the relieving controller makes a statement, or otherwise indicates to the controller being relieved, that position responsibility has been transferred. MANOPS 113.3 states that after the transfer, the controller being relieved shall remain for monitoring purposes jointly with the relieving controller. During this time, the relieved controller is to reinforce the position relief briefing and assist the relieving controller in becoming familiarized with the position. MANOPS 113.4 states that the pre-relief and post-relief overlap time requirement shall be based on traffic volume and complexity, and that each controller is to use his best judgment in
evaluating the situation and taking the appropriate time to effect a complete change of information. The survey of other ATS units showed that, although each transfer is unique and must be treated separately, a monitoring time of two minutes is considered the maximum amount of time a relieved controller would normally remain behind to monitor the position during periods of light traffic.

In this occurrence, the relieving controller indicated to the controller being relieved that the position responsibility had been transferred by unplugging the latter's headset from the communications jack, and plugging his own headset in - extra jacks are available for additional headsets to be plugged in as required. The relieved controller, believing the relieving controller now had the whole picture, left the tower cab without delay, not verifying that his colleague now had the complete airfield traffic picture.

Management personnel at Dorval, Mirabel, and Quebec City airports stated that when an aircraft has been cleared into position on an active runway by a controller about to be relieved, the transfer of responsibility is not normally effected until that aircraft has been cleared for take-off. During occasions where the transfer must occur while an aircraft is holding position on the active runway, the relieved controller would monitor until that aircraft has been cleared for take-off. The Montréal/Dorval tower has specific written guidance to this effect in their unit operations manual, in accordance with ATSAMM Articles 203.3 and 203.4. No such guidance was contained in the Ottawa ATC operations manual.

1.17.2.2 Use of a Transfer of Position Responsibility Checklist

ATSAMM Article 203.3 states that the "Regional Director, ATS (RDATS) shall ensure that unit guidelines are developed, which provide direction for controllers and specialists to follow, at the time of transfer of position responsibility." Article 203.4 also provides the same direction to unit managers, and further states that unit managers shall develop a checklist for each operational position, to be used at the time of transfer of position responsibility. The note to this Article states that the following items may be included in the checklist, as appropriate:

- potential conflicts, arrival and departure information, and traffic patterns;

- status of NAVAIDs and communications, etc.;

- flow restrictions;

- special use airspace;

- NOTAMs;

- PIREPs;

- airport status, RSC/JBI, NOTAMs, etc.; and

- weather (impact on traffic).

A checklist incorporating the above items was available at the console for the OSS, ground control, and clearance delivery positions, but none was found at the airport control position. During the visit to the tower by the investigation
staff, where airport control transfer of position briefings were observed, the checklist was not being consulted. When queried as to the location of the checklist for that position, none of the controllers remembered seeing it in the recent past, and it was remarked that the checklist had likely been missing for quite some time. The investigation could not clearly establish whether the transfer of position responsibility checklist was in place or not at the time of the September 1996 unit evaluation; however, Officers who conducted the Ottawa unit 1996 evaluation clearly stated that the transfer of position checklist was at the airport controller's console at that time.

Within the unit, it was felt by some individuals that the decision to require the use the checklist was likely a "knee-jerk" reaction to a previous operation irregularity. Some controllers stated that each has his own way or sequence of ensuring that essential items are covered during transfer of position briefings, and that a checklist may not work best for everyone.

In another recent TSB investigation, A95A0046, the Board found that sub-standard work practices can result from not taking advantage of mandatory tools or aids, like a checklist. The report on that occurrence stated that checklists can be useful tools to promote both efficiency and safety, especially in circumstances where a series of critical actions must be routinely carried out. To fulfil their aim, checklists must be designed and located so as to be useful to the user.

1.17.2.3 Handover Procedure

During the investigation it was determined that neither controller was happy with the handover procedure. The handover was characterised as "sloppy," there was some preoccupation with the intensity of the approach lighting on runway 32, and there were assumptions made regarding each other's knowledge of the situation. Both controllers later noted that the use of the checklist would have reduced the likelihood of the occurrence.

1.17.2.4 Use of Headsets by Controllers During Transfer of Position

The Ottawa tower communications setup allows controllers to listen to incoming radio communications on personal headsets or via a common speaker system. Most controllers prefer to use headsets, as it reduces distractions and background noise.

At the time of the occurrence, the controllers were communicating with aircraft using headsets. Only those who wear a headset and who are plugged into the appropriate communications jack can therefore listen to incoming communications, although one can generally listen to outgoing communications when standing close to the controller on duty. Relieving controllers are required to listen to communications during the pre-relief period. As stated previously, there are extra plug-in jacks available.

The relieving controller did not have his headset plugged in during the pre-relief period; therefore, it was not possible for him to hear ACA330 request the clearance for takeoff. Although he was standing behind his colleague, he did not hear him clear the aircraft to position on runway 25. He was also considering a request from a local light aircraft on the north part of the field for special VFR
authorisation. In any case, he was not aware that ACA330 had been cleared to position on runway 25.

The MANOPS directives pertaining to radio communications during transfer of position responsibility stipulate that the relieving controller shall, among other requirements, observe the operational situation during the pre-relief monitoring period, and listen to communications. A review of procedures in use at this and other towers revealed that it was uncommon for relieving controllers to plug in their headsets during the pre-relief period, unless traffic volume and complexity were high. A number of airport control handovers were observed by the investigators during a visit to the tower. The relieving controllers were not observed plugging their headsets in during the pre-relief monitoring period. The intent of the MANOPS directive to listen to communications during the pre-relief monitoring period was, thus, not always heeded at this and at other units.

1.17.2.5 Flight Progress Strips

In work situations where safety critical information must be remembered and acted upon, special procedures are often devised. A performance aid, or job aid, is any device that a person uses to ensure completion of an activity. It is designed for immediate use, and can assume a wide variety of physical forms, or may be written or computer-based. A performance aid helps by reducing the cognitive processing requirements of an activity; thus, it serves as an aid to memory, it improves efficiency and reliability of performance, and it improves safety. Performance aids provide the most benefits where completion of the task is critical, and where the consequence of error can be serious. They are also most effective when normal verification methods or sensory perception is not available, or is reduced.\(^{(5)}\) A performance aid that provides a single message can easily be used by many individuals.

Errors can still happen when a standardized performance aid is used; however, it is important to note that when an error is made with the same performance aid used by all, the error is more likely to be captured because all the individuals in the group understand the implications of the performance aid. Conversely, when different individuals use their own, unique performance aids for a particular activity, the potential for teamwork is compromised.

MANOPS provides specific direction to IFR controllers with respect to flight progress strip manipulation and marking. One of these directions concerns "strip-cocking," a method which involves lifting the corner of the strip holder out of the strip bay. This reminds the controller that further action has yet to be performed regarding a particular aircraft under his control. There are no specific rules or guidelines that apply to strip-cocking in VFR operations. Some airport controllers cock the strip as a reminder that an aircraft is on an active runway without a take-off clearance. Some controllers never cock the strips, while others use different mnemonic methods. The relieved controller had cocked the strip for ACA330 to remind himself that he had cleared the aircraft to position on runway 25, and that the aircraft was now obstructing that runway. The relieving controller never used this method, and he did not notice the cocked strip cue as he took over from the other controller. Discussions during the investigation revealed that the majority of airport controllers do not feel that a standard is required in this respect, rather that each controller should be allowed to use whatever works best for him or her; management supports this view.
On 1 February 1991, two aircraft collided on the runway at Los Angeles Airport. The National Transportation Safety Board (NTSB) of the United States investigated this catastrophic accident, and their report on the collision contained the following: "The Safety Board believes that there is no existing automated monitoring system on which a tower can rely to ensure that human performance errors will always be detected." The report also states that local and ground controllers must rely almost totally on their eyes, ears and memory to perform their duties. The NTSB believed that "any job aids and procedures, such as strip marking and flight strip forwarding, which are designed to improve each airport controller's performance, should be adopted and emphasized, repeatedly, until other independent, automated systems become available."

1.18 Organizational and Management Information

1.18.1 TC's ATS Standards Division Audit and Inspection Responsibilities

Prior to 1 November 1996, NAV CANADA prepared for the transfer by Transport Canada (TC) of the air navigation services and its existing ATS operational units. The privatization process included an application for an ATS Operations Certificate to meet the regulatory requirements to operate air traffic control units and flight service stations across Canada, starting 1 November 1996. All 136 ATS units were transferred and certified in time for the privatization, with the understanding that NAV CANADA's operational units would be the subject of an "Air Traffic Services audit" by ANS Inspectors under a ministerial delegation of authority.

On 1 November 1996, the Government of Canada sold the assets and transferred the responsibility for the operation of Canada's civil air navigation system to NAV CANADA. Since then, TC's role in this regard has changed from that of owner, operator and regulator to that of regulator alone. Concurrent with the privatization of the air navigation services, TC's Air Traffic Services Standards Division of the Air Navigation Services and Airspace (ANS&A) Branch became, in part, responsible for overseeing the ATS provider's compliance with Part VIII of Canadian Aviation Regulations.

Initial ATS audits are conducted, in the form of a site manual verification by ANS Inspectors, following the Minister's approval of an ATS Operations Certificate, or following the addition of an operational unit to be listed on the same ATS Operations Certificate. Other ATS audits are conducted as required. ATS inspections are the subject of separate activities.

In order to ensure the continued safe operation of the Canadian air navigation system, TC has created the Office of Air Navigation Services and Airspace Safety Oversight, tasked with the custody of the air navigation and airspace safety oversight policy and program. The goal of the safety oversight function is to advance safety by:

- continuously monitoring the national civil air navigation system and environment;
- reducing the likelihood of accidents and incidents; and
- discouraging non-compliant behaviour or practices.

TC Audit results are forwarded to NAV CANADA for information and corrective action, as required.

1.18.2 Unit Management Supervision and Turnover

The unit manager of the Ottawa Tower/Terminal Control Unit (TCU) had been in the position for two years. Since January 1992, there had been four different unit managers and six different operations managers in the unit.

1.18.3 NAV CANADA’s ATS Audit Organisation and Evaluations

The Director, ATS, is the functional specialist responsible for the ATS function in Canada and the integrity of the National system. The Chief, ATS Monitoring and Evaluations, is the functional specialist charged with the responsibility of assessing the integrity and effectiveness of ATS operations, including the extent of adherence to, and appropriateness of, existing policies, standards and procedures. The Chief authorizes headquarters ATS evaluations officers to conduct, on an ongoing basis, the evaluation of all ATS units. The evaluations division comprises the Manager, a Superintendent ATC, seven ATC inspectors, a Superintendent FSS, three FSS inspectors, one clerk, one secretary and a statistical systems analyst.

General direction and information by which the ATS evaluations division conducts its activities is contained in ATSAMM Section 260, Unit Evaluations. This direction is amplified in ANS Policy Document 100.204.2. The evaluations division also uses document NP7993, ATS Evaluation Guidelines, in the conduct of unit audits. Evaluations of ATS units are to ensure that provision of service is maintained at the highest standard; and that all units and personnel apply in an approved manner the policies, standards, rules, procedures and separation minima.

ATSAMM 263 directs that routine evaluations of ATS units shall be conducted at least every three years, and an interim evaluation at each major location and other selected units shall also be carried out when necessary. During evaluations, identified problems or deficiencies are reported as "Items of Consequence." This term defines a practice which has an impact on the system, or is a deviation from the standard or approved procedure. Corrective action is required for all identified items of consequence. ATSAMM 266.5 requires that each Regional Director, ATS, advise the Chief, ATS Monitoring and Evaluations, of the status of action taken with respect to identified problems within 60 days of receipt of an evaluation report, and at 90-day intervals until all outstanding items have been resolved. Follow-up evaluations are carried out, normally within 12 months, when a unit is found to not meet the standard.

The Evaluation Guideline states that evaluation officers will, among other activities, monitor operations by whatever means are appropriate. No amplifying details of this general directive are found in the available documentation, other than in ATSAMM 262.2, which gives a general overview of the scope of evaluations. In the absence of specific procedures, there is scope for variation from evaluator to evaluator, with the consequent possibility of a safety item
being overlooked.

1.18.4 Ottawa ATS Routine Evaluations

There was an evaluation of the Ottawa ATS in 1992 and a subsequent evaluation in September 1996. The second evaluation occurred two months prior to the transfer by TC of the air navigation services and its existing ATS operational units to NAV CANADA. Although the responsibility for the follow-up action to this latter TC evaluation became that of NAV CANADA, it should be noted that the personnel performing both functions remained essentially the same.

One observation in the 1992 evaluation was that only one ASDE monitor was in place in the tower, and that a second one in storage should be installed by the airport controller's console. The 1996 evaluation report identified the failure to install the second ASDE monitor in the cab as a deficiency to be corrected. The report further commented that this deficiency had also been reported in the 1992 unit evaluation, and had thus remained uncorrected for more than four years. At the time of this occurrence the second monitor was not installed. No paper work was found indicating that any follow-up action on this deficiency had been taken in the intervening years between the two evaluations, and no documentation could be found in the unit files pertaining to the requirement that the second ASDE monitor be installed without delay.

The 1996 review of management contained the following observation: "The lack of management continuity has had a detrimental influence on morale and unit administration." The review also uncovered two items of consequence directly associated with supervision by management. The first one, rated as a major deficiency, was that there were no apparent controls in place to ensure that operational personnel demonstrated proficiency. The second observation, assigned a regular category, indicated that there was no position responsible to verify licence validation certificates for supervisors.

A review of the 1996 evaluation revealed that the following procedural deviations, uncovered during the course of this occurrence investigation, were missed during that evaluation:

- the relieving controller's KVT annual exam had not been completed for at least three years;

- no unit documentation could be found on the amplifying guidelines the unit manager is required to provide to enable airport controllers to determine that the runway is clear whenever operating during restricted visibility or at night, including any additional restrictions or operational limitations applicable at his site; and

- no unit documentation could be found on the amplifying guidelines the regional and unit managers are required to provide with respect to the transfer of position responsibility.

In all, the 1996 evaluation identified 12 items of consequence requiring a response from the Regional Director, ATS, by 29 November 1996. A verification with NAV CANADA on 30 April 1997 revealed that the required response had not yet been sent to the Chief, Evaluations. Further, there was no indication that
the evaluations division had queried the lack of response.

1.18.5 Past Safety Action

The 1990 special investigation CASB report into Air Traffic Control Services in Canada concluded that:

the current staffing crisis [in 1990], the frequency of serious ATC operating irregularities, the forthcoming implementation of significant equipment enhancements, forecast traffic growth for the next decade, and anticipated high staff turnover, all suggest a need for an extraordinary effort to ensure the maintenance of quality control. Therefore, the CASB recommended that, during this highly dynamic period:

The Department of Transport increase its efforts for monitoring ATC operations through unit evaluations to ensure consistent application of prescribed standards and procedures. (CASB 90-48)

Transport Canada responded to this recommendation as follows: "All efforts will be made to maintain the unit evaluation cycle. When resources permit, the cycle will be increased to ensure compliance with national policies and to ensure the consistent application of prescribed standards and procedures." It is worth noting that although an increase in monitoring levels was recommended, the TC response stated that efforts would be made to maintain the cycle, and that it would be increased when resources permitted. The TSB was recently provided with documentation from the former Transport Canada ATS Evaluations Branch, dated January 1993, which proposed downsizing the unit evaluation program for all units. This proposal was submitted to the then-Director ATS for his approval. This approval was reportedly granted. During the period 1991 to the present, ATSAMM 263 has not been amended to reflect the changes that occurred to the evaluation cycle policy during that time frame. NAV CANADA stated that, effective September 1997, it has modified the ATS unit evaluation cycle to a two- or three-year cycle, depending on the unit, and that the Ottawa tower/TCU is now on a two-year evaluation cycle.

2.0 Analysis

2.1 General

The information gathered during the investigation indicates that both controllers met medical fitness requirements, were rested and under no significant stress at the time. There were no indications that the performance of the flight crews or of the aircraft systems contributed to the incident. The appropriate navigation aids and communication frequencies were also all serviceable. The communications between the flight crews of both aircraft and the tower were normal, and the flight crews followed ATC instructions as directed. The weather conditions were such that the controllers could not see the threshold of runway 25.

The analysis will concentrate on the interactions between the two controllers, their actions and the procedures used during the transfer of position sequence, and the impact of the location of the ASDE monitor on this event. The analysis will also cover the adherence to directives and procedures at the unit's supervisory and management levels, and the audit practices, procedures and
tracking within NAV CANADA's Monitoring and Evaluations Division.

2.2 Handover Coordination

2.2.1 Pre-relief Procedures

The handover procedure was characterised as having been generally sloppy. Based on the two controllers' descriptions of what transpired, there were problems with both how the information was transferred by the out-going controller and how it was received by the relieving controller. The result was that the relieving controller did not develop an appropriate awareness of the whole situation, which led to his final unsafe act of clearing an aircraft to land on a runway occupied by another aircraft.

The sequence of events leading to the occurrence was initiated by the relieving controller who did not actively listen to incoming communications during the pre-relief period. The sequence was continued by the relieved controller, who omitted to pass on the position of ACA330 to his colleague during the relief briefing. Although MANOPS clearly states that the above actions are requirements during handover procedures, and both individual controllers recognize the importance of passing the information, because of assumptions and distractions, safety information was not passed. Because the required job aid, the checklist, was not being used, an opportunity to catch the error was lost.

2.2.2 Post-relief Procedures

Once a transfer of position is effected, the relieved controller is no longer responsible for the position. In accordance with MANOPS, a relieved controller, following a transfer of position, is required to remain at the position for an appropriate period of time. Because of the varying volume and complexity of traffic that can be experienced at handover time, the length of the monitoring period is left to the discretion of the relieved controller. The word appropriate is understood by controllers to include "no monitoring time at all" when traffic conditions and circumstances permit.

The following factors influenced the relieved controller's decision to not remain behind following the handover: the traffic density was light at the time; the relieved controller usually worked the same shift as his supervisor and trusted the latter's knowledge and competence; the supervisor was also the unit training officer; and finally, the supervisor pulled the relieved controller's headset communication jack out and plugged his own in, a non-verbal cue that he was now accepting responsibility for the position.

During the investigation, the question was assessed as to whether there should be a mandatory minimum monitor period following every handover. In this occurrence, nearly four minutes elapsed between the time the handover was effected and the first radio communication between the relieving controller and ANU403. Typically, this would constitute an inordinately long time for a relieved controller to remain behind for monitoring purposes during periods of light traffic density. Therefore, staying behind for "an adequate period of time" following handover would have been insufficient for the relieved controller to notice that his colleague had an incorrect picture of ACA330's position. Although the role of
the brief period of overlap after the turnover appears not to have been a specific factor in this occurrence, a number of situations could be envisioned when no overlap could create unsafe conditions.

### 2.2.3 Controller Decision Making

The relieving controller believed that ACA330 was still on the taxiway, and his decision to clear ANU403 to land was the consequence of that belief. The controller's mental model of the situation was faulty because it was based on incomplete information as a result of the inadequate handover carried out by both controllers.

Although the ASDE and the ACA330 crew's position report could have also provided the controller with information about the aircraft's position, neither piece of information was compelling enough to affect the mismatch between the controller's mental picture and the actual situation. The ASDE monitor location did not lend itself to easy viewing from the airport controller's position. The controller stated that he looked at the monitor from his position and noticed the radar return from BRM600 on the taxiway leading to the threshold of runway 25, but he interpreted that information to be the return for ACA330. Although the radar return for ACA330 on the threshold was most likely also displayed, it went unnoticed either because the return was not compelling enough from the controller's viewing position or because the utility of the ASDE as a job aid was not being realized due to the ASDE's problematic location. With respect to ACA330's position report, the phrase "in position, ready to go, 25" is technically correct, and would normally be interpreted to mean the aircraft was on the runway, but the controller had already concluded that the aircraft was holding on the taxiway, and he did not notice the discrepancy.

### 2.3 Transfer Procedures

#### 2.3.1 Use of the Transfer of Position Responsibility Checklist

The analysis of the reason(s) why the checklist had not been used for some time revealed that there was an attitude of "too many, not enough, or inappropriate items" on the checklist. The following factors probably led to this attitude: unit guidelines for controllers to follow at the time of transfer of position responsibility were not available; the checklist was not available for the position at the time of the occurrence, and neither the operating controllers, the supervisors, nor unit management were aware that it had been missing for some time; and, the evaluations division did not have specific written procedures to ensure the checklist was both available and utilized, and had therefore not specifically reported on this aspect during the last routine evaluation. It is clear from the above that the lack of adherence to directives pertaining to the use of the checklist had been an accepted practice at the unit's airport control position for some time.

#### 2.3.2 Communications Monitoring

Since the controller being relieved was aware that relieving controller was standing close by and ready to assume control, he incorrectly assumed that the relieving controller had heard him clear ACA330 to position on runway 25. As a result, he did not consider it necessary to remind the relieving controller of this
fact. The relieving controller missed the opportunity of listening to the incoming and outgoing communications at the time of the pre-relief monitoring period, and, having unplugged the headset of the controller being relieved, did not learn that ACA330 was on the runway.

2.3.3 Flight Progress Strip Marking

The methods used to ensure key or critical information is retained by the individual, and transferred properly to others (e.g., the cocking of strips to identify that further work is required, and how it is both transferred, received and acknowledged), are not standardized by procedures for VFR controllers. Without standardization, the style and method of noting critical actions that require further action can vary and create opportunities for misunderstanding, as was the case in this incident. Interviewed controllers stated that they did not believe a standard method to indicate that an aircraft was on a runway without a take-off clearance was required.

2.4 Location of the ASDE Monitor

The ASDE is a tool to aid the controller in identifying aircraft and vehicle position on the ground, especially at night and in conditions of poor visibility. Since the ASDE was not located in a "user-friendly" viewing position for the airport controller, its usefulness as a system defence was diminished, which may have contributed to the relief controller’s lack of situational awareness. In this occurrence, where the controllers could not see the threshold of runway 25, the ASDE information was important and warranted careful consideration.

Reportedly, at this unit, the ASDE was considered more of a useful tool to the ground controller than to the airport controller. The lack of additional unit guidelines on the use of the ASDE did not reinforce the requirement for the airport controller to pay close attention to the ASDE monitor. Management's verbal requests to maintenance to install a second monitor by the airport controller's console were not carried out. To properly interpret the ASDE information, the airport controller had to get up from his console area and walk over to the monitor. The above factors likely combined to decrease the perceived usefulness of the ASDE by the airport controllers.

2.5 Language of Communications

When the relieving controller cleared, in French, ANU403 to land on runway 25, the crew of ACA330, on the runway, did not appreciate the impending unsafe condition. The capability of both flight crews to understand the clearance would have provided an additional defence mechanism by which the controller error could have been detected.

Ten seconds after ANU403 was cleared to land, the airport controller asked ACA330 to confirm that they were ready, to which ACA330 replied "Yeah, Air Canada three-thirty is in position, ready to go, 25." The controller told ACA330 that there was an aircraft two miles out on final and they would go after he was down. Neither of the ANU flight crew remembered hearing the last exchange between the controller and ACA330, 40 seconds before the risk of collision occurred; ANU403 had already been cleared to land. It is possible that the flight crew of ANU403 were concentrating on their final approach and on the acquisition of the runway environment at the time to the point where they did
not hear the transmission, particularly because it was not in the language they had been using with ATC.

There were exchanges, in French, between ATC and ANU403 that referred to their landing on runway 25. These exchanges, if understood by the Air Canada flight crew, would have provided an opportunity to avoid the risk of collision. Canada opted for the two-language operation at many of its ATC units to avoid the risks of mis-communication associated with crews having to operate in their second language. That leaves the alternate risk of some important information not being understood because it is in the other language. These risks were identified and offset by special procedures such as the highlighting of the relevant controller's "strips". During the TSB survey of two years of operations of the three major ATS units in Québec, nothing was found to indicate that bilingual air traffic control is a factor in air proximity events. There was nothing to indicate that the bilingual service problem in this event was the result of a systemic deficiency.

2.6 Unit Management

The lack of continuity in both the unit and operations managers' positions had a detrimental effect on the capability of these two offices to provide effective guidance with regard to the directives and to monitor compliance with the standards. A lack of management oversight in the following areas of the tower operation was noted: the unresolved problem of the location of the ASDE monitor; controls to ensure that operational personnel demonstrate proficiency; the availability and use of handover checklists; monitoring of supervisors' qualifications; and the unit training officer not writing the required KVT exam.

2.7 NAV CANADA Audit Procedures and Tracking

CASB Recommendation 90-48 urged the Department of Transport to increase its efforts for monitoring ATC operations through unit evaluations to ensure consistent application of prescribed standards and procedures. At that time, the standard for unit evaluation cycles was two years for major units, and three years for smaller ones. Despite the CASB Recommendation 90-48, TC increased the cycle to three, four, or five years in June 1993. In September 1996, the NAV CANADA Monitoring and Evaluation Division was required to conduct an evaluation of the Ottawa tower at least once every four years. The four-and-a-half-year interval between the last two Ottawa evaluations indicates that the Monitoring and Evaluation Division was still not meeting its stated requirement, and had in fact decreased its monitoring activities in the period between the predecessor Board's 1990 recommendation and the September 1997 change.

At the time of the occurrence, the NAV CANADA Monitoring and Evaluation Division did not have a defined set of audit verification points established to verify that ATS units were complying with standard practices and procedures. Division auditors did not detect that there were no amplifying guidelines in the unit's operations manual, as required, and they did not verify that operational personnel were properly certificated, all of which demonstrate a deficiency in compliance verification. As a consequence, safety items, such as the requirement to use the checklist, were missed. Finally, the NAV CANADA Monitoring and Evaluation Division, because of its methodology, did not detect tardy unit responses to deficiencies identified during audits, and unresolved
deficiencies previously identified are not being eliminated through systematic follow-up.

Canada's air traffic system is presently in a period of great change, the air industry is growing rapidly, and its personnel turnover is high; the conditions are probably just as dynamic as those which existed at the time of the CASB's 1990 special investigation into ATC Services. The CASB report on its investigation suggested that there was "a need for an extraordinary effort to ensure the maintenance of quality control." It is the Board's opinion that effective monitoring of the system is, now, more important than ever. However, this investigation has shown that the low frequency and lack of thoroughness of the Ottawa tower's evaluation has impeded NAV CANADA's ability to detect, and therefore correct, unsafe practices at that unit.

3.0 Conclusions

3.1 Findings

1. The control tower was staffed in accordance with unit policy at the time of occurrence.

2. The relieving controller had not completed the required KVT in the last three years.

3. The prevailing visibility at the time of the occurrence precluded controllers from seeing the threshold of runway 25.

4. The relieved controller did not advise the relieving controller that he had cleared ACA330 to position on runway 25.

5. There was no ASDE monitor available at the airport controller's console; this had been identified as a deficiency in the two previous audits.

6. The airport controller could not adequately view the ASDE monitor from his console position.

7. ANU403 was cleared to land on runway 25 by the relieving controller while ACA330 was holding in position on the threshold of the same runway.

8. The relieved controller used the strip-cocking method to remind himself that an aircraft was on an active runway, but the relieving controller did not use this method and did not notice the cocked strip after he took over.

9. There is no standard method of ensuring that VFR controllers remember that they have cleared an aircraft to position on a runway but have not cleared it for take-off.

10. The relieving controller did not monitor incoming radio communications during the pre-relief period.

11. The transfer of position responsibility checklist was not available at the airport controller's position at the time of the occurrence, and had reportedly been missing for some time.

12. Unit management personnel were not aware that the checklist was not
available at the airport controller's console.

13. The flight crew of ACA330 did not understand the radio transmission clearing ANU403 to land on runway 25, because the clearance was in French.

14. Unit management did not provide the required amplified guidance with respect to the transfer of position responsibility, nor with respect to the use of the ASDE at night and during periods of reduced visibility.

15. Unit management did not ensure all operational controllers complied with the requirement to write the KVT annually.

16. The NAV CANADA Monitoring and Evaluation Division did not have a defined set of audit verification points established to verify that ATS units were complying with standard practices and procedures.

17. The NAV CANADA Monitoring and Evaluation Division, because of its methodology, did not detect tardy unit responses to deficiencies identified during the Ottawa unit audit, and unresolved deficiencies previously identified were not being eliminated through systematic follow-up.

18. Transport Canada's ATS monitoring and evaluations division conducted the last two routine evaluations of the Ottawa ATS unit over a time span of four and one half years, when the stated requirement is to conduct an evaluation at least every four years.

3.2 Causes

A risk of collision occurred as the result of an ineffective controller handover procedure. Contributing to this occurrence were the following: no method other than memory was used to ensure the completeness of the handover briefing; the relieving controller did not adequately monitor incoming communications; the location of the airport surface detection equipment monitor was inadequate for airport controller use; there was no standard method by which controllers kept track of uncompleted critical actions; there were deficiencies in the management and supervision of the unit; and, NAV CANADA audit procedures of the unit were inadequate.

4.0 Safety Action

4.1 Action Taken

4.1.1 ASDE Location

The airport controller could not adequately view the ASDE monitor from his console position. The ASDE monitor was replaced by a larger one by the end of March 1997 as a temporary measure until a second monitor was installed at the airport controller's position in April 1997.

4.1.2 Transfer of Position Responsibility Checklist

The transfer of position responsibility checklist was not available at the airport controller's position at the time of the occurrence, and had reportedly been missing for some time. The checklist has since been made available at the
position, and the Unit Manager has taken action to ensure direction to control staff is in place for the use of the checklist at the time of position responsibility transfer.

4.1.3 Follow-up to Items of Consequence

The NAV CANADA Monitoring and Evaluation Division, because of its methodology, did not detect tardy unit responses to deficiencies identified during the Ottawa unit audit, and unresolved deficiencies previously identified were not being eliminated through systematic follow-up. NAV CANADA has indicated that, since January 1997, a systematic process has been in place to facilitate timely follow-up to items of consequence identified during unit evaluations.

4.1.4 Use of Checklists During Unit Evaluations

The NAV CANADA Monitoring and Evaluation Division did not have a defined set of audit verification points established to verify that ATS units were complying with standard practices and procedures. NAV CANADA is currently evaluating the use of checklists as an integral part of the unit evaluation process.

4.1.5 Unit Management's Implementation of ATSAMM Directives and Guidelines

Unit management did not provide the required amplified guidance with respect to the transfer of position responsibility, nor with respect to the use of the ASDE at night and during periods of reduced visibility. NAV CANADA reports that the Ottawa Unit Manager has now provided such guidance.

4.1.6 Annual Knowledge Verification Test Requirements

The NAV CANADA Monitoring and Evaluation Division did not have a formal procedure to verify the currency of knowledge verification tests for each operational controller during unit evaluations. The Monitoring and Evaluations Division is currently evaluating a checklist to be used during unit evaluations. This checklist includes a specific directive for Evaluations Officers to ensure a current copy of the KVT is on file for each operational controller.

4.1.7 Implementation of Ergonomic Presentation of Equipment in Tower Cabs

NAV CANADA reports that in August 1997, NAV CANADA'S ATS System and Equipment Requirements Division tabled initiatives to address the ergonomics for the integration of current and future equipment into tower cabs.

4.1.8 Frequency of Unit Evaluations

Transport Canada's ATS Monitoring and Evaluations Division conducted the last two routine evaluations of the Ottawa ATS unit over a time span of four and one half years, when the stated requirement is to conduct an evaluation at least every four years. NAV CANADA has recently implemented a two- or three-year
evaluation cycle, depending on the size of the unit. Furthermore, a Safety Management program has been implemented which aims to integrate sound risk management standards, methodologies and tools into company policies and practices.

4.2 Action Required

4.2.1 Control Tower Performance Aid

The controller being relieved cocked the flight progress strip of the aircraft that had been cleared to position. The relieving controller did not attend to the cocked flight progress strip left by the relieved controller because he did not use this memory aid. Currently, some controllers use the strip-cocking method, whereas others use a different performance aid or simply rely on their memory. In tower operations, there is presently no requirement for a standard method to be used by airport controllers to remind themselves or others that they have cleared an aircraft into position on a runway without having issued a take-off clearance.

As a result of the aircraft runway collision at Los Angeles Airport on 1 February 1991, the NTSB recommended that any job aids and procedures, such as strip marking and flight strip forwarding, which are designed to improve each airport controller's performance, should be adopted and emphasized, repeatedly, until other independent, automated systems become available. In Canada, the lack of standard methods for reminding controllers of critical actions that must be performed was identified in another occurrence (A96O0196), and is also an issue being looked at in a broader context in the ongoing investigations A97H0007 and A97P0133.

An ATS Information Bulletin (ATSI-8709) was issued on 14 December 1987 stating that: "the cocking of flight progress strips is a long established control technique to remind controllers (VFR or IFR) that some type of action must be performed." Although the procedure is mandatory for IFR operations, it is not a requirement in tower operations.

Without some form of accepted standardization in tower operations, the style and method of noting critical activities which require further action by an airport controller could vary and create opportunities for misunderstandings. Because misunderstandings between controllers could result in accidents, the Board recommends that:

NAV CANADA institute without delay a standard method to remind airport controllers of critical actions that have not been completed.

A98-01

4.3 Safety Concerns

4.3.1 Unit Guidelines, Rules and Directives

The NAV CANADA Monitoring and Evaluation Division did not have a defined set of audit verification points established to verify that ATS units were complying with standard practices and procedures. During the Ottawa routine
evaluation in 1996, important procedural deviations were not identified and it is possible that, since similar evaluation methods were in place during previous inspections of other units, the same or similar omissions may have occurred at those facilities.

NAV CANADA is evaluating a formal checklist methodology for use in unit evaluations. This approach should, in the long term, facilitate a comprehensive verification of the applicable standards of service. Nevertheless, the Board is concerned that, in the short term, existing deficiencies may continue to go undetected until all units have been evaluated in accordance with the new verification methodology.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 12 August 1998.

Appendix A - List of Supporting Reports

The following TSB Engineering Branch Report was completed:

LP 41/97 ATC Tape Transcript

This report is available upon request from the Transportation Safety Board of Canada.

Appendix B - Glossary

ANS Air Navigation Services
ASDE Airport Surface Detection Equipment
agl above ground level
ATC air traffic control
ATS Air Traffic Services
ATSAMM Air Traffic Services Administrative and Management Manual
CASP Canadian Aviation Safety Board
EST eastern standard time
hr hour(s)
IFR instrument flight rules
KVT knowledge verification test
LOC BC Back Course localizer for non-precision approach procedures
MANOPS Manual of ATS Operations
NTSB National Transportation Safety Board (United States)
OSS Operational Support Specialist
PIREP pilot report of weather conditions in flight
RDATS Regional Director, ATS
SPECI special weather report
TAF Aerodrome Forecast
TC Transport Canada
TCA Terminal Control Area
TCU Terminal Control Unit
TSB Transportation Safety Board of Canada
UTC coordinated universal time
VFR visual flight rules
1. See Glossary at Appendix B for a list of acronyms.

2. All times are EST (coordinated universal time minus five hours) unless otherwise noted.

3. Visual flight rules

4. Instrument flight rules

Air 1997

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.

Risk of Collision Between
Air Atlantic British Aerospace
Jetstream 41 C-FTVQ and
Department of National Defence
Lockheed T-33 Pirate 61
Fredericton, New Brunswick 16 nm SE
17 April 1997

Report Number A97H0004

Synopsis

Air Atlantic Flight 427, a Jetstream 41, had departed Saint John, New Brunswick, and was approaching Fredericton from the south-east along the Saint John River. Pirate 61, a military T-33 jet aircraft engaged in a military training exercise, was established in a holding pattern along the Saint John river. A risk of collision occurred when the two aircraft passed within 100 feet of one another.

Other Factual Information

The Jetstream, with a crew of three and 16 passengers onboard, had departed Saint John, New Brunswick, on an instrument flight rules (IFR) flight plan at 1122 Atlantic daylight time (ADT). This was a regularly scheduled commercial flight to Fredericton. The aircraft had been cleared to the Fredericton airport via direct to the Frenn intersection then direct to Fredericton, at an altitude of 5,000' above sea level (asl).

Once airborne out of Saint John, the crew of the Jetstream requested clearance to proceed "visual, around the camp", which was approved by the Moncton Area Control Centre (ACC). Provided that the crew kept the river to the left side of the aircraft, this route would ensure that the aircraft remained clear of the Gagetown restricted area CYR 724 (refer to appendix A). While this route kept the Jetstream within the designed protected airspace of its direct route to the Frenn intersection (V310 airway), the aircraft was as much as 1.6 nautical miles left of the centreline of the airway. This was a digression from the IFR requirement that the flight adhere as closely as possible to the centreline of the cleared routing. This adhoc "visual, around the camp" procedure had been a common IFR practice for a number of years whenever visual meteorological conditions (VMC) prevailed between Saint John and Fredericton. Generally, the
route started toward the Frenn intersection, but turned left before reaching it and followed the right side of the river to Fredericton.

At 11:30:03, the Moncton ACC controller, observing a possible conflict, advised the Jetstream crew of westbound VFR traffic at the aircraft's 11 o'clock position six miles at an unconfirmed altitude of 4,300 feet. The crew of the Jetstream noted traffic on their traffic collision avoidance system (TCAS)\(^{(2)}\) corresponding to that position; however, the traffic was not detected visually. At 11:30:32, the controller informed the flight that the same traffic, possibly a high performance jet, was now at its 12 o'clock position five miles and was turning to an opposite direction at an unconfirmed altitude of 4,100 feet. The crew again noted a return on their TCAS corresponding to this latest information, but the traffic was not seen, despite both pilots looking out for it. At 11:31:01, the controller advised the Jetstream crew that the target was now at their 12 o'clock for three miles at 4500 feet and climbing. At that time, radar data indicates that the Jetstream was at 4,961 feet and commenced a shallow descent. The captain finally visually detected a military T-33 aircraft when it suddenly appeared on an apparent collision course. The captain steepened the descent and commenced a shallow-banked turn to the right. Both crew members observed the belly of the T-33 crossing in front of them in a steep-banked, climbing attitude proceeding from the bottom left to the top right of the Jetstream's pilot windscreen. The T-33 was observed to totally fill the pilot's windscreen, and the crew estimated the distance to be approximately 50 feet.

Pirate 61, a military T-33 aircraft with one pilot onboard, had departed Canadian Forces Base (CFB) Greenwood, Nova Scotia, to participate in a military training exercise in CFB Gagetown's military restricted area CYR 724. The flight was being conducted in accordance with visual flight rules (VFR).

The purpose of the T-33's mission was to assist in the training of forward air controllers in directing air strikes against simulated ground enemy targets within CYR 724. This was but one of a number of such missions in an exercise named Nimrod Gale which was scheduled from 16 April to 2 May 1997. Throughout the exercise intense artillery, small arms fire, and jet fighter and helicopter activity was planned within CYR 724. In the interest of safety, aircraft awaiting specific taskings were required to remain clear of CYR 724 until authorized to enter the area by the forward air controllers. The presence of numerous weapons ranges on the western side of the Gagetown training area precluded any overflights coming from the west. Several geographical areas surrounding the restricted area had been designated as VFR holding points for these aircraft. These holding points, the majority being to the east and south of CYR 724, had been in use on such exercises over the previous 10 years. Dependant on operational circumstances, aircraft could be required to loiter in the vicinity of these holding points for varying lengths of time.

One such holding point was Initial Point (IP) Delta, situated at the northern tip of Gagetown Island on the Saint John river. This IP is located within the specified boundaries of V310 airway and is approximately 2.4 nautical miles west of the airway's centre line. V310 is classified as Class E controlled airspace in which IFR and VFR flight operations are authorized. The lateral dimensions of the controlled airspace for this airway are 4 nautical miles each side of its centreline. This IP also lies within two miles of the direct route between the Saint John airport and Frenn intersection. It should also be noted
that the Saint John River is a popular route for aircraft operating on VFR flight plans between Saint John and Fredericton.

The occurrence T-33 aircraft had arrived early at the southern boundary of the restricted area. The pilot was informed by the military forward air controller that his first run to the target would begin from IP Delta. The pilot flew to this IP, remaining clear of the range and following the river at 4500 feet asl. This altitude was chosen by the pilot because it satisfied the VFR direction of flight altitude requirement, and because of noise abatement, fuel conservation, and ease of navigation considerations. The pilot's intent was to enter a holding pattern over IP Delta while awaiting his instructions for his simulated bombing run. The T-33 arrived at its holding point at approximately 11:28 at which point the pilot entered a left-hand racetrack holding pattern. Radar data reveals that the aircraft's altitude fluctuated by plus or minus 200 feet while in the holding pattern.

The pilot of the T-33 first saw the Jetstream in a descent, overtaking and flying under him from the 7 o'clock position while the T-33 was in a left-hand orbit and passing through a north-westerly heading. This occurred as he was commencing his second racetrack pattern. The T-33 pilot estimated that when he saw the Jetstream that the two aircraft were between 300 and 500 feet apart.

At approximately 11:31:28, the two aircraft came close to colliding after approaching each other head on at a closure rate of approximately 400 knots. The distance between the two aircraft at their closest separation was estimated, based on the Jetstream pilots' observations and radar data, to be less than 100 feet.

The weather at the time of the occurrence was described by both crews as good with some haze in the area. The nearest aviation weather reporting station was at CFB Gagetown, 11 nautical miles to the west. At 11:41, the weather observed at Gagetown was as follows: light winds, visibility 15 statute miles in light rain showers, scattered cloud at 5,100 feet, broken cloud at 8,000 feet, and an overcast layer at 25,000 feet.

Pilots operating IFR are required to provide their own separation visually from VFR aircraft when operating in visual weather conditions. Similarly, pilots of aircraft flying under VFR are required to provide their own separation from other aircraft. Both aircraft, therefore, were being flown using the see-and-avoid principle for collision avoidance. The effectiveness of this concept is dependant on the flight crew detecting aircraft on collision courses and taking appropriate and timely avoiding action. Breakdowns in the see-and-avoid principle are due almost entirely to the failure to see a threat aircraft. A pilot's ability to visually detect another aircraft is affected by many factors. Elements pertinent to this occurrence include physiological limitations of the human visual system, the pilot's awareness of the presence of another aircraft, and conspicuousness of the aircraft.

The human visual system has physical limitations which reduce effective visual performance. For example, people are particularly attuned to detecting movement but are less effective at detecting stationary objects. Unfortunately, because of the geometry of collision flight paths, an aircraft on a collision course will appear to be a stationary object in the pilot's visual field.
In a potential mid-air collision situation, aircraft size and speed will influence a pilot's ability to acquire a target visually. In general terms, assuming that a pilot is looking in the correct direction, the visual detection of a target is largely a function of its size. A pilot will only see an approaching aircraft when the size of the target becomes large enough to meet the minimum resolution capability of the eye. The target will grow slowly, becoming conspicuously large only in the final brief period before collision when effective evasive action may not be possible. In fact, according to a 1989 USA Department of Transport report on the study of the effectiveness of the see-and-avoid concept, at closing speeds of 400 knots and above, escape from collision in these encounters is primarily due to chance.

It is generally recognized that traffic advisories will improve a pilot's ability to visually acquire another aircraft. Research conducted by the Lincoln Laboratory during traffic alert and collision avoidance system (TCAS) flight testing confirms that the advisory provides advance warning of a potential conflict and will tend to increase the time that the crew will devote to the visual search for the traffic. Moreover, the advisory will aid the pilot in concentrating the visual search in the proper direction. These studies showed that guidance as to where to look increased the acquisition probability for the pilots, and found that a pilot who had been alerted to the presence of another aircraft was eight times more likely to see the aircraft than was a pilot who had not been alerted. In this instance, the T-33 aircraft was equipped with only one, single-channel ultra high frequency (UHF) radio. The primary medium for aeronautical communications in Canada is very high frequency (VHF) and very few (if any) civilian aircraft are equipped with UHF radios. The T-33 aircraft is the only Canadian military aircraft in service today which is equipped only with a single UHF radio. The pilot was monitoring his operational UHF frequency. Under these circumstances, the pilot could not be informed by ATS of other aircraft traffic in his area. Moreover, the T-33 was not equipped with a TCAS which could have alerted the pilot of an approaching aircraft.

The contrast between an aircraft and its background affects significantly an aircraft's detectability, target detectability being hampered when the target's outline and brightness interacts with a complex and similar background. This detectability problem, known as contour interaction, is reduced by rapid angular motion relative to the background; however, as previously mentioned, collision or near collisions will not involve rapid relative motion. At the time of the occurrence, most of the snow along the Saint John river had melted, and snow patches still covered parts of the typically greyish and drab early spring countryside. The T-33 aircraft involved in this occurrence was painted in various shades of grey in a low-contrast camouflage pattern. This pattern would have, by its very design, rendered the aircraft relatively indistinguishable from its background. Similarly, the blue and grey paint scheme of the Jetstream would have provided little contrast when viewed against the cloud cover.

**Analysis**

The probability of a mid-air collision in a given airspace is predicated, in part, on the number of aircraft operating in that airspace. The area immediately east of the Gagetown restricted area CYR 724 possesses two characteristics which attracts IFR and VFR traffic. On the one hand, aircraft operating IFR between
Saint John and Fredericton are obliged to fly along the V310 airway and, pilots operating VFR between these two points are naturally inclined to follow the Saint John river. Given this concentration of civilian aviation traffic along this corridor, the use of IP Delta as a holding point for the T-33 military aircraft exposed military aircraft holding in this corridor to an increased potential for a mid-air or near mid-air collision with the civilian traffic. The informal practice of IFR traffic using the river as a "visual, around the camp" route further increased the volume of traffic over and near IP Delta.

The crew of the Jetstream sighted the T-33 during the final seconds of their approach while the pilot of the T-33 aircraft sighted the Jetstream after the near collision event had occurred. This occurrence illustrates the limitations of the see-and-avoid concept in a number of ways.

The Jetstream crew were alerted to the military traffic by the ATS controller and by their TCAS equipment. They were actively looking for the military jet traffic, but, despite their highly motivated efforts to sight the traffic, the crew were unsuccessful in seeing the T-33 until the very final seconds.

When first advised of the T-33's presence, the Jetstream crew were overtaking the T-33 and were above and six miles behind it. The T-33 would have been below the horizon, and its low contrast paint scheme and relatively small size when viewed from this distance and against the surrounding terrain would have rendered the aircraft virtually impossible to detect. When advised that the T-33 was at five miles and had turned toward them, still below their altitude, the Jetstream crew's problem in detecting the T-33 was further compounded by a reduction in its profile which was now being viewed head-on and by the target now remaining more or less stationary in their field of view due to its collision trajectory. The closing speed of 400 knots limited significantly the time available for detection.

When advised that the T-33 was at 4500 feet and three miles climbing directly toward them (this information was also displayed on their TCAS), the crew unknowingly exacerbated the situation by commencing a shallow descent toward the target. This descent was not initiated consciously and was likely due to the crew focusing their attention toward locating the target, with a resulting lapse in the maintenance of altitude control.

The T-33 pilot, on the other hand, was contending with his own set of problems. The aircraft was equipped with only one UHF radio, and operational requirements dictated that the pilot monitor the forward air controller's frequency. The pilot, therefore, was unable to advise any ATC agency of his intentions nor was he able to be informed of the presence of the Jetstream. Moreover, the T-33 was not equipped with TCAS equipment which could have alerted the pilot of an aircraft approaching on a collision course. As a result, the pilot was required to scan his entire visual field rather than concentrate his scan in the direction of the approaching Jetstream.

When the T-33 initially entered the holding pattern, it was being overtaken directly from above and behind by the Jetstream, where it would not have been visible to the T-33 pilot. When the T-33 pilot entered his turn to the south-east, in a direction directly toward the Jetstream, the aircraft were approximately five miles apart. At that distance, the Jetstream would have presented a relatively small visual target, and its blue and grey colour scheme would have blended in
with its background when viewed against the existing high cloud cover.

Findings

1. The two aircraft came close to colliding after approaching each other at a closing speed of approximately 400 knots.

2. The crew of the Jetstream sighted the T-33 during the final seconds of their approach, while the pilot of the T-33 sighted the Jetstream after the near collision event had occurred.

3. The risk of collision occurred over a military visual holding point established within the confines of airway V310 and along a known VFR route.

4. The Jetstream crew was flying an informal "visual, around the camp" IFR procedure.

5. The T-33 was not equipped with onboard radio (VHF) or electronic equipment (TCAS) to alert the pilot to the presence of other aircraft.

6. The T-33's camouflage grey paint scheme blended in with the surrounding terrain.

7. The relatively small profiles of both aircraft when viewed head on made it difficult for the crews involved to visually detect either aircraft.

8. The high closure rate provided little time for the crews to detect the approaching aircraft.

Causes and Contributing Factors

Neither flight crew saw the other aircraft in time to avoid the risk of collision. Contributing to the occurrence were the inherent limitations of the see-and-avoid concept which preclude the effective separation of aircraft with high closure rates and T-33's camouflage paint scheme combined with its relatively small profile, which rendered the aircraft virtually invisible against its geographical background.

Safety Action

Following this occurrence, DND personnel briefed all CFB Greenwood squadron pilots to exercise added vigilance when flying VFR. T-33 close air support pilots have been briefed to hold on the western side of the Saint John river when using IP Delta (as well as two other IPs in the immediate area) and to overfly the IPs themselves only when commencing their final run to the target. Exercise planners have been requested to remove five other IPs in the vicinity of the Saint John River from future exercises, and squadron pilots were briefed not to use these IPs in the future.

The T-33 aircraft fleet is presently undergoing an update, to be complete by the year 2000, which will provide for both UHF and VHF communications capability and the fitment of wing-tip strobe lights. When upgraded aircraft arrive on squadron, procedures will be initiated to ensure that ATC control frequencies are monitored on VHF while working missions in CYR 724 on UHF.
On 4 September 1997, NAV CANADA directed Moncton ACC to discontinue the use of the phraseology "visual around the camp is approved". Moreover, Moncton ACC were directed that, in the case of aircraft en route from Fredericton to Saint John requesting to proceed VFR, the aircraft may do so in accordance with VFR until a specified time, altitude or location (see MANOPS 444.2).

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 23 December 1997.

Appendix A

1. All times are ADT (Coordinated Universal Time minus three hours) unless
otherwise noted.

2. TCAS is an independent system designed to support the air traffic control system and complement the "see-and-avoid" concept. TCAS continuously scans the airspace around an aircraft and seeks a response from the transponders of nearby aircraft. TCAS monitors flight paths based on the responses from the transponders. The system generates a traffic advisory (TA) or resolution advisory (RA) when any flight path is going to enter the collision zone around the aircraft. The TCAS on the occurrence aircraft was an early model which did not provide a resolution advisory.


Air 1997

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 Occurrence Report
Loss of Centerline Landing Gear
Air Canada
Airbus A340-313 C-FYLD
Frankfurt, Germany
01 September 1997

Report Number A97H0008

Summary

The Air Canada Airbus A340-313 was on a flight from Frankfurt, Germany, to Vancouver, British Columbia. During rotation for lift-off in Frankfurt, a loud bang was heard in the cabin. Several passengers reported feeling the floor of the cabin rise with the bang. When the flight crew selected the landing gear up after take-off, it did not retract. On a subsequent recycling, the landing gear retracted but there was an indication of a disagreement in gear position. Departure control informed the flight crew that landing gear pieces, later identified to the flight crew as being from the centerline landing gear, had separated from the aircraft. The captain advised the cabin crew to prepare for an emergency landing. The flight crew lowered the landing gear using manual gear extension procedures. The aircraft landed at Frankfurt without further incident after having circled for two hours burning off and jettisoning fuel. There was no injury and no additional damage to the aircraft.

Ce rapport est également disponible en français.

Other Factual Information

The rotation speed at take-off was about 153 knots. At 90 feet above ground level the ram piston, lower torque link, axle, wheels, and tires of the centerline landing gear separated from the aircraft. The separated landing gear, which weighed about 630 kilograms, travelled several thousand feet across airport property but did not cause any damage.

The aircraft was equipped with this centerline landing gear to permit operation with an increased maximum certified operating weight of 271
000 kilograms. For the occurrence flight, the take-off weight was about 224 900 kilograms.

The centerline landing gear is a dual-wheel, forward-retracting gear that incorporates a mechanical downlock and an airframe-mounted uplock. It is positioned under the centre of the fuselage and directly in line with the rear wheels on the left and right main landing gear bogies. The centerline landing gear's primary purpose is to carry a share of the aircraft weight on the ground so as to not overload the main landing gear. Three major assemblies make up the centerline gear: a shock strut, a drag stay with a downlock, and a retraction actuator. The shock strut has a transverse axle on which the two centerline wheels and tires are mounted. One purpose of the shock strut is to decelerate the downward motion of the aircraft without applying damaging loads to the gear attachment points.

The shock strut is a two-stage, oleo/pneumatic shock absorber that takes energy from the in-stroke, such as on landing, by utilizing a dual-diameter, ram-like piston to compress gas and displace hydraulic fluid. As the ram piston moves into the cylinder of the shock strut under the tire compression forces, it displaces hydraulic oil into the upper chamber which is designed to gradually increase resistance as the piston strokes inwards. The upper chamber is called the stage 1 low-pressure chamber and is statically charged with a hydraulic oil/nitrogen mixture to about 700 pounds per square inch gauge (psig). The lower chamber is called the stage 2 high-pressure chamber and is statically charged with nitrogen gas to about 2 000 psig.

Two damping rings act as valves to restrict the flow of hydraulic fluid in one direction but not in the other. The in-stroke damping ring restricts the rate at which fluid can be pushed past it into the upper chamber on the in-stroke but allows relatively unrestricted flow in the opposite direction. The rebound damping ring works in the opposite sense. Together they serve to control the rate of in-stroking and the rate of rebound of the gear.

The seal between the low-pressure chamber and the high-pressure chamber is a floating piston which is free to move downwards inside the ram piston and further compress the high-pressure charge once the low-pressure chamber exceeds 2 000 psig on the in-stroke. This increases the energy-absorbing volume of gas under compression and slows the build-up of pressure in the stage 1 chamber.

The charges in the two chambers are replenished by a servicing technician through separate fill valves designated as Valve "A" for the low-pressure chamber and Valve "B" for the high-pressure chamber. Corresponding "A" and "B" gauges are mounted on the gear leg for reading the static chamber pressures.

The order in which the chambers are ground-serviced is critical to ensuring that the system is charged properly. The proper procedure calls for the high-pressure, 2 000 psig chamber to be charged first. If the low-pressure, 700 psig chamber were to be charged first, the subsequent filling of the high-pressure, 2 000 psig chamber would
cause both chambers to be charged to 2 000 psig. Such a condition would cause the oleo to become very stiff and lose much of its ability to function as a shock absorber.

On 22 August 1997, nine days prior to the incident in Frankfurt, the aircraft had a hydraulic failure which necessitated an emergency gear extension for landing. An emergency extension does not extend the centerline gear. As a consequence, a servicing crew had to discharge both chambers in the centerline gear on the ground in order to extend it for resetting. The chambers then had to be recharged. The recharging was completed according to the guidance provided by instructions on a plate attached to the gear leg, Inflation Chart placard P/N 15272-103. The example on this plate reads as follows:

EXAMPLE:-
GEAR FULLY EXTENDED (H = 18.9 INCHES) AND AT 20C
INFLATE PORT "A" TO 700 PSIG (48.3 BAR)
INFLATE PORT "B" TO 1 993 PSIG (137.4 BAR)

While the placarded instructions above it are correct, the example has its steps in the wrong order. If the example were followed in the order presented, then the procedure would be completed in reverse order, resulting in a Stage 1 low-pressure chamber charge of nearly 2 000 psig, that is, about 1 300 psig too much. An over-charged centerline gear strut was found on a Gulf Air A340 during a routine check for leaks in March 1999.

A review of the aircraft maintenance manual (AMM) instructions on the servicing of the centerline gear revealed that they would benefit from clarification. In the aircraft maintenance manual, AMM 32-15-00-401, on page 8 at E., there is a series of steps leading to TASK 12-14-32-614-806 for recharging the centerline landing gear. If this task is carried out exactly as given in 12-14-32 on page 394, dated Jul 01/97, the strut pressures will be correct. There is a danger, however, of the servicing technicians departing from the correct procedure, on noting low Stage 1 pressure. When the Stage 2 pressure is released in this servicing process, the Stage 1 pressure falls to less than half of its usual static value of 700 psig. This is due to the expansion of the Stage 1 volume by the floating piston moving downwards. This is normal; the Stage 1 pressure will return to its nominal static value when the Stage 2 chamber is re-inflated to 2 000 psig. The servicing technicians need to be aware of this. As well, they need to have a clear understanding of what is occurring inside the gear.

Required monitoring of the centerline landing gear's pressure gauges was being completed by the operator's servicing technicians according to the procedures supplied by the manufacturer. The Daily Gas Pressure Monitoring check, gear leg placard P/N 15716-101, was written in such a way as to suggest that there was a minimum acceptable pressure reading but no unacceptable maximum for each of the centerline gear gauges, and that any pressure above the minimum, short of the gauge's red line, would pass. Gauge "A", the gauge for the low-pressure chamber, is readable to a maximum of 3 000 psig. Gauge
"B", the gauge for the high-pressure chamber, is readable to 2 500 psig. This situation could be misleading in that the gauge with the higher scale reads the lower pressure, and a 2 000 psig reading on a gauge calibrated to 3 000 psig does not appear excessive.

Information from the aircraft's digital flight data recorder, on the two flights prior to the incident flight, indicates that the centerline gear strut did not compress enough on landing. The dial face of the gear's low-pressure gauge was marked by its pointer at 1 700 psig during a shock load such as occurred when the landing gear was lost. The acceleration reaction of the aircraft to the landing gear's expulsion resulted in a calculated Stage 1 chamber pressure in excess of 2 000 psig. Stress analysis determined that the nominal pressure of 700 psig was insufficient to fail the weakened gland nut, yet the gland nut failed. These facts are consistent with an overcharging of the Stage 1 low-pressure chamber to about 2 000 psig. This is the pressure that would exist on reverse order charging of the gear chambers which the servicing instructions fail to caution against and provide a placarded example on the landing gear leg with the recharging steps in reverse order.

A gland nut retains a seal carrier in place and thereby keeps elastomeric ring seals positioned to prevent leakage of the strut's compressed gas and hydraulic oil from where the piston emerges out of the cylinder. On take-off from Frankfurt, the initiating event that led to the gear departing the aircraft was a failure of the gland nut. The failed gland nut displayed a defective thread profile that had been present from the time of manufacture. This defect was the result of improper lathe thread cutting technique, in that the cutting tool of the lathe was not backed out sufficiently to clear the thread when the lathe was reversed. An extra groove was cut in the flank of the thread by the same tool that made the original thread, thereby weakening it. This resulted in the gland nut having less retention strength than it was designed to have.

**Analysis**

The separation of the centerline gear on take-off was the result of a combination of an over-pressure condition in the strut and a gland nut that was weakened by a manufacturing defect.

When the aircraft was serviced in Vancouver, nine days prior to the accident, the maintenance crew followed the procedures depicted on the instruction plate on the gear leg. The information on the plate was exemplified in such a way as to invite a reversal in the order of charging for the system. Reversing the order results in an overcharged gear strut. Once the initial charging procedures were completed, there was little possibility that an overcharge would be discovered during routine monitoring inspections as the Daily Gas Pressure Monitoring check only insured that the gear strut pressures were above minimum values. There was nothing in the check to alert ground maintenance workers to an overcharged condition that was still well below the red line on the gauge.
The following Engineering Branch reports were completed:

- LP 136/97 FDR/CVR Analysis
- LP 141/97 Gland Nut Examination
- LP 142/97 Centerline Landing Gear

**Findings**

- The shock strut assembly of the centerline landing gear had a Stage 1 static pressure that was considerably higher than it should have been.

- The placarded instructions for servicing the gear's shock strut were exemplified in such a way as to invite a reversal in the order of charging of its low-and high-pressure stages.

- A reversal in the order of charging of the shock strut stages results in a very stiff, overcharged condition for the gear.

- Instructions for recharging of the centerline gear in the aircraft maintenance manual (AMM) at TASK 12-14-32-614-806 dated Jul 01/97 need clarification.

- The Daily Gas Pressure Monitoring check was unlikely to alert service technicians to an overcharged condition.

- The strength of the gland nut was reduced as a result of a manufacturing defect.

**Causes and Contributing Factors**

The centerline gear separated from the aircraft on take-off when the weakened gland nut was forced out by excessive gas pressure.

Contributing factors to the occurrence were as follows: the placarded servicing instructions for the shock strut contained an error in the example, which led to overcharging of the strut system; the existing Daily Gas Pressure Monitoring check was inadequate to alert service technicians to the overcharging of the strut; the scaling of the low-pressure gauge was such that its red line and its needle position would not arouse suspicion when the strut was overcharged; and the gland nut was weakened by a manufacturing defect.

**Safety Action**

All stocks of centerline landing gear gland nuts were checked by Messier-Dowty for correctness of thread profile. All 59 gland nuts installed on aircraft were inspected. One more mis-machined nut was found with the same incorrect thread profile as that of C-FYLD.

The thread profiles of all gland nuts are now being 100 percent inspected at Messier-Dowty and at the manufacturing subcontractor by
additional methods that will expose any faulty thread profile.

All Aircraft Maintenance Manual procedures on CLG servicing have been revised to improve their clarity; they are available in the 01 July 1998 AMM revision.

The Daily Gas Pressure Monitoring Check procedure was modified in order to add a check for over-pressure and to make it clearer; the TR was available 15 June 1998.

Modifications to the gauges and placards have been produced and were incorporated in Messier-Dowty production units as of February 1999.

A modification to make the gland nut of steel instead of aluminium has been produced and incorporated in Messier-Dowty's April 1999 production.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 23 June 1999.
Air 1997

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.


Report Number A97H0012

Summary

The CL-600-2B16, N8MC, serial number 5329, departed Iqaluit, Northwest Territories, en route to Seattle, Washington, and was initially cleared direct to the geographic point of latitude 63 degrees north (N) and longitude 080 degrees west (W) at flight level (FL) 240, and then subsequently to FL 350. British Airways Flight 279 (BAW279), a Boeing 747-400, G-BNLK, was en route from London-Heathrow, United Kingdom, to Los Angeles, United States, via Iqaluit at FL 350. To ensure the required spacing between the two aircraft, N8MC was to be re-routed via 64N 070W, then to 63N 080W, with a restriction to remain at FL 330 or below until reaching 64N 070W. By the time this change in routing and the restriction was actually given to the pilots of N8MC, they had already flown past 070W and were intercepting the amended outbound track. In order to determine the impact of the routing change on other traffic, the data controller working at the Montreal Area Control Centre (ACC), Nuvilik sector, used the radar data processing system (RDPS) to display the track for N8MC on a nearby radar display. However, in entering the new route, the data controller inadvertently entered the wrong coordinates for the second point along the route and was thereby convinced that N8MC’s position was much farther north in relation to BAW279 than it was in reality. This error was not detected by the controller. As a consequence, the altitude restriction to remain below FL 330 was cancelled. Lateral spacing between BAW279 and N8MC was reduced to approximately 9 nautical miles (nm) laterally and 1,500 feet vertically, where 20 nm or 2,000 feet was required.

Ce rapport est également disponible en français.

Other Factual Information

The Montreal ACC is made up of four specialties, East, North, South and Terminal, each of which is further divided into a number of sectors. The North specialty is a high-level specialty which controls air traffic FL 290 and above for most of the province of Quebec as well as the north-eastern approaches into Canadian airspace from the oceanic control areas. The East specialty is a low-level specialty responsible for controlling most of the province of Quebec north of 47N latitude, with the exception of Québec City areas. Individual sectors within a specialty may be controlled individually or combined, depending on operational
requirements on a particular day.

The East specialty of Montreal ACC is composed of five sectors. On the morning of the occurrence, these five sectors had been combined into two, one of which was comprised of James Bay, Hydro, and Nuvilik sectors. This was a normal and accepted procedure for a Sunday morning. Iqaluit Airport lies within the Nuvilik sector. The combined Nuvilik/James Bay/Hydro sector extends up to and including FL 280. These three sectors have partial radar coverage. Non-radar control procedures are utilized where radar coverage is not available. The airspace in which this occurrence took place was beyond radar coverage.

The Brevoort sector is one of the sectors within the North specialty of Montreal ACC, and controls the airspace overlying the northern part of the Nuvilik sector from FL 290 and above, as well as the oceanic approaches to northern Canada. Radar coverage in the Brevoort sector is available from the sector’s eastern boundary to a few miles west of Iqaluit. The North specialty is equipped with the Northern Airspace Display System (NADS), which provides a visual display of the estimated and/or confirmed positions of aircraft flying within the sector and provides conflict prediction.

Staffing in the East and North specialties of the Montreal ACC at the time of the occurrence was in accordance with unit policies and was reported to be compatible with the workload. The traffic volume and complexity were assessed as moderate. The combined Nuvilik/James Bay/Hydro position was staffed with a data controller and a radio controller who was monitoring a trainee in the radio position. It is the radio position that was in direct contact with the aircraft and was responsible for initiating control actions to separate aircraft. The data controller maintains the data board and coordinates flight information with other sectors and units. The supervisor for the East specialty was working another control position at the time of the occurrence. The supervisor for the North specialty was standing back and assisting with coordination of flight information as required within his own specialty.

At the time the North specialty controller issued the revised route and altitude restriction to N8MC, the East specialty Nuvilik/James Bay/Hydro sector radio controller, a trainee monitored by an on-the-job instructor (OJI), was busy with other traffic in the southern part of the combined sector and was using the Chibougamau radar to provide radar control services there. It is the role of the OJI to provide the trainee with on-the-job experience while at the same time ensuring compliance with all applicable rules and regulations pertaining to the provision of air traffic control services. The OJI must be able to monitor closely all air traffic control (ATC) communications and take over the position from the trainee without requiring a briefing from the trainee. The OJI is provided training in instructional, interpersonal, and debriefing techniques in accordance with NAV CANADA-approved training courses. A controller may volunteer to receive initial training to become an OJI.

The Nuvilik radio controller was expecting Air Baffin Flight 200 (BFF200), a Beech 200 aircraft flying from Puvimituq, Quebec, at FL 250 and estimating Iqaluit at 1415.\(^{(1)}\) At 1337, the Nuvilik radio controller issued a clearance to BFF200, through Kuujjuaq Flight Service Station (FSS), to fly the 275 radial of the Frobay very high frequency omni-directional range (VOR) inbound to Iqaluit and to maintain FL 250. On initial contact with BFF200, 92 nm south-west of Iqaluit at FL 250, the Nuvilik radio controller cleared BFF200 to maintain 16,000 feet above sea level (asl) (see Appendix A - Sequence of Events).

At the same time, the Brevoort sector in the North specialty was controlling BAW279, which reported to the Brevoort sector controller that it had passed the Frobay VOR, located 2.4 nm south-east of the Iqaluit Airport at 1354, at FL 350, and was estimating BODRA intersection located at 6217’N 080W at 1433.

N8MC departed runway 18 at Iqaluit Airport at 1341, with a clearance from Iqaluit direct to a
geographic position of 63N 080W (see Appendix B - Relative Aircraft Tracks), outbound on the 308 radial of the Frobay VOR, and with a clearance to climb to FL 240. On departure, N8MC was issued a restriction to cross 20 nm from the Frobay VOR, at 15,000 feet asl or below, to ensure the required separation between N8MC and BFF200. Five minutes later, at 1346, N8MC reported crossing 21 nm, upon which the Nuvilik radio controller issued a clearance for N8MC to climb to FL 280 and to report passing FL 240. The North specialty Ungava NADSPosition accepted the departure time for N8MC from the Nuvilik data controller and subsequently confirmed that FL 350, along with an amended route and an altitude restriction, was acceptable.

At 1349, eight minutes after N8MC departed Iqaluit, one minute after BAW279 had estimated passing overhead the Frobay VOR, the Nuvilik radio controller issued a revised altitude and altitude restriction, received from the Brevoort sector, to N8MC, to climb to FL 350 and to cross 64N 070W at FL 330 or below. This position was not on the route initially given to N8MC. Moments later, the radio controller issued a revised route to N8MC to proceed from the aircraft’s present position direct 64N 070W, then 63N 080W, then on the flight-planned route. The controller also reiterated the restriction to remain at FL 330 or below. One and a half minutes later, the pilot of N8MC reported that the aircraft had already passed 64N 070W and was turning right to intercept the route to 63N 080W. The pilot also asked for confirmation that it was the correct action, to which the radio controller replied in the affirmative and, at 1353, N8MC requested confirmation that a climb to FL 350 was now authorized.

The Nuvilik controller then realized the aircraft had passed 070W and immediately approved the climb to FL 350. Thirty seconds later, the Nuvilik radio controller asked N8MC if the aircraft was established on the track between 64N 070W and 63N 080W, to which the pilot responded that he was 12 nm to the east of the track, heading toward it. The Nuvilik radio controller then stated to the pilot that the aircraft must be established on the specified track and to maintain FL 330 or below until established on the track. One minute later, at 1356, the pilot indicated, as a result of a request from the controller, that the aircraft was now 5 nm from the track and was complying with the restriction to remain at FL 330 or below until established on the track. Almost immediately, the data controller advised the radio controller that the high-level sector had cancelled all restrictions for N8MC. The Nuvilik radio controller informed N8MC of the cancellation and requested a report when level at FL 350 and an estimate for 63N 080W.

Three minutes later (at 1358:48), the Nuvilik radio controller advised the pilot of N8MC that the next sector was unable to accept the aircraft at FL 350, and that the flight was to descend to FL 310. The pilot stated that the aircraft was climbing through FL 335 and that he was descending back to FL 310. At 1402, N8MC reported levelling at FL 310, and shortly thereafter, indicated the aircraft was 127 nm from the Frobay VOR. The two aircraft (N8MC and BAW279) came within 9 nm and 1,500 feet of each other while procedures require a lateral separation of 20 nm or vertical separation of 2,000 feet.

At no time did the Nuvilik radio controllers (trainee nor OJI) ascertain the exact position of N8MC, either by requesting a position from the Frobay VOR, or an exact latitude/longitude. There was some discussion between the trainee and the OJI as to the position of this flight relative to the track and the applicability of the altitude restriction, but the OJI did not direct the trainee to specifically confirm the exact position of the flight. Because the trainee and OJI were busy with other traffic in the southern sector under radar control, they were unaware of the efforts of the Nuvilik data controller trying to resolve the conflict between N8MC and BAW279 with the North specialty controllers and supervisor, and thereby allow N8MC to continue the climb without requiring the flight to level off at an intermediate altitude.

The Nuvilik data controller was responsible for coordinating clearances (and other flight
information for N8MC) with other sectors in the Montreal ACC. After the Nuvilik data controller received the departure time for N8MC from Iqaluit FSS, he passed the information to the Ungava NADS position. Shortly thereafter, the Ungava NADS controller issued a restriction for N8MC to the Nuvilik data controller. N8MC was to be re-routed via 64N 070W, and restricted in altitude to cross that position at FL 330 or below, to provide the required separation with BAW279. This information was placed on the flight progress strip for N8MC by the NADS controller, handed to the Nuvilik data controller who then placed the flight progress strip in the appropriate section of the data board for the radio controller. The data controller was unable to verbally brief the radio controller on the restriction because the sector radio controller was busy with other control duties, but he physically pointed out the strip to the OJ. The trainee radio controller, however, did not pass this restriction until N8MC had climbed above FL 250. He reasoned that, once N8MC was above this altitude, it would be clear of the conflicting inbound traffic, and could then be safely re-routed in any direction as it continued the climb. Neither the trainee nor the OJ perceived that there was a requirement to pass on the restriction quickly because of the proximity of the new coordinate to Iqaluit, nor the rapidity at which N8MC was climbing; the CL600 Challenger executive jet is known by controllers to be capable of a rapid climb to altitude.

Aircraft departing Iqaluit and climbing into the high-level airspace are initially cleared to maintain an altitude of FL 280 or below. Once the flight departs, coordination is initiated with the high-level sectors for route and higher-altitude approval. It is the controller at the NADS position who activates the information on the flight and determines if there are any conflicts with other traffic. The route and altitude approval and any restrictions are then passed to the low-level sector for relay to the aircraft. Once the flight is clear of any conflict in the low-level sector's airspace, control is then passed to the high-level sector. There are normally few delays encountered by departing traffic from Iqaluit with this method of operation, as the traffic levels are normally low.

Controllers working in the low-level Nuvilik sector are generally not as cognizant of where latitude/longitude coordinates are situated in relation to airports, geographic reference points, navigational aids, or the intersections they more normally use in their day-to-day controlling activities. There was no plotting board at the Nuvilik/James Bay sector position; normally there would be one at that position. It is the controller's responsibility to ensure that all required equipment is available. The plotting board includes a chart covering the controller's area of responsibility and a specialized ruler to determine aircraft tracks between different points and the airspace to be protected for a particular aircraft. It could not be determined, during the investigation, why there was no plotting board at the Nuvilik sector.

Many controllers consider the plotting board a less accurate method of depicting aircraft tracks when compared with using the range bearing line (RBL) function of the RDPS. This function allows controllers to enter two coordinates and display the resulting track between the two points on the radar display. The trainee radio controller was, however, busy with traffic in the southern sector, so the radar display could not be de-centred to the area around Iqaluit without losing the radar information for the southern sector. In an effort to assist, the data controller walked over to another, unused console on the other side of the operations room and entered into the RDPS what he thought were the correct coordinates for the new route N8MC was to fly. There was a perceived urgency by the Nuvilik data controller to complete this action as N8MC was quickly approaching Brevoort sector controlled airspace and would have to be handed over to that sector soon.

The Nuvilik data controller intended to use the RBL to compare the track originally requested by the pilot with the revised track. He correctly typed in the coordinates for the originally cleared track from Iqaluit to 64N 080W. For the revised track, however, the data controller incorrectly typed in the second position as 65N 080W instead of 63N 080W. This resulted in a displayed track which was considerably farther north than the originally
requested track, and also farther north than the amended track issued in conjunction with the altitude restriction. The Nuvilik data controller did not detect the error and therefore surmised that N8MC was to the north of the revised track, and so informed the North specialty supervisor. The North specialty supervisor then informed the Nuvilik data controller that the FL 330 altitude restriction was cancelled. This information was then passed by the Nuvilik data controller to the Nuvilik radio controller.

The Nuvilik radio controller kept N8MC on his frequency in order to ensure communication and separation with BFF200 inbound to Iqaluit. The Nuvilik sector serves as a relay for the Brevoort sector, as this sector does not have any communications capability with aircraft departing Iqaluit. If the Brevoort sector has any restrictions or instructions for aircraft climbing to high-level airspace, that information will be relayed via the Nuvilik sector. While serving as a relay, it is not always considered necessary that the Nuvilik controllers have all the traffic information in the high-level airspace. However, Nuvilik controllers are responsible for providing separation for flights within their own area of responsibility up to FL 280. The Nuvilik radio controller, therefore, had to confirm where the revised route would take N8MC and determine how this restriction would affect separation with BFF200. The North specialty controller, on the other hand, was not made aware that the revised routing might affect separation with another aircraft in the Nuvilik sector and thereby result in a delay in passing the restriction to N8MC.

In a restructuring between the East and North specialties, which took place a few years before this occurrence, a number of the more-experienced controllers were moved to the North specialty. As a result, the East was left with reduced controller experience levels. It was generally accepted that the North specialty was a more difficult specialty in which to qualify. It was also perceived by some controllers that it was easier to qualify in the East. This led to somewhat strained communication between the two specialties, which affected the ease with which information was exchanged. As a result, a lack of cooperation and an underlying climate of dissonance had been allowed to fester between the two specialties and, at times, hindered the free flow of communications between the North and the East specialty controllers during this particular shift. For example, the Nuvilik data controller did not ask the North supervisor for more information relating to the revised route for N8MC (which the data controller knew was available on the NADS display) in the North specialty, but chose instead to add to his own workload by plotting the tracks himself at another console. Communication problems were not evident in other specialties in the ACC. Shortly before this occurrence, a new manager responsible for the East specialty was appointed, and it was reported that communication between the two specialties had improved.

**Analysis**

There were two issues to be resolved by the Nuvilik radio controller before the restriction issued by the Ungava NADS controller could be issued to the aircraft. The first was the separation problem to be resolved with BFF200 before altering the route of N8MC. Secondly, the Nuvilik radio controller did not have a clear mental picture of where the coordinate 64N 070W was in relation to the flight; therefore, he was reluctant to issue this restriction until separation with the inbound BFF200 was assured. The radio controller did not have access to a plotting board as there was none at the sector at the time, and he could not off-centre his radar display because he was controlling traffic in the southern part of the combined sector. As a result, there was a delay in passing the revised clearance to the aircraft.

The North specialty controller would have been aware that the coordinates for the altitude restriction for N8MC were close to Iqaluit, necessitating a quick relay to the aircraft in order to give the crew time to comply with this restriction. The North specialty controller, unaware that the Nuvilik radio controller was busy with other control duties, expected that the restriction would be passed immediately upon receipt. The fact that none of the Nuvilik
sector controllers had a clear mental picture of the proximity of the restriction point to the point of departure further delayed the issuing of the information to the aircraft.

The Nuvilik data controller became concerned that the restriction was not being passed, so in an effort to assist the radio controller, he plotted the revised course for N8MC on a vacant radar display and used the RBL function to plot the original and amended tracks for N8MC. In the rush to complete the task, the coordinates for the original track were entered in error, causing an RBL to be displayed that showed a false original track in relation to the amended track.

The data controller did not intentionally plan to enter the wrong coordinates into the RDPS computer, resulting in an unintentional action that did not go as planned. This type of error occurs where actions are based on stored routines and there is little, if any, conscious decision making, as for example the largely automatic procedural routines of entering information to generate an RBL. The pre-conditions to these types of errors are distractions or preoccupations with other than the immediate task. In this case, incorrectly plotting the aircraft's position by the data controller was an error of inattention. As a result of the time pressures felt by the data controller, in that the aircraft was nearing Brevoort controlled airspace, the controller did not adequately check the coordinates he had entered before executing the command to display the RBL.

The North specialty controller had two advantages over the Nuvilik controllers with respect to the altitude restriction as it applied to N8MC. Firstly, the North specialty was equipped with a NADS, which provided a visual display of the track based on the coordinates entered by the controller, as well as data derived from the flight plan. Secondly, the North specialty controllers were used to working with latitude and longitude coordinates on a routine basis, so they were familiar with the impact a change would have on the current track of an aircraft. The NADS is not available to the Nuvilik sector control positions. The North specialty controllers did not offer additional information to the Nuvilik sector controllers regarding the impact of the restriction on the initial track of N8MC, and the Nuvilik data controller chose to plot out the new track himself rather than ask the North specialty controllers.

Strained communication between the North and East specialties affected the ease with which control information should have been exchanged and was more apparent between certain individuals than others. The Nuvilik data controller did not ask the North supervisor for clarification. The operation of the ATC system is dependant on complete and timely coordination between units in order to provide a safe and efficient environment for users of the system. Supervisors, as the first line of oversight within a particular unit, must be particularly aware of brewing conflicts and take immediate steps to minimize their effects on the operation. A free and open forum rather than a climate of dissonance must be fostered to prevent bottlenecks in the critical flow of information. Although this communication problem did not appear to have an impact on the ACC as a whole, it did affect communications between the North and the East specialties during this particular work shift.

The Nuvilik radio controller was a trainee monitored by an OJI. In order to provide maximum benefit to the trainee under increasingly more difficult and challenging traffic conditions, the OJI is sometimes placed in a delicate position of allowing more and more freedom to the trainee as training progresses. The trainee was working under the authority of the OJI's ATC licence, and it is the OJI who retains the responsibility for ensuring that the requisite minimum separation standards are applied.

When the Nuvilik data controller placed the flight data strip for N8MC containing the altitude restriction on the data board beside the trainee, it was the OJI, standing behind the trainee, who noticed it. The OJI, however, was not concerned that the restriction was not
immediately passed, because he knew that the conflict between N8MC and BFF200 had to be solved first. The OJI maintained a stand-back posture although he was not positive of the exact position of the aircraft in relation to the assigned track, even after the altitude restriction for N8MC was cancelled by the trainee. The OJI allowed the situation to deteriorate into the loss of separation by not providing firmer guidance to the trainee to alleviate the uncertainty with respect to the aircraft's position.

This loss of separation occurrence is classified as an air proximity event in which safety was not assured.

Findings

- Staffing in the Montreal Area Control Centre East specialty met unit standards.
- The Nuvilik combined sector controllers' workload was assessed as moderate.
- The East specialty supervisor was working at a control position, and the North specialty supervisor was acting as a stand-back supervisor/coordinator.
- There was no plotting board at the Nuvilik sector position, requiring the data controller to use a radar display to plot aircraft tracks.
- Some East specialty controllers are not familiar with latitude and longitude positions in relation to their normally used airports, geographic reference points, navigational aids, or air route intersections.
- The Nuvilik radio controller was not able to assess routing changes for N8MC without changing the centre of the radar indicator module, which would result in the loss of the radar display for the southern part of the sector.
- The Nuvilik sector did not have a NADS display to show relative tracks for N8MC and other relevant traffic.
- The Nuvilik trainee radio controller did not know the exact position of N8MC when the altitude restriction was cancelled, which led to the loss of separation.
- The OJI did not intervene in a timely manner to prevent the loss of separation when it was apparent to him that the trainee was unsure of the position of N8MC in relation to the aircraft's assigned track.
- The Nuvilik data controller entered the wrong coordinates when generating an RBL on a vacant radar display, and he did not detect the error. As a result, he advised the North specialty supervisor that N8MC was north of track rather than south of track, the aircraft's actual position.
- The Nuvilik data controller did not seek clarification from the North specialty controllers regarding the revised track for N8MC when he was unsure where the revised track was in relation to the aircraft's current track. The climate of dissonance that had been allowed to develop between some of the controllers in the East and North specialties contributed to the lack of communication.
**Causes and Contributing Factors**

The loss of separation occurred when N8MC's altitude restriction was cancelled because the data controller inadvertently entered the wrong coordinates into the RDPS computer, resulting in a misinterpretation of the position of N8MC in relation to BAW279.

Factors contributing to this occurrence were the lack of a plotting board at the Nuvilik sector, the East specialty controllers unfamiliarity with latitude/longitude coordinates in relation to their normally used control techniques, the strained interpersonal communication problems between some controllers in the East and North specialties, confusion among controllers as to how soon after receipt of an amendment the information must be relayed to the aircraft, the Nuvilik sector controller not issuing the revised route and altitude restriction to N8MC in a timely manner, the lack of an appropriate display in the Nuvilik sector to provide a more complete traffic picture for the controllers, and the OJI not intervening when he was unsure of the position of N8MC in relation to the outbound track.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 28 April 1999.

**Appendix A - Sequence of Events**

<table>
<thead>
<tr>
<th>Time (UTC)</th>
<th>Time (min) Before/After Occurrence</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1326</td>
<td>-30</td>
<td>BAW279 passes 64N 060W, estimating Frobay VOR at 1348</td>
</tr>
<tr>
<td>1334</td>
<td>-22</td>
<td>Nuvilik sector controller issues ATC IFR departure clearance through Frobay FSS for N8MC</td>
</tr>
<tr>
<td>1341</td>
<td>-15</td>
<td>N8MC departs Iqaluit, departure time passed to Ungava NADS</td>
</tr>
<tr>
<td>1343</td>
<td>-13</td>
<td>Nuvilik radio controller issues restriction to N8MC to cross 20 DME of the Frobay VOR at 15,000 feet asl or below</td>
</tr>
<tr>
<td>1345</td>
<td>-11</td>
<td>initial radio contact between Nuvilik radio controller and BFF200</td>
</tr>
<tr>
<td>1346</td>
<td>-10</td>
<td>N8MC cleared to maintain FL 280 and to report leaving FL 240</td>
</tr>
<tr>
<td>1346</td>
<td>-10</td>
<td>N8MC reports 21 DME from Iqaluit</td>
</tr>
<tr>
<td>1349</td>
<td>-7</td>
<td>N8MC cleared to maintain FL 350 with a restriction to cross 64N 070W at FL 330 or below</td>
</tr>
<tr>
<td>1350</td>
<td>-6</td>
<td>Re-routing issued to N8MC to proceed direct 64N 070W, then 63N 080W, flight planned route, and advised that the restriction to cross 64N 070W at FL 330 or below still applies</td>
</tr>
<tr>
<td>1352</td>
<td>-4</td>
<td>N8MC advised having already passed 64N 070W and was turning to intercept the track between 64N 070W and 63N 080W</td>
</tr>
<tr>
<td>1353</td>
<td>-3</td>
<td>Nuvilik sector controller approves climb to FL 350 once N8MC has passed 070W</td>
</tr>
<tr>
<td>1354</td>
<td>-2</td>
<td>BAW279 passes Frobay VOR at FL 350</td>
</tr>
<tr>
<td>1355</td>
<td>-1</td>
<td>N8MC advised 5 nm from track and restricted to FL 330 until on the track</td>
</tr>
<tr>
<td>1356</td>
<td>0</td>
<td>N8MC informed that all restrictions were cancelled</td>
</tr>
</tbody>
</table>
| 1358       | 2                                 | N8MC advised by Nuvilik sector controller that the next sector is
1358 2 unable to accept the aircraft at FL 350 and issued descent to FL 310

1358 2 N8MC advised at FL 335 and commencing descent to FL 310

1402 6 N8MC advised at FL 310

Appendix B - Relative Aircraft Tracks

Relative Tracks - N8MC/BFF200/BAW279
Vicinity Iqaluit 20 September 1997

1. All times are coordinated universal time (eastern daylight time plus four hours) unless otherwise noted.

Updated: 2002-10-06
Air 1997

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 Occurrence Report
Loss of Directional Control
Nakina Outpost Camps & Air Service Ltd.
Cessna 208B Caravan C-FTZF
Nakina Airport, Ontario
3 January 1997

Report Number A97O0001

Summary

At approximately 1110 eastern standard time (EST)\(^{(1)}\), the pilot commenced a scheduled cargo flight from Nakina, Ontario, to Fort Hope in a Cessna 208B Caravan, serial number 208B0389. The pilot reported that he selected the flaps to 20°, lined up on runway 09, and set the power at around 1,600 to 1,700 foot-pounds of torque. The torque redline is 1,865 foot-pounds. About 3/4 of the way through the take-off run, the aircraft began to yaw to the right, which the pilot initially compensated for by applying left rudder. As the airspeed increased and the nosewheel lifted off the runway, the right yaw became more pronounced, and the aircraft became more difficult to control. The aircraft became airborne at about 85 knots indicated airspeed (KIAS), with the pilot using left rudder and left aileron in his attempt to compensate for the yaw; however, he was not able to gain control of the aircraft. The aircraft touched down briefly on the runway, then became airborne again as the take-off continued. While flying at less than 20 feet above ground level over a small, frozen lake immediately off the end of the runway, the aircraft descended and struck the snow-covered surface of the lake. The aircraft was in a nose-high, right-wing-low attitude when it struck the ice. The aircraft flipped over and came to rest in an inverted position, approximately 1,000 feet past the end of the runway and 200 feet to the right of the extended right edge of the runway. The pilot received only minor injuries. He exited the aircraft and walked back to the flight office.

*Ce rapport est également disponible en français.*

Other Factual Information
The weather at the time of the occurrence was good with scattered cloud, visibility greater than 15 miles, wind calm, and temperature -12° Celsius. Runway 09 is asphalt covered and 3,500 feet long by 100 feet wide. It had been plowed, and the surface condition was compacted snow.

The pilot was certified and qualified to conduct the flight in accordance with existing regulations. His total flying time was 3,200 hours, of which 1,300 hours were obtained on the Caravan aircraft.

The aircraft was loaded with a small quantity of foodstuff in the front cabin among the passenger seats, 71 pieces of three-eighths-inch plywood in the right side of the centre cabin, and another small quantity of foodstuff in the rear cabin. The cargo load was to be delivered to Fort Hope. The maximum allowable take-off weight of the aircraft was 8,710 pounds, and the actual take-off weight was calculated to be 8,582 pounds. The centre of gravity was calculated to have been within the approved limits. The calculated take-off speed for the weight and conditions was 70 to 75 KIAS.

Examination at the site showed that all three blades of the propeller were bent and twisted from contacting the snow and ice. Both wings were damaged but remained attached to the fuselage, and the wing flaps were partially extended. The rudder and vertical stabilizer were crushed and bent to the left. The internal rudder lock was not engaged. The rudder trim was indicating full right rudder trim; however, the rudder trim was positioned at nearly the full left trim position. The flaps were indicating 10° down, and the actual flap position corresponded with the indicator.

The aircraft flight control system consists of conventional aileron, elevator, and rudder controls, with wing spoilers interconnected with the ailerons. The controls are manually activated through conventional cable and pulley systems. All controls were continuous and functional at the accident site. The wing spoilers were found retracted, and they reacted normally to aileron control inputs.

The aileron and elevator are trimmed manually through typical cable and pulley systems to servo tabs on the control surfaces. Each of these trim systems was found to be continuous. The rudder trim system is different in that there is no servo tab on the rudder; it is the rudder that is moved, through the nosewheel steering bungee, to apply trim. The rudder trim system is actuated by manually rotating a trim wheel. The trim wheel is attached to a flexible shaft, which rotates as the wheel is turned, and the far end of the flexible shaft is attached to a rigid shaft. The rigid shaft has two sets of threads. The first set of threads goes through a rudder pedal actuator nut, and the second set of threads goes through a nosewheel steering slider. When the trim wheel is rotated, the rudder actuator nut and the steering slider are both moved along the shaft in one direction or the other. The rudder pedal actuator nut is connected directly to the right rudder pedal torque tube. Movement of the nut in an aft direction equates to left rudder pedal input, and movement in the forward direction equates to right rudder input. At the accident site, the rudder pedal actuator nut was found in
the aft direction, with one thread on the shaft exposed; this equates to approximately full left rudder trim. This finding was confirmed by a Cessna representative who was working with the investigators at the site. With the trim in this position, the left rudder pedal would be down, and the rudder and nosewheel would be deflected to the left. The trim and rudder pedal relationship is such that full trim would displace the rudder pedal by ½ of its travel.

The rudder trim indicator system consists of a pointer arm (trim indicator) on top of the trim wheel and a follower arm beneath it. There is a single, helical groove on the bottom of the trim wheel. The follower arm (bottom arm) has a protrusion which rides in the groove in the trim wheel. As the trim wheel is rotated, the protrusion is dragged either inwards or outwards, moving the top arm, which indicates the trim position.

When examined at the site, the rudder trim indicator was showing full right rudder trim. It was found that, with the aircraft inverted, the rudder trim indicator could be moved easily to indicate any setting simply by pushing it to the trim wheel and then sliding the indicator to any position. The trim wheel was slightly out of place, and the protrusion on the follower arm was not properly in its groove. With the aircraft upright, the indicator could be moved by pressing on it, which caused the protrusion on the follower arm to come out of the groove in the trim wheel; the trim indicator could then be moved through about 3/4 of its travel, from full right indication to ½ left indication. When the trim wheel was lifted to the full extent that the flexible cable would allow (approximately 1/16 inch), the protrusion was not in its groove, and it was possible to move the indicator through its full travel.

The Cessna representative stated that it is difficult to move the trim indicator on new aircraft at the factory. There have been no service bulletins issued by Cessna regarding this trim system. Records indicate that there had not been any recent work done on the rudder trim system.

In preparation for departure, the pilot had conducted the aircraft walk-around inspection and actioned the normal check-lists. In checking the rudder trim, the pilot turned the trim wheel in both directions and then set the trim so that the trim indicator showed slightly to the right of centre. During the trim check, he did not turn the trim wheel through its full left and right travel, as required in the checklist. The pilot taxied the aircraft for departure, making three left turns to position the aircraft on the runway centre line for take-off.

Analysis

The only anomaly found on examination of the aircraft and crash site was that the rudder trim was close to its full left rudder trim position, while the indicator showed full right trim. Because the trim is manual, and the time from when the pilot first experienced difficulty controlling the aircraft until it crashed was very short, it is unlikely that the pilot made any rudder trim adjustment after initially setting the trim for take-off. Therefore, barring any tampering with the aircraft after the crash, it
is probable that the rudder trim was set to the left before the pilot started his take-off. During taxi, the three left turns to position the aircraft on the runway centre line may have hidden the fact that the rudder trim was not in the neutral position as the pilot expected. With the rudder trim deflected, the rudder pedals and nosewheel would also be deflected to about ½ their travel in the same direction as the trim. The pilot did not comment on rudder pedal position, so it could be that he interpreted some deflection as a result of the left turns. With the trim set to nearly full left, full rudder authority would still be available; however, pressure on the opposite rudder pedal would be required to maintain the rudder and nosewheel in their neutral positions.

Under normal circumstances, the rudder trim would be approximately neutral for take-off. The pilot indicated that he exercised the rudder trim and set it for take-off, and it is inconceivable that he would intentionally set the trim to the nearly full left position. It is likely that when the pilot entered the aircraft, the rudder trim indicator was indicating right rudder although the trim was actually neutral or near neutral. When the pilot exercised the rudder trim, he would have brought the indicator to neutral but, in so doing, moved the rudder trim to almost full left. It was demonstrated that the trim indicator could be moved without moving the trim wheel and without affecting rudder position. This could have been done by some inadvertent action, such as dragging a coat over the trim indicator while a pilot was exiting the aircraft.

With the rudder deflected to the left, as it would be with the trim set to nearly full left, the aircraft should have yawed and rolled to the left during the take-off. However, the pilot stated that he applied left rudder and left aileron in his attempt to control the yaw to the right. No satisfactory explanation was found to account for this inconsistency.

Findings

- During the take-off, the aircraft reportedly yawed to the right, and the yawing became more pronounced as the airspeed increased.

- The pilot reportedly applied left rudder and left aileron in his attempts to maintain control of the aircraft, but he was unsuccessful and it crashed.

- Prior to the take-off, the pilot verified rudder trim operation but did not turn the trim wheel through its full left and right travel, as required by the checklist.

- The pilot set the rudder trim indicator pointer to the slightly right-of-centre position for take-off.

- The rudder pedal actuator nut was found in the aft direction with one thread on the shaft exposed, which equates to the rudder beingpositioned at approximately the full left trim position.

- The rudder trim indicator could easily be moved, without moving
the trim wheel or affecting the actual rudder trim position, to indicate any trim setting.

- The aircraft take-off weight and centre of gravity were within approved limits.

**Causes and Contributing Factors**

The pilot experienced directional control difficulties during the take-off run, probably because the rudder trim was set at the near full left position. Because the rudder trim indicator could be moved without affecting the actual rudder trim, it is probable that it did not reflect the actual position of the rudder trim.

*This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 23 September 1997.*

1. All times are EST (Coordinated Universal Time minus five hours) unless otherwise noted.

---

Updated: 2002-10-06

**Important Notices**
Air 1997

The Canadian Forces Directorate of Flight Safety (DFS) investigated this occurrence on behalf of the Transportation Safety Board of Canada (TSB) under the terms of the Memorandum of Understanding governing Co-ordinated Investigations of Transportation Occurrences. This occurrence was investigated for the purpose of advancing transportation safety. It is not the function of the investigation to assign fault or determine civil or criminal liability.

Aviation Occurrence Report
Loss of Control
Government of Canada
Department of Transport
Aircraft Services Directorate
Beechcraft King Air A90 C-FCGE
North Bay, Ontario
18 March 1997

Report Number A97O0043

Synopsis

C-FCGE, a Beechcraft King Air A90, was on a training flight in level cruise at 11 500 feet above sea level (asl) in the vicinity of North Bay, Ontario, when the crew experienced a vibration in their aircraft and an uncommanded turn to the right. The decision was made to divert to North Bay. During the descent, a severe vibration developed and control of the aircraft was briefly lost. After this severe vibration ceased and control was regained the aircraft required significant left rudder to maintain co-ordinated flight. An uneventful landing was completed. No injuries occurred.

Other Factual Information

The Beechcraft King Air owned by the Government of Canada and operated by Transport Canada's Aircraft Services Directorate at Ottawa, Ontario, was being flown by a crew of two on a routine training flight. There were no other persons on board the aircraft. After an uneventful first leg the crew landed in North Bay, Ontario at 1800 eastern standard time (EST)\(^{(1)}\), refuelled, carried out normal pre-flight inspections and departed 45 minutes later for another training flight with Ottawa as the planned destination after a round-robin routing. After approximately one hour of flight, while in level cruise at 11 500 feet asl, the crew experienced a slight vibration and a shallow uncommanded right turn. The aircraft was returned to level flight, the autopilot was selected off and a cockpit check was completed when another uncommanded but steeper turn to the right developed. The aircraft was once again returned to level flight and, as the vibration was continuing, a decision was made to land in North Bay due to its close proximity.
During the descent, at approximately 8 500 feet asl, a severe vibration developed which violently shook the aircraft and rapidly moved the rudder and ailerons causing the hands and feet of the pilot flying to be displaced from the control wheel and rudder pedals. After approximately 30 to 45 seconds, the vibration stopped and control was regained. The descent was then continued at 140 knots, as the aircraft seemed controllable at this speed. However, to maintain coordinated flight, the crew had to hold approximately 2/3 left rudder. The remainder of the descent, approach and landing were uneventful and the aircraft landed safely. No injuries occurred. A maintenance recovery team was dispatched and examined the aircraft. They determined that the hardware connecting the rudder trim actuator push/pull rod to the rudder trim horn was missing. After replacement of the missing hardware and a free play check, the aircraft was ferried to Ottawa. The aircraft was returned to service after a severe turbulence check and non-destructive testing (NDT) of fittings in the empennage and wings.

The rudder trim is set by turning a wheel in the cockpit. This movement is converted into a fore and aft motion of the push/pull rod. The rod, attached by a clevis and bolt to a horn on the starboard side of the rudder trim tab, displaces the tab either to the left or right. This causes the rudder to be moved in the opposite direction thereby trimming out the control forces necessary to maintain co-ordinated flight. (See Figure 1)

![Rudder Trim Tab Location and Parts](image)

The hardware attaching the push/pull actuating rod to the rudder trim horn was last replaced when the aircraft was painted during the period 25 January 1995 to 10 March 1995. Since then, the last maintenance completed in this area was the rudder trim tab free play check on 24 January 1997. Part of this check calls for a visual inspection of the trim tab actuating system and directs that any inconsistencies be rectified prior to the free play check. No problems were detected and the component passed the check. As a result, the attaching hardware was not disturbed during the process. The aircraft flew a total of 59 hours between the free play check and the occurrence.

The Beechcraft 90, A90, and B90 Series Illustrated Parts Catalogue (IPC Fig 54, page 3, Index #42) specifies that the attachment hardware used to connect the rudder trim actuator include an AN173 bolt (no length specified), two AN320-3 castellated nuts and two AN380-2-2 cotter pins.

The aircraft operator also uses Beechcraft 100 aircraft in a similar role. The Beechcraft 90 and 100 are alike in many respects including the rudder trim tab and
actuator. The IPC for the Beechcraft 100 specifies an AN173-5 bolt in this assembly along with one AN960-10L washer, one AN320-3 castellated nut and one MS24665-132 cotter pin (IPC 27-21-01, page 3, Index #3).

Inspection of other Beechcraft A90 aircraft used by the operator revealed that the rudder trim actuator is typically attached to the horn using an AN173-5 bolt, washers of varying thickness and number (to ensure the correct orientation of the cotter pin hole in the bottom of the bolt with the indentations in the nut), one AN320-3 castellated nut and one cotter pin.

**Analysis**

**Securing Hardware**

The bolt and associated hardware securing the push/pull actuating arm to the rudder trim tab horn was missing after the occurrence. There are several possibilities as to why the bolt failed to remain secure. Possibilities are - it was not there on take-off, it fell out at some point, or it broke during flight. The first hypothesis is not likely, as the crew would have noticed this during pre-flight inspections or in flight prior to the occurrence.

In order for the bolt to fall out during flight the cotter pin would have to either been missing prior to or broken during the flight, the nut would have to back off and the bolt would have to move upwards against gravity. The cotter pin was present during the previous free play check and, as there is no force on the pin, it is unlikely that it would subsequently break. Installations of this assembly were inspected on the operator's other King Air aircraft and it was noted that the bolt threads were painted. This would decrease the likelihood of the nut backing off even if the cotter pin were missing. Furthermore, the bolt is held in place by a bushing in the trim tab horn. The fit between the bushing and the bolt is quite tight. This ensures that the rudder trim will pass the free play check which demands a tolerance of only 0.021 inches.

The third hypothesis, that the bolt broke in flight, is the most likely scenario. The fracture would not have been due to overload stresses because there was no evidence of deformation on the clevis or trim tab horn. However if there were cyclic loads of sufficient magnitude present, the bolt could have failed in fatigue without damaging the surrounding components.

As the shank of the AN173-5 bolt does not extend all the way through the lower arm of the clevis, a fatigue crack could have developed at the threads due to a stress concentration as a result of the shear load. The shank of the bolt, however, is thicker than the threads and therefore prevents them from coming in contact with the clevis and bearing any load.

The bolt may have been manufactured from sub-standard material or not been an aircraft quality part. As the bolt was not recovered, it was not possible to examine it. Several samples of attaching hardware from the parts bin in the operator's supply section (bolts, washers, castellated nuts and cotter pins) were examined to confirm conformance with respective specifications. Most met the specifications, however, one was found to be non-conforming and many showed evidence of previous use notwithstanding the operator's policy that only new parts are used when assemblies like this are replaced. It is possible, that a sub-standard part either similar in appearance to the correct part or purposely manufactured to a lower standard and supplied as an aircraft quality part, was mistakenly installed after the aircraft was

painted by the operator two years previously.

The bushing was recovered from the aircraft by pressing it out of the horn. It was compared to another bushing from the operator's supply section. The original was 0.002 inches in diameter smaller and had a rougher finish than the new bushing. It was noted that it was difficult to insert an AN173 diameter bolt into it. The normal practice when completing this assembly is to try several bolts in the fitting and use the one that gives the tightest fit. Given the close tolerances required for this fitting and a bushing that had a slightly smaller inside diameter, the possibility exists that a technician might have used a non-conforming bolt in this installation if it resulted in the tightest fit.

In summary the attaching hardware securing the rudder trim tab to the actuator did not remain secure. The reasons for this could not be conclusively determined.

**Vibration and Loss of Control**

The initial indication of difficulty during this occurrence was a slight vibration and an uncommanded turn to the right. The vibration may have been a result of a trim tab "buzz" due to play in the tab. The amount of free play allowable in this mechanism is quite small (0.021 inches). As a result any wear on the bolt would have a significant impact. If wear on the bolt progressed sufficiently to allow vibrations or "buzz" to commence, the bolt could fail quickly. Fatigue fractures of aircraft bolts have been known to occur in cyclic load situations in a matter of hours after installation\(^2\). The turn to the right could have resulted from a slight rudder trim tab displacement as the bolt was wearing and the fitting was becoming looser.

The second event that occurred was a severe vibration and loss of control. Examination of the rudder trim system determined that when disconnected, the push/pull actuating rod is free to rotate and/or move slightly in the vertical or horizontal plane. If the push/pull actuating rod moved slightly up or down the trim tab would be completely free to move. As a result there is a possibility that tab flutter could occur at airspeeds well below Vne. If this occurred the result would be large oscillatory displacement of the rudder. According to the AGARD aerodynamics textbook "a number of accidents and near accidents have occurred from flight failures in control linkages of tab systems."\(^3\) The large control deflections and loss of control experienced by the flight crew could have resulted from rudder tab flutter. The source of excitation, which started the flutter condition, is unknown but a change in airspeed, altitude and/or aircraft attitude probably was the cause of the severe vibrations stopping. Fortunately, the flight conditions that initiated the rudder tab flutter were not present for the remainder of the flight.

When the crew finally regained control of the aircraft they noted that 2/3 rudder was required to maintain co-ordinated flight. If the push/pull actuating rod moves slightly up or down and inward toward the aircraft body, the arms of the clevis can end-butt against the horn (see Figure 2) and force the tab to the left. If this occurred, the rudder would be displaced to the right requiring left rudder input to maintain co-ordinated flight. Tests on another King Air showed that when the rod is in this position the trim tab would be displaced approximately half its maximum deflection if the trim tab control started in the neutral position. The air stream would be sufficient to hold the tab horn firmly against the clevis unless another buzz was introduced. These tests also showed that this was a fairly stable position for the clevis that would not shift with control inputs or minor vibration.
Illustrated Parts Catalogue

The description of the attaching hardware for the rudder trim tab actuator in the IPC for the King Air 90 is confusing when compared to the IPC for the King Air 100. In the former the length of the bolt (IPC Fig. 54, page 3, part 54-42) is not defined (i.e. should be AN173-5 or -6) and, immediately following this entry, the IPC lists two castellated nuts and two cotter pins which appear to be part of this assembly. The extra nut and pin are actually used to secure the bolt (part 54-40) that attaches the front of the actuator to the aircraft. As well, the build-up description does not call for any washers, which are necessary to ensure the hole for the cotter pin in the bolt is within the indentations of the nut to allow the pin to seat properly. The IPC for the King Air 100, on the other hand, lists these parts in a more logical manner with each assembly (bolt and securing hardware) listed separately. Beechcraft acknowledged this inconsistency and is amending the IPC to correct this deficiency. Standard industry practices, as used by the aircraft operator's technicians, would call for the use of washers in the attachment for the King Air 90.

The Canadian Air Regulations (CAR) prohibit the substitution of parts listed in the manufacturers IPC unless accompanied by approved data acceptable to the Minister\(^4\). A technician referring to the IPC for guidance on how to attach the rudder trim tab actuating arm to the horn would be faced with an obvious error in the parts list. According to the CARs, an operator faced with this dilemma must identify the problem to the manufacturer and then wait for him to amend the IPC or issue data acceptable to the Minister to substitute the specified parts for a more logical assembly. This delay could result in an unacceptable grounding of an otherwise serviceable aircraft. Previously an operator could refer to a substitution guide or similar document and install an equivalent part identified therein in cases such as this. With the onset of the CARs, this is no longer possible.
Before the enactment of the CARs the operator handled this discrepancy by either referring to the IPC description in the King Air 100 manual for guidance on how to complete this assembly or using the identical build-up that had previously been installed.

Findings

- The attaching hardware securing the rudder trim tab to the actuator did not remain secure. The reasons for this could not be conclusively determined.

- Tests of a sampling of attaching hardware from the operator's supply system revealed one bolt which did not conform to the AN173 specifications and several that showed evidence of prior usage.

- A minor vibration and uncommanded right turn developed, which the crew was able to control. Later a severe vibration developed, which resulted in the crew losing control of the aircraft, but the vibration stopped when the parameters that sustained it changed as the aircraft descended. Left rudder was then required to maintain co-ordinated flight.

- The King Air 90 IPC does not identify the length of the bolt to use to connect the actuator to the horn. As well the description of the assembly is confusing and not consistent with how the King Air 100 IPC describes the assembly. The assembly normally used was an AN173-5 bolt, two washers, an AN320-3 castellated nut and a cotter pin.

- The Canadian Aviation Regulations do not permit the substitution of parts listed in the manufacturer's IPC unless accompanied by approved data acceptable to the Minister of Transport.

Causes and Contributing Factors

The bolt securing the rudder trim actuator to the rudder trim tab horn became detached for reasons that could not be conclusively determined. The rudder trim tab was then free to either oscillate or be held to the left by the disconnected trim tab actuating arm.

Lack of detail and an inconsistent and confusing description of the parts required for the attachment of the actuating arm to the trim tab in the Illustrated Parts Catalogue as well as the possibility that a non-conforming bolt was used when the fitting was last installed may have also contributed to the bolt not remaining secure.

Safety Action

Action Taken

Immediately after the occurrence, the operator inspected the rest of their fleet to ensure the condition and conformity of the Rudder Trim Tab attachment hardware.

Action Required

TSB liaise with Transport Canada to have Beechcraft review and revise the IPCs of the Beechcraft 90, A90 and B90 aircraft to reflect the correct AN hardware for the rudder trim tab to rudder trim actuator attachment.
TSB liaise with Transport Canada to have CAR 571.13 revised to make it more realistic and operationally feasible for operators.

Initiatives currently underway throughout the aviation community to identify and eradicate non-conforming parts be continued. While this occurrence cannot be positively identified as being due to this problem, it is a possible scenario that cannot be eliminated. Education of aviation personnel, through this and similar occurrences where problems associated with these parts are revealed, should continue.

Department of Transport - Aircraft Services Directorate institute procedures to ensure that all parts issued from their supply section conform to the specifications required in appropriate publications.

ADDENDUM

The following actions have been taken by the TSB and Transport Canada in addressing the Safety Actions Required, as in the public report:

- Transport Canada has written the Federal Aviation Administration recommending that Raytheon Beech be contacted to have the Aircraft Maintenance Manual amended to include complete assembly instructions and illustration.

- Transport Canada does not recognize the Illustrated Parts Catalogue as an authoritative document for the purposes of assembly, only for the identification of appropriate parts. Therefore, Transport Canada does not agree that CAR 571.13 should be revised.

- Transport Canada, Aircraft Services Directorate, has verified that all parts in their parts supply section conform to the required specifications and are in the appropriate bins. This activity is on-going.

All warehouse and procurement staff and aircraft maintenance engineers (AME) in the Aircraft Services Directorate have received training on bogus parts to increase awareness on this issue.

The Aircraft Services Directorate Maintenance Control Manual was amended to enhance parts control procedures.

1. All times are EST (Coordinated Universal Time minus 5 hours) unless otherwise noted.


3. AGARD Manual of Aeroelasticity Part V, Chapter 3, "Flutter of Control Surfaces and Tabs"

4. CAR 571.13 and Airworthiness Manual 571.13, including information notes.
Air 1997

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 Occurrence Report
Loss of Engine Power
Ottawa Aviation Services Inc.
Diamond DA20-A1 Katana C-FTKZ
Cornwall Regional Airport, Ontario
15 April 1997

Report Number A97O0055

Summary

The aircraft, with an instructor pilot and private pilot on board, departed Ottawa, Ontario, on a planned night cross-country training flight to Cornwall, Mirabel, Quebec, and return to Ottawa. During the climb to cruise flight, the smell of hot oil was detected in the cockpit. The engine oil temperature was observed to be higher than normal, but the oil pressure was normal. The smell was attributed to possible spillage during the addition of oil to the aircraft engine (Bombardier-Rotax GMBH Type 912A3) before departure. The smell faded away and did not reoccur, so the flight was continued. After arriving at Cornwall, a touch-and-go landing was completed on runway 28. At about 300 feet above ground level (agl), the after take-off checks were completed and the engine oil temperature was again noted to be higher than normal, but now the oil pressure was observed to be lower than normal. At about 500 feet agl, a decision was made to return to the airport and land on the reciprocal runway, runway 10. The private pilot completed the turn back to the airport; however, being close to the runway the aircraft was high on the approach. The private pilot placed the aircraft into a forward slip to quickly lose altitude, but the instructor determined that the aircraft could not be landed on the remaining runway without experiencing a runway excursion. The instructor pilot took control of the aircraft and initiated an overshoot at low level. Shortly thereafter the aircraft engine lost all power, and the instructor pilot carried out a forced landing into a field adjacent to the airport. During the landing, the nose gear was torn from the aircraft causing the aircraft to flip over. The crew sustained minor injuries, and the aircraft was substantially damaged.

Ce rapport est également disponible en français.
Other Factual Information

The instructor pilot and private pilot were qualified and certified for the flight in accordance with existing regulations. The private pilot was receiving dual instruction toward his night rating when the accident occurred.

The aircraft was examined and no abnormalities were noted except with the aircraft engine. During the examination of the engine it was observed that a clamp installed on the No. 2 exhaust pipe to secure asbestos tape to the pipe had been chafing the outboard end of the pressure oil filter. This chafing action, sustained by the vibration of the engine during operation, had worn a hole in the filter case that allowed oil to escape from the engine which resulted in diminished oil pressure. The No. 2 exhaust pipe is fastened to the No. 2 cylinder head on studs by M8 self-locking nuts (Rotax part number (P/N) 942-035). It was discovered that these nuts had lost their torque and became loose which allowed the exhaust pipe to become loose, causing contact with the oil filter. Oil had sprayed over the windshield of the aircraft.

The exhaust nuts on Nos. 1 and 4 cylinders were also found loose but the exhaust nuts on the No. 3 cylinder were tight. Review of the aircraft maintenance records revealed that work had been done on cylinder Nos. 1, 2, and 4 that involved the removal and installation of the exhaust nuts.

The locking mechanism of the M8 lock nut is an oval-shaped thread hole manufactured into the nut cylinder which, on installation on the exhaust stud, pinches the stud thread. During removal of the lock nut, the pinch on the stud thread is reduced and the locking capability is diminished. The aircraft maintenance manual states that "self locking nuts must be replaced with new items after removal in the event that the friction torque has diminished". Testing conducted at the Transportation Safety Board of Canada, Engineering Branch, determined that each time a M8 lock nut is installed and removed from an exhaust stud on the ROTAX engine, the friction torque diminishes. Investigation also determined that the exhaust nuts on the occurrence engine had been re-installed and that the maintenance facility had no M8 self-locking exhaust nuts in their spares stock.

A spring contained in the original oil pressure filter (Rotax P/N 825-700) was causing cracks to develop in the end of the filter housing. Diamond Aircraft recommended the replacement of this assembly in Diamond Aircraft Alert Service Bulletin No. DA20-79-04A, Rev. 0, issued 10 January 1997, with oil filter Rotax P/N 825-701. The replacement filter is dimensionally longer than the original filter and, when installed on the engine, reduces the end clearance with the No.2 exhaust pipe. Further, each time the filter is required to be replaced, the No. 2 exhaust pipe must be removed and reinstalled.

Analysis

The decision-making process which surrounded the decision by the flight instructor to conduct an overshoot procedure at night with an
indication in the cockpit of low engine oil pressure was examined. In hindsight and with the knowledge of outcome, this decision may appear to be incorrect; however, the decision and the factors influencing the decision must be examined in light of the situation facing the instructor pilot at the time. When the instructor pilot observed that there was a problem with the oil pressure, he immediately instructed the student pilot to turn back to the runway for a landing. The instructor pilot's decision to land the aircraft as soon as possible indicates he considered this situation an emergency and acted accordingly. He did not immediately take control of the aircraft as the flying pilot was maintaining control of the aircraft and was completing the turn back to the airport in accordance with procedures for landing.

Because the flying pilot did not successfully complete the approach to land on the remaining runway, it could be argued that the instructor pilot should have taken control earlier and guaranteed the landing to be completed on the runway. As it was dark and there was a mist on the canopy, it is not known at what time the instructor pilot could clearly determine his height and position relative to the runway or if the contaminated curved canopy distorted his perception. However, it is apparent that, as soon as the instructor pilot believed the flight was not progressing as it should have been, (i.e., the aircraft was too high), he immediately assumed control.

Once it was apparent that the aircraft was too high to successfully effect a landing on the runway, the instructor pilot was faced with two options: land straight ahead or overshoot and attempt another landing. The instructor knew that if he landed off this approach, he would experience a runway excursion and most likely damage the aircraft. Not knowing what was beyond the surface of the runway and that damage to the aircraft was likely, the instructor pilot decided to overshoot.

Attempting an overshoot at night with low oil pressure was the riskier of the two options. However, the instructor pilot, knowing he had an engine that was still producing power, believed that there was a possibility of completing a safe landing. The decision to overshoot rather than land straight ahead is consistent with framing bias where the decision is framed as a choice between two losses: sure loss and uncertain loss. Landing straight ahead would have most likely guaranteed sure loss, that is damage to the aircraft and possible injuries. In conducting the overshoot, the possibility existed that the aircraft would not have been able to successfully complete the landing; however, that possibility was less known and not as certain as the sure loss that would have been experienced during a runway excursion. Typically, when faced with these types of probabilities, people are prone to accept the uncertain, albeit riskier loss. In the case of the instructor pilot, it appears that his decision was consistent with this type of bias.

In this occurrence investigation the exhaust nuts on three of the four cylinders were found loose. It was determined that after maintenance that involved removing the exhaust system, the self-locking exhaust nuts were not replaced as recommended by the aircraft manufacturer. This style of lock nut is designed to be used only once as the removal
reduces the locking qualities to where reinstallation is not recommended.

The replacement oil filter played a minor role in this occurrence. The increased length placed the end of the filter closer to the exhaust pipe; however, had the pipe been installed and secured with new lock nuts torqued to specification, the end clearance would have been maintained and chaffing prevented.

Findings

- The instructor pilot chose to overshoot and attempt another landing rather than land straight ahead.
- The replacement oil filter, being physically longer than the original oil filter, reduced the end clearance between the filter and the No. 2 exhaust pipe.
- The self-locking exhaust nuts that secure the exhaust pipe to the cylinder head were found loose on three of the four cylinders.
- The loose exhaust lock nuts allowed the No.2 exhaust pipe to move into contact with the oil filter housing and a clamp installed on the pipe chaffed a hole in the housing.
- There were no M8 lock nuts (ROTAX P/N 942-035) in the spares stock at the maintenance facility.
- The hole in the pressure oil filter housing allowed the lubricating oil to escape from the engine. When the quantity of oil in the engine became insufficient to supply the oil pump, the oil pressure deteriorated.
- The aircraft maintenance manual states "self locking nuts must be replaced with new items after removal in the event that the friction torque has diminished."

Causes and Contributing Factors

The self-locking exhaust nuts, re-installed against the aircraft manufacturer's recommendation, came loose and allowed the exhaust pipe to move into contact with the pressure oil filter housing. The vibration of the engine during operation caused a clamp installed on this pipe to chaff a hole into the housing allowing the engine lubricating oil to escape. This resulted in the loss of engine oil pressure. Contributing to this occurrence was the increased length of the replacement oil filter and the lack of replacement nuts.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 22

Updated: 2002-10-06

Important Notices
Air 1997

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 Occurrence Report
Reversed Elevator Trim Tab Control
Kelowna Flightcraft Ltd.
Convair 340/580 C-GKFO
Hamilton, Ontario
14 May 1997

Report Number A97O0077

Summary

The Convair 340/580 aircraft, serial number 78, was being utilized on a regularly scheduled courier flight carrying freight between Hamilton, Ontario, and Mirabel Airport, Quebec. The flight was being conducted at night, on an instrument flight rules (IFR) flight plan departing at 0029 eastern daylight saving time (EDT). During the take-off roll, as the aircraft was approaching lift-off speed, it pitched nose-up to a climb attitude and became airborne with very little input from the captain. The aircraft continued to increase its nose-up attitude despite the captain's efforts to control it. Even with full nose-down trim and the pilots' considerable force on the controls, the nose of the aircraft continued to rise. Both pilots had to use their feet to push the control column forward; they were able to maintain pitch control of the aircraft. After some experimentation with various power and flap settings they found that they could put the aircraft in a descent by entering a moderate turn. After having notified Hamilton air traffic control (ATC) that they were having control difficulties, they returned to Hamilton for landing. They requested that the emergency response vehicles be called out for the landing. The crew safely landed the aircraft on runway 24 at 0043 before the arrival of the emergency response vehicles. There was no damage and no injuries.

Ce rapport est également disponible en français.

Other Factual Information

On the evening of 13 May 1997, the flight crew arrived at the Ontario Flightcraft facility at the Hamilton Airport to prepare for a scheduled courier flight from Hamilton to Halifax, Nova Scotia, via Montreal,
Quebec. The aircraft had been loaded, and documentation, including weight and balance, maintenance records, and flight plan, was checked by the flight crew prior to boarding the aircraft. It was noted by the flight crew that considerable maintenance work had been done to the aircraft and that some of the work had involved the elevator and elevator trim.

The Convair has been described by flight crews as being very heavy on the controls. On this flight, the first abnormal symptom occurred during the take-off roll when the aircraft reached \( V_r \) (rotation speed); it almost lifted off the runway by itself. The captain (the pilot flying) immediately began trimming the aircraft nose-down. As the aircraft became airborne, picking up speed, the nose pitch-up force became stronger, requiring significant counter-pressure on the control column to keep the nose in a normal climb attitude. The pilot continued to increase the nose-down trim and he noted that, as the aircraft was accelerating, the pitch-up force was increasing. He asked for assistance from his first officer as he reached full nose-down trim. Both crew members came to the conclusion that they had a centre of gravity (C of G) problem, either from incorrect loading or due to the load shifting on take-off.

The first officer (a qualified training captain) immediately unfastened his seat belt and brought both feet up to the control column so that he could exert greater forward pressure on the control column. The captain also placed his feet on the control column. The aircraft reached an altitude of approximately 6 700 feet above sea level (6 000 feet above ground level). The captain was able to make turns by controlling with his feet. The flight crew tried varying engine power settings, cycling the landing gear and flaps, but none of the configurations had a significant effect on the aircraft pitch attitude. The landing gear was left extended and the flaps were left at 10 degrees.

Because the flight was not following the standard instrument departure route (SID), ATC began to query the intentions of the flight crew. The flight crew were slow to respond but did indicate that they had a flight control problem and were returning to land on runway 30R. When the controller asked the nature of the control problem, the first officer replied that they were too busy to explain. As the aircraft circled the airport, the captain looked and did not see the rotating beacons of any of the emergency response services (ERS) equipment; the controller informed him that 911 had been called and the ERS equipment was on the way.

As they brought the aircraft around, the flight crew noted that, during the turns, when the bank angle exceeded 10 degrees, the nose would drop and the aircraft would descend. Using this technique, the crew was able to bring the aircraft around and line up for a landing on runway 24. When the aircraft was on short final, about to cross the runway threshold, the captain removed his feet from the control column so that he could have control with his hands for the landing. This action reduced the counter-pressure on the control column and resulted in the aircraft flaring for the landing. The aircraft touched down firmly on runway 24 and the crew was able to bring it to a complete stop on the runway. ERS had not yet arrived at the airport. Following the landing
the aircraft taxied normally to the Ontario Flightcraft hangar.

At the hangar, the aircraft load was inspected, the C of G was recalculated, and the load was re-weighed. All indications were that the aircraft weight and balance were within limits. When the aircraft was inspected in detail, it was discovered that the elevator trim tab was in the full nose-up position and moved in the opposite direction to the trim control wheel and to the trim indicator in the cockpit. There was no damage to the aircraft structure or any of its components.

The captain had worked for the company for about two years. He had approximately 8 000 hours flying time, of which 25 hours were on the Convair aircraft, models 580 and 5800. Most of his experience was as a first or second officer on the Boeing 727 aircraft. He had recently been upgraded to captain status on the Convair. This flight was part of the captain's line check.

The first officer was a qualified training captain on the Convair aircraft. He had accumulated a total flying time of 16 500 hours, of which 5 500 hours were on Convair aircraft.

Kelowna Flightcraft Ltd. had operated a maintenance base at Hamilton for three years. The base had expanded recently because of the company's work with Greyhound Air, and because of continued growth in the courier air freight industry. The expansion required new staff but the company found that there were few licensed aircraft maintenance engineers (AME) available, so they hired apprentices. There are no regulations regarding the ratio of licensed engineers to apprentices in a company. Over half of the employees at the Hamilton base were apprentice engineers. At the time of the occurrence, there were approximately 110 maintenance personnel at the Hamilton base. Of these, there were 36 who were directly involved in aircraft line maintenance. The line maintenance personnel were divided into 4 crews of 9 and were required to maintain 24-hour coverage. To do this, the crews worked rotating 10-hour shifts. The maintenance work, involved in this occurrence, took place on the second and third nights of a four-night work cycle. The crew had been working the night shift for a period of five weeks. They were on days off from May 6 to May 8 and started back on the night shift schedule on May 9; it was their last night shift cycle before returning to the day shift cycle.

The occurrence aircraft was a Convair 440 which had been converted by supplemental-type certificate to a Convair 580. This was an older generation aircraft for which the company had not yet developed a complete set of work or task cards. The aircraft had 70 883.3 hours (110 707 cycles) total time as of 10 May 1997. The aircraft was brought into the Hamilton maintenance base five days prior to the occurrence flight for the completion of numerous maintenance tasks. Included in those tasks were a number of non-destructive tests (NDT) for corrosion and crack inspection. These NDT were part of an on-going aging-aircraft inspection program. Part of this inspection included an ultrasonic and an X-ray inspection of the horizontal stabilizer attachment fittings. Although the X-ray inspection was negative, the ultrasonic inspection produced a positive indication on one of the
horizontal stabilizer attachment fittings. The right horizontal stabilizer and elevator were removed to gain access to the fitting for a visual inspection. The elevator and stabilizer were removed as a single unit, which meant that only the elevator connection bolts, the stabilizer connection bolts, and the elevator trim cables needed to be disconnected. The elevator trim cables were not marked when they were disassembled; it is not a procedure specified in the maintenance manual, but is one that is considered good practice in the industry. When the stabilizer was removed, it was determined that there was a small amount of corrosion on the fitting lug. The fitting was repaired, and the horizontal stabilizer and elevator were reinstalled.

The maintenance crew that removed the stabilizer assembly was not available when it was time to reinstall the stabilizer. The crew that was present to finish the job normally consisted of a crew chief, two lead AMEs, and six apprentices. When the reinstallation of the stabilizer assembly began, one of the lead engineers was absent because he had requested a day off, and the other lead engineer had phoned in to say he would not be available because of illness; therefore, the crew consisted of the crew chief and six apprentices. The crew chief had an energetic, hands-on, supervisory style, and he provided close supervision. He took two of his apprentices and showed them how to install the stabilizer and elevator. He then took one of the apprentices inside the tail of the aircraft to hook up the elevator trim cables. The crew chief selected the cables and the apprentice installed the turnbuckles. The crew chief then provided the apprentices with the appropriate information on bolt torque and cable tension and left them to complete the job. It was the view of the crew chief that he was helping the apprentices with the routine but important task of installing and inspecting the stabilizer, elevator, and elevator trim systems. The apprentices, on the other hand, viewed their task as lending a hand to the crew chief who was responsible for the work. All of the work related to the reinstallation of the elevator and stabilizer was completed on the Sunday, 11 May 1997, on the night shift. The following night, both lead AMEs were available so the crew was at full staff. On this shift, the crew chief instructed one of the AMEs to complete an "independent inspection" of the work. After inspecting the work, the AME pointed out to the apprentices several items which had not been properly completed, including missing cotter pins and locking clips, a nut which was not fully installed on its bolt, and lock wire which was not of adequate thickness. The apprentice then redid the work and presented it for reinspection. Because of concurrent tasks, the AME did not reinspect the work until the end of the shift, and he did not have any assistance while accomplishing the inspection. Since the details had been completed satisfactorily, he checked that the system was free from binding by running the trim system from full nose-down to full nose-up trim. He then checked that the elevator trim tab was at full deflection when the trim control was moved to full nose-down and full nose-up selections, and that the tab was in neutral when the trim indicator indicated neutral. Since the elevator trim tab is not visible from the cockpit, this involved setting the trim in the cockpit, exiting the aircraft, and walking around to the aircraft tail to check the trim tab position.
The elevator trim tab control cables run side-by-side, under the floor along the belly of the fuselage into the tail section where they angle upwards to the rear bulkhead. At the bulkhead, the cable direction changes to the right and the cables run one on top of the other (the inside cable becomes the top cable) along the spar out into the right horizontal stabilizer. This change of orientation (side-by-side to one on top of the other) means that the cables are not parallel as they angle up to the rear bulkhead. This change of orientation is represented on the aircraft maintenance manual diagrams as the cables coming together to a point at the rear bulkhead pulleys. Two turnbuckles are located midway along the rising span of the cable run in the tail section and allow the trim cables to be separated when the removal of the trim control is necessary. The turnbuckles are only slightly staggered when the control is in the neutral position. Looking at the two-dimensional drawing of the cable installation in the aircraft maintenance manual does not immediately indicate that the cables do not cross each other when correctly installed.

At the end of the shift, the lead engineer assisted the crew chief in filling out the aircraft logbooks. According to the maintenance logbook entry, the horizontal stabilizer and elevator were reinstalled and the rigging was checked as per the maintenance manual, although no one actually completed the task of checking the rigging. The crew chief had asked an apprentice to follow the rigging procedure as detailed in the maintenance manual, and he had highlighted two of the important tasks of the rigging by telling him to pay special attention to the cable tension and to a particular dimensional check. The apprentice understood the instruction as a request to check the cable tension and dimension, which he did; the rigging was not performed properly.

The maintenance entry was signed as having been completed by the AME who had actually completed the "independent inspection", while the "independent inspection" was signed off by the crew chief who supervised the task. This occurred at the end of the shift when logbooks from several aircraft were being completed and signed by the two AMEs. Both AMEs felt confident in the other's work, and they simply signed off the work completed by the crew, regardless of their personal involvement. The previous concept, as outlined in Airworthiness Manual (AWM) 571.209, was that the inspection would be completed by a person who was completely independent from the persons who accomplished the work.

This incident occurred as the Hamilton base was undergoing a managerial change. The nature and complexity of the Hamilton operation had changed and Kelowna Flightcraft Ltd. felt that a new manager was necessary. One of the first initiatives of the new manager was a change in shift schedule. However, the old shift schedule, which was generally disliked by the employees, was still in use at the time of the occurrence. The old shift schedule was a complex cycle that repeated every eight weeks. It involved working between four and seven consecutive days, followed by three to six days off. Each shift was 10 hours long. In this occurrence, the elevator trim tab had been installed by a crew that was working their last set of nights, after having
been on night shifts for five weeks. (The actual control cable attachment was accomplished between the hours of 0300 and 0500. (1) These times coincide with the low point in a person’s normal circadian rhythm.

Kelowna Flightcraft Ltd. has numerous bases throughout Canada, with line maintenance at each base. The company has adopted a centralized system of maintenance control with maintenance planning being accomplished at the company’s head office in Kelowna, British Columbia. An index sheet detailing the work to be done on a particular aircraft was faxed to the base where the aircraft was located. At the end of the shift, the base would fax details of the work that had been performed back to the maintenance control office. Task cards were used to detail the work required for the regularly scheduled inspections. Non-scheduled maintenance was done by reference to the company’s maintenance control manual (MCM). The removal and re-installation of the horizontal stabilizer on this night was done by reference to the MCM.

Initial training for new apprentices was limited to self-study of the company’s policy and procedures manual. The crew chief and lead hand were responsible for on-the-job training to ensure that the apprentices learned how to do the various tasks required of them. Licensed engineers received aircraft type training leading to type endorsements for the various aircraft that the company operated. No additional training was given to help the crew chief to carry out the supervisory and training aspects of the job.

The "independent inspection" is required by the Canadian Aviation Regulations (CARs) as a recognition of the possible serious consequences when flight controls or power plant controls are worked on. CARs Standards 571.10 specifies that work that disturbs engine or flight controls be inspected for "correct assembly, locking and sense of operation, by at least two persons, and the technical record contains the signatures of both persons. Information Note: One of the signatures required by this section may be that of the person who has signed the maintenance release."

Part of the "independent inspection" is the requirement to inspect for correct sense of operation (i.e. that the trim tab moves in the desired direction); there is no requirement to check for correct range of travel. On this aircraft, it is not possible to observe the motion of the trim tab from the cockpit. To accomplish the "independent inspection", the AME moved the control fully through the entire range of motion and checked the actual position of the trim tab three times by going to the back of the aircraft and observing the tab in the full-up, full-down, and the neutral position. The elevator trim tab moves in a direction opposite to the elevator. Moving the cockpit trim control towards the nose-down position causes the trim tab to move trailing edge up, while moving the control towards nose-up causes the tab to move trailing edge down. No one who worked on the system checked the elevator trim for correct rigging.

The flight crew was aware that the elevator and elevator trim had been
affected by the maintenance work performed; however, because the flight was a cargo flight, the nose-up tendency of the aircraft was quickly assumed to be caused by a load shift problem, rather than a flight control problem.

ERS presence was not immediately available because there are no emergency rescue personnel at the airport at night. Hamilton Airport has on-site ERS from 0700 to 2330, after which the airport is serviced by the Glanford Fire Department.

The aircraft was equipped with an intercom system which incorporated a hot mike to facilitate crew communication. To transmit via very high frequency (VHF) radio, the pilot must depress and hold a push-to-talk (PTT) button. In a typical installation, the PTT button is located on the pilot's control wheel, but on this aircraft the button is located on an intercom box that is mounted on the cockpit wall beside the pilot seats. In order for the crew to use the PTT button, they must remove one hand from the control column, left hand for the captain or right hand for the first officer.

**Analysis**

Aviation maintenance professionals require an extremely broad range of skills, and they are subjected to the pressures of keeping all aircraft in revenue service, working during evening hours under severe time constraints, maintaining an ageing fleet, and dealing with other factors that affect human performance. The ultimate fear of any maintenance professional (supervisor, AME, apprentice, or inspector) is that an error, once committed, will remain undiscovered and ultimately lead to an accident. The serious consequences of an error in the installation/rigging of flight or engine controls is recognized by both the industry and Transport Canada, thus engine or flight control maintenance is treated differently than other maintenance tasks. The requirement for a second person to formally inspect this work is intended to prevent the aircraft from being dispatched with control problems. In this occurrence, five people had a hand in the installation/rigging/inspection of the elevator trim tab control system of this aircraft, and it was still released with the elevator trim control operating in reverse.

The task of hooking up the control cables is, in itself, very basic. There are only two cables and it does not require training to expert levels to understand the system and to recognize that the consequences of hooking the cables up backwards can be disastrous. This analysis will focus on how five aircraft maintenance professionals (with different levels of experience) worked on this system and allowed the aircraft to be dispatched with the elevator trim operating backwards.

The job performed by the maintenance crew when they set out to reinstall the horizontal stabilizer and elevator was not technically complex. It involved positioning and bolting the stabilizer and elevator in place and reconnecting and tensioning the elevator trim tab cables. The job was straightforward enough that the crew chief could allow two apprentices to complete it without direct continuous supervision.
However, there are a number of seemingly insignificant factors which compounded to make the task more error-prone.

First, the crew had been working the night shift for a number of weeks and, since the individuals would revert to a regular daytime schedule on their days off, they had experienced five changes in sleep patterns in the past five weeks, from daytime to nighttime. The control attachment was done at the low point in the circadian rhythm, when each of the individuals involved would be at their lowest level of alertness, suggesting that fatigue may have been a factor in the occurrence.\(^{(2)}\) No one on the crew was aware of the degrading effects that shift work has on human performance. The crew chief was simultaneously responsible for assigning and supervising the work of six apprentices that night, a task that would require maximum alertness and awareness on his part. The apprentices, despite low levels of experience, were task oriented. Fatigue would make it more difficult for them to view the project as a whole, compared to the relative ease of viewing and completing a single task. Even during the completion of the individual tasks, fatigue and/or complacency contributed to a number of relatively minor errors in installation, which the lead hand identified during his first inspection.

This was an older generation aircraft for which the company had not yet developed a complete set of work or task cards. All maintenance work was performed with reference to the aircraft maintenance manual. The maintenance manual contains detailed instructions on how to remove and install the elevator and how to remove and install the stabilizer, but does not provide instruction for the task of removing and installing the stabilizer with the elevator attached. Thus, a significant amount of interpretation is required. When he connected the control cables, the crew chief had no objective cues to help him decide which cable ends should be attached together. The cables were identical, the turnbuckle locations were not significantly staggered to prevent incorrect installation, and the cables had not been marked when they were disassembled. The crew chief relied on the subjective appearance of the installation, and he believed that they were correctly connected. Comparison with the two-dimensional drawing of the cable installation in the aircraft maintenance manual would not immediately indicate to him that the cables did not cross each other when correctly installed. In fact, after the occurrence, the cable arrangement was described as looking wrong when correctly hooked up and looking right when hooked up backwards. Adding to his false sense of security, he knew that when the controls were rigged, an "independent inspection" would be carried out. In fact, he had the system double-checked, first by the AME and later by another apprentice.

The crew chief's hands-on supervisory style may have been more efficient in getting the job completed, but it prevented the apprentices who were working on the installation from gaining an overall picture of the work being carried out. Although they were in a learning position, there was no formal and little informal technical training for the apprentices. In this instance, there was no explanation of how to choose which of the cable ends were to be connected together, nor
was there an explanation of how to ensure that the job was completed correctly. The job was initiated by the crew chief, then turned over to the apprentices to complete. The two apprentices completed the tasks as they thought they had been assigned; they did not feel responsible for the overall installation. This lack of communication was also a factor with the third apprentice who was later assigned to check the rigging. He did not fully understand what he was being asked to do, nor did he appreciate the significance of rigging the controls. His focus was on two of the installation tasks that formed only a small part of the overall rigging procedure.

Another significant factor in this occurrence is the quality and quantity of training that the personnel received. The apprentices who carried out much of the work in the installation had never accomplished this task before, a fact that the crew chief was not aware of. Since the continuous and progressive training of the apprentices is not a formal process, he would have been aware only if the apprentices had informed him. The crew chief, who was required to supervise and train the apprentices, had himself never received supervisory training. Training on soft issues, such as supervisory skills and interpersonal communication, is still quite rare in the aircraft maintenance industry.

The CARs require that two individuals inspect the control system for correct assembly, locking, and sense of operation, and that both individuals record their signatures in the technical record. There is no requirement that either individual be independent of the work being done. The AME who accomplished the "independent inspection" did not notice that the controls were incorrectly connected. There are two separate issues relating to this check: the independence of the check, and the contents of the check. The former concept, as outlined in AWM 571.209, was that the inspection would be completed by a person who was completely independent from the persons who accomplished the work. This person would approach the inspection with fresh eyes, and therefore he would see errors overlooked by the person who actually performed the work. He would also have an interest in ensuring that the work was correct since his signature indicates that he is taking on responsibility for work which he did not complete. In practice, the work accomplished is often signed off by one of the AMEs who performed the work, and the "independent inspection" is signed off by another person working on the same job. This casual attitude toward the signature for the "independent inspection" is evident in this occurrence. The two AMEs were concerned only that both their signatures were recorded in the logbook, not what their individual signatures represented. Each AME simply signed one of the two blanks on the logbook, regardless of who had done the work and who had inspected the work. The content of the check is also at issue. The intention of the check was to examine for correct assembly, locking, and sense of operation. The AME did check for correct assembly and locking and did find some discrepancies, which he rectified. These are areas he knew the apprentice had completed. He then performed a very cursory inspection of the system, visually checking for full movement of the tab and ensuring that the turbuckles were not interfering with the pulleys. However, without a second person to assist him, on this aircraft, it was
more difficult to adequately check either the range of travel or the sense of operation.

Although the captain was licensed and qualified for the flight, his experience on Convair aircraft was extremely limited. When checking the maintenance records prior to the flight, he did note the amount of maintenance work that had been completed on the aircraft, but rather than suspecting potential problem areas, he viewed this as an indication that the aircraft was being kept in great shape. When the aircraft began to pitch nose-up during the take-off run, the crew misdiagnosed the problem as one associated with the aircraft C of G rather than the trim setting.

Findings

- There were four maintenance crews maintaining 24-hour coverage via a complicated shift rotation. The crew had been working the night shift for five weeks and were on the second and third nights of a four-night block.

- The maintenance crew consisted of three licensed AMEs and six apprentices. On the night the cables were connected, two of the licensed AMEs were not at work.

- The maintenance crew that removed the stabilizer and elevator assembly was not the same crew that reinstalled the assembly.

- When disconnected, the elevator trim cables were not marked so there were no easy references when they were reconnected.

- The elevator trim cables were crossed during the installation because the crew chief did not identify the elevator trim cables.

- When the AME was conducting the final inspection of the installation, he was working alone. Therefore, he relied on operating the trim and checking the movements of the surfaces. He did not notice that the trim tab was moving in the opposite direction to the input in the cockpit.

- The AME who inspected the installation signed in the maintenance log as having accomplished the work, and the crew chief signed as having inspected the work.

- The maintenance entry indicated that the elevator trim system had been rigged when it had only been reconnected.

- The company did not have a complete set of maintenance task cards available for all spontaneous maintenance tasks. To complete this task, the crew were relying on the aircraft maintenance manual.
- The elevator trim control cable diagram in the aircraft maintenance manual is ambiguous and could be interpreted as having the trim cables crossing each other.

- Although the company provided adequate technical training for licensed AMEs, there was no training for the apprentices and no human factor or supervisory training for the crew chiefs, nor is there a regulatory requirement for this training.

- CAR 571.10 requires that two persons inspect any engine or flight controls which have been disturbed (commonly known as the independent or dual inspection). There are no criteria as to who those persons may or may not be.

- CAR 571.10 does not specifically require that controls be checked for range of travel.

- Airport ERS were not available for the landing because, after midnight, the airport relies on the municipal fire department for crash fire rescue.

- To transmit via two-way VHF radio, the crew members had to remove one hand from the control column to depress the PTT button.

- The captain's inexperience on type, combined with the crew's predisposition toward a C of G problem related to a load shift, led to the crew incorrectly diagnosing the trim problem.

### Causes and Contributing Factors

The aircraft was dispatched with the elevator trim operating in reverse due to a series of maintenance errors. Contributing to this occurrence were that the crew chief connected the elevator trim control cables in reverse, and that the AME who was tasked subsequently with inspecting the work did not properly assess the sense of operation and trim direction.

### Safety Action

Following the occurrence, Kelowna Flightcraft Ltd. proceeded with the change of shift work scheduling to a more workable two week shift schedule.

Kelowna Flightcraft Ltd. has amended the maintenance training program to include supervisory training for crew chiefs and plans human factors training for all AMEs in the future.

Kelowna Flightcraft Ltd. has amended the independent inspection of flight controls to include the inspection and sign-off by a qualified flight crew member.
Following the occurrence, Kelowna Flightcraft Ltd. modified the aircraft so that the PTT button was located on the control column.

Kelowna Flightcraft Ltd. has recognized the potential for hooking the trim cables in reverse, and future developments of the model 5800 will be designed with the intent of ensuring that the trim cables are significantly staggered to make it difficult to connect the cables in reverse.

Kelowna Flightcraft Ltd. is in the process of writing task cards for the removal of assemblies. These task cards will contain a caution note about trim cable connections.

Transport Canada issued Airworthiness Notice No. C010 Edition 1, dated 10 October 1997, entitled Inspections of Control Systems, which explains the regulations applicable to the maintenance of engine and flight controls and outlines the applicable standards for control systems maintenance. The document emphasizes the requirement that the person performing the dual inspection be independent of the original work and that the inspection include a verification of the range of operation of the control system.

In the 4/97 issue of Transport Canada's Aviation Safety Maintainer, the article "Exploring the Problem of Misconnected Controls" uses the circumstances of another crossed flight control accident (TSB Report No. A97C0089) to raise the question as to why so many people would miss such an important item as the integrity of flight controls. It concludes with a challenge to the reader to develop a methodology that uses all the tools available to avoid lapses that result in mis-rigged controls.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Jonathan Seymour, Charles Simpson, W.A. Tadros and Henry Wright authorized the release of this report on 13 January 2000.

1. All times are EDT (coordinated universal time minus four hours) unless otherwise noted.


R.M. Coleman, Wide Awake at 3:00 a.m., By Choice or by Chance? (New York: W.H. Freeman & Company, 1986).
Air 1997

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 Occurrence Report
Wheels-Up Landing - Unintentional
North American Airlines Ltd
Swearingen SA226-TC C-FEPW
Ottawa/Macdonald-Cartier International Airport, Ontario
13 June 1997

Report Number A97O0100

Summary

The aircraft was transporting express mail from Hamilton to Ottawa, Ontario. The flight was uneventful to Ottawa; however, the aircraft landed on runway 25 with the landing gear retracted. After the aircraft skidded to a stop, a fire erupted in the area of the right engine. The two flight crew members, the only persons on board, quickly exited the aircraft via the main door, and the fire was extinguished by airport firefighters. Neither flight crew member was injured, and the aircraft was substantially damaged.

Ce rapport est également disponible en français.

Other Factual Information

The flight crew were properly licenced and certified to conduct the flight. The pilot had a total flying time of approximately 2,240 hours, of which 1,930 were on the occurrence aircraft type. The co-pilot received his commercial pilots licence in 1988 and had approximately 500 hours total flying time. He completed his instrument rating on 15 December 1996 and his initial training on the SA226-TC was completed in March 1997 in British Columbia with a different company. He had not flown for 44 days at the time his recurrent training was completed on 09 June 1997. This was the co-pilot's third day of operational flying for the company; he had accumulated approximately 55 hours total time on the aircraft type.

The co-pilot was flying the aircraft for a radar-vectored, localizer/back-course approach to runway 25 of the Ottawa/Macdonald-Cartier airport.
Descending out of 10,000 feet above sea level, the crew completed a briefing for the approach. The weather conditions at the time did not necessitate a full instrument approach briefing because the crew expected to fly the approach in visual conditions. Air traffic control requested that the crew fly the aircraft at a speed of 180 knots or better to the Ottawa non-directional beacon (NDB), which is also the final approach fix (FAF) for the approach to runway 25. At approximately eight nautical miles from the airport the aircraft was clear of cloud and the crew could see the runway. In order to conduct some instrument approach practice, the pilot, who was also the company training pilot, placed a map against the co-pilot's windscreen to temporarily restrict his forward view outside the aircraft. The approach briefing was not amended to reflect the simulated instrument conditions for the approach. The co-pilot accurately flew the aircraft on the localizer to the FAF, at which point, he began to slow the aircraft to approximately 140 knots and requested that the pilot set ½ flap, which he did. Once past the FAF, the copilot's workload increased, and he had difficulty flying the simulated approach. On short final to runway 25, the pilot removed the map from the co-pilot's windscreen. The co-pilot noted that the aircraft was faster and higher than normal and he tried to regain the proper approach profile. By the time the aircraft reached the threshold of the runway 25, it was approximately 500 feet above ground, and at a relatively high speed, so the pilot took control of the aircraft for the landing. The pilot attempted to descend and slow the aircraft as it proceeded down the length of the runway and stated that he had just initiated an overshoot when he heard the first sounds of impact.

Runway 25 is 8,000 feet long. The first signs of impact on the runway were made by the propellers, with propeller marks beginning about 4,590 feet from the threshold of runway 25. The aircraft came to rest about 6,770 feet from the threshold, and a fire broke out in the area of the right engine. The co-pilot opened the main door of the aircraft while the pilot shut down the aircraft systems, and both exited the aircraft uninjured.

The maximum speed for extending the landing gear on this aircraft is 176 knots, and the company standard operating procedures (SOPs) for a normal instrument approach stipulate that the aircraft should cross the final approach fix at a speed of 140 knots, with a ½-flap setting, and with the landing gear lowered.

The company SOPs require that all checklist items, from the after start checks through to the after landing checks inclusive, be actioned through a challenge and response method with each item called individually. The first item of the before landing checks is "Landing gear .....Down/3 greens". The co-pilot did not recall being challenged for the landing gear check, and the pilot could not remember selecting the landing gear switch to the down position. Neither pilot checked for the three green lights prior to the occurrence. The pilot stated that it was his habit to check if the landing lights were on prior to landing because it was his habit to turn them on only after the landing gear had been extended. He remembered checking to see that the landing lights were on and so was satisfied that the gear was down. The co-pilot assumed
that, because the aircraft had passed the NDB, the before landing checks had been completed; they are normally completed before or at that point during an approach. Neither pilot recalled hearing a gear warning horn prior to the impact.

When the aircraft systems were inspected, the landing gear selector was found in the up position. Tests were conducted on the landing gear warning system which revealed that the gear warning horn did not function. A closer examination of the system revealed a faulty diode. The diode was replaced and when the warning system was checked again, it functioned properly. The pilot stated that the gear warning horn on the aircraft had functioned properly during the training for the co-pilot one week earlier.

**Analysis**

New flight crew members take time to adjust to operating procedures and the flow of task completion. Therefore, the experienced crew member must be rigid in adherence to procedures and vigilant to all operations in the cockpit, all of which increase the workload on the experienced member. In this occurrence, the combination of the co-pilot's low flying experience, his lack of experience in instrument conditions, and the relatively high speed to the Ottawa NDB resulted in a high workload situation. This is supported by the co-pilot's statement that the operation became busy after the aircraft crossed the NDB. Concurrently, by simulating an instrument approach, the pilot was not only required to carry out routine duties but also had to concentrate on the actions of the co-pilot. When the co-pilot became overwhelmed, the pilot's already demanding workload was unexpectedly increased as he was required to take control of the aircraft.

Typically, the before landing check is carried out prior to or at the FAF. However, for this crew, the focus prior to the NDB was on the simulated instrument approach, and, immediately after, on the need to reduce speed and altitude. In attending to those immediate demands, the crew forgot to complete the before landing check. Each crew member recalled considering some elements of the checklist, but neither can recall carrying out the checklist in a challenge and response manner, and the aircraft was landed with the landing gear retracted.

Several factors point to the possibility that neither crew member had a full appreciation of the developing situation: the pilot did not take control until the aircraft was over the threshold of the runway; neither crew member related the excess aircraft speed to the fact that the landing gear had not been lowered; the pilot continued with the landing, despite the aircraft's altitude and speed over the threshold; and the pilot was surprised when the aircraft hit the runway just as he was about to initiate an overshoot.

The addition of impromptu instrument training exacerbated the co-pilot's workload and subsequently that of the pilot. The increased workload contributed to the breakdown in coordination and communication and resulted in the before landing check not being completed. While practising approaches during favourable weather
conditions on operational flights provides the opportunity to develop and maintain proficiency, appropriate planning is necessary to ensure all contingencies have been considered.

The pilot's habit of checking for landing light activation to connote completion of the before landing check is an unsafe practice; checking the landing lights does not ensure that all items on the checklist list have been completed. The final link in the chain of events which led to the occurrence was the failure of the landing gear warning horn to warn the pilots that the landing gear was not locked down.

Findings

- The flight crew were certified and qualified for the flight in accordance with existing regulations.

- The simulated instrument approach training was not planned nor discussed prior to its undertaking, and resulted in an increased workload for both crew members.

- The company standard operating procedures were not followed.

- The before landing checklist was not completed, and the aircraft's landing gear was not selected down for landing.

- The landing gear warning horn did not function because of the failed electric diode.

- The aircraft contacted the runway with the landing gear in the retracted position.

Causes and Contributing Factors

The aircraft was landed with the landing gear retracted because the flight crew did not follow the standard operating procedures and extend the landing gear. Contributing to the occurrence were the lack of planning, coordination, and communication on the part of the crew; and the failure of the landing gear warning system.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 21 May 1998.
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 Occurrence Report
Stall - Spin
Douglas De Nien Sparrow Hawk CF-ASQ
Grand Valley (Private Aerodrome), Ontario
23 June 1997

Report Number A97O0103

Summary

The pilot flew his amateur-built aircraft from his home base at Nobelton, Ontario, to a friend's private aerodrome near Grand Valley to pick up a part for another vintage aircraft that he owned and flew. After getting the part and having a brief conversation with his friend, he took off towards the north-west. He climbed to about 500 feet above ground level (agl), reversed course to the left, and flew a low pass at 75 to 100 feet agl over the departure runway towards the south-east, a manoeuver he had carried out on previous take-offs. About half way along the 1,800 foot runway, the aircraft climbed to 300 to 350 feet agl then pitched nose down and rolled to the right. It descended in a steep, nose-down, right-banked attitude and struck the ground near the south-east end of the runway after rotating through 270 degrees. There was no engine sound as the aircraft descended. The aircraft came to rest on the nose and right wing where it struck the ground. The aircraft struck the ground with little or no forward speed, and there was no wreckage trail. The pilot was fatally injured.

Ce rapport est également disponible en français.

Other Factual Information

The weather at the time of the accident was as follows: high scattered cloud, visibility 25 miles, light winds from the west, temperature 27°C, and dew point 15°C.

Records indicate that the aircraft was equipped and maintained in accordance with existing regulations for amateur-built aircraft. Construction of the single seat biplane aircraft was completed by the pilot in 1970. It was powered by a 100-horsepower Continental O-200-
A aircraft engine and had a maximum authorized gross weight of 1,050 pounds. Total airframe time was 1,177 hours.

The pilot was certified and qualified in accordance with existing regulations. He had flown a total of 1,248 hours and had flown nearly all of the 1,177 hours accumulated on the Sparrow hawk aircraft. There was no evidence that incapacitation or physiological factors affected the pilot's performance.

There was no evidence of pre-impact failure of the aircraft airframe or flight controls that would contribute to the accident, nor was there evidence of internal failure of the aircraft engine or any of its components. The engine rotated freely, and there was adequate lubrication. The emergency locator transmitter (ELT) was found with the function switch secured in the OFF position with a piece of styrofoam.

The aircraft fuel tank was destroyed on impact. There was no evidence of fuel at the accident site and examination of the fuel lines and carburettor did not reveal any trapped fuel. There were no fuel records found for the aircraft. The pilot purchased fuel in two five-gallon (23 litre) fuel containers at the aerodrome where he based the aircraft and fuelled the aircraft himself. He last purchased 46 litres of fuel 11 May 1997. There was one fuel container full of fuel and one container empty at the hanger where he stored the aircraft. Records show the aircraft flew 2.0 hours on 11 May 1997 and another total of 1.5 hours on three short flights, plus the time it flew on the day of the accident. The aircraft fuel tank capacity was 18 Imperial gallons (82 litres).

Analysis

The wreckage distribution, impact angle, and lack of forward speed indicate that the aircraft was in a stalled condition when it struck the ground. Because of the pilot's familiarity with the aircraft, it would seem unlikely that he would stall the aircraft on climb out, unless something unexpected occurred.

Based on there being no evidence of fuel found at the accident site or during the detailed examination of the engine, and the lack of engine noise as the aircraft descended, it is concluded that the engine stopped because of fuel exhaustion during the climb. The nose-high attitude of the aircraft, along with the characteristic high aerodynamic drag of the biplane would have resulted in a rapid loss of airspeed when engine power was lost. The pilot may have banked the aircraft aggressively to manouevre for a landing on the aerodrome, and the wing stalled. The aircraft was at too low an altitude for the pilot to affect recovery from the stall before the aircraft struck the ground.

Findings

- The aircraft was equipped and maintained in accordance with existing regulations and approved procedures.

- The pilot was certified and qualified to conduct the flight.
There was no evidence of fuel found at the accident site or during the examination of the aircraft engine.

It was concluded that the aircraft engine stopped because of fuel starvation during the climb at low altitude.

The aircraft stalled at too low an altitude for the pilot to effect recovery.

Causes and Contributing Factors

Following an engine stoppage caused by fuel exhaustion, the aircraft stalled at too low an altitude for the pilot to recover.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 06 March 1998.

Updated: 2002-10-06
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 Occurrence Report Roll-Over On Landing
Alpine Helicopters Limited
Bell 212 (Helicopter) C-GALI
Mica Creek, British Columbia 3 nm SW
01 March 1997

Report Number A97P0044

Summary

At about 0830 Pacific standard time, the Bell 212 helicopter (serial number 30525) with the pilot, 11 passengers, and the ski-guide on board, was on approach to a prepared landing site in the Monashee Mountains near Mica Creek. About 200 feet from touchdown, the occupants heard a loud explosion and saw several cockpit warning lights illuminate; simultaneously, the number 1 engine stopped. The pilot continued the approach, but the low rotor rpm warning horn came on and the helicopter turned gradually to the right, forcing the pilot to land in an adjacent, unprepared area. The passengers reported that the initial touchdown was not hard, but the helicopter then tipped over onto its left side in the waist-deep snow, and the main rotor blades struck the surface. The main transmission was ripped out, and one rotor blade struck the cockpit roof, severely damaging the overhead electrical circuit breaker panels. The 11 passengers in the cabin quickly evacuated the helicopter without difficulty, using the right-hand sliding door. The ski-guide, who was seated in the left pilot seat, broke open and escaped through the roof window above him. He returned with two other passengers to extract the pilot through the same window opening. Despite the rollover, the number 2 engine continued to run for 15 minutes, when another loud explosion was heard, and this engine stopped. Two small engine bay fires began but quickly self-extinguished. There were no other injuries. The helicopter was substantially damaged. The emergency locator transmitter (ELT) activated during the accident and its signal was received by the SARSAT (search and rescue satellite-aided tracking) network.

Other Factual Information
The pilot was certified, trained and qualified for the flight in accordance with existing regulations. He was on the last day of a two-week tour of duty at the Mica Creek Lodge. The guide and other witnesses reported the weather at the accident site as more than 4 miles visibility in very light snow with an overcast or broken layer of clouds at about 7,500 feet and a light wind from the south. The accident occurred at the 5,500-foot level, about 50 feet from the intended landing site.

The weight and centre of gravity of the helicopter were within the prescribed limits. The manufacturer's performance charts indicate that the helicopter was capable of a single-engine rate-of-climb of 250 feet per minute, given the flight conditions of that day. However, in this instance, the pilot was committed to touchdown because the helicopter was in a slow and shallow descent for a landing when the number 1 engine stopped, and was too slow and too close to the ground to arrest the rate-of-descent with only one engine. In the attempt to continue the approach to the intended site, the main rotor rpm decayed, and the pilot was forced to land at an unprepared site.

On examination, both engines were found to have suffered uncontained power turbine failures. A power turbine wheel, when operating under load, will rapidly accelerate to high speed if it is suddenly uncoupled from that load. The normal maximum rotational speed of the power turbine wheel in the PT6T-3 engine is 33,000 rpm. Pratt and Whitney Canada (P&WC), the engine manufacturer, report that the designed fracture speed for the blades is between 45,700 and 51,600 rpm, and that the blades are designed to fracture in an overspeed situation before the disc speed is high enough to cause it to fail. The number 1 engine power turbine wheel had shed about three-quarters of its blades with the remaining quarter grouped together on one section of the wheel.

![Combining Gearbox diagram]

**Figure 1 - Combining Gearbox**

The number 2 engine power turbine had shed all of its blades. The blades from both wheels broke through their respective steel...
containment rings, through the combustion cans, and finally through the outer casings of both engines. Although the engine structure did not restrain the blades when they separated from the turbine disk, the blades did not cause further significant damage to the helicopter structure.

The engines were examined, and the shafts connecting each engine’s power turbine to the combining gearbox (C-box) were found to have failed. The input shaft for the number 1 engine had failed at the number 5 bearing, located at the front of the C-box. The bearing had disintegrated and the shaft had melted. The shaft for the number 2 engine failed just aft of the power turbine. It was determined that this shaft had failed due to insufficient lubrication at the number 4 bearing. All bearings in the number 2 engine showed signs of heat distress, the result of insufficient lubrication as the engine continued to run while the helicopter was on its side. The gas-producing sections of both engines turned freely, and no anomalies were found that would have caused either engine to overspeed.

The C-box was dismantled. The clutch assembly for the number 1 engine exhibited extreme wear. The clearance between the outer and inner clutch surfaces was 0.0137 inches beyond tolerance. The engagement surfaces were rough, and there were indications that the clutch had been slipping. According to the clutch manufacturer, a clutch worn to this extent can slip at normal torque loads. The inner shaft's end movement, or float, was measured to be 0.029 inches, well beyond the overhaul standard of between 0.002 and 0.004 inches. Spacing shims within the clutch assembly were also found to be worn and the inner races of the clutch bearings had grooves worn into them.

The coupling shaft between the number 1 engine clutch and the final output helical gears was found to have sheared. The fracture surfaces of this shaft had smeared when the two halves had rubbed against each other after breaking; however, the general characteristics of the failure were consistent with a torsional overload in the direction of normal driving loads.

Analysis by the TSB Engineering Branch determined that the clutch met the manufacturer's specifications for material and hardness. It was found that the grooves in the inner races were caused by wear. When the clutch is engaged, as it is during all normal operations, the outer and inner shafts turn together as one unit, and there is no relative movement of the clutch bearings. Drive system vibrations could cause the stationary ball bearings to wear grooves into the bearing races. The wear on the shims and the grooves in the inner races permitted the inner shaft end float to increase.

Eight days before the accident, the C-box chip detector warning light had illuminated and, on inspection, fuzz and two fine metal slivers were found on the chip plug. The material was removed and retained. The C-box oil and filter were changed, and an engine run was carried out. After the accident, the material removed from the chip plug was analysed by the TSB Engineering Branch and found to be the same material as found in the clutch. The clutches are lubricated by the C-
box lubrication system.

Two weeks before the accident, the tail rotor drive shaft experienced an unexplained torque overload that damaged the 90-degree gearbox. As a result, the 90-degree gearbox, the drive shaft, the 42-degree gearbox, and the hanger bearings were replaced. The replacement 90-degree gearbox, which was in the helicopter at the time of the accident, was compared with the gearbox that was involved in the earlier incident; both gearboxes exhibited almost identical damage patterns.

Technical records indicate that the helicopter was maintained in accordance with existing regulations and standards of airworthiness. Since their overhauls, the number 1 engine had accumulated 2,822 hours, the number 2 engine had accumulated 930 hours, and the C-box had accumulated 2,920 hours. The normal time between overhauls for the C-box is 4,500 hours. The C-box was last overhauled at the P&WC service centre in St. Hubert, Quebec, and the maintenance release was dated 27 January 1993.

Several safety measures taken by the company enhanced the survivability of this accident. The company strongly recommended and encouraged its pilots to wear helmets. The pilot's head injuries would have been more severe, and likely fatal, had he not been wearing a helmet. The company ensured that the passengers received a thorough pre-flight briefing and, as a result, egress from the cabin was quick and orderly. The passengers kept their seat belts on until they had firm hand holds and were prepared to climb out of the cabin, and they used the specially painted seat legs as a ladder to climb out of the helicopter, which was on its side.

**Analysis**

Both engines suffered uncontained failures of the power turbine blades because of failures in the drive train from the engine to the final output shaft. The failures of the input shafts for both engines are considered secondary. The primary failure was the failure of the number 1 engine clutch coupling shaft. This shaft sheared due to the excessive loads placed on it when the worn clutch began to slip and then suddenly re-engaged. The power turbine wheel then oversped sufficiently for the turbine blades to fracture. After it failed, the wheel contained only one-quarter of its blades, and the resulting imbalance placed extreme loads on the number 5 bearing. The number 2 engine continued to run while the helicopter was on its side, and the engine eventually failed because of a loss of lubrication.

No single factor was found that would have caused the clutch to wear. The bearing races probably began to wear while the clutch was engaged, and the ball bearings wore grooves into the races due to drive system vibrations. The grooves would have caused greater stress on the outer race during clutch freewheeling (when there would have been relative motion between the inner and outer races of the bearings), and this would have accelerated the wear in the bearings. The wear on the clutch engagement surfaces may have been caused by contamination from the wear metals of the bearings.
Both the tail rotor system torque overload experienced two weeks before the accident, and the C-box chip light warning experienced eight days before the accident, were likely caused by the wear in the clutch. Although both incidents were investigated by maintenance staff, the maintenance staff did not make a connection between the two events, nor did the symptoms lead them to suspect a clutch malfunction. The operational environment in which the helicopter worked was not unusual, and no operational practice was identified that would have contributed to abnormal clutch wear. Further, there is no significant history of worn or slipping clutches on the Bell 212 helicopter.

The following Engineering Branch report was completed:

**LP 38/97 - Combining Gearbox**

**Findings**

- The pilot was certified, trained, and qualified for the flight in accordance with existing regulations.
- The maintenance records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.
- The weight and centre of gravity were within the prescribed limits.
- The number 1 engine clutch coupling shaft sheared because of the excessive loads placed on it when the worn clutch slipped and then suddenly re-engaged. The power turbine wheel then oversped sufficiently for the turbine blades to fracture, with blades from both power turbine wheels breaking through their respective steel containment rings.
- The number 2 engine continued to run while the helicopter was on its side, and the engine eventually failed because of a lack of lubrication.
- No single definitive cause for the significant clutch wear was determined.

**Causes and Contributing Factors**

The number 1 engine clutch coupling shaft sheared because of excessive loads placed on it by the worn and slipping clutch. The power turbine then oversped, causing the engine to lose power, and forcing the pilot to land at an unprepared landing site.

**Safety Action Taken**

Since the accident, the operator has introduced a cost-sharing programme with its pilots to assist them with the purchase of their flight
This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 25 February 1998.
Air 1997

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 Occurrence Report
Loss of Separation between
Cypress Jetprop Charter Ltd.
Convair CV580 C-GTTG
and Canadian Regional Airlines
de Havilland DHC-8 C-GTAI
Vancouver, British Columbia 8 nm S
11 March 1997

Report Number A97P0057

Summary

The Convair 580, call sign REGS 33, was inbound to Vancouver International Airport from the Abbotsford, British Columbia, airport on an instrument flight rules (IFR) flight at 4,000 feet above sea level (asl) and on an assigned heading of 260 degrees magnetic. At 1641 Pacific standard time (PST)\(^{(1)}\), a Canadian Regional Airlines de Havilland DHC-8, flight number 1255 (CDR 1255), took off from runway 08 at Vancouver International Airport, on an IFR flight to Victoria, and turned to an assigned heading of 140 degrees magnetic; Vancouver departure control then cleared CDR 1255 to 4,000 feet asl. At 1643, the Vancouver departure controller realized that the two aircraft were in conflict and he immediately instructed REGS 33 to turn left to 170 degrees magnetic and CDR 1255 to descend to 3,000 feet asl. The spacing between the aircraft was reduced to 0.75 nautical miles (nm) horizontally and 400 feet vertically when the required minimum is either 3 nm horizontally or 1,000 feet vertically. There was no risk of collision since both aircraft were in visual meteorological conditions, and each flight crew had the other aircraft in sight.

Other Factual Information

The Convair 580 had a crew of two pilots and a Transport Canada (TC) inspector in the jump seat conducting a pilot proficiency check on the pilot-in-command. The flight was on the return leg of an IFR round-robin flight between the Vancouver and Abbotsford airports. Before departing Vancouver, at about 1535, the Convair 580 crew had filed an IFR flight plan indicating the planned itinerary, the aircraft's true airspeed of 295 knots, and the call sign of REGS 33. After the planned approaches at Abbotsford were completed, the aircraft was cleared by air traffic control (ATC) to the Vancouver VORTAC (very high frequency omnidirectional range tactical air navigation aid) at 4,000 feet asl, via the Abbotsford non-directional beacon (NDB).
The Canadian Regional DHC-8 was on a scheduled IFR flight from Vancouver to Victoria, via the Vancouver VORTAC and the "DUNCN THREE" arrival procedure, with a flight-planned true airspeed of 236 knots. Shortly after take-off, and while heading 140 degrees magnetic, the aircraft was cleared to maintain 4,000 feet asl. At that time, the two aircraft were on converging tracks and had been cleared to the same altitude. When the aircraft first appeared on the controller's indicator module, they were about 16 nm apart. At 1643, when the aircraft were 3 nm and 400 feet apart, a loss of separation occurred. The Vancouver departure controller realized that the two aircraft were in conflict moments before the loss of separation occurred, and he immediately instructed REGS 33 to turn left to 170 degrees, and CDR 1255 to descend to 3,000 feet asl. Although these instructions began to correct the conflict, the spacing between the aircraft was reduced to 0.75 nm and 400 feet.

As a Canadian air carrier, Cypress Jetprop Charter Ltd. normally uses the approved radio telephony call sign of "SKYBIRD," followed by the flight number. For this occurrence, because a TC inspector was conducting a pilot proficiency check, the flight was operating under the call sign of "REGS," followed by the inspector's personal number "33". TC inspectors commonly employ the REGS call sign as a way to alert ATC that they are conducting a flight test. Some controllers associate the REGS call sign with smaller, slower commuter aircraft rather than with larger, faster aircraft such as the Convair.

The Vancouver departure controller had 17 years of ATC experience and 7 years within the unit, and was licensed and qualified for the job. He had been working the swing shift (1000 -1800) for the previous two days, which had been preceded by four days off. He had been in the south departure controller position for about 45 minutes when the loss of separation occurred.

The ATC equipment was working normally, and there was an unrelated navaid problem with the instrument landing system (ILS) on runway 08L. The flight progress strips were up-to-date and in place although their placement on the left side of the controller's indicator module (IM) may not have been conducive to an easy scan of the display. Staffing at the time was normal, the work load was at a moderate pace, and its complexity was assessed as heavy. The departure sector is normally staffed by both a data controller and a radar controller; however, the radar controller is the only person who can fully monitor the pace and intensity of traffic in the departure sector. Because of requirements to engage in non-control activities, the data controller is generally unable to maintain a mental "picture" of the traffic in the departure sector. The departure controller was working between eight and ten aircraft at the time and, of those, two aircraft required extra attention. The first was a departure from the Boundary Bay airport that involved an easterly climb to 7,000 feet asl in the departure sector; the second was another Canadian Regional flight, which the departure controller was routing around an area of bad weather.

The loss of separation occurred in class "C" airspace, about two nautical miles southeast of the Vancouver VORTAC. At the time of the occurrence, runway 08R was in use at the Vancouver airport and the standard procedures in effect were that arrivals were cleared to descend to 8,000 feet asl, while departures were cleared to climb to 7,000 feet asl until clear of traffic. These procedures ensure that opposing traffic will have a minimum of 1,000 feet of vertical separation. In an exception to these procedures, an IFR aircraft inbound from Abbotsford, below 8,000 feet asl, would be routed through the Vancouver departure area at the altitude requested by the pilot. This arriving traffic, which might be on a flight track opposing departing traffic in the same sector, would be placed under the authority of the departure controller.
rather than that of the arrival controller.

Since aircraft speed is not normally used by departure controllers as a means of establishing initial separation on departure, the departure controller did not attend to the speed display in the aircraft data block; therefore, he did not assimilate that REGS 33 was indicated on the ATC flight data strip as a relatively fast Convair 580. He assumed that the REGS 33 call sign referred to a small, slow type of aircraft, with a speed in the order of 140 to 160 knots, and he predicated the separation between the two aircraft on that false assumption. According to the recorded radar information, REGS 33 was cruising at 220 knots and CDR 1255 was climbing at 160 knots. The loss of separation occurred before the controller recognized that his original plan of separation was inadequate.

Analysis

Air traffic controllers sometimes form mental images of recurring call signs; they associate a certain type and speed of aircraft with the particular call sign they hear. When this happens, they may not assimilate all the information from the data strips. Frequent exposure to TC inspection flights leads some controllers to associate the generic REGS call sign with smaller, slower aircraft.

The departure controller, responsible for an arriving aircraft that was traversing the departure sector at an altitude much lower than the standard of 8,000 feet asl, thought that he was dealing with a type of aircraft that had an airspeed comparable to that of the departing flight CDR 1255 (about 160 knots), and he established his separation strategy accordingly. It is likely that he was distracted by the aircraft departing from Boundary Bay, and in particular by the second Canadian Regional flight, which was encountering bad weather and which needed to be re-routed. As a consequence, it is likely that his attention became channelized and he did not recognize the developing conflict between CDR 1255 and REGS 33. The significant difference between REGS 33's anticipated and actual airspeed had critically affected the rate of closing. Because the two aircraft had been cleared to the same altitude with the expectation that their tracks would not intercept with less than the minimum radar separation, the controller did not recognize the impending conflict in time to prevent the loss of separation.

Findings

- A loss of separation occurred; however, there was no risk of collision as both pilots had each other in sight.

- The departure controller's airspace separation plan was based on his expectation that both aircraft would operate at about the same airspeed, as he associated REGS 33 with slower, smaller aircraft.

- The departure controller did not observe the speed of the Convair displayed in the radar data block and in the ATC flight data strip.

- An aircraft that had departed from Boundary Bay and the routing of another aircraft around an area of bad weather are likely to have distracted the departure controller, causing him to channelize his attention, and to miss the developing conflict between the two occurrence aircraft.

Causes and Contributing Factors
The loss of separation occurred because the departure controller based his separation strategy on the Convair being slower than it actually was, even though the proper airspeed information was available from the radar-displayed data block and the ATC flight data strip. Contributing to the occurrence were two aircraft that required special attention and may have distracted the controller.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 06 March 1998.

Appendix A

1. All times are PST (Coordinated Universal Time minus 8 hours) unless otherwise noted.
Air 1997

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 Occurrence Report
Loss of Cyclic Control -
Collision with Terrain
Coulson Airplane Ltd.
Sikorsky S-61N (Helicopter) C-GBRF
Stave Lake, British Columbia
19 April 1997

Report Number A97P0094

Summary

At 1415 Pacific daylight time (PDT) the two pilots of a Sikorsky S-61N helicopter, serial number 61748, took off from the Stave Lake airstrip, British Columbia, to return to heli-logging operations in an area about two nautical miles (nm) from the airstrip. Following four uneventful lifting cycles, while manoeuvring over the logging area, the aircraft started an uncommanded, nose-down attitude change that the pilot was unable to counteract with rearward cyclic control. Seconds later, cyclic control returned. The pilot, flying from the left seat, attempted another approach from a different direction with the same result. The pilot and co-pilot then assessed that they had significant flight control problems and decided to return to the airstrip to carry out a running landing. The pilot established a slow and shallow final approach path profile to land at the airstrip. The helicopter then approached the intended landing site with a slight nose-up attitude, at a ground speed of 10 to 15 knots, and about 10 feet above the ground. When the pilot began to level the helicopter, the nose continued to pitch down quickly. The pilot applied collective pitch and rearward cyclic, but the helicopter descended nose-down into the trees at the end of the airstrip and rolled over, coming to rest on its left side. The pilot was seriously injured, and the co-pilot was fatally injured. There was no fire and the helicopter was substantially damaged.

Ce rapport est également disponible en français.

Other Factual Information

Earlier that day, the pilots had taken off from the service pad, and
resumed heli-logging operations. After 6.5 hours of heli-logging without incident or difficulty, they returned to the service pad at 1345 for midday maintenance, refuelling, and crew relief.

When the first upset occurred, the pilot assessed that it had been caused by a wind shift. Seconds later, when the helicopter gained airspeed, cyclic control seemed to return to normal, and he flew away to attempt an approach from a different direction. On the second attempt, the upset and loss of control were more pronounced. Cyclic control again returned when the helicopter descended and increased airspeed; this time, however, the pilots heard a distinct, loud "bang" behind them when the helicopter recovered to about the nose-level attitude.

The short, one-minute flight back to the airstrip was uneventful until the pilot again tried to hover to release the 200-foot long-line; the nose dropped once more without cyclic input. As in the previous episodes, cyclic control appeared to return when airspeed increased, and when the nose was returning to the nearly-level attitude, the pilots heard the loud "bang" again. The pilot aborted this approach and flew away to set up another approach from the opposite direction. On this approach, the pilot jettisoned the long-line, and carried on flying to make a left-hand circuit back to the service area, with the intention of carrying out a slow, running-landing at the end of the airstrip. During the next few minutes of flight, the "banging" increased in frequency and was without apparent association with any flight control input. The pilot deliberately established a slow and shallow final approach path profile for the attempted landing, in an effort to avoid the known, uncontrollable flight regime.

The operating environment was unremarkable in comparison to previous heli-logging operations and sites. The weather conditions during the period leading up to the accident were reported by witnesses at the site as being good, with light winds and occasional light rain showers; such conditions are consistent with the visual meteorological conditions (VMC) requirement of this operation. The operating terrain, environment, and weather are therefore not considered as contributory factors in this accident. The pilot at the time of the accident was also the pilot-in-command and had been employed by Coulson Aircrane for five weeks, having recently worked for other Canadian operators of heavy helicopters, such as the S-61. He had accumulated a total of about 8000 hours flying, of which 7500 hours were in helicopters, and 2500 hours in the S-61. He held a valid Canadian airline transport helicopter pilot licence (ATPL(H)) and medical certificate, and endorsements for other medium and light helicopters. He had also held a Canadian Group 4 instrument rating, but it had expired in February 1996. An instrument rating is not required for heli-logging in the S-61. His flying experience included instrument flying rules (IFR) offshore operations, as well as about 2500 hours in heli-logging operations. His most recent pilot proficiency check (PPC) was in March 1997, and was carried out, as on previous occasions, with a high degree of competence.

The pilot-not-flying was acting as the co-pilot during the accident flight,
and had been employed by Coulson Aircrane for three years, having also worked for other Canadian operators of both light and heavy helicopters; he had accumulated a total of about 11 400 hours flying, of which all but 150 hours were in helicopters, with 4000 hours in the S-61. He held a valid ATPL(H) and medical certificate, and was endorsed for other light, medium, and heavy helicopters. He had also held a Canadian Group 4 instrument rating, but it had expired in February 1993. Although he was the co-pilot during this mission, he was an experienced logging captain in the S-61, and was the lead pilot for the Stave Lake logging operations. His overall flying experience included international, offshore IFR operations, and he had been involved in heli-logging operations for about five years. His most recent PPC was in February 1997, and was carried out with a high degree of competence. He had demonstrated strong inter-personal skills, and had a detailed working knowledge of the S-61 and its systems, and an effective sense of problem-solving.

The helicopter's weight and centre of gravity (CG) at the time of the accident were estimated to have been within acceptable limits. The weight of the helicopter was approximately 13 200 pounds, and the CG approximately 261 inches from the datum. The maximum certificated weight of the S-61N helicopter is 20 500 pounds, and the permissible CG range for the estimated weight at the time of the accident was 254.0 to 280.0 inches from the datum.

In general, the "vertical reference" flying technique used in heli-logging involves rapid and extreme flight control inputs, with the helicopter constantly experiencing attitudes and rates of attitude-change greater than during conventional route flying. Furthermore, the demands on the engine/transmission system can cycle from low to high power several times during the load pick-up and drop-off, imposing high stress and cycle counts on critical components.

On helicopters used in vertical reference flying, such as the S-61, cockpit dimensions and fuselage width require the pilot-flying to lean markedly to one side to be able to clearly see the long-line and load suspended below the helicopter. Because such a body position is physically impossible to achieve by a pilot wearing the shoulder harness of the seat restraints, it is a wide-spread practice for the pilot manoeuvring the helicopter to use the seat belt portion only. In helicopters dedicated to vertical-reference flying, it is common for the shoulder straps to be semi-permanently stowed behind the seat back to prevent them from interfering with the pilot's movements.

The pilot-in-command, seated on the left side, had remained secured in his seat during the impact and rollover, and sustained serious injuries from the disruption and break-up of the cockpit around him. He had not used the shoulder harness of his seat restraint; the shoulder straps had been re-routed behind the seat-back pad, making them difficult to retrieve in flight. It was not determined if his injuries would have been lessened had he worn the shoulder straps. Although the impact forces in this accident were survivable, the co-pilot perished as a result of being crushed by the helicopter as it rolled over. He was found out of his seat, a short distance away from the cockpit. Both pilots' seat
restraints were examined by the TSB Engineering Branch to determine if the co-pilot's had failed or had released prematurely. The shoulder harness portion of his seat restraint was found free and available; however, it could not be determined if the co-pilot was using the shoulder straps at the time of the accident. Medical information revealed that the co-pilot had been wearing the seat belt portion. The laboratory examination (LP 120/97) revealed that the seat belt had not failed, and that it was functioning correctly; it was not possible to determine when the seat belt had undone. Both pilots were wearing flight helmets.

In heli-logging operations using the S-61 helicopter, it is a standard practice for the pilot-flying to occupy the left-hand seat, and for the pilot-not-flying to be in the right seat; the pilots in this accident were seated in this fashion. The pilot-flying manoeuvres the helicopter for all phases of flight, while the pilot-not-flying manipulates the engine speed select levers to maintain acceptable main rotor rpm, monitors the engines and ancillary systems, and records the loads picked up during the cycle. This division of work-load allows the pilot-flying to concentrate solely on manoeuvring the helicopter. At the end of a period of flying, usually about an hour, the flight crew will return to the service site to refuel and to exchange places before continuing for another cycle. This flying/non-flying cycle ensures a balanced work-load among the pilots, and reduces fatigue. An examination of the work and duty cycles of both pilots involved in this accident revealed that they had begun the logging operation only the day before the accident, and that they had followed the rest and work periods required by regulation. Based on the recent personal histories of the flight crew, pilot proficiency is not considered a contributing factor in this accident.

Almost one month earlier, on 21 March 1997, the same pilots experienced an almost identical episode of uncommanded nose-down attitude change with the same aircraft, accompanied by the loud "bang," in the same phase of flight. On this occasion, the pilots were able to bring the helicopter back to the service area and land without further incident. Following an extensive inspection, site maintenance personnel found no particular discrepancy with the helicopter or its systems. One of the aircraft engineers on site sprayed the "boot strap" springs at the base of the primary hydraulic servos with WD-40, a light lubricant/cleaner, as part of his trouble-shooting process to eradicate a possible cause of the problem. It could not be determined, however, whether that action was effective, but the aircraft continued to fly after that servicing, without any recurrence of the symptoms, for a total of about 120 hours, until the problem returned on the day of the accident. During this interval, the helicopter had been engaged in several types of flying operations, such as heli-logging and ferry flights, and no instances of abnormal performance of the helicopter or any of its systems were reported by the flight or maintenance crews that flew and attended the helicopter. The accident investigation has not revealed a chain-of-events in the first incident that would lead to identifying the causes or contributing factors relating to the loss of control in the accident flight.
The helicopter was manufactured in 1975 and had accumulated about 13,725 hours of flight time, of which about 5,000 hours were in the heli-logging environment with Coulson Airplane. The maintenance records of the helicopter were examined and no deficiency or discrepancy was found. Records show that the aircraft had been maintained under a progressive maintenance schedule in accordance with existing directives and regulations. The helicopter was not equipped with either a cockpit voice recorder or flight data recorder (CVR/FDR); nor was either required by regulation.

Recent maintenance to the helicopter involved the scheduled removal and replacement of several components; each of these components was examined during the investigation and no defect was found.

Following a preliminary examination of the wreckage at the site, the airframe, engines, and ancillary systems were transported to secure facilities and examined in greater detail. Because of the level of interest that the international helicopter industry had in the proceedings of this investigation, the TSB enlisted technical expertise from the North American helicopter industry.

The entire helicopter was critically examined. Particular attention focused on the helicopter flight controls and hydraulic systems, the auto-pilot, the drive train, and the main rotor gearbox and head. Systematic examination revealed that all component breakage and damage were attributable to the impact forces of the accident. With few exceptions, no abnormalities were identified; those exceptions are described briefly in the following paragraphs. In summary, no evidence was found of any pre-existing condition, deficiency, or component or system malfunction that could have caused, or contributed to, the accident.

Examination of the hydraulic flight control systems and pumps revealed that slight buffing was found on a flange inside the locking collar connecting the two piston halves in the fore-aft primary hydraulic servo; since these parts of the servo experience no relative motion after assembly, the buffing was assessed as an assembly-related mark. It was determined that the buffing had no impact on the function of the servo. In the auxiliary hydraulic pump (serial number JO-622) a "Dubbel" ring and seal unit was found to have been installed incorrectly at the last overhaul; tests showed that the inverted seal had not affected the output of the pump, but it is likely that after further hours in service, the seal would have begun to leak, requiring the removal and replacement of the pump.

During the examination of the primary hydraulic system, it was found that one of the wires leading to the cannon plug on the Primary Pressure Switch (3-way valve) had pulled out from its terminal post. The TSB Engineering Branch examined the wire and concluded that it had "...failed in a progressive manner under cyclic(2) loading...." likely as a result of vibration. The examination could not accurately establish when the wire broke (refer to TSB Engineering Branch report LP 107/97). The effect of this fracture on the in-flight operation of the
hydraulic systems would have been twofold: with the wire in the broken state, the auxiliary hydraulic system could not have been selected OFF by either pilot; if the wire broke after the auxiliary hydraulic system had been selected OFF, the hydraulic system would have been automatically restored to ON. The wire did not have an effect on the operation of the primary hydraulic system itself. Both pressure switches were examined and tested for specification conformance and functionality; both units were unremarkable. The surviving pilot did not recall any unusual indications or abnormal operation of either hydraulic system before or during the accident flight.

The automatic flight control system (AFCS) and associated controls were examined at the TSB Engineering Branch laboratory. No pre-existing mechanical or electrical defect was found. The AFCS was not functioning at the time of the accident, since it had been purposely selected OFF by the pilot-in-command at the beginning of the series of the cyclic pitch control difficulties, and had not been re-engaged. No evidence of intermittent or uncommanded AFCS input was found, and the surviving pilot reported no incidence of autopilot involvement during the control upsets. The AFCS system is thus not considered to have been a factor in the loss of control.

The S-61N was powered by two General Electric (GE) CT58-140-1 gas-turbine engines. An examination of the engines, the engine mounts, the controls and accessories, the throttles, and the airframe high speed shafts, revealed no evidence of any malfunction, defect, or anomaly. Fuel samples taken from the helicopter after the accident were tested for contamination; none was found. The engine inspection revealed minor damage to both engines resulting from the impact, but no condition was found that would have prevented the normal operation of either engine. Coupled with the evidence from witnesses at the accident site and the surviving pilot, the engines are not considered to have contributed to the loss of control.

**Analysis**

The investigation into this accident included examination of environmental, technical, human, and operational factors, and an in-depth examination of the mechanical aspects of this helicopter, its component parts, and their service life and history. Extensive examination and testing to date have not found any anomaly or defect that is likely to have contributed to, or caused, the nose-down attitude change on the day of the accident.

Although it could not be determined in the case of the co-pilot, it is likely that neither pilot was wearing his shoulder harness. Accident investigation and research carried out by the TSB has consistently shown that the use of the shoulder harness portion of the seat restraint system is effective in reducing or preventing injury during moderate impact forces. While it is unknown if the use of the shoulder harness in this particular accident would have prevented or lessened the co-pilot's fatal injuries, the situation where the left pilot seat shoulder harness was essentially unavailable, is cause for concern. Given that vertical reference flying necessitates upper-body freedom of movement, the
universal dismissal of the shoulder harness, in its present configuration, is almost inevitable. However, the practice of restricting the shoulder straps in some manner prevents the pilot from gaining immediate access to them in the event of an emergency. Furthermore, it is likely that the regular non-use of the shoulder harness will diminish the pilot's awareness of its safety advantages, and at the same time reinforce a less-than-ideal safety practice.

The following TSB Engineering Branch reports were completed:

- LP 71/97 - Hydraulic Fluid Examination
- LP 105/97 - Trim Diode Adapter Examination
- LP 107/97 - "D"-pin Connection Failure Examination
- LP 120/97 - Seat Belt Examination

The following additional engineering examinations were completed:

- CT58-140-1 engines examination - GE Aircraft Engines
- Primary and Auxiliary hydraulic components examination - HASC
- X-ray examination of the hydraulic servos and manifolds - Bacon Donaldson
- Flight Controls examination - Sikorsky Aircraft Corporation
- Main rotor swash plate examination - Sikorsky Aircraft Corporation
- Main rotor head spindle bearings examination - ACRO Aerospace
- Main rotor head examination - HeliPro
- Hydraulic pumps (2) test and examination - Columbia Helicopters

**Findings**

- The pilots were licenced and qualified in accordance with existing regulations.
- Records indicate that the helicopter was certificated, equipped, and maintained in accordance with existing regulations and approved procedures.
No indication was found of any malfunction or pre-existing mechanical defect with the helicopter, its engines, or its systems, that could have contributed to the accident.

The helicopter's weight and centre of gravity were within certificated limits.

Neither weather conditions nor operating environment were factors in the accident.

The uncommanded nose-down attitude change and loss of rearward cyclic pitch control occurred for undetermined reasons.

The pilots were unable to prevent the helicopter from pitching nose-down.

Immediately before striking the trees, the helicopter reached a nose-down attitude at a height from which it was impossible for the pilots to recover.

Causes and Contributing Factors

The pilots experienced a loss of rearward cyclic pitch control, at a height from which they could not recover before striking the ground. The reason for this loss of control could not be determined.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 15 April 1999.

1. All times are PDT (coordinated universal time minus seven hours) unless otherwise noted.

2. "Cyclic" in this context means repetitive motion; not to be confused with the cyclic control.
Air 1997

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 Occurrence Report
Loss of Separation - No Risk of Collision
Between Canadian Regional Airlines Ltd.
de Havilland DHC-8-300A C-FTAK
and Vancouver Professional Flight Centre
Cessna 172M C-GHNV
Vancouver, British Columbia 15 nm S
16 May 1997

Report Number A97P0133

Summary

The Cessna 172 departed Boundary Bay airport, British Columbia, on an instrument flight rules (IFR) flight to Nanaimo and climbed to 2,000 feet above sea level (asl) in accordance with a clearance issued from the Vancouver departure controller. About the same time, a Canadian Regional de Havilland DHC-8, flight number 1360 (CDR1360), was inbound to Vancouver from Victoria at 3,000 feet asl and was nearing Boundary Bay. CDR1360 was operating IFR under the control of the Vancouver arrival controller, and the Cessna was operating IFR under the control of the Vancouver departure controller; the Cessna 172 departure clearance had not been coordinated with the Vancouver arrival controller. The arrival controller saw the Cessna 172 in level flight at 2,000 feet asl and assumed that it was operating under visual flight rules (VFR). The arrival controller issued a clearance to CDR1360 for a visual approach to runway 26 right, with a restriction to maintain 2,500 feet until established on final approach. CDR1360 descended out of 3,000 feet and passed ½ to ¾ nautical miles (nm) behind, and about 500 feet above the Cessna 172, and both aircraft were in level flight as they passed. The separation standard required is 3 nm or 1,000 feet vertically. There was no risk of collision.

Ce rapport est également disponible en français.

Other Factual Information

At the time of the incident, the Vancouver area control centre (ACC) terminal specialty was operating with the following five control positions
open: arrival; departure; data; VFR Terminal Area; and, coordinator. The terminal specialty was short two staff members at the time of the occurrence, and the supervisor was attempting to schedule relief breaks for the various control positions. The arrival position was being used to conduct training with a qualified on-job-instructor (OJI) remaining responsible for the position, while overseeing the actions of the trainee. During on-job-instruction, the attention of an OJI must be divided between monitoring information on the radar scope and monitoring the student's actions. Throughout a training session, it remains the responsibility of the OJI to ensure that all control actions are taken in accordance with approved standards and procedures. In addition to his control responsibilities, the OJI must determine when would be the best time to make a teaching point with the student, or to debrief some situation that they may have recently encountered. This range of activities requires high levels of attention and vigilance as well as an ability to effectively manage available time. However, human attention is a limited resource, and an OJI will not be able to adequately process as many information sources, in a divided attention situation, as he could otherwise process in a routine control situation. The air traffic services (ATS) network attempts to mitigate this risk by directing that all control activities are to take precedence over training functions.

There are several small airports in the vicinity of the Vancouver International Airport (VIA) and movements to and from these airports must be integrated into the VIA traffic flow. Boundary Bay is one of these small airports and is located about 10 nm southeast of VIA. The Boundary Bay airport has a control zone that extends out to 3 nm and up to 1,500 feet.

The runway in use at VIA, at the time of the incident, was runway 26. When runway 26 is in use, the Boundary Bay control zone underlies the Vancouver arrival controller's airspace. Under these conditions, the Vancouver terminal specialty procedures, Article 350.3, require that any IFR departures out of Boundary Bay be controlled by the arrival controller. Changes can be made to a published procedure, but these changes must be coordinated between the involved controllers. In this incident, article 350.3 of the terminal procedures was not followed; it was the departure controller who received the flight data strip for the Cessna 172 and planned to control the aircraft from the departure position. Under these circumstances, because the departing aircraft would be required to enter the arrival controller's airspace, it was necessary to coordinate the flight with the arrival controller. Information obtained during interviews following this occurrence showed that this work practice was not uncommon, and that the procedural defence provided by article 350.3 was routinely being circumvented by an internal coordination between the departure and arrival controller.

Article 300.2 of the Vancouver terminal specialty procedures states, in part, that "coordination is the sole responsibility of the coordinator...and shall not be initiated by other control positions." In this incident, the departure controller informed the coordinator about the departing Boundary Bay aircraft, and the coordinator provided a release authority
for the flight. The coordinator was then required to inform the arrival controller about the Boundary Bay departure; however, the coordinator had noticed that the arrival controller was busy debriefing his trainee about another issue, and, because he was aware that there is often a delay of up to 10 minutes between the time of release and the actual takeoff time, the coordinator decided that it would be more effective to pass information regarding the Boundary Bay departure after the aircraft was airborne.

At this point, the supervisor returned to the terminal specialty from a break and initiated several position changes to allow some relief for the controllers. As one of these changes, the coordinator was moved to the departure control position. During the hand-off, the outgoing coordinator omitted to brief his replacement about the un-coordinated departure from Boundary Bay.

A position hand-off guideline is posted at each control position and is available for use as a memory aid when transferring the responsibility of a control sector to another controller. The first item on the hand-off guideline requires the departing controller to brief on "potential conflicting, and arrival/departure traffic information...". The published hand-off guideline was not used by the departing coordinator when he was relieved. Instead, he used a mental checklist as the basis for covering the essential items of information; the resultant briefing did not include information related to the un-coordinated Boundary Bay departure and the potential conflict that it could cause. It is generally accepted by the terminal controllers and supervisors interviewed, that use of this type of formal job-aid is not essential, and that the use of a mental checklist is adequate.

There were no visual cues or job aids at the coordinator's work station that would have highlighted that the coordination of the Boundary Bay departure had not been completed. As a result, the incoming coordinator was forced to rely on the memory and thoroughness of the departing coordinator to update him on the expected activity from Boundary Bay.

Air traffic control (ATC) use various visual displays to communicate information that will enable a controller to make decisions or take action. In the design of an ATC display, it is important that the symbols used be easily recognized and understood. Additionally, it is important that these symbols are interpreted in a consistent way by all controllers, otherwise there may be an elevated risk of error if the same symbol has one meaning for one controller but a different meaning for another.

In the Vancouver ACC, there is no consistent, single method of identifying a VFR flight using the information provided in the aircraft's data tag. In some circumstances VFR flights may be assigned an abbreviated identifier; or they may be assigned a full identifier with a "V" included in a separate field in the tag; or, occasionally, they may be assigned a full identifier, without the "V", in which case they may be distinguishable as VFR aircraft by noting the controller's jurisdiction symbol (CJS). On the other hand, IFR flights are consistently assigned full 5-letter identifiers to make them distinguishable as operating IFR.
The Cessna 172 departing from Boundary Bay had displayed an aircraft identifier of C-GHNV.

When the Cessna 172 departed from Boundary Bay, the departure controller believed that the data tag clearly indicated it was an IFR flight because of its full 5-letter data tag, coupled with the departure controller's CJS. When the aircraft reached 2,000 feet agl, the departure controller overheard the arrival controller discussing with the trainee both the presence of the Cessna 172 and the wake turbulence separation requirements that would have been relevant between it and CDR1360. As a result, the departure controller concluded that it would be unnecessary to point the aircraft out, or to inform the arrival controller that the Cessna 172 was operating under IFR.

The Vancouver terminal specialty is physically located near the main entrance to the operations room. Space is limited, and all control positions are situated near, or adjacent to, each another. It is common in this environment for one controller to observe and overhear the activities taking place at another control position. In general, the close proximity of the control positions appears to have influenced the development of a number of informal work practices; communication between work stations is often accomplished without the use of the ACC interphone system, and some controllers are apparently adjusting their work practices based on activities that are being conducted at other control positions. The departure controller did not hear the arrival controller issue the approach clearance for a visual approach to runway 26 right with a restriction to maintain 2,500 feet until established on final approach to CDR1360, but did note that CDR1360 had begun a descent. He quickly interceded to inform the arrival controller of the problem.

Analysis

The coordinator did not immediately inform the arrival controller about the impending departure out of Boundary Bay. The coordinator's duties do not state specifically when that coordination must occur. In this incident, the coordinator was aware that the OJI had been debriefing the trainee and decided that he would delay the coordination until the Cessna 172 was airborne. This decision to delay the coordination appears to be based on an intent to reduce interruptions to the OJI, thus aiding in the training of the student. In effect, the coordinator's actions were adversely influenced by his intent to facilitate training.

The terminal specialty was two staff members short, and the supervisor was attempting to schedule relief breaks for the controllers. These changes are routine and necessary to provide rest to the controllers throughout their shifts. Hand-off briefings are required during all position changes, and a checklist is available at each position to aid in the transfer of essential information between controllers during these changes. Because the use of the published hand-off guidelines, in general, is not considered essential, controllers consider the mental checklist to be adequate. In this instance, the outgoing coordinator omitted to brief his replacement about essential information related to the un-coordinated departure out of Boundary Bay.
Because there were no other visual cues or job aids at the coordinator's work station that could highlight the fact that the coordination had not been completed, the incoming coordinator was forced to rely on the memory and thoroughness of the departing controller to update him on the expected activity out of Boundary Bay airport. This type of situation results in a passive rather than active transfer of information, reduces defences that rely on redundancy, and increases the risk of error.

After being relieved as coordinator and assigned to the departure control position, the controller again became aware that he had not completed the coordination action regarding the Boundary Bay departure. However, because he was now controlling that aircraft, he decided to monitor the situation and deal with any conflicts as they may develop. In effect, however, the departure controller was routing one of his aircraft through the arrival controller's airspace without having first coordinated this action.

As the Cessna 172 climbed to 2,000 feet, the departure controller overheard the arrival controller discussing, with the trainee, both the presence of the aircraft and the wake turbulence requirements that were necessary between it and CDR1360. This information fortified the departure controller's mental model that the arrival controller was aware of the aircraft and was handling the situation, with reference to the arriving CDR1360.

The departure controller based his actions on a belief that the data tags associated with specific aircraft are displayed in a way that clearly distinguishes whether the aircraft is operating under visual or instrument flight rules. However, the arrival controller was aware of numerous exceptions to the way the data is displayed and, as a result, did not use the display format as an indicator of a flights operating rules; rather, he relied more heavily on being informed in advance that IFR aircraft would be entering his airspace.

In this incident, the arrival controller was aware of the presence of the Cessna 172. However, because he had not been informed that an IFR aircraft would be entering his airspace, he concluded that the aircraft was a VFR flight, operating above the Boundary Bay control zone. Although the display indicated a full data block with the departure controller's CJS, this information was apparently not compelling enough for him to recognize the developing conflict. It is also possible that the controller's ability to actively monitor all aspects of the arrival control position was degraded by an increased workload brought on by his responsibilities and activities as an on-job-instructor.

Based on a compelling mental model that the Cessna 172 was operating under VFR, the arrival controller provided an approach clearance to CDR1360 that allowed the aircraft to descend to 2,500 feet; that altitude would provide a minimum spacing of 500 feet between the inbound IFR flight and what he perceived to be a VFR aircraft. The arrival controller's concerns related to wake turbulence separation requirements were discussed with the trainee and resolved by ensuring that CDR1360 passed behind the Cessna 172.
A loss of separation did occur, but there was no risk of collision because a minimum of 500 feet of vertical spacing had been assured by the clearance and because CDR1360 passed behind and clear of the departing Cessna 172.

**Findings**

- The arrival position was being staffed by one qualified controller and a trainee; in addition to his control responsibilities, the arrival controller was acting as an on-job instructor (OJI).

- The coordinator did not inform the arrival controller about the Cessna 172 departing Boundary Bay airport.

- Because the outgoing coordinator relied on a mental checklist during the hand-off briefing to the incoming coordinator, essential information regarding the Cessna 172 was omitted.

- There were no visual cues or job aids at the coordinator's work station that would have highlighted that the coordination had not been completed.

- There is no consistent, single method of identifying a VFR flight using the information provided in the aircraft's data tag.

- The arrival controller believed that the Cessna 172 was operating VFR and issued a clearance to CDR1360 that allowed the spacing between the aircraft to be $\frac{1}{2}$ to $\frac{3}{4}$ nm and about 500 feet.

- The procedural safeguard provided by terminal procedures, article 350.3, was routinely being circumvented by an internal coordination procedure between the departure and arrival controllers.

**Causes and Contributing Factors**

A loss of separation occurred because the arrival controller issued a clearance to CDR1360 that allowed the separation to reduce below 1,000 feet and 3 nm between CDR1360 and the Cessna 172. Contributing to this loss of separation were an incomplete departure coordination, an incomplete hand-off briefing, inconsistent interpretation and use of data tags between controllers, the use of local work practices that are not consistent with published procedures, and the arrival controller's belief that the Cessna 172 was flying under VFR.

**Safety Action Taken**

The following action was taken by Nav Canada after the occurrence:

- An Operations Bulletin was issued restating and emphasizing the coordination required for Boundary Bay departures when
runways 26 R and L are active; 

- The position hand-off guidelines, previously found on an Operational Information Display System (OIDS) page, have been added to the Video Information Display System (VIDS) as a screen saver for easier access; and,

- In response to the lack of visual displays to the controllers informing them of Boundary Bay traffic, flight data strips are now generated for both the Arrival and Departure positions. Controllers are directed to post these strips until the aircraft is clear of their airspace.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 26 August 1998.

Updated: 2002-10-06
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 Occurrence Report
Loss of Separation Between
Central Mountain Air
Beechcraft 1900D C-GCML
and Air BC de Havilland DHC-8-300 C-FACV
Vancouver, British Columbia
17 May 1997

Report Number A97P0135

Summary

The AirBC DHC-8 (ABL819) departed runway 26 left (L), at Vancouver, on an instrument flight rules (IFR) flight for Prince George, British Columbia. The Vancouver tower controller initially cleared the aircraft to climb on the runway heading and contact Vancouver departure control. When ABL819 reported on the departure frequency, the departure controller issued a standard clearance to the aircraft to maintain runway heading until 3,000 feet, and then turn right to a heading of 335°; this clearance is to protect the missed approach area for the north parallel runway. At the time that the clearance was issued, the Vancouver air traffic control (ATC) radar indicated that the ABL819 was climbing at a speed of about 150 knots. A short time after ABL819 departed, the tower also cleared a Central Mountain Air Beechcraft 1900D (GLR738) to depart runway 26L, and to climb on the runway heading and contact Vancouver departure control. GLR738 acknowledged the clearance, took off from runway 26L, and accelerated rapidly to a speed of about 190 knots. The spacing between the two aircraft quickly reduced as a result of this airspeed differential, and a loss of separation occurred when the aircraft closed to within 2 nautical miles (nm) horizontally and 300 feet vertically in an area where either 3 nm or 1,000 feet is required. In response, the controller instructed GLR738 to reduce speed to 140 knots in an attempt to stabilize the spacing that remained and to prevent it from reducing further.

Ce rapport est également disponible en français.

Other Factual Information
The Vancouver tower controller was responsible for establishing the initial separation between the two departing IFR aircraft under procedures authorized by ATC Manual of Operations (MANOPS) article 551.4. Under those procedures, the tower controller can apply separation between an aircraft taking off and other radar-controlled aircraft provided that, in the controller's judgement, the departing aircraft will be radar identified within one nm off the end of the runway, and that radar separation will be established at that point. However, because aircraft have a range of performance characteristics, the initial spacing applied by the tower controller to meet the MANOPS criteria varies and is based on the controller's judgement.

Controllers become accustomed to the initial climb profiles of different aircraft types through continual on-the-job exposure, and are normally able to judge the initial horizontal spacing that will be required to ensure the IFR separation standard will be met; in most cases, this spacing will not be less than three nm. When controllers are unsure of an aircraft's performance characteristics, they can refer to applicable ATC flight data strips which provide information on the aircraft types as well as their cruise speeds. In this incident, the en route speed of the DHC-8, on the flight data strip, was about five knots faster than that of the following Beechcraft 1900D.

The Beechcraft 1900D aircraft type had only recently begun operating in the Vancouver area, and air traffic control personnel were not yet fully familiar with its performance characteristics. The aircraft has good acceleration and climb performance and, although the aircraft operating manual recommends that initial climbs be conducted at 160 knots, a pilot may elect to climb at some other speed depending on operational conditions or personal preference. In this occurrence, the tower released GLR738 when the preceding aircraft (ABL819) was about 3 ¾ nm west of the airport, but south of the extended centre-line of the runway. There were no speed or climb rate restrictions in GLR738's departure clearance, and the pilot elected to climb out at about 190 knots, and with a high vertical speed; the use of this climb profile was motivated by a desire to keep the aircraft moving quickly, so as not to disrupt the flow of faster jet traffic.

GLR738 first appeared on the departure controller's indicator module (IM) as an uncorrelated target, and the data tag, which would normally show the aircraft's speed, was not available. Additionally, the departure controller had not been expecting a high-overtake situation immediately after take-off and, by the time he recognized the rapid closure rate, the loss of separation had already occurred.

After this loss of separation occurred, other controllers in the terminal specialty reported that they had seen similar "run-down" events involving the Beechcraft 1900D. However, these prior events had not resulted in losses of separation, and had not been formally reported to the supervisory staff at Nav Canada.

In the week following this loss of separation, two more similar incidents occurred. In both cases, the involved controllers anticipated the problem, were adequately prepared, and responded in time to ensure
the separation was maintained. After the Vancouver supervisory staff became aware of the repetitive nature of this problem, they took action to ensure that adequate initial separation would be provided, and they issued operations letters in both the Vancouver Area Control Centre (ACC) and the Vancouver tower. Those letters laid out a plan based on what was coordinated between Nav Canada and the airline companies that were operating the Beechcraft 1900D.

Twenty-six days after this occurrence, a similar loss of separation was reported in Calgary, again involving a Beechcraft 1900D departing behind a DHC-8 (Transport Canada CADORS No. 97C0345). Nav Canada conducted a preliminary investigation into this Calgary event; there were no formal reports to other units regarding the results of that investigation.

**Analysis**

The Beechcraft 1900D aircraft was new to the Vancouver area, and air traffic control personnel were not yet familiar with its performance characteristics. The tower controller noted, on the flight data strip, that GLR738 had filed a slightly slower cruise speed than ABL819. Based on that information, he judged that GLR738 could depart with about minimum spacing from the preceding aircraft. As a result, he released GLR738 with an initial spacing of about 3½ nm, just above the separation standard of 3 NM.

After being released by the tower, GLR738 took off from runway 26L, accelerated rapidly, and began a steep climb profile. By the time the crew of GLR738 had contacted the departure controller, the Beechcraft 1900D's climb speed was about 40 knots faster than that of the preceding DHC-8, and the initial spacing that had been provided by the tower had eroded.

Three miles ahead, ABL819 had drifted south of the extended runway centre-line while tracking west from the airport. When the crew of ABL819 reached 3,000 feet, they initiated a right turn to 335° in accordance with their clearance; that northbound turn, coupled with the aircraft's south offset from the runway centre-line, caused the flight paths of ABL819 and GLR738 to converge, and further reduced the spacing between the two aircraft.

The departure controller was not anticipating a separation problem immediately after take-off and had very little time to recognize and react to the high closure rate. When he became aware that a loss of separation was occurring, he attempted to apply speed control to stabilize the situation. The controller did not attempt to level the Beechcraft 1900D at 2,000 feet because, in his judgement, the separation would be re-established more quickly by allowing the aircraft to continue the climb rather than by levelling or descending it.

Some controllers were previously aware of problems related to the Beechcraft 1900D's initial climb profile. These prior situations had not been formally reported so the repeat nature and impact of the problem was not captured by the Nav Canada reporting system; therefore, not
all controllers were aware of the situation.

Nav Canada supervisors at Vancouver were quick and effective at resolving the Beechcraft 1900D separation problem at a local level. Operations Letters were disseminated in both the ACC and the tower to ensure controllers were aware of the performance characteristics of the Beechcraft 1900D, and the resolution of the initial spacing was coordinated with local carriers that are using the new model Beechcraft 1900D. However, information related to this local problem, and its regional fix, was not disseminated within the Nav Canada network.

Findings

- The tower controller is required to judge the initial spacing between successive IFR departures; other than operational experience, the controller has limited data on which to make this judgement.

- The tower controller was unaware of the initial climb performance of the Beechcraft 1900D and based its initial separation from the preceding aircraft on a comparison of their en route speeds; these speeds were not representative of the aircraft's initial climb profile.

- GLR738 was given no climb-rate restrictions, and the pilot allowed the aircraft to accelerate to about 190 knots after take-off; this higher speed caused the aircraft to close rapidly on the preceding DHC-8.

- The departure controller was not anticipating a separation problem immediately after take-off and, when the Beech 1900D took off, the controller had very little time to recognize and react to its high closure rate with the preceding aircraft.

- Although other controllers had seen similar "run-down" events, the Nav Canada reporting systems were unable to capture this data before the loss of separation incident occurred.

- Once aware of the repetitive nature of the problem, Nav Canada supervisory personnel were quick and effective in resolving the issue at a local level.

- Information related to this local problem, and its regional fix, was not disseminated between the Nav Canada units.

Causes and Contributing Factors

The departure controller had insufficient time to recognize and react to an unexpected high-overtake situation immediately after take-off. Contributing to this occurrence was a lack of awareness, by the involved controllers, of the initial climb performance capabilities of the Beechcraft 1900D.
Safety Action

Safety Action Taken

The Vancouver ACC and Tower supervisors issued operations letters to resolve the problem of initial spacing for the Beechcraft 1900D. Those letters were based on a plan that was coordinated between Nav Canada and the airline companies that are operating the Beechcraft 1900D.

Central Mountain Air has instructed its pilots to adhere to a 160 knot climb speed when following DHC-8 aircraft.

Nav Canada has developed and implemented a new reporting system and database effective January 1, 1998; this new system will allow the company to conduct better trend analysis and to identify system deficiencies.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 10 September 1998.

Updated: 2002-10-06

Important Notices
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.

Loss of Separation between
Air Canada Boeing 767 C-GAUB (ACA109)
and
Morningstar Air Express Inc.
Cessna 208 Caravan C-FEXX (MAL7072)
Vancouver, British Columbia
30 May 1997

Report Number A97P0153

Synopsis

At about 1454 Pacific daylight time (PDT), the Vancouver ATC Arrival controller cleared ACA109, an Air Canada Boeing 767, for an instrument landing system (ILS) approach to runway 08 Left at Vancouver International airport. This clearance was accepted and read-back in error by ACA897, an Air Canada Boeing 747, but neither the controller nor the crew of ACA109 detected the incorrect aircraft identification. The ACA109 continued on its last assigned vector and flew through the localizers for runways 08 Left and Right at 3,000 feet, on a course toward a Morningstar Cessna 208, inbound to the airport at 3,000 feet. The controller identified the potential conflict and issued avoidance vectors to both aircraft; this action, however, did not prevent the loss of separation between them. The aircraft spacing had been unintentionally reduced to 2.11 nautical miles (nm) at the same altitude, with the aircraft on diverging headings, in an area where either 3 nm lateral or 1,000 feet vertical separation was required. Although there was a loss of separation, there was no risk of collision. The controller then re-sequenced the aircraft for landing at Vancouver without further event.

Other Factual Information

In the five minutes leading up to the loss of separation, the Boeing 767 (ACA109) was north-east of Vancouver, inbound from Toronto, and was carrying out the BOOTH FOUR standard terminal arrival procedure (STAR) leading to an ILS approach to runway 08 Left (L). At the same time, the Boeing 747 (ACA897) was north of Vancouver, inbound from London, U.K., also for runway 08L. The Cessna 208 (MAL7072) was to
the south on the V338 airway, arriving from Victoria, heading for runway 08 Right (R).

Air traffic control (ATC) communication tapes and radar data show that at 1453:14, the ATC arrival controller cleared ACA109 to turn left to a heading of 170° and to maintain 2,000 feet; the pilot acknowledged that instruction, and the aircraft then turned left to 170° and continued descent, at this time through 5,300 feet. The clearance to 2,000 feet was to provide the required vertical separation of 1,000 feet with MAL7072, and the controller had predicated his traffic control sequencing based on ACA109 descending to 2,000 feet. ACA109 levelled off at 3,000 feet, however, and when the controller saw that the ACA109 had not yet reached the assigned altitude, he instructed MAL7072 to turn 10° left to provide more lateral spacing.

When the pilot of ACA897 checked-in on the inner arrival frequency, the arrival controller purposely did not immediately acknowledge, instead the controller focussed on giving ACA109 an approach clearance, since it was a higher ATC priority. Accordingly, he instructed ACA109 to turn to a heading of 110° to intercept the localizer, and cleared it to conduct the ILS approach to runway 08L. Noticed by neither the controller nor the ACA109 crew, this clearance was read-back in error by ACA897. At that time, ACA897 was about 18 nm north of Vancouver, in a descent through 6,000 feet to 4,000 feet. The aircraft was over an area of high terrain where the minimum vectoring altitude (MVA) was 3,700 feet. ATC is not authorized to clear aircraft to fly below the MVA; furthermore, considering the number of aircraft in the area and the potential for conflict, ATC would likely not issue an approach clearance to an aircraft in this location.

The captain of ACA897 did not question the ATC clearance he believed was for his aircraft. After accepting this clearance, the pilot of ACA897 began a left turn and continued descending. About 5 seconds later, the controller instructed ACA897 to turn 10° right and to maintain 4,000 feet. The pilot of ACA897 asked for confirmation of these instructions, and the controller instructed the aircraft to turn right to a heading of 190° and to maintain 4,000 feet. ACA897 acknowledged this clearance, and without further comment about the approach clearance received and acknowledged just a few seconds earlier, the pilot turned back to a heading of 190°, and continued to descend to 4,000 feet; the aircraft did not descend below MVA.

The pilots of ACA109 heard the pilot of ACA897 accepting an approach clearance for the ILS to runway 08L, and although they were in a location on the arrival path where they were expecting an approach clearance, they assumed that the clearance was intended for ACA897 - even though their own call-sign was used - because ACA897 had accepted it so quickly and because the controller had acknowledged the read-back.

At 1454:48, the controller observed that ACA109 was about to fly through the localizer for runway 08L at 3,000 feet and 90° to the localizer, and he asked the pilot if he was going to intercept the localizer. The pilot replied that they did not know they had been cleared
to intercept the localizer. On some occasions in the past at other Canadian airports, the captain of ACA109 had been given radar vectors which had flown him through the localizer to provide increased aircraft spacing on the final approach. In this incident, he reasoned that the delay in the approach clearance may also have been deliberate. As well, in the 30 seconds between ACA897 accepting the wrong clearance and the controller asking ACA109 his intentions, the first 25 seconds was continuous communication between the controller and other aircraft; the pilot of ACA109 was reluctant to request further clearance because he did not want to risk transmitting over any instructions from ATC. For the captain of ACA109, not receiving the anticipated approach clearance during the only 5-second period of free radio space would have been the only clue he would have had that his aircraft had been missed in the ATC approach sequence, and he then had insufficient time to prevent crossing the localizers.

Based on the projected flight path of ACA109 which had now crossed both localizers at 3,000 feet, the controller immediately instructed MAL7072 to quickly turn right to a heading of 060° to maintain lateral separation. At 1455:00, the controller instructed ACA109 to "...maintain 2,000, expedite descent", and to turn right to a heading of 230°. The pilot acknowledged these instructions; however, the captain had already begun a firm, left turn back to the airport, and the aircraft was now headed directly toward MAL7072. The captain had been anticipating a left turn, and he thought the controller had instructed him to turn to a heading of 230°, a heading which was consistent with his expectations. The first officer then asked for confirmation of the heading, and when the controller repeated the 230° heading, the captain began a turn to the right. The aircraft continued at 3,000 feet.

![Flight Paths](image)

At 1455:34, the controller again instructed ACA109 to descend, using the phrase "...descend to 2,000 now"; 26 seconds later, the aircraft began to descend from 3,000 feet. In the meantime, the delay caused by this additional communication exacerbated the collision course.

---

geometry with MAL7072, and the arrival controller turned MAL7072 to a heading of 120°; this action, however, did not prevent the loss of separation between ACA109 and MAL7072.

During this latter period, the captain of ACA109 had disconnected the autopilot and was hand-flying the aircraft because the electronic flight control systems would not have permitted a sharp intercept turn back to the localizer. He was also initially unaware of the urgency of the situation until the controller instructed them to descend to 2,000 feet "...now." Conventional caution requires that, when the Boeing 767 is being flown in the hand-flying mode, pilots refine their control inputs to avoid sharp aircraft response and passenger discomfort. This flying technique, however, can result in slower aircraft response to pilot commands, and could introduce an element of delay to some ATC instructions.

At the time of this incident, the arrival controller was working both arrival positions, arrival high and arrival low. The complexity of the terminal operations was light to moderate, and the controller was actively controlling eight aircraft. This position combination was a routine arrangement in the Vancouver Area Control Centre, and was the result of both personnel shortages in the terminal specialty and reduced air traffic volume traditionally experienced at that time of the day. In this incident, the positions had been combined because of the low traffic volume. Efforts had been underway by Nav Canada to resolve this personnel shortage, and as an interim measure, staff shortfalls were compensated for by combining controller positions, by increasing overtime requirements, and by restricting traffic flow both into and out of the airport.

To maintain safe and responsive air traffic flow, pilots are required to comply with ATC clearances accepted by them, and with ATC instructions directed to and acknowledged by them, subject to their final responsibility for the safety of their own aircraft. In part, MANOPS 133.4 requires ATC controllers to obtain an accurate readback when issuing or relaying an amendment to an IFR clearance or instruction. In sections 201.5 and 201.6, controllers are required to ensure that the readback of a message is correct, and to identify and correct any errors.

To ensure effective, consistent, and correct communication between ATC and aircraft, the Transport Canada document entitled the "Aeronautical Information Publication" (AIP) contains, in part, examples of radio telephony phrases, and, specifically in section COM 5-7, pilots are instructed to acknowledge all messages directed to them. In this incident, the acknowledgements should have, and did, take the form of a repeat of the clearance with the aircraft call-sign. International protocols regarding the position of the aircraft call-sign in radio messages have been developed over the years, and it is now a standard practice for pilots to place the aircraft call-sign at the end of their message when reading back a clearance. In this incident, that convention was also followed.

To provide communication precision and consistency, article 507.1 in
MANOPS, details the safety-alert phraseology to be used when a controller becomes aware that an aircraft is at an altitude which places it in unsafe proximity to another aircraft. That phraseology uses compelling language to elicit a prompt response from the pilot, and would be made, for example, as follows: "(Call sign)...Traffic Alert...Climb to (altitude) feet immediately." In this incident, although the controller did not use the safety-alert terminology outlined in MANOPS, he did use language which identified a sense of priority when he said "...expedite..." and "...now."

A key factor in communications between pilots and controllers is "readback/hearback", which is the process of mutual verification of information passed between them. The pilot's readback of ATC instructions serves as a double-check to catch communication errors; hearback is the process where the controller actively monitors the pilot's readback for deviation from the original instruction. Research has shown that when it comes to listening, humans hear what they are expecting to hear, hear what they want to hear, and frequently do not hear what they do not anticipate hearing. Speech communication is influenced by a set of expectations that exists merely by knowing what activity is being performed. In any given situation, humans recall the educated expectation they think is most appropriate for the particular activity. It is this expectation that helps a person understand the message; if the message is inappropriate or totally unexpected, the expectation may hinder the understanding of the message. The phenomenon of expectation is particularly common and hazardous in the readback/hearback process, especially if non-standard phraseology is used.

In the context of air traffic control, pilots frequently read back and act upon clearances that they were expecting to receive, and not the actual clearance parameters given them by the controller. Often, a controller does not detect the erroneous readback from the pilot because his attention had been diverted to resolving a concurrent air traffic control issue. In the North American ATC environment, readback/hearback errors such as these occur constantly, and result in operating irregularities such as deviation from assigned altitudes, and turns to incorrect vector headings.

In the aviation system, communication has come to serve a central role in the creation and maintenance of proper situational awareness. The likelihood of successful communications depends on several factors, such as the level of attention of the recipient, the level of comprehension of the recipient, the level of acceptance of the message, and the effectiveness of the feedback from the recipient to the communicator.

Analysis

The circumstances of this incident led the investigation to focus on the readback/hearback process, and the operational reasons surrounding the actions of the flight crews and controller involved. The pilot-controller communication errors made in the readback/hearback process led to the flight crew of one aircraft continuing descent to an
altitude that could have been unsafe, and led to the flight crew of a second aircraft flying through the approach paths for two runways at a busy, international airport, lose separation with yet a third aircraft, and to conflict with several other aircraft in the vicinity.

The chain of events starting at 1453:14 that led to this incident was circumstantial and comprised many elements; the most notable are summarized in the following items:

- although instructed to maintain 2,000 feet, ACA109 remained at 3,000 feet;
- the controller focussed on turning ACA109 onto final for runway 08L and he did not immediately respond to the ACA897 initial check-in transmission;
- ACA109 did not hear the approach clearance intended for them;
- ACA897 intercepted the approach clearance intended for ACA109;
- the controller did not detect the incorrect call-sign during the readback from ACA897;
- ACA109 assumed the clearance was for ACA897;
- ACA897 did not challenge a rapid and significant revision to an approach clearance;
- ACA109 did not seek further clearance as it approached the localizer;
- the captain of ACA109 misheard the controller's heading instruction;
- ACA109 turned left after crossing the localizers without ATC instruction; and
- ACA109 did not descend in a timely manner.

Despite the call-sign for ACA109 being clearly at the beginning of the controller's communication, the crew of ACA897 had assumed that the approach clearance (intended for ACA109) was directed to them because the controller's response immediately followed their initial-contact radio transmission. However, these instructions from the controller, which included a final approach clearance, when the aircraft was still 18 nm away from the airport, would have been atypical in these circumstances, and should have alerted these pilots to an
abnormal situation or development; similarly, the lack of an altitude restriction would have been irregular considering that the floor for radar vectoring was 3,700 feet in that area. It was not determined why the pilots of ACA897 believed that such an approach clearance would have been appropriate for their aircraft and circumstances. Nevertheless, they accepted and began to follow a clearance that would have placed the aircraft below MVA. It was also not determined why they did not subsequently question the significant and rapid change to their approach clearance.

It could not be determined why the pilots of ACA109 did not identify the approach clearance from the arrival controller as being theirs, even though this clearance was issued when their aircraft was at a location where they were, and should have been, expecting such a clearance. They heard the pilot of ACA897 accepting an approach clearance, and assumed that the clearance was indeed intended for ACA897, because ACA897 had accepted it so quickly and because the controller had acknowledged the read-back.

At 1453:14, before ACA109 had turned toward the localizer, the controller planned a procedure of vertical separation between ACA109 and MAL7072, whereby he would maintain 1,000 feet between them; hence his instruction for ACA109 to maintain 2,000 feet. To the controller, his plan was seemingly in place when ACA109 acknowledged that instruction. The in-flight circumstances which rapidly developed and ultimately led to the loss of separation could have been avoided had ACA109 descended to 2,000 feet before it missed the approach clearance and flew through the localizer.

The arrival controller identified a developing traffic conflict between ACA109 and MAL7072 when he challenged ACA109 as it approached the localizer for runway 08L. At this time, there was ample room for the controller to manoeuvre the aircraft to maintain the required separation standard of either 1,000 feet vertically or 3 nm horizontally. His corrective actions were appropriate and would have prevented the loss of separation had ACA109 reacted correctly and in a timely fashion to his instructions to turn to a heading of 230° and maintain 2,000 feet. The command itself, however, was not sufficiently imperative to elicit an immediate response from the pilot, since the word "maintain" does not imply any level of immediacy or urgency. Nevertheless, the controller did use language that inferred priority of action; however, the pilots initially did not perceive that inference.

Once ACA109 crossed the localizer and did not follow the flight path anticipated by the controller, the last procedural safe-guard available to the controller would have been vertical separation; it was, however, negated owing to ACA109 still being at 3,000 feet, and continuing to remain at that altitude until well after the loss of separation had occurred. In these circumstances, the controller had no other option than to issue significant heading vectors to the aircraft to place them on diverging headings - a course of action that prevented the risk of collision.

Findings
- The pilot of ACA897 accepted and read back the approach clearance intended for ACA109.

- The pilots of ACA109 did not recognise that ACA897 had read back the clearance intended for ACA109.

- The controller did not detect the incorrect call sign when ACA897 read back the clearance intended for ACA109.

- The captain of ACA897 accepted a clearance which would have allowed the aircraft to descend below a minimum safe altitude.

- Without ATC instruction, ACA109 began a left turn after crossing the localizers.

- The controller took appropriate and timely action when he recognised a developing loss of separation.

- The captain of ACA109 thought the controller had instructed him to turn to 130°, when it was 230°.

- ACA109 did not descend in a timely manner, and the resultant delay contributed directly to the loss of separation.

- The controller did not use the safety-alert terminology outlined in MANOPS.

- A loss of separation occurred when ACA109 turned left into the protected airspace of MAL7072 at the same altitude.

- There was no risk of collision.

Causes and Contributing Factors

The loss of separation occurred as a result of ACA109 turning left after crossing the localizers and not descending when instructed by the controller. Contributing to the incident were pilot-controller hearback/readback errors, incorrect educated expectations, incorrect assumptions, and reduced situational awareness.

Safety Action

In light of this and other similar occurrences, the TSB forwarded an Aviation Safety Advisory to Nav Canada concerning the lack of use by controllers of appropriate safety alert phraseology in situations which should elicit a sense of urgency or immediacy. The Advisory suggested that Nav Canada may wish to place greater emphasis on the use of standard safety alert phraseology in situations in which ATC separation
standards have been breached or in which there is imminent danger of collision between two aircraft or between an aircraft and the terrain.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 22 April 1998.

1. All times are PDT (Coordinated Universal Time minus seven hours) unless otherwise noted.
Aviation Occurrence Report
Fuel Exhaustion
Kenn Borek Air Ltd.
de Havilland DHC-6 Twin Otter, C-FPAT
Yakoun Lake, British Columbia
17 June 1997

Report Number A97P0169

Summary

The float-equipped de Havilland DHC-6 Twin Otter, serial number 2, departed Langara at about 1350 Pacific daylight time, with 8 passengers and 2 pilots, for a 35-minute visual flight rules (VFR) flight to Alliford Bay, in the Queen Charlotte Islands on the west coast of British Columbia. About 20 minutes after departure, the forward fuel tank low-level caution light illuminated, even though the forward fuel gauge indicated 310 pounds of fuel. The captain consulted the emergency checklist which indicated that this situation could be caused by a blocked ejector pump, slowing transfer of fuel to the collector cell. The captain continued the flight with no further action since he assessed that gravity feed would be sufficient to ensure proper fuel supply to the engine. About five minutes later, the low fuel pressure caution lights came on and the number 2 engine stopped. The forward fuel gauge indicated about 200 pounds. At this time, the aircraft was near Yakoun Lake, and the captain decided to land there to assess the problem. The aircraft landed without further event, but the number 1 engine also stopped as the captain attempted to taxi to the beach area. The fuel tanks were found to be empty. Another Twin Otter was dispatched to Yakoun Lake by the company to deliver an aircraft maintenance engineer (AME) and two drums of fuel to the downed aircraft and to carry the passengers to their destination. The aircraft was refuelled from the drums and the engines were restarted. The aircraft was later ferried back to Alliford Bay without further incident.

Ce rapport est également disponible en français.

Other Factual Information
The operation on the day of the incident involved flying passengers between the base at Alliford Bay and a fishing lodge at Langara. The pre-flight fuel calculations made by the pilots on the company flight planning form indicated that each flight would consume 340 pounds of fuel; 50 pounds for the start, taxi, and climb, plus 290 pounds for the en route phase. These figures were based on a calculated en route time of 29 minutes and a fuel burn of 600 pounds per hour.

Prior to the first flight, the captain used a dipstick to determine that there was a total of 550 pounds of fuel in the aircraft tanks. The fuel gauge indications matched the dip, however the aft tank gauge was working intermittently. The captain added 600 pounds of fuel and the aircraft departed for Langara. The aircraft then returned to Alliford Bay and the captain added another 600 pounds of fuel. No records of the refuelling were kept, so there was no independent means of verifying the quantity of fuel loaded. The aircraft departed for Langara again, and, because of reports of poor weather, the captain took a longer route along the west coast of the island. The actual en route times for these flights were 39 minutes, 39 minutes, and 43 minutes respectively, considerably longer than the 29 minutes originally flight-planned. Fuel flow readings taken during the flights indicate that the aircraft was burning 600 pounds of fuel per hour.

The aircraft journey logbook entry for the first flight indicated a fuel weight of 850 pounds at departure. The captain reported that the actual fuel weight was 1,150 pounds. With this amount of fuel on board, the actual take-off weight would be 11,095 pounds, which is 95 pounds above the maximum certificated gross weight of the aircraft. On the return flight from Langara, the journey logbook again indicated a fuel weight of 850 pounds, even though no fuel was taken on at Langara. Prior to the second flight from Alliford Bay to Langara, 600 pounds of fuel was added and the journey logbook indicated a fuel weight of 1,200 pounds. The next flight, from Langara to Alliford Bay, was the incident flight, and the journey logbook entry indicates a fuel load of 860 pounds at departure. At the time of the incident, the weight and centre-of-gravity of the aircraft were calculated to have been within prescribed limits.

At the time of the second departure from Langara, the forward fuel gauge was indicating about 450 pounds, but now the aft tank gauge was not working at all. The captain believed that the aft tank contained the same quantity as the forward tank, and he believed that the forward gauge was accurate, since it had been accurate when he checked it in the morning. Fuel was available at another dock at Langara, and the captain was aware that he could refuel there.

The captain was certified, trained, and qualified for the flight in accordance with existing regulations. This was the second day that he had been flying this particular aircraft and he had not noticed any discrepancies with the aircraft on the previous day. The first officer was new to the company and had started working in the Queen Charlotte Island operation four days prior to the incident.

The two standard fuel tanks in the Twin Otter are located in the belly of
the fuselage. Normally the forward tank feeds the number 2 engine, while the aft tank feeds the number 1 engine. Each tank comprises four cells connected together, one of which is the collector cell into which fuel is transferred from the other cells through a booster pump operated ejector. A capacitance type fuel quantity indicating system measures the amount of fuel in each cell, and a fuel gauge for each tank displays the fuel quantity in pounds. If electrical power to the fuel indication system is lost, the gauges remain at the same indication displayed when power was lost. Several company AMEs reported that fuel gauge indication problems were common due to the location of the system’s wires in the belly of the fuselage and the aircraft operation in salt water.

A physical check of the fuel in the tanks can be made with a fuel quantity dipstick. The dipstick is inserted in the fuel filler neck into cell number 1 of the forward tank, and into cell number 7 of the aft tank. This measurement will only be accurate if the fuel level in each cell of the tank is the same. This requires that the aircraft be level, and that 15 minutes elapse since the engines were operated or since the last refuelling. The dipstick is calibrated in 200-pound increments and is intended to provide an approximate reading of fuel in each tank. Flight Safety International's DHC-6 training manual advises that the dipstick is a secondary means of checking fuel quantity, and it is not intended to replace the fuel gauges. The normal procedure followed by the operator's Twin Otter pilots was to dip the tanks each morning, before the first flight, and compare the readings to the fuel gauge readings.

There are two fuel low-level caution lights, one for each tank. Each caution light is activated by a float switch in its respective collector cell when the fuel in that cell reaches a predetermined level. In level flight, the forward tank low-level light should activate when 75 pounds of useable fuel are remaining. Seventy-five pounds of fuel would provide one engine with sufficient fuel to operate for 15 minutes at cruise power settings. The aft tank low-level caution light did not illuminate during the incident flight, although it should have illuminated when there was 110 pounds of useable fuel remaining.

Kenn Borek Air Ltd. has established a minimum equipment list (MEL) for the DHC-6 aircraft. The MEL allows dispatch of an aircraft with one fuel gauge inoperative provided that the following operating procedures are followed:

- the problem must be noted in the logbook and deferred by a licenced AME;

- the quantity of fuel on board the aircraft must be determined before each flight, either through the use of a dipstick, or by filling the tank to capacity;

- both fuel flow indicators and both low-level caution lights must be operating normally; and,

- the inoperative fuel quantity gauge must be placarded as such.
The above procedures were not followed on the day of the incident. Some operational penalties are incurred if these procedures are followed. For instance, it is difficult without a working gauge to determine the quantity of fuel on board the aircraft before each flight. The fuel dip will only be accurate after the aircraft has sat idle for at least 15 minutes, causing a delay for each flight. The company chartering the Twin Otter was informed by the operator that the aircraft could carry a payload of 2,700 pounds from Langara to Alliford Bay. This figure was based on a fuel load of 800 pounds. If fuel loads were greater than 800 pounds, a reduction of payload would be required. An examination of the journey logbook entries for the previous month shows that the provisions of the MEL were not used during that time.

The base AME at Alliford Bay rectified the fuel gauge problems after the flight and before the Transportation Safety Board (TSB) was made aware of the incident. He dipped the tank and checked the fuel gauge when the aircraft arrived at Alliford Bay, and noted that both the dip and the gauge were in error, given the known fuel quantity that was loaded into the aircraft at Yakoun Lake. The engineer replaced two electrical cable ends and a connector, and cleaned the connector blocks and plug ends in the fuel quantity indication system. He then checked the system and found it to be accurate.

On 8 July 1997, investigators carried out calibration testing on the occurrence aircraft to determine the accuracy of the forward fuel tank gauge, the dipstick, and the fuel low-level warning lights. The forward fuel tank was drained, and fuel was measured into the tank. As fuel was added, the fuel gauge reading was compared to the amount of fuel added. At fuel quantities above about 100 pounds, the fuel gauge was found to read about 14% less than the actual fuel in the tank; at lower quantities, the error was from 16 to 20%. After adding 407 pounds of fuel to the tank and waiting 30 minutes, the tank was dipped and the fuel quantity dipstick read about 385 pounds. The low fuel caution light was found to function normally.

Analysis

The following table compares the pre-flight fuel calculations to the amount of fuel burned, and it compares the fuel load recorded in the journey logbook to the fuel load calculated from the fuel burn. All of the calculations are based on the figures given above.

<table>
<thead>
<tr>
<th>Departure/destination</th>
<th>Planned fuel burn</th>
<th>Actual fuel burn</th>
<th>Fuel load, as recorded in journey log</th>
<th>Fuel load, based on actual fuel burn and captain’s statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alliford Bay/ Langara</td>
<td>340</td>
<td>440</td>
<td>850</td>
<td>1150</td>
</tr>
<tr>
<td>Langara/ Alliford</td>
<td>340</td>
<td>440</td>
<td>850</td>
<td>710</td>
</tr>
</tbody>
</table>
The pilots’ pre-flight calculations were somewhat optimistic; however, pre-flight plans are often slightly inaccurate. Of greater concern are the gross errors made in the journey logbook regarding the quantity of fuel on board. These figures are normally based on actual fuel burns or accurate measurements of fuel on board. The quantities listed in the journey logbook for this day were not consistent with known and measured quantities, nor with the fuel calculations that should have been made as the flights progressed. The only other source these figures could have been derived from were the fuel gauge indications, even though only one gauge was functioning. The captain believed that the forward gauge was accurate, and he assumed that the aft tank would be carrying the same amount of fuel. He relied on the forward fuel gauge for all of his fuel load information, but this gauge proved to be inaccurate.

The means of establishing the fuel quantity in this particular operation is problematic. Twin Otters, operating on floats in a salt water environment, have a history of fuel gauge problems. Additionally, the fuel dip should be considered an approximate indication rather than an accurate measurement. The pilots do not fill the tanks to capacity since that would reduce the payload. The only method available to the pilot to reliably establish the fuel quantity on board is to closely monitor the fuel burn during the course of the flights. The amount of fuel that the captain loaded onto the aircraft is not consistent with him having accurately monitored the fuel burn during the flight. According to the captain, he refuelled the aircraft twice, each time adding 600 pounds of fuel; pre-flight planning, however, indicated that 680 pounds would have been required after each round trip. The flights were longer than planned, which should have alerted the captain that more fuel was required. For instance, after the 43-minute flight from Alliford Bay to Langara, the fuel load in the journey logbook was reduced by only 340 pounds of fuel, even though the fuel burn was likely about 480 pounds.

 Contributing to this incident were the unserviceability of the aft fuel gauge, the inaccuracy of the forward gauge, and that the MEL procedures for continued operations with an unserviceable fuel gauge were not followed. It is not clear why the procedures were not followed, but the negative operational impact of complying with the MEL procedures may have deterred the captain from entering the defect into
the logbook. Had the MEL procedures been followed, the tank would have been filled, or additional fuel dips would have been made, and the low fuel situation would likely have been identified or prevented.

The procedure of dipping the tanks each morning as a means of checking fuel gauge accuracy has limitations that must be understood. The design of the fuel tanks makes the fuel dip technique prone to error. When the dip and the gauge are the same, it is possible that both are equally in error.

The captain decided to land after the number 2 engine stopped because he recognized conflicting information regarding the fuel quantity status and he was unable to resolve the conflict. Rather than attempt to proceed on the single engine, he chose to land at Yakoun Lake, ten minutes short of his destination, and this action likely prevented a serious accident.

Findings

- The forward fuel gauge was inaccurate, and the aft fuel tank gauge was unserviceable.

- The procedures required by the MEL to continue operations with an unserviceable fuel gauge were not followed.

- The pilots did not accurately monitor fuel consumption during flight.

- The captain relied on the forward fuel gauge and the dipstick for his fuel load information.

- The captain landed after the number 2 engine stopped because of conflicting information about the fuel quantity.

- The procedure of dipping the tanks is a secondary method of determining the fuel quantity and gives an approximate reading.

- The recorded fuel loads found in the journey logbook reflect neither the pilots’ calculations nor the actual fuel onboard.

Causes and Contributing Factors

The aircraft ran out of fuel because the pilots did not establish the fuel quantity onboard before or during flight. Contributing to the incident were the unserviceable and inaccurate fuel gauges, and that the pilots did not accurately monitor fuel burn in-flight or follow applicable MEL procedures.

Safety Action

The company has instituted a procedure at the Alliford Bay operation
whereby the pilots must log the amount of fuel loaded into the aircraft, and this entry must be witnessed by another person.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 25 February 1998.
Air 1997

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
Collision With Terrain
Northern Mountain Helicopters Inc.
Bell 206B (Helicopter) C-GVQK
Bear Valley, British Columbia
30 July 1997

Report Number A97P0207

Summary

The pilot of the Bell 206B helicopter (serial number 478) was engaged in transporting survey crews in the Bear Valley area, about 45 nautical miles (nm) north of Mackenzie, British Columbia. On the morning of the accident, he had begun flying at about 0645 Pacific daylight time (PDT). A survey crew contacted the pilot by radio at about 1200 and requested a pick-up for about 1400; they also informed the pilot of a 100- to 150-foot ceiling and a visibility of about 300 metres (1000 feet). At about 1445, the pilot was attempting to locate the survey crew at the 5100-foot elevation, but low cloud, fog, and precipitation prevented him from making visual contact with the landing area. The pilot was in two-way radio contact with the ground crews and remarked that the lower pick-up pad was fogged in and that he could not see the trees or ground below him. The pilot continued manoeuvring in the area, searching for the landing pad. Witnesses on the ground then saw the helicopter appear from the base of the low cloud, in a right-hand, descending turn, roughly in a 40-degree nose-down and 40-degree right-bank attitude before it struck trees and collided with the terrain at 5200 feet above sea level (asl), inside a cirque. The pilot was fatally injured, and the helicopter was destroyed by impact forces and a post-crash fire.

Ce rapport est également disponible en français.

Other Factual Information

The helicopter was manufactured in 1969, and maintenance records reveal that the helicopter was certificated, equipped, and maintained in accordance with existing regulations and approved procedures. As of
26 July 1997, it had 11 640 hours of flight time, and the Allison 250-C20B engine had 10 003 hours. The helicopter's weight and centre of gravity at the time of the accident are not conclusively known, but based on the day's previous activities, it is estimated that the weight and balance were within the prescribed limits and that there was sufficient fuel on board for the flight.

The helicopter struck the rocky surface at a high impact angle and was damaged by an intense post-crash fire, except for the aft section of the tail boom, the tail rotor assembly, two doors, and fragments of the skid gear. No flight or engine instruments were recovered, except for the face of the engine torque gauge. The TSB Engineering Branch examination of this dial did not reveal any impact-related reading. All flight controls were destroyed by impact and fire. The main rotor gearbox and the engine gearbox were also destroyed by fire. An examination of the gears and bearings that remained did not reveal any anomaly or indication of pre-impact distress or malfunction. The aircraft systems were examined to the degree possible, and no sign of a malfunction was found.

Four days before the accident, the pilot had experienced smoke in the cockpit resulting from an electrical short circuit in the directional gyro (DG). Company maintenance personnel in Mackenzie removed the DG and inspected the associated wiring loom and cannon plug; the helicopter was then test-flown and returned to the Bear Valley camp without the DG installed. The removal of the DG did not affect the airworthiness of the helicopter. The DG was not required for the pilot to navigate in visual meteorological conditions (VMC), since a magnetic compass was installed in the helicopter as standard equipment. The absence of the DG could have affected the pilot's ability to fly in instrument meteorological conditions (IMC). The accident helicopter was not authorized to fly under instrument flight rules (IFR) conditions.

Witnesses recalled that when the helicopter departed on this trip, waves of low cloud and fog were moving through the area, and the visibility had diminished to about one mile in drizzle; the sky condition at the drop site was described as a solid overcast around 600 feet above ground level (agl). These weather conditions reportedly persisted throughout the day. Witnesses also reported that there was very little wind at the time of the accident, that light rain was falling, and that the fog and low cloud coming up the slope caused an overcast ceiling of about 300 feet agl. About two hours after the accident, the same weather conditions prevented another helicopter from landing at the accident site. The weather reporting station nearest the accident area is 45 nm away in Mackenzie. At 1300, the automated weather observation system (AWOS) at Mackenzie had recorded a measured ceiling of 700 feet overcast and a visibility of more than 9 miles. At 1400 the sky condition was 500 feet scattered, 1600 feet broken, and 2800 feet overcast, and the visibility was more than 9 miles, in very light drizzle. In the hour between these reports, four special observations recorded a broken ceiling as low as 500 feet. Based on witnesses accounts, however, the weather conditions at the accident site were significantly different from the Mackenzie AWOS. This was
likely because of the distance and the mountainous terrain, which is known to create unpredictable local weather conditions.

The 45-year-old pilot had recently begun his career in aviation, and had accumulated about 400 hours of total flying time. He held a Canadian commercial helicopter pilot licence (CPL-H), endorsed for the Bell 47 and 206 helicopters, for daylight flying only, and a valid medical certificate. The pilot did not hold an instrument rating, nor was it required, since this operation was to be conducted under visual flight rules (VFR). The pilot had attended a course on pilot decision making in April 1997. His only exposure to instrument flying was during basic training toward his CPL-H.

In early May 1997, the pilot had successfully completed the operator's Upgrade Training Program, which included mountain-flying and reduced-visibility training, and his pilot proficiency check. On May 12 he began as a base pilot in Mackenzie, and on July 2 the pilot assumed his duties at the Bear Valley camp. The Bear Valley contract was the pilot's first commercial assignment and his first exposure to remote-base and self-dispatch operations. He was expected to make routine operational decisions involving customer requirements, weather, helicopter serviceability, and the suitability of the terrain, although he could easily consult with the operations bases in Prince George or MacKenzie. On July 7 he experienced a main rotor blade strike during a confined-area approach in the Bear Valley area. The next day, the company chief pilot carried out an evaluation flight and debriefing with him before he returned to the Bear Valley operation and continued his assignment.

The pilot had flown about 120 hours in the 30 days before the accident and at least 16 hours in the last 3 days; he was scheduled to begin his time off the following day. An examination of the pilot's flight time/days off records revealed at least 12 instances in the previous 70 days where his flight- and duty-times exceeded the limits specified in the Canadian Aviation Regulations (CARs Sections 700.16, 720.16, and 720.17). During the 30 days before the accident, the pilot did not have the required 8 hours of rest on five occasions and had exceeded the 14-hour duty time limit on eight occasions, the most recent being on the day before the accident.

It is apparent from his records that the pilot had been filling in the forms incorrectly. If filled in correctly, these records would have allowed the pilot and the operator to accurately maintain and monitor his flight time and duty time to prevent him from exceeding the daily and cumulative limits specified in the CARs.

On 28 April 1992, Transport Canada (TC) conducted a regional audit of Northern Mountain Helicopters Incorporated (NMH) and identified several areas of non-conformance, mainly regarding pilot training records, flight- and duty-time records, and aircraft journey log entries. As a result of this audit, the company pledged to undertake a plan to rectify the areas of concern. TC carried out another in-depth audit of the company between May 11 and May 22, 1998, which focussed on the 18-month period from October 1996 to May 1998. The purpose of
the audit was to assess the operator's level of conformance with the regulations and standards governing the operations of Canadian air operators. The results of this 1998 audit noted that significant changes in the company structure and operations following the 1992 audit were insufficient to address all of the noted deficiencies.

In the six-year period between the audits, the TC Centre (TCC) in Prince George, British Columbia (B.C.), had carried out maintenance inspections and audits of several NMH bases. These inspections/audits and their results were recorded in the Prince George TCC, but were not forwarded to the TC Pacific Region office in Vancouver, and the 1998 audit did not reflect the Prince George inspections. The inspections carried out by the TCC identified frequent maintenance-related deficiencies; TCC inspectors later assessed most of the company's responses to these findings as satisfactory.

Nevertheless, in January 1996 a TCC audit of the NMH aircraft and maintenance facilities identified 17 deficiencies, several of which were recurring since the audit carried out in January 1994. As a result, TC Airworthiness sent a letter to NMH stating that TC was alarmed at the results, and warned that the Approved Maintenance Organization Certificate, number 144-90, would be suspended if the company did not meet the requirements of the letter. The certificate was not suspended at that time.

In December 1997, about five months after the accident, TC Pacific Region issued NMH two Notices of Suspension, one each for the Canadian Air Operator Certificate, number 1518, and the Approved Maintenance Organization Certificate, number 144-90, because TC determined that the company had failed to comply with the conditions required for the issuance of these certificates. Following response by NMH to the conditions of the suspensions, TC later withdrew the Notices of Suspension.

At the time of the 1998 audit, NMH offered domestic, non-scheduled international, and aerial work air services from the main base at Prince George, B.C., and from eleven sub-bases in B.C., one sub-base in Ontario, and two international operational bases in Sudan and Congo. NMH operated a mixed fleet of about 70 aircraft and held Air Operator Certificate number 1518. The operator employed about 130 pilots and operated under Subparts 702, 703, and 704 of the CARs in diverse flight operations such as general charter, heli-logging, forest fire management, aerial construction, and seismic support.

As a result of the 1998 audit, a total of 54 airworthiness findings and 17 operational findings were made, several of which TC assessed would have had an impact on flight safety. TC technical inspectors noted several deficiencies in the areas of technical records, maintenance schedules, defect deferral, maintenance dispatch, and quality assurance. According to TC, the airworthiness findings suggested that the company had less-than-acceptable control over various components on the maintenance system and that, as evidenced by the number and seriousness of the findings, the company had made little effort to comply with all aspects of the (then) new CARs.
TC operational inspectors identified several areas of concern resulting from the audit. The most important of these were the lack of effective flight and duty time monitoring, and poorly kept pilot training records. These deficiencies had the potential to adversely affect flight safety. The TC auditors found that the flight crew training program was lacking in several areas, notably in training for flight in reduced visibility. Further, pilot training records were found to have been inaccurate and incomplete. The TC auditors found that the system in place for tracking pilot flight and duty times was extraordinarily inaccurate and ineffective. As well, the auditors made five findings regarding company pilots exceeding the flight- and duty-time limitations contained in the CARs. Three of these findings concerned the accident pilot: he had less than the required minimum rest periods on five occasions; he had duty time in excess of the maximum on five occasions; and he had been given only two days of rest in the 31-day period before the accident (OP-09-01 to OP-09-03).

In partial summary, the audit revealed the following about the operator:

- the maintenance control system did not comply with Commercial Air Service Standards;

- company aircraft were not maintained in accordance with an effective maintenance control system that met the requirements of CAR Part VII - Commercial Air Services, Subpart 6 - Aircraft Maintenance Requirements for Air Operators;

- pilots had not completed the required ground- and flight-training programs;

- the system to monitor flight time, duty time, and rest periods was not followed; and,

- each pilot was not provided with the required time free from duty.

On 4 June 1998, as a result of this audit, TC issued the operator a Notice of Suspension under Section 7.1(1)(b) of the Aeronautics Act, effective 8 June 1998. To avoid further action against the operator's Air Operator Certificate, TC required the operator to comply with the conditions specified in the Notice of Suspension within 30 days. On 8 June 1998, a Special Inspection Team from TC examined the operator's compliance with the conditions. In summary, TC found that the operator had "co-operated on all levels with a clear understanding of deficiencies identified." As well, TC noted that "steps were already being taken to correct deficiencies and prevent future occurrence." Accordingly, the Notice of Suspension was withdrawn.

Nevertheless, the operator's responses to the operational finding concerning the accident pilot (OP-09-01 to 03) were all assessed as unacceptable by TC in July 1998. The TC inspector noted that the operator's responses put into question the operator's grasp of the flight-
and duty-time limitations. The inspector also noted that more was needed to educate the flight crews about flight and duty times and to enforce the limitations of the CARs. TC has continued to monitor the operator since that time and has assessed as satisfactory the operator's response to each deficiency noted since.

Fatigue is a debilitating phenomenon which slows reaction time, reduces concentration, and can lead to errors of attention. The performance and judgement of an individual suffering from fatigue becomes degraded, and one common effect is an increase in that individual's willingness to take risks and a tendency to finish tasks more quickly. The two most common causes are insufficient rest and a lack of sleep. Research shows that, although individual needs vary, the majority of the population requires between 7.5 and 8.5 hours of sleep in a 24-hour period. If people obtain less than their requirement, they develop a sleep debt, which is cumulative. This occurs when insufficient quantity of sleep continues over several consecutive days. For example, missing one hour of sleep per day for four days has about the same effect as missing fours hours of sleep in one night. Furthermore, the impact of sleep debt is compounded when it is combined with a long day.

On the ground, spatial orientation is sensed by the combination of vision, muscle sense, and specialized organs in the inner ear, which sense linear and angular accelerations. Vision is the strongest of the orienting senses, and in visual flight, the pilot relies on regular visual references with the ground and horizon to control the aircraft attitude and altitude. If a pilot is in cloud, the visual reference to the ground and horizon is lost. As a result, the available cues (solely from the external forces on the body) often produce spatial disorientation in flight, because the pilot has a false impression of aircraft attitude and motion. Under these conditions, the pilot is completely dependent on the flight instruments and learned flying skills for control of the aircraft. Inexperienced pilots with little instrument time are particularly susceptible to spatial disorientation when they are confronted with no external visual attitude references. Without suitable flight instruments or skills, a disoriented pilot would quickly lose control of the aircraft. Research found in the FAA Advisory Circular 60-4A, shows that a pilot can take as long as 35 seconds to re-establish full control of an aircraft by using instruments alone. In that period, the pilot spends at least five seconds recognizing that a hazard exists, determining the necessary corrective action, and responding to it. Instrument flight training in itself does not prevent disorientation, rather it provides the pilot with the ability to overcome it.

Analysis

The pilot may have decided to attempt the crew pick-up in adverse weather conditions because of his reluctance to leave the survey crews stranded and his desire to do well in his first unsupervised assignment. His assessment of the potential risks involved may have been influenced by his limited experience.

The survey crews saw the helicopter emerge from the low clouds in an
extreme flight attitude, which was not consistent with controlled flight in this type of helicopter. The crews' description of the brief flight path before impact, as well as wreckage and impact characteristics, indicate that the pilot had insufficient time or altitude to prevent the collision with the terrain. Such a loss of control most likely was the result of spatial disorientation.

While the possibility exists that a mechanical malfunction did occur, no definitive conclusions about the mechanical condition of the helicopter can be drawn from the available wreckage. The remainder of the analysis will focus on the possible human performance aspects of this accident.

The absence of the DG, while not affecting the pilot's ability to navigate in VMC, could have limited his ability to maintain control in IMC. Although the weather conditions reported by ground observers were not consistent with VMC, the actual in-flight conditions experienced by the pilot are not conclusively known. It is probable the pilot encountered the same conditions as those that were observed and that, as a result, he rapidly became disoriented.

The pilot had, on occasion, exceeded the limitations concerning flight time, duty time, and rest periods. As well, several days before the accident, he had entered into a period when, although individuals can vary, the average person would have experienced serious cumulative sleep debt. Although the pilot recorded a normal sleep period immediately before the day of the accident, it is possible that the effect of the recent sleep debt may have adversely affected his performance or decision-making ability. It could not be determined if fatigue-related factors contributed to the circumstances of this accident; nonetheless, the workload and schedule of the pilot included periods when the risk of fatigue-related performance decrements would have been elevated.

TC audit findings show that the operator had not exercised effective operational control of the company's maintenance and operational activities. In particular, the method for tracking pilot flight and duty time was ineffective and inaccurate. This allowed the accident pilot to exceed the maxima, and it prevented the operator from monitoring and regulating the pilot appropriately. Such lack of operational control and administrative support may have increased the burden of workload on the accident pilot, perhaps exacerbating his overall stress and fatigue levels and diminishing his judgement.

The TC audit of the company in 1992 revealed several areas of non-conformance, and the company pledged to rectify the areas of concern. However, it was not until the regulatory audit from 11 to 22 May 1998, following this occurrence, that TC carried out another audit of the company.

TC issued repeated warnings of suspension of the company's maintenance and operational activities during the period between the audits, ultimately precipitating the most recent Notice of Suspension of the Air Operator Certificate in June 1998. Following the 1992 Transport Canada audit, deficiencies related to the company's air operator
certificate and the approved maintenance organization certificate, were either not eliminated or were allowed to re-emerge.

**Findings as to Causes and Contributing Factors**

- The weather in the vicinity of the accident made it unlikely that the flight could be completed in visual meteorological conditions.

- The helicopter emerged from the low cloud base in a steep, nose-down turn, and there was insufficient altitude and time to prevent the aircraft from striking the ground.

- The pilot likely experienced spatial disorientation and lost control of the helicopter.

**Findings as to Risk**

- The pilot's work/rest schedule increased the probability of him making fatigue-related errors in both aircraft handling and judgement.

- According to the company records, the pilot had, on several occasions, exceeded the legislated flight- and duty-time limitations of the CARs.

- Transport Canada audits carried out after the accident revealed deficiencies in the company's control of maintenance and operational activities.

- Following the 1992 Transport Canada audit, deficiencies related to the company's air operator certificate and the approved maintenance organization certificate, were either not eliminated or were allowed to re-emerge.

- The pilot had no formal instrument flying training or experience beyond that provided in his commercial helicopter flight training syllabus.

**Other Findings**

- The pilot was licensed and qualified for VFR flight.

- The pilot did not hold an instrument rating nor was one required for the planned operation.

- Records indicate that the helicopter was certified, equipped and maintained for the operation.

- No indication was found of any pre-impact failure of the helicopter, its engine or systems.
This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board authorized the release of this report on 17 August 2000.

1. All times are PDT (Coordinated Universal Time minus seven hours) unless otherwise noted.
Air 1997

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
Flight Control System Malfunction
Columbia Helicopters Inc.
Boeing Vertol BV-234 (Helicopter) C-FHFH
Comox Lake, British Columbia
30 October 1997

Report Number A97P0303

Synopsis

The Boeing Vertol BV-234 helicopter (serial number MJ001), with two pilots on board, was engaged in heli-logging operations in the Comox Lake area on Vancouver Island, British Columbia. At 1615 Pacific standard time, ground personnel attached a log, estimated to have weighed 16 000 pounds, to the hook at the end of the 250-foot long-line suspended below the helicopter. The helicopter had lifted the log two-thirds of the way off the steep terrain, with one end still in contact with the ground, when it commenced a rapid right turn. In the next 5 to 10 seconds, the helicopter continued to turn rapidly to the right several times, travelled laterally, then descended in a nearly-level attitude and struck the ground. The helicopter broke up at impact and the two pilots suffered fatal injuries; there was a limited post-accident fire.

Ce rapport est également disponible en français.

Table of Contents

1.0 Factual Information

1.1 History of the Flight
1.2 Injuries to Persons
1.3 Damage to Aircraft
1.4 Other Damage
1.5 Personnel Information
1.6 Aircraft Information
1.7 Meteorological Information
1.8 Aids to Navigation
1.9 Communications
1.10 Aerodrome Information
1.11 Flight Recorders
1.12 Wreckage and Impact Information
1.13 Medical Information
1.14 Fire
1.15 Survival Aspects
2.0 Analysis

2.1 Introduction
2.2 Flight Control System Malfunction
2.3 Survival Factors

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors
3.2 Findings as to Risk
3.3 Other Findings

4.0 Safety Action

5.0 Appendices

Appendix A - Glossary

1.0 Factual Information

1.1 History of the Flight

Earlier on the morning of the accident, the helicopter had flown three cycles\(^{(1)}\) for a total of 3.9 hours on logging operations before shutting down for a lunch break. During the first cycle, the pilots had complained about intermittent operation of the lower hook on the long-line and occasional popping of the associated circuit breaker, which seemed to occur during periods of heavy rain. During the refuelling break before the second cycle began, company maintenance engineers examined the hook and the helicopter but found no discrepancies. The helicopter then took off. The pilots reported no further difficulties with the hook system. However, the third cycle was interrupted by an electrical storm and the pilots returned for the lunch break.

After the lunch break, the crew completed another 1.9 hours of logging without incident; the crew then returned for fuel and the last planned pilot change-over for the day. At 1541 Pacific standard time (PST),\(^{(2)}\) the pilots took off and carried out 10 uneventful turns;\(^{(3)}\) the accident occurred on the eleventh turn. At 1615, ground personnel attached a log, estimated to have weighed 16 000 pounds, to the hook at the end of the 250-foot long-line suspended below the helicopter. The helicopter had lifted the log two-thirds of the way off the steep terrain, with one end still in contact with the ground, when witnesses observed the helicopter commence a rapid right turn. In the next 5 to 10 seconds, the helicopter continued to turn rapidly to the right several times, travelled laterally, then descended in a nearly-level attitude and struck the ground.

1.2 Injuries to Persons

<table>
<thead>
<tr>
<th></th>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Serious</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Minor/None</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1.3 Damage to Aircraft

The helicopter struck the ground in a high rate of descent on a 60-degree slope at about
1800 feet above sea level at latitude 4934’ north, longitude 12517’ west, at the south end of Comox Lake. The blade strike marks of the forward rotor blades on the mountainside are consistent with a flat fuselage attitude at impact. The helicopter broke into three sections at impact, with the breaks at fuselage stations 160 and 440. In general terms, the three sections were as follows: the cockpit, forward rotor, and transmission; the main fuselage; and the aft fuselage section, aft rotor, engines, and aft transmission. The forward section remained in the general area of impact. The 250-foot long-line remained attached to the fuselage belly hook, became entangled in the trees and fallen logs during impact, and held the main fuselage on the slope midway along the wreckage trail. The aft section tumbled some distance down the slope before it came to rest amongst the logs.

1.4 Other Damage

A fuel spill resulted from the ruptured fuel tank, and some minor damage was sustained due to the small fire.

1.5 Personnel Information

<table>
<thead>
<tr>
<th></th>
<th>Pilot-in-Command</th>
<th>Co-Pilot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>47</td>
<td>51</td>
</tr>
<tr>
<td>Pilot Licence</td>
<td>ATPL-H</td>
<td>ATPL-H</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
<td>1 January 1998</td>
<td>1 February 1998</td>
</tr>
<tr>
<td>Total Flying Hours</td>
<td>18 000</td>
<td>20 000</td>
</tr>
<tr>
<td>Hours on Type</td>
<td>1000</td>
<td>1200</td>
</tr>
<tr>
<td>Hours Last 90 Days</td>
<td>77</td>
<td>237</td>
</tr>
<tr>
<td>Hours on Type Last 90 Days</td>
<td>77</td>
<td>237</td>
</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Hours Off Duty Prior to Work Period</td>
<td>12.5</td>
<td>24+</td>
</tr>
</tbody>
</table>

The pilot flying at the time of the accident was also the pilot-in-command and had been employed by Helifor Industries Ltd. for 15 years. He had accumulated a total of about 18 000 flight hours in helicopters, 1000 hours in the BV-234, and another 11 000 hours in a similar tandem rotor helicopter, the BV-107. The pilot held a valid Canadian airline transport helicopter pilot licence (ATPL-H), medical certificate, and endorsements for other light and heavy helicopters. His flying experience included about 11 000 hours in vertical reference and heli-logging operations. His most recent pilot proficiency check (PPC) took place in March 1997, and was carried out with a high degree of competence, as it had been on previous occasions.

The pilot-not-flying was acting as the co-pilot during the accident flight and had been employed by Helifor for 19 years, having worked with both light and heavy helicopters. He was a senior captain for the company and had accumulated a total of over 20 000 flight
hours, all but 100 of which were in helicopters, with 1200 hours in the BV-234, and 16 000 hours in other tandem rotor helicopters. He held a valid ATPL-H and medical certificate, and was endorsed for other light, medium, and heavy helicopters. Although he was the co-pilot during this mission, he was an experienced vertical reference and logging pilot and was the assistant chief pilot for the BV-234. His most recent PPC took place in March 1997, and was carried out with a high degree of competence, as on previous occasions.

1.6 Aircraft Information

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Boeing Aircraft (formerly Boeing Vertol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and Model</td>
<td>BV-234</td>
</tr>
<tr>
<td>Year of Manufacture</td>
<td>1981</td>
</tr>
<tr>
<td>Serial Number</td>
<td>MJ001</td>
</tr>
<tr>
<td>Certificate of Airworthiness</td>
<td>Issued March 1997</td>
</tr>
<tr>
<td>Total Airframe Time</td>
<td>16 570 hours</td>
</tr>
<tr>
<td>Engine Type (number of)</td>
<td>Lycoming Gas Turbine AL5512 (2)</td>
</tr>
<tr>
<td>Rotor Type (number of)</td>
<td>Tandem (2)</td>
</tr>
<tr>
<td>Maximum Allowable Take-off Weight</td>
<td>51 000 pounds</td>
</tr>
<tr>
<td>Recommended Fuel Type(s)</td>
<td>Jet A, Jet A-1, Jet B</td>
</tr>
<tr>
<td>Fuel Type Used</td>
<td>Jet A</td>
</tr>
</tbody>
</table>

The helicopter was owned by Columbia Helicopters of Oregon, U.S.A., and was on lease to Helifor Industries Ltd. of Vancouver. The helicopter was imported into Canada in 1997; the previous U.S. registration for this helicopter was recorded as N234CH. The maintenance records of the helicopter were examined, and no deficiency or discrepancy was found. Records show that the aircraft had been maintained under a progressive maintenance schedule in accordance with existing directives and regulations, and had been thoroughly inspected at 15 044 hours in March 1997.

The helicopter had been last weighed in June 1996. The empty weight had been recorded as 21 697 pounds; with modifications, the present empty weight was about 22 500 pounds. At the time of the accident, the total weight of the helicopter was about 24 400 pounds, including the crew at 375 pounds (estimated) and 1500 pounds of fuel. The maximum certificated weight of the BV-234 helicopter with internal loads only is 48 500 pounds. The maximum certificated weight of the BV-234 helicopter when carrying external cargo is 51 000 pounds. With the log attached and free of the ground, the helicopter would have weighed about 40 400 pounds. The helicopter's centre of gravity at the time of the accident was estimated to have been within acceptable limits.

1.7 Meteorological Information

The operating environment was unremarkable relative to other heli-logging operations and sites. The weather conditions during the period leading up to the accident were reported as being overcast, light wind, and occasional light rain showers. These conditions are consistent with this operation's visual meteorological conditions requirements. The operating terrain, environment, and weather are not considered to be contributing factors in this accident.

1.8 Aids to Navigation
Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome Information

Not applicable.

1.11 Flight Recorders

The helicopter was not equipped with either a cockpit voice recorder or flight data recorder, nor was either required by regulation.

1.12 Wreckage and Impact Information

The quantity of fuel remaining in the fuel tanks was checked after the fuselage was recovered from the mountain side. Tank No.1 contained about 125 Imperial gallons, and tank No.2 contained about 70 Imperial gallons; however, the latter tank had ruptured on impact and an unknown amount of fuel was lost. Fuel samples taken from the helicopter after the accident were tested for contamination; none was found. Neither fuel exhaustion nor contamination is considered to have been a contributing factor in this accident.

Following a preliminary examination of the wreckage at the site, the entire helicopter was transported to secure facilities and examined in greater detail. The airframe, engines, and ancillary systems were critically examined; particular attention was focussed on the helicopter flight controls and hydraulic systems, the auto-pilot, the drive train, and the engines and related systems. After detailed examination of the components, a basic reconstruction of the airframe and rotor systems was completed. No anomalies were noted with either the airframe or the rotor systems, and systematic examination revealed that all component breakage and damage were attributable to the impact forces.

The BV-234 was powered by two Allied Signal (Lycoming) AL5512 gas-turbine engines. An examination of the engines, the engine mounts, the controls, and the ancillary accessories revealed no indication of any malfunction, defect, or anomaly. The engine inspection revealed damage to both engines resulting from the impact. The engines were also found to have been at a low power setting. No anomaly was found with the engines' maintenance histories. The engines are not considered to have contributed to the loss of control.

Examination of the helicopter's drive train system, transmissions, synchronizing shafts, and drive shafts, as well as the complete rotor system revealed no pre-impact failures.

The entire flight control system consists of levers, connecting links, bellcranks, and actuators located within the cockpit, the forward cabin section, the tunnel on top of the main cabin section, the aft cabin section, and the forward transmission fairing and pylon. The flight control system transfers the pilots' cockpit control movements to the two rotor heads to maintain helicopter attitude, altitude, heading, and speed.

The hydraulic flight control system consists of two similar but independent systems, identified as No.1 and No.2 hydraulic systems, and provides hydraulic assistance (or boost) to the pilots for flight control movements. Each system operates at a pressure of 3000 pounds per square inch (psi), with a range between 2500 and 3200 psi pressure; each has its own hydraulic tank, pump, valves, filters, and fittings, but the actuators are dual assemblies.
Actuators powered by the hydraulic systems are of three basic types: dual upper boost actuators (UBAs) for eliminating rotor loads from the control systems; dual lower stick-boost actuators (LBAs) for eliminating control weight and friction forces; and dual extensible link actuators (ELAs) to provide automatic flight control system (AFCS) inputs to the mechanical flight control system. There are four LBAs, one each for the pitch, roll, and yaw axes, and one for thrust (or collective), and three ELAs, one each for the pitch, roll, and yaw axes.

Pressurized fluid flows from the tanks to the flight control pumps and to the actuators; return fluid from the actuators flows back to the tanks. Each system provides hydraulic pressure to operate the two UBAs in both the forward and aft pylons, the three ELAs, and the four LBAs. Since each actuator is a dual element, the flight controls can be operated on a single system; however, it is impossible to control the helicopter without hydraulic system power.

![Schematic of flight control system](image_url)

**Figure 1 - Schematic of flight control system**

The flight control system was examined, and where possible, examined as installed in the accident helicopter. The components were then removed and systematically examined in greater detail. Impact damage to the yaw pedals showed that the left pedal was fully forward, the yaw connecting link had broken in compression, some rod ends beyond the mixing unit had broken in tension, and the walking beams had broken in overload. During the examination of the actuators in the flight control closet, it was noted that the walls of the enclosure were wet with hydraulic fluid. The actuators were removed, identified, and transported for examination and functionality check. Other than impact damage, no anomalies were found with any of the actuators, except for the damage to the yaw LBA.

The hydraulic flight control system was examined entirely. The hydraulic tanks were found empty except for traces of hydraulic fluid. The fluid was similar in texture and colour to MIL-H-5606B, which is the specified fluid. The hydraulic flight boost pumps, flight boost manifolds, lower control modules, emergency hydraulic pump, and AFCS pressure filters were examined and functionally checked. Other than impact damage and the effects of the
damage on the components functionality, no discrepancies were found. Analyses of the sample of the hydraulic fluid collected during these examinations determined that most were normal. However, some samples had a slightly-elevated water content which was attributed to rain contamination after the accident and during the recovery and transportation of the wreckage.

The yaw LBA (part number 234HS560-3 / serial number 0053V) had accumulated 5443 hours total time since new and consists of two separate actuators—the upper and the lower units. The upper actuator is supplied with hydraulic pressure from the No.2 hydraulic system, and the lower actuator is supplied by the No.1 hydraulic system. Each unit is designated by its respective hydraulic system. The seal around the actuating rod in the No.1 (lower) yaw LBA was found extruded from around the rod, and functional bench-testing revealed a slight leak from the broken seal. Functional testing also revealed that the No.2 yaw LBA would not maintain hydraulic pressure, and a rupture about one inch long was found in the cylinder wall. The actuator was then examined by three independent laboratories to determine the mode of failure and to identify the actuator material.

These examinations determined that the cylinder wall exhibited no signs of progressive failure in the form of pre-cracking, and it is believed to have burst in a single, instantaneous manner. The material was identified as the AA7075 alloy specified by the manufacturer. Measurements and engineering analysis of the burst actuator cylinder revealed that the cylinder had ruptured outwardly, and when the cylinder burst, the piston had been in a position that was consistent with normal and static right yaw pedal input made by the pilot. This action would have positioned the associated servo valve in the closed or slightly-open position. Fracture analysis shows that when the LBA cylinder burst, the piston moved down from a nearly centred position to bottom and fractured the yaw connecting link.

The seal around the actuating rod in the No.2 (upper) roll LBA was found extruded from around the rod, and is considered to have been squeezed out during airframe breakup. The upper cylinders of the pitch and roll LBAs were measured and no sign of distortion from overpressure was noted.

It is estimated that the hydraulic systems would have maintained suitable working pressure for one to two minutes given the in-flight damage to the yaw LBA seen in the accident helicopter. TSB Engineering Laboratory analysis of the two hydraulic gauges concluded that 1800 and 2650 psi hydraulic pressure was present in the No.1 and No.2 systems, respectively, at the time of electrical discontinuity during airframe breakup. Furthermore, it was determined that none of the annunciator lights were illuminated at impact. (Refer to LP 180/97.) Information gathered from the helicopter manufacturer indicated that the pressure required to burst the actuator is in the order of 10 000 psi. A flight control system relief valve is located in the lower control pressure control module and is set for 1950 psi maximum, at a flow rate of 3 gallons per minute. The following technical information was obtained from the manufacturer:

...under normal operating conditions, this valve relieves excessive or back-driving pressure in the stick boost actuator when the actuators servo control valve is open to the over-pressurized side of the piston. However, under extremely rapid application of overload to the actuator, when the servo valve is closed or only partially open, very high pressures can be generated within the cylinder due to trapped fluid condition. In such a situation, the trapped/restricted fluid will never reach the relief valve to be relieved.

The factual information and circumstances of this accident, along with the operational specifications of the flight control system, were provided to a hydraulic systems specialist, who conducted a series of dynamic hydraulic simulations of the helicopter's flight control...
system in an effort to achieve the high pressures required, as indicated by the manufacturer, to burst the LBA cylinder wall. The simulations determined that it was possible to achieve the high peak pressures required to burst the LBA cylinder.

The yaw connecting link (part number 114C1013-34) was found broken in two at its midpoint, but attached at one end to the LBA and the other to the yaw transfer bellcrank. The sections were examined by the TSB Engineering Laboratory for material analysis and to determine the mode of fracture. Optical binocular microscope examination of the fracture surfaces show an irregular transverse rupture, exhibiting 45-degrees-slant crack surfaces with a uniform matte grey appearance. The fracture was accompanied by a 50-degree-bend, with severe ovalization of the tube cross-section. This examination found no sign of pre-cracking or progressive failure. It was concluded, on the basis of optical microscope examination, that the link had broken in overstress by compression. Independent engineering examinations of the link confirmed that it had broken in column-loading, and determined that the rapid downward force when the cylinder burst was sufficient to break the link at its midpoint and introduce plastic deformation at the fracture site, similar to the bend found. Energy dispersive X-ray analysis determined the link material to be AA2024, consistent with the requirements of the manufacturer. The pitch, roll, and thrust connecting links installed in the flight control closet adjacent to the yaw connecting link were not damaged. Had the yaw connecting link broken as a result of impact, the adjacent links would have been similarly damaged.

The AFCS is a dual stabilization system, with independent electrical power and mechanical connections. These two systems operate simultaneously to stabilize the helicopter about the pitch, roll, and yaw axes, and to provide improved control response. Through the use of the flight director, the AFCS automatically maintains selected airspeed, attitude, bank angle, and heading. AFCS control of the aircraft is through movement of the electro-hydraulic and electro-mechanical dual ELAs in the flight control system.

The three ELAs--pitch, roll, and yaw--are installed between the LBAs and the flight control mixing complex and each receive distinct electrical inputs from the two AFCS computer units. Each ELA is composed of two single extensible links. System pressure enters each extensible link through a pressure port. The upper extensible link is pressurized by the No.2 hydraulic system and is controlled by the No.2 AFCS computer. Similarly, the lower extensible link is pressurized by the No.1 hydraulic system and controlled by the No.1 AFCS computer. Extending or contracting these links moves the flight controls and, in turn, the pilot valves of the UBAs.

Since all AFCS inputs take place after the LBAs, the inputs are not felt in the flight controls by the pilot. The UBAs transfer all pilot control movements into swashplate motion to control pitch of the rotor blades thereby controlling attitude, altitude, heading, and speed of the helicopter.

Each AFCS computer is provided with built-in test equipment (BITE) capability. This particular function enables maintenance staff to conduct an operational self-test of each system, and improves diagnosis of system faults. The BITE tests the AFCS computers and all associated actuators, as well as the control position transducers. When a BITE test is conducted on the ground, the ELA is positioned to null. A calibrated command is then sent by the AFCS to the ELA to extend. The ELA would respond, and the feed-back loop would carry this information back to the AFCS. If the AFCS had a failed U12 when the BITE test was conducted, the ELA would move to the fully-extended position when power is applied to the system. Then, when the AFCS commands the ELA to extend, the actuator cannot respond, and the feed-back loop informs the computer identifying an unserviceability. The pre-flight checks before the last take-off revealed a serviceable AFCS.
Both AFCS computers were examined and bench-tested. No faults were found with the No.1 AFCS computer. However, bench-testing of the No.2 AFCS computer determined that an integrated circuit component on the A4 yaw axis circuit card, identified as the U12 analog switch, had failed allowing an output of 11 volts direct current (VDC) to the No.2 yaw ELA. Analysis of the switch determined that it had failed as a result of electrical overstress of unknown origin. Since the U12 switch also controls the rate at which the voltage is applied to the ELA, such a failure would cause almost instantaneous ELA movement.

Although this same voltage is applied to the ELA during the BITE test, the voltage is slowly ramped up to the 11 VDC value. When maintenance performs the BITE test, the aircraft is on the ground, the engines are not running, no flight control inputs are made, and only one hydraulic system is pressurized. Both AFCS systems had been checked serviceable by the maintenance crew on the morning of the accident, and rechecked by the pilots during take-off; no anomalies were detected. It is standard operating procedure to have the AFCS selected "ON" during heli-logging operations, and both systems were found selected "ON".

The pitch, roll, and yaw ELAs were examined and functionally checked where possible; other than impact damage, no discrepancies were noted. Each ELA incorporates lock pistons that engage when the pressure in the respective hydraulic system drops to about 60 psi. During disassembly and examination of the yaw ELA, investigators noted that the lock pistons were in the locked position, consistent with low system hydraulic pressure. It was further noted that the piston slot was torsionally distorted around the lock piston, indicating that the piston was in the slot when the distortion occurred. All of this shows that the ELAs were damaged during airframe destruction and had lost hydraulic pressure before they were damaged.

1.13 Medical Information

Based on the autopsy, toxicology, and medical records, there was no indication the crews' performance was degraded by physiological factors. Medical information reveals physical injury to both pilots that is consistent with force being applied to the left yaw pedal at impact.

1.14 Fire

There was a small, limited-area, post-accident fire.

1.15 Survival Aspects

Both pilots sustained fatal injuries from the disruption and impact forces of the aircraft around them. The pilot-in-command was separated from his seat during the impact and break-up, and medical information confirmed that he had been wearing his lap belt. However, he was not wearing his shoulder harness at the time of impact. The co-pilot remained in his seat during the impact and break-up, and was found a short distance away from the cockpit section. He had not been wearing the shoulder harness portion of his seat restraint.

On helicopters used in vertical reference flying, such as the V-234, cockpit dimensions and fuselage width require the pilot flying to lean markedly to one side, usually to the left, to be able to clearly see the long-line and load suspended below the helicopter. It is physically impossible to use the shoulder harness in this position. Pilots in this industry have uniformly adopted a practice of using the lap belt portion, leaving the shoulder harness free. This practice allows the upper torso to lean markedly under the centrifugal forces of a rapid hovering turn. This movement away from the flight controls could make it difficult for a pilot to effectively manipulate the helicopter, and if the centrifugal forces were sufficiently great, it could prevent the pilot from returning to a normal, seated flying position.
In heli-logging operations using the BV-234 helicopter, it is standard practice for the pilot flying to occupy the left-hand pilot seat, and for the pilot-not-flying to be in the right-hand seat; the pilots in this accident were seated in this fashion. The pilot flying manoeuvres the helicopter for all phases of flight, while the pilot-not-flying monitors the engines and ancillary systems, records the loads picked up during the cycle, and communicates constantly to the pilot and, from time to time, to the logging ground crew below. This division of workload allows the pilot flying to concentrate solely on manoeuvring the helicopter. At the end of a period of flying, the flight crew will return to the service site to refuel and to exchange places before continuing with another cycle. This flying/non-flying cycle ensures a balanced work-load among the pilots and reduces fatigue. An examination of the work and duty cycles of both pilots involved in this accident revealed that they had followed the rest and duty periods required by regulation. Based on the flight crew's recent personal histories, neither pilot proficiency nor fatigue is considered a contributing factor in this accident.

2.0 Analysis

2.1 Introduction

The investigation into this accident included examination of environmental, technical, human, and operational factors, and an in-depth examination of the helicopter and its component parts, including their service life and history. There was nothing found during the investigation indicating that the total weight of the helicopter or the external load played any part in this occurrence. The practices and procedures used in the logging operation were evaluated, and no remarkable deviations were noted. Extensive examination and testing of the helicopter and its systems revealed that the only anomaly was in the yaw axis of the aircraft flight controls, specifically the U12 analog switch in the yaw axis of the No.2 AFCS computer.

2.2 Flight Control System Malfunction

The position of the yaw LBA piston when the cylinder burst was in a right yaw condition. Since the hydraulic condition to burst the cylinder requires the servo valve be in a closed or partially open position, it can be said that the LBA piston was in a stabilized right yaw position immediately before the burst occurred. Such a condition is likely to have been the result of a normal yaw input by the pilot to begin the helicopter turning right. It is likely that the U12 switch failed at this point and began the chain of events that caused the LBA to burst.

The investigation determined that when the U12 analog switch in the yaw axis of the AFCS failed, 11 VDC was applied directly to the No.2 yaw ELA. As a result, the No.2 yaw ELA rapidly and fully extended. It could not be determined why the cross-coupling function of the AFCS did not counter the erroneous signal, but it is possible that the rate of this signal exceeded the cross-coupling capability of the No.1 AFCS.

Under normal circumstances, a controlled extension force from the ELA is transmitted to the control mixing complex, which then translates the extension into mechanical inputs to the UBAs. In the accident, a sudden force displaced the input rod seal in the No.1 LBA and caused the No.2 LBA cylinder wall to burst. The downward motion of the LBA piston also caused the yaw connecting link to buckle and break under column-loading. It is likely that the sudden force was the result of rapid ELA extension with the ELA output meeting a control system resistance, causing the force to instantly rebound down to the yaw LBA output rod. The control system resistance may have occurred because the extension speed exceeded the capability of the UBAs to respond. It is also possible that the sudden fracture of the yaw connecting link created an upward input to the LBA servo valve and amplified the right turn.
Hydraulic control to the other axes of flight was available, as demonstrated by the apparent lateral and vertical control during the rotation leading to impact, and by the indications of system pressure captured on the hydraulic pressure gauges in the cockpit. It is clear from the yaw pedal damage and injury to the pilots that they were attempting to counter the right yaw when the helicopter crashed. Had the connecting link still been intact, any left pedal input would have been transmitted to the LBA and even with the burst cylinder, flight control movement would have been transmitted to the rotor systems with effect. Furthermore, full left pedal would have caused the servo valve to remain open, thereby removing one of the conditions for bursting the LBA cylinder. However, the helicopter did not respond to the pilots' corrective action because the broken yaw link prevented their left yaw input from reaching the LBA. Under the circumstances of the rapid, right yaw, the pilots would likely have become disoriented and unable to prevent the helicopter from striking the terrain.

2.3 Survival Factors

The degree of destruction as a result of impact forces made this accident unsurvivable.

It is known that the pilots were not wearing their shoulder harnesses at the time of impact. Although it is doubtful that the use of the shoulder harness would have lessened either pilot's injuries, the benefits of the torso restraint were greatly compromised, which likely reduced either pilot's ability to effectively control the helicopter.

Accident investigation and research carried out by the TSB has consistently shown that the use of the shoulder harness portion of the seat restraint system is effective in reducing or preventing injury during moderate impact forces. Given that vertical reference flying requires upper-body freedom of movement, the practice of not using the shoulder harness will continue to be widespread. The risk associated with this practice is that pilots will not be restrained effectively in the event of an in-flight emergency.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

- The U12 analog switch installed in the yaw axis of the No.2 AFCS computer failed in electrical overload, and sent an instantaneous extension signal to the No.2 yaw ELA.

- The rapid ELA extension in the yaw flight control system almost certainly caused the yaw LBA to burst and broke the yaw connecting link, preventing the pilot from countering a right-yaw condition.

- Without yaw control, the pilots likely became disoriented and could not prevent the helicopter from striking the terrain.

3.2 Findings as to Risk

- The practice of not using shoulder harnesses during vertical reference flying exposes pilots to greater risk of ineffective restraint during an in-flight emergency.

3.3 Other Findings

- No indication was found of any malfunction or pre-existing mechanical defect with the engines or related systems that could have contributed to the accident.

- The only pre-impact anomalies identified with the helicopter during the investigation were the U12 analog switch in the yaw axis of the flight control system, the burst yaw
LBA, and the fractured yaw connecting link. No other systems revealed pre-impact failures.

4.0 Safety Action

Columbia Helicopters Inc. determined, with the agreement of the Boeing Company, that the likelihood of a recurrence of the identified malfunction falls outside the certification limits (a probability of failure of $10^{-9}$). Work to reduce further the likelihood of this type of failure is, therefore, not required. However, Columbia Helicopters Inc. has undertaken intensive experimentation and research in an effort to identify any further causal elements.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board authorized the release of this report on 13 February 2001.

Appendix A - Glossary

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFCS</td>
<td>automatic flight control system</td>
</tr>
<tr>
<td>ATPL-H</td>
<td>airline transport pilot licence - helicopter</td>
</tr>
<tr>
<td>BITE</td>
<td>built-in test equipment</td>
</tr>
<tr>
<td>CCDA</td>
<td>collective cockpit control driver actuator</td>
</tr>
<tr>
<td>C.P.</td>
<td>Collective pitch</td>
</tr>
<tr>
<td>DASH</td>
<td>differential airspeed hold actuator</td>
</tr>
<tr>
<td>ELA</td>
<td>dual extensible link actuator</td>
</tr>
<tr>
<td>Ext links</td>
<td>extensible links</td>
</tr>
<tr>
<td>fwd</td>
<td>forward</td>
</tr>
<tr>
<td>LBA</td>
<td>dual lower stick-boost actuator</td>
</tr>
<tr>
<td>LCT</td>
<td>longitudinal cyclic trim</td>
</tr>
<tr>
<td>LP</td>
<td>laboratory project (of the TSB Engineering Laboratory)</td>
</tr>
<tr>
<td>M.B.</td>
<td>magnetic brake</td>
</tr>
<tr>
<td>PPC</td>
<td>pilot proficiency check</td>
</tr>
<tr>
<td>psi</td>
<td>pound(s) per square inch</td>
</tr>
<tr>
<td>PST</td>
<td>Pacific standard time</td>
</tr>
<tr>
<td>TSB</td>
<td>Transportation Safety Board of Canada</td>
</tr>
<tr>
<td>U12</td>
<td>integrated circuit component on the A4 yaw axis circuit card</td>
</tr>
<tr>
<td>UBA</td>
<td>dual upper boost actuator</td>
</tr>
<tr>
<td>UTC</td>
<td>Coordinated Universal Time</td>
</tr>
<tr>
<td>VDC</td>
<td>volts direct current</td>
</tr>
<tr>
<td>°</td>
<td>degree(s)</td>
</tr>
<tr>
<td>'</td>
<td>minute(s)</td>
</tr>
<tr>
<td>&quot;</td>
<td>second(s)</td>
</tr>
</tbody>
</table>

1. A cycle is best described as a continuous series of log transportation movements (turns) by the helicopter.

2. All times are PST (Coordinated Universal Time (UTC) minus eight hours) unless otherwise noted.

3. A turn is best described as one complete cycle of the helicopter picking up the log,
delivering it to the drop point, and returning to the pick-up point to repeat the operation. A turn usually took about three minutes to complete.

4. Vertical reference flying refers to pilots manoeuvring the helicopter, with a long-line cable attached to the fuselage, by using the cable and the ground directly below the helicopter as primary sources of hover reference. It is a highly demanding flight regime.

---

Updated: 2002-10-06

Important Notices
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 Occurrence Report
Collision with Water
Terry Air Cessna 402C C-GKWV
Mackenzie, British Columbia 23 nm N
16 December 1997

Report Number A97P0351

Summary

The Terry Air Cessna 402C, serial number 402C0515, had been chartered to transport passengers and equipment to the Bear Valley airstrip in northern British Columbia. The scheduled departure time of 0830 Pacific standard time (PST)\(^1\) was delayed because of inclement weather in Mackenzie; the aircraft eventually departed at 1210. The 40-minute flight to Bear Valley was reported to have been uneventful. After arriving in Bear Valley, the passengers and cargo were off-loaded, and about 500 pounds of cargo and two other passengers were loaded for the return flight to Mackenzie. The aircraft left Bear Valley at 1302. The pilot contacted Terry Air dispatch by radio at 1320 and reported that he was out of the Peace Arm, estimating Mackenzie at 1340. The dispatcher informed the pilot that the visibility at Mackenzie had dropped to two miles. At about 1330, the pilot transmitted, "Terry Air, KWV." The pilot's voice did not sound distressed, and the tone and content of the communication sounded like a normal initiation call. No further transmissions were heard from the pilot. At about 1350, Terry Air personnel began a communication search and emergency response. Search and Rescue and the Royal Canadian Mounted Police (RCMP) searched the area north of Mackenzie and found small pieces of floating wreckage near the west shore of Williston Lake. None of the occupants of the aircraft were found at this time. The bodies of the two passengers were later found and recovered.

Ce rapport est également disponible en français.

Other Factual Information

When the pilot left Mackenzie, he followed Williston Lake northward for about 50 nautical miles (nm), and then turned east into the Peace Arm.
toward Bear Valley. The ceiling at the time was overcast at about 2,000 feet above ground level (agl), and there was slight turbulence at the entrance to the Peace Arm. The pilot then descended to remain below the cloud and continued in visual meteorological conditions (VMC). Passengers described the actions completed by the pilot; that information is consistent with his using the autopilot for the en route portion of the flight and his not making any radio calls after leaving Mackenzie.

For the return trip to Mackenzie, the pilot had loaded about 500 pounds of cargo in the forward cabin area, immediately aft of the pilot seats, and secured it laterally using cargo restraint straps; as well, about 100 pounds of freight was loaded into the nose locker. Witnesses reported that the pilot did not use the aircraft's wing lockers and that they remained closed during the stop-over at Bear Valley. The aircraft's weight at the time of the accident is estimated to have been about 6200 pounds, with the centre of gravity at about 156 inches from the datum; both of these values are within the certificated limits.

The exact route for the return flight to Mackenzie is unknown; however, based on the pilot's radio report and the crash site location, his likely route was west from Bear Valley to Williston Lake, and then south to Mackenzie. The altitude for the return trip is unknown, but to remain in VMC, the pilot would have been limited by the overcast layer at about 2,000 feet agl, and by the localized weather conditions reported by several pilots who had flown through the area previously.

The aircraft wreckage was found near the centre of Williston Lake and the mouth of Six Mile Creek and was concentrated in an area of about 100 feet in diameter. The water depth at the crash site was about 160 feet, too deep for scuba divers. Several commercial dive teams completed underwater searches using remotely operated vehicles equipped with video recording systems. After several search efforts, two bodies were located and subsequently recovered, along with a large portion of the associated wreckage in the summer of 1998. This wreckage, as well as the video record taken during the underwater searches, were analysed by the TSB.

The aircraft sustained severe impact damage. The damage patterns on both sides of fuselage and nacelle sections appeared generally symmetrical. The wet fuel bay sections had been torn open. The right wing appeared to be attached to the fuselage, and the wing tip was detached and visible. The nose section of the aircraft was fragmented, and a large section of the right cabin wall was torn open and detached aft of the right wing. The air stair door appeared to be attached and closed. The left nacelle baggage compartment door and its latch were found in an open position before the wreckage was disturbed for recovery.

The forward end of the cabin floor, the left sidewall of the forward cabin, and the right horizontal stabilizer had been crushed in a symmetrical pattern at an angle of 45 to 60 degrees. These crush lines may indicate a steep nose-down attitude at impact, or may have been produced by hydraulic forces applied to the aircraft during a more level
impact.

All damage to the primary wing structure was attributed to the impact forces. The empennage sustained severe impact damage, although the rudder and the vertical fin appeared to remain attached. The horizontal stabilizer was pivoted to the right and was nearly detached. The left horizontal stabilizer had sustained severe leading edge mechanical damage outboard of butt line 61.50, and a triangular-shaped section of the aerofoil was missing. The top surface of the stabilizer displayed two sets of wrinkles, one set being a mirror image of the wrinkles visible on the top surface of the right horizontal stabilizer. The left elevator horn was undamaged and there was no evidence of flutter on the elevator control stops. A small piece of yellow, man-made material, similar to plastic, was lodged in the elevator skin adjacent to the left outboard elevator hinge. The horizontal stabilizer assembly, the left nacelle wing locker, and the recovered foreign substance were forwarded to the TSB Engineering Laboratory for further examination to determine if the damage to the horizontal stabilizer may have occurred before the water impact (LP 001/99).

All discontinuities noted in the flight control system were overload in nature and were attributed to the severe impact forces. Elevator and rudder trim tab actuator measurements were taken. The validity of these measurements as an indicator of the aircraft's pre-impact status is considered to be low because both trim systems are cable-operated and, therefore, subject to movement during a crash. Additionally, the rudder trim actuator was near its full travel position and its actuating cable had failed in overload.

The positions of the landing gear selector and the landing gear uplocks indicate that the landing gear was UP at the time of the accident. Additionally, the wing flap selector was positioned at the 15-degree setting; this selection is supported by the position of the flap actuator chain links and the actuator preselect switch lever, both of which indicated that the flaps were at an intermediate position at impact.

An examination of the left engine found no defect that would have resulted in a sudden or significant loss of power. There was no noticeable difference between the positions of the throttles, propeller controls, or condition levers; all were advanced to positions that were consistent with normal operation. The operation of the engines is supported by cockpit instrument indications captured at impact. The left airspeed indicator, the left turn and bank, the left direction indicator, the engine tachometer, the fuel flow gauge, and the right airspeed indicator minus the dial were forwarded to the TSB Engineering Laboratory for examination. From that examination, it was determined that:

- the heading captured on the direction indicator was 180 degrees;
- the left and right tachometers indicated 2 600 and 2 300 revolutions per minute (rpm), respectively;
- the fuel flow gauges revealed an estimated 160 to 170
pounds per hour; and

- an airspeed indication could not be recovered from the instrument.

The left crew seat had detached from the seat pedestal and was not recovered with the wreckage. However, an examination of the recovered sections of the pilot's station showed that the pilot's seat belt had been buckled, and that the floor section securing the left seat belt anchor had detached from the airframe due to overload; the seat belt would not have restrained the pilot, or held him in the wreckage after this failure occurred. There was no sign of fire on any of the examined components.

The flight dynamics of the aircraft before impact, the original impact point, and the flight attitude at impact were not determined. There were no known eyewitnesses to the crash. The aircraft did not carry flight data or cockpit voice recording devices; this equipment is not required by regulation. Additionally, because the crash occurred on water, there were no ground scars to capture data related to the original impact point and flight attitude. Finally, the high degree of hydraulic damage caused by the water impact tended to mask evidence that would normally be captured by the wreckage.

Terry Air was licensed to operate an air taxi service using a Cessna 402 and a Piper Seneca III aircraft; the company's main base is at Mackenzie. An air operator certificate, number 8360, issued by the Minister of Transport, was in effect at the time of the accident and authorized the company to carry passengers and freight under day, visual flight rules (VFR) or, when authorized by an air traffic control unit, special VFR conditions. Flight operations under instrument flight rules (IFR) or under the VFR over-the-top provisions were specifically prohibited according to the air operator certificate.

Terry Air flight operations were controlled by an operations manager. The operations manager did not hold a current aviation licence, and he had delegated some of his supervisory duties to the company chief pilot; it was the chief pilot who was involved in this accident. The chief pilot was responsible for the direction of safe flight operations and for the professional standards of the flight crews under his authority. At the time of the accident, the company employed one other pilot, and the flying duties were split between him and the chief pilot.

The aircraft was manufactured in 1981, was imported into Canada under an export certificate of airworthiness, issued on 26 April 1996, and was most recently maintained by Hill Aircraft Service Ltd. A review of the aircraft documents revealed that the aircraft was maintained in accordance with the Cessna 402 Progressive Care Program and in accordance with existing directives. The aircraft was last inspected on 06 November 1997, at about 16 612 hours' total airframe time, about 35 hours before the accident.

The aircraft was involved in a landing accident on 18 September 1997; it struck a pile of logs, damaging the left wing tip, the left de-ice boot,
and the left aileron. Maintenance records indicate that these components were replaced. The left wing was inspected, and no corrosion or significant damage was found. After the repairs were completed, the chief pilot carried out a flight test and accepted the aircraft back into service. On 03 November 1997, Transport Canada maintenance inspectors reviewed the wing repair records and inspected the aircraft; they concluded that the repairs had been performed correctly and that the aircraft was airworthy. Since the repairs, the aircraft had accumulated about 60 flight hours; there is no indication of any unrectified defect or deferred maintenance action against the aircraft over the period leading up to the accident.

The accident pilot held a Canadian airline transport pilot licence, a current medical certificate, and an endorsement for the aircraft type. He had accumulated about 5 500 flight hours, much of which were VFR flying in northern Canada. He had worked for a regional air carrier in 1991 and 1992 and, at that time, had type-endorsements on the BA31 Jetstream and the de Havilland DHC-8. The pilot's instrument rating had lapsed, and he had failed his two most recent instrument flight tests with Transport Canada inspectors. An instrument flight rating was not required by regulations providing flight operations were conducted under the conditions of the air operator certificate.

Flights between Mackenzie and Bear Valley are conducted entirely within Class G airspace. In the Williston Lake area, flight service stations (FSS) at Prince George and Fort Nelson provide limited in-flight services to low-level aircraft on 126.7 megahertz (MHz). This communication capability does not cover the entire lake, nor does it extend into the Peace Arm. Pilots use 123.2 MHz as well as a VHF/FM radio system for communicating with the logging camps and for providing flight-following reports to their dispatchers.

On the day of the accident, the central interior of British Columbia was under the influence of a strong, south-westerly flow aloft; two weather systems which were embedded in this flow affected the Williston Lake area. The leading disturbance was a Pacific frontal system which traversed the central interior in the morning, crossing southern Williston Lake at about 1000. A second, smaller system crossed the coast of British Columbia that same morning and the eastern edge of the associated cloud shield reached the Williston Lake area near noon. The trailing edge of this second system passed out of the Williston Lake area at about 1500.

The airmass was moist and stable in the lowest levels but fairly unstable further aloft. The Williston Lake area was generally covered with broken layers of stratus based at 3 000 to 6 000 feet above sea level and topped at 7 000 feet. There were also local embedded alto cumulus castellanus (ACC) clouds generating heavier snow showers which reduced the visibility to as low as ½ mile and formed local precipitation ceilings of 500 feet agl; tops of these clouds reached as high as 21 000 feet.

An analysis of the weather at the Mackenzie airport showed that precipitation from the second weather feature began at 1215. By 1300,
the ceiling had dropped to 1500 feet with a visibility of 3 statute miles (sm). Over the next hour and 45 minutes, the weather conditions deteriorated and remained below VMC. During that period, the Mackenzie automated weather observation site (AWOS) issued 15 special weather reports because of the rapidly changing weather conditions; the lowest ceiling was 200 feet, with 1 sm visibility.

North of Mackenzie, in the vicinity of the accident site, the southern arm of Williston Lake narrows to form a channel. Air flowing northward through this constriction tends to be squeezed and forced gently upwards; this action tends to enhance the risk and intensity of precipitation in the area.

Two aircraft landed at Mackenzie between 1300 and 1315; both had flown through the area where the accident would later occur. The pilots reported that they had encountered significant degradation to the in-flight visibility because of moderate snow. Upon encountering the weather, both pilots had to descend to about 200 feet agl to maintain visual contact with the shoreline and the surface of the lake; neither reported any accumulation of ice on their aircraft. These adverse conditions extended from Scott Creek, at the north end of the Williston Lake narrows, through to Mackenzie. A number of scheduled flights from Mackenzie were subsequently cancelled because of the poor weather conditions. Conclusions of a meteorological analysis following the accident were that the conditions in the narrows at the time of the accident were likely worse than those described by these two pilot reports (pireps), and that the forward visibility in the area may have dropped to as low as ½ mile in heavy snow.

The Cessna 402 had been specifically chartered for this trip because of its higher load-carrying capability. Originally, a stop of 2½ hours had been planned at Bear Valley, with the return trip scheduled to arrive back in Mackenzie at about 1200. The normal seating arrangement incorporated two crew and seven passenger seats; for the accident flight, the first four passenger seats had been removed to accommodate the cargo.

Terry Air's company operations manual (OM) identified the pilot-in-command as responsible for the formulation, execution, and amendment of an operational flight plan, and for ensuring that the flight is conducted in accordance with all applicable regulations. The OM required pilots to obtain appropriate weather information for every flight. Each morning, the Terry Air dispatcher obtains preliminary weather information from an Environment Canada/

NAV CANADA internet site. On the morning of the accident, this information was obtained at 0856 and included terminal area forecasts and actual weather reports for Mackenzie, Fort Nelson, Prince George, and Fort St. John, all valid at 0800. Also, the dispatcher obtained a satellite image of the cloud cover that was over the area at 0730. The weather information did not contain an area forecast, a surface analysis, upper level winds, a significant weather chart, or available pilot reports for the area. Pilots with Terry Air were required to augment preliminary information by obtaining a weather briefing from the FSS in
Prince George before their flights and by contacting personnel at the outlying camps for the latest conditions at the destination airfields. TSB investigators reviewed the Prince George FSS briefing logs, the FSS audio recordings that cover radio frequency and telephone channels, the Terry Air company telephone records of all outgoing calls, as well as records of all incoming calls to the two "1-800" numbers listed in the Canada Flight Supplement. Investigators found no record of the pilot obtaining a formal weather briefing before either flight from Mackenzie or Bear Valley.

Terry Air is required to maintain a flight-following system to monitor a flight's progress and to notify appropriate company personnel and search and rescue authorities when a flight is overdue or missing; this function is normally performed by the dispatcher. Pilots aid in this function by reporting their movements using available communication facilities. On this flight, the pilot contacted the Prince George FSS on radio frequency 126.7 MHz before leaving Mackenzie for the outbound flight to Bear Valley. At that time, he advised the FSS of his departure from Mackenzie, his flight route, and that there was two inches of snow on the runway at Mackenzie. There is no record of any further radio calls from C-GKWV on 126.7 MHz. Using the FM radio, the pilot reported his departure from Mackenzie to the company dispatcher; this was the only transmission received from the pilot during the outbound leg to Bear Valley. On the return trip to Mackenzie, the pilot broadcast his departure time as 1302 on the FM radio; that report was not heard by the company dispatcher likely because of radio coverage limitations, but the Bear Valley camp informed the dispatcher of the aircraft's departure by telephone at 1305. The pilot contacted the dispatcher at 1320, after leaving the Peace Arm, and gave 1340 as an estimate for Mackenzie.

Canadian Aviation Regulations 703.27 and 703.29 provide a level of safety to VFR operations by legislating minimum obstacle clearance requirements, and by requiring pilots to avail themselves of current weather reports and forecasts before commencing a flight. In part, these regulations require that no person shall commence a VFR flight unless current weather reports and forecasts indicate that the weather conditions along the route to be flown, and at the destination aerodrome, will be such that the flight can be conducted in compliance with VFR. Additionally, except when conducting a take-off or landing, no person shall operate an aeroplane in day, VFR flight at less than 300 feet agl or at a horizontal distance of less than 300 feet from any obstacle.

**Analysis**

A complicated weather pattern was affecting the area; the essential elements of this weather were the risks of encountering reduced ceilings and visibility in the vicinity of a surface trough or in the area of embedded ACC/towering cumulus (TCU) clouds. With the exception of these localized risks, the flying area was generally overcast and suitable for VFR flight.

There was no indication that the pilot obtained a complete pre-flight
weather briefing before either flight from Mackenzie or Bear Valley; without such a briefing, he would not have been aware of information contained in the area forecast, the surface analysis chart, the significant weather chart, or the pireps for the area; specifically, he would not have been aware of the risk of reduced visibility below VMC in the vicinity of embedded ACC/TCU clouds.

While the pilot was in Bear Valley, the weather in the Mackenzie region began to deteriorate to below VMC minimums. Although specific information about these deteriorating weather conditions had been discussed on the radio by two other pilots, the pilot of the accident aircraft would not likely have heard these transmissions because, at the time they were made, he was flying westward in the Peace Arm and was outside radio coverage. It is unlikely that the reported conditions would have improved significantly over the short period leading up to the accident; in fact, the general trend at Mackenzie was for a continued degradation of both the ceiling and the visibility, to the point that subsequent flights out of Mackenzie were cancelled.

When the pilot reported out of the Peace Arm at 1320, the company dispatcher informed him that the visibility at Mackenzie had dropped to two miles. Although informed of the deteriorating visibility, the pilot did not contact the Prince George FSS for a weather update; therefore, he would not have been aware of the new terminal forecast for Mackenzie effective at 1300. As well, he would not have known that the AWOS in Mackenzie was generating numerous special reports on the rapidly changing weather conditions, nor would he have been aware that the visibility in Mackenzie had dropped below VMC.

The Terry Air company OM specifically disallows operations under IFR or VFR over-the-top. The pilot, without an instrument rating, only had as permissible options, when encountering deteriorating weather, to turn back to his departure point or proceed to another suitable airport.

The crash site location reveals that the pilot entered the area of deteriorating weather and reduced visibility. It is therefore likely that he encountered similar conditions to those reported by the pilots who had flown through the narrows before him. In both those cases, the degraded weather had forced those pilots to descend to about 200 feet agl to maintain visual reference with the shoreline. The risks of conducting VFR flight under these conditions are known and are mitigated, to a degree, by the establishment of a minimum obstacle clearance altitude of

300 feet agl and by a minimum visibility requirement of 2 miles. Continuing a VFR flight at an altitude or visibility below these stated minimum values is considered to be unsafe and is not permitted by regulation.

The lack of radio calls on frequency 126.7 MHz, as noted on both the outbound and return legs of this trip, increased the risk to the flight by degrading the continuity of the flight-following. The lack of radio transmissions increased the risk of meeting opposing traffic in narrow areas of the lake and reduced the opportunity for other aircraft or FSS
facilities to communicate pertinent information related to weather or flight safety.

A witness report of the pilot's radio call at about 1330 establishes that, in the time frame immediately preceding the accident, the radio transmitter was operational, was tuned to the Bevel Mountain FM frequency, and electrical power was available to run the radio system.

The precipitating cause of this accident is not known; however, because the pilot did not report any ongoing problem to the dispatcher or the FSS, it is likely that this accident occurred suddenly, and with little warning. Because the weather was known to be below VMC, the risk of inadvertently striking the terrain while in controlled flight was increased. However, it is also possible that some unknown mechanical malfunction may have occurred.

This aircraft had been involved in a previous accident. Its repair and return to service after that accident were checked and monitored by an approved maintenance organization, and by both the chief pilot and maintenance manager of Terry Air. Additionally, the aircraft had passed an independent inspection conducted by two Transport Canada airworthiness inspectors. The aircraft had flown more than 60 hours after being accepted back into service following the wing repair and was reported to have had no documented unserviceabilities raised against it by either of the company pilots. For those reasons, the possibility of a causal link between the previous repair activity and the current accident is considered unlikely.

The likelihood of an in-flight break-up is considered to be remote; a major structural failure at altitude would normally cause aircraft wreckage to be scattered over a wide area; the debris trail associated with this accident was found within a small area which contained the major structural components of the aircraft.

There was no evidence of any fire damage on any of the examined pieces which included cockpit, engine and interior cabin components.

An evaluation of the recovered wreckage indicates that both aircraft power plants were likely operating at or above normal cruise power settings at the time of the crash. Regardless, pilots should normally be able to maintain control of an aircraft in the event of an engine failure, especially if operating under visual conditions as required by the operating certificate.

Crush angles on the recovered wreckage are inconclusive; they may indicate that the aircraft struck the water in a steep nose-down, slightly left-wing-low attitude, or they may have been caused by hydraulic action when the aircraft entered the water in a more level flight attitude.

The left horizontal stabilizer exhibited a mechanical damage pattern that appeared inconsistent with damage on adjacent portions of the aerofoil. Despite a detailed engineering examination of the involved components (LP 001/99), results were inconclusive as to whether this impact damage took place in flight, or at some time during the break-up
sequence before the stabilizer contacted the water. There was no
evidence of paint, bird, animal, or vegetation transfer in the vicinity of
the damaged aerofoil. The yellow material found wedged in a fracture
adjacent to the outboard trailing edge of the left horizontal stabilizer
was not identified, nor was there sufficient physical evidence to
conclude that it was part of the object responsible for the damage.
Although the left baggage compartment was found with its door open
and latch in the open position, it could not be conclusively determined
that the compartment door was open before impact.

The extensive break-up and fragmentation of large sections of the
airframe indicate that the aircraft sustained a rapid deceleration on
impact. The deceleration would have produced high g-force levels,
above the seat belt design criteria and near maximum human tolerance
levels. The likelihood of survival in this case would be low because of
the overstress and failure of the seat restraint systems. The presence
and the method of securing the interior cargo would have further
degraded the chance of survival for the occupants.

The following Engineering Branch reports were completed:

LP 094/98 Exhaust Stacks Analysis
LP 001/99 Wreckage Evaluation

Findings

- The aircraft had been involved in a previous landing accident at
  Bear Valley on 18 September 1997; the likelihood of a link
  between the previous damage and the Williston Lake accident is
  considered to be remote.

- There were no reported aircraft unserviceabilities before the
  flight, and aircraft maintenance records indicate that the aircraft
  was maintained in accordance with the applicable standards of
  airworthiness.

- The aircraft's weight and balance were within the certificated
  limits.

- In accordance with its air operations certificate, Terry Air is
  licensed as a day VFR operation only with operations under IFR
  or under VFR over-the-top specifically disallowed.

- A complicated weather pattern was affecting the area; the
  essential elements of this weather were the risks of encountering
  reduced ceilings and visibility in the vicinity of a surface trough or
  in the area of embedded ACC/TCU clouds.

- There is no evidence that the pilot obtained a complete weather
  briefing before either the flight from Mackenzie to Bear Valley, or
  the return.
There is no record to indicate that the pilot made any position reports on 126.7 MHz on the flight from Mackenzie or Bear Valley.

Over the period of this flight, the weather from Scott Creek, at the northern end of the Williston Lake narrows, through to Mackenzie dropped below VMC because of a localized disturbance related to embedded ACC/TCU clouds.

Although two other pilots had reported difficulty with the weather south of Scott Creek, the pilot of the accident aircraft would likely not have been aware of this because he was in the Peace Arm, beyond radio coverage.

Based on the crash location, it is apparent that the pilot continued southward and entered the area of reduced visibility.

The pilot was experienced at operating under VFR but had recently displayed some weaknesses in his instrument flight ability. His instrument rating had lapsed and he was not authorized to conduct instrument flight under the conditions of his licence.

Any attempt to continue the flight at low altitude in below VMC conditions would have increased the risks associated with the operation.

Recovered wreckage indicates a likelihood that both engines were operating at or above cruise power at the time of the crash.

Flight dynamics before impact are not known.

Crush angles on the recovered wreckage are inconclusive; they may indicate that the aircraft struck the water in a steep nose-down, slightly left-wing-low attitude, or they may have been caused by hydraulic action when the aircraft entered the water in a more level flight attitude.

The likelihood of an in-flight break-up is considered to be remote.

There was no sign of any fire damage to either engine or cabin components.

There is evidence to conclude that the leading edge tip of the left horizontal stabilizer was struck by an object before the stabilizer struck the water, but the nature of this object was not identified; likewise, it was inconclusive as to whether this impact took place in flight, or at some time during the break-up sequence before the stabilizer contacted the water.
The source of a small piece of yellow material found wedged in the fracture adjacent to the outboard trailing edge of the left horizontal stabilizer was not identified, nor was there sufficient physical evidence to conclude that it was part of the object responsible for the damage.

The accident was not survivable.

**Causes and Contributing Factors**

The cause of this accident is undetermined; however, it is probable that low-level, visual flight in deteriorating weather contributed to the accident.

**Safety Action**

**Safety Action Taken**

Elevated risks associated with air taxi operations have been recognized throughout the industry. In response, Transport Canada formed a task force which included representatives from Transport Canada system safety, commercial and business aviation and airworthiness branches, to study the safety of air taxi operations (SATOPS). The objective of the task force was to identify how the safety of air taxi aircraft can be improved and to recommend ways to reduce the number of accidents. In the SATOPS Final Report Spring 1998, a number of areas have been identified where improvements could be made to increase the safety of air taxi operations. The SATOPS recommendations have been divided into 13 general categories: Airworthiness, Client Pressures, Communication, Decision Making/Human Factors, Flight Training Units, Management, Navigation, Operating Pressures, Operating Problems, Statistics, Training, Transport Canada, and Weather. Transport Canada will produce a status report which will be published every six months to track the ongoing progress of the implementation plan and to advise the industry of the status of the recommendations.

Following this accident, Terry Air signed a memorandum of understanding with the Prince George FSS; the FSS will provide Terry Air with available weather information, excluding graphic products, on a scheduled basis.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 28 July 1999.*

---

1. All times are PST (Coordinated Universal Time (UTC) minus eight hours) unless otherwise stated.
Updated: 2002-10-06

Important Notices
The Transportation Safety Board (TSB) of Canada 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 Occurrence Report
Risk of Collision between ATR 42-300 C-FTCP of Inter-Canadien Aéropatiale and a convoy of snow removal vehicles Quebec/Jean-Lesage International Airport, Quebec
10 January 1997

Report Number A97Q0005

Synopsis
Inter-Canadien Flight 1628, an ATR 42-300 (Serial No 143), was cleared to take off from runway 06. This regularly scheduled passenger flight links Quebec City, Quebec, and Baie-Comeau, Quebec. During climb-out, the aircraft flew over a convoy of six snow removal vehicles travelling in the opposite direction at the midway point of the runway. The flight crew reported the incident to the air traffic controller, then continued the climb and flew on to the destination without further incident.

Ce rapport est également disponible en français.

Other Factual Information

At 0819, eastern daylight time (EDT),(1) a convoy consisting of six snow removal vehicles under the direction of the maintenance supervisor (Staff 22) was authorized by the ground controller to proceed onto runway 06 via taxiway Bravo, runway 30 and taxiway Golf. At 0824, the convoy entered runway 06 and cleared it six minutes later via taxiway Alpha to allow an aircraft to land. After clearing the taxiway, Staff 22 reported to the ground controller that the vehicles were going to work on the apron and asked to be advised when the runway was available. At 0837, the aircraft landed and was cleared to leave the runway via taxiway Alpha and travel to the apron. About one minute and twenty-four seconds later, the ground controller advised Staff 22 that the runway was available. Shortly thereafter, the ground controller was relieved for a rest break, by the shift supervisor.

Staff 22 and the five other vehicles then left the apron and entered runway 06 via taxiway Alpha without requesting permission to proceed. At 0841, Inter-Canadien 1628 (ICN 1628) was cleared by the ground controller to proceed onto runway 06. The investigation revealed that the communication was heard by two vehicle drivers while the convoy was on runway 06, about 1,000 feet from the intersection with taxiway Alpha. The drivers were under the impression that the controller would warn them if they had to clear the runway. Shortly thereafter, the convoy of vehicles turned around and headed towards the right side of runway 24.

At 0845, the air controller cleared ICN 1628 to take off from runway 06. The co-pilot was at the aircraft's controls during the take-off run. At rotation speed, he noticed that there were vehicles on the runway and pitched the nose of the aircraft up more steeply than normal. Shortly thereafter, the captain reported to the air controller that there were several vehicles on the runway. In the meantime, Staff 22 advised the ground controller that an aircraft had just flown over the vehicles. The aircraft was estimated to have taken off approximately 3,000 feet from the threshold of runway 06 between 1,000 and 1,500 feet before the area where the vehicles were. The climbing aircraft flew over the vehicles at an altitude of between 200 and 300 feet. Runway 06/24 is 9,000 feet long and 150 feet wide.

The weather conditions prevailing at Quebec City at the time of the occurrence were as follows: surface winds from 090 degrees magnetic at 15 knots gusting to 20 knots; visibility ½ mile in average-intensity and blowing snow; vertical visibility 60 feet; temperature minus 7 degrees Celsius; dew point minus 8 degrees Celsius; barometric pressure 29.36 inches of mercury; obscuring phenomenon due to snow; opacity 8/10. The runway and the apron could not be seen from the control tower because of the weather conditions.

The frequency 121.9 megahertz was used for communications between the control tower personnel and the snow removal vehicles. Use of the ground control frequency for communications with all airport vehicles is the established standard procedure. The maintenance frequency was used for communications between the snow removal personnel. This frequency is also used by all airport vehicles, but is not available to air traffic personnel. It is a work tool and helps to
reduce congestion on the ground frequency. Staff 22 stated that he did not hear the ground controller clear ICN 1628 to proceed because the maintenance frequency was congested. The communication equipment was working properly at the time of the occurrence.

Controllers occupied the ground and air positions in the control tower, and there was also a shift supervisor present. Staffing met unit standards. The transfer of responsibilities between the supervisor and the ground controller for his rest break was done in accordance with standard procedures. The supervisor knew that Staff 22 had been advised that the runway was available, and he was under the impression that the snow removal vehicles would continue to work on the apron. The workload was assessed as light, with normal complexity. The personnel on duty in the control tower and the snow removal personnel were certified and qualified.

In the tower, red and green warning lights report movements and obstacles on the runways. The ground controller attends to the warning lights. A green light indicates that the runway is clear, and a red light indicates that the runway cannot be used. In the present case, the green warning light for runway 06 was lit. In addition to these lights, vehicle information is recorded and updated on red progress strips showing the number and position of vehicles and placed directly under the flight progress strips. In the present case, there was a red strip on the ground and air controllers’ data blocks. At the time of the occurrence, each strip indicated that the six snow removal vehicles were on the apron. The airport is not equipped with Airport Surface Detection Equipment (ASDE). An ASDE is a very useful tool for navigation on the ground, as it can detect potential conflict situations, especially if visibility is restricted.

In performing their duties, the air traffic and maintenance personnel were using the Snow Removal Manual 1996-1997, Jean-Lesage International Airport, 23 October 1996 and the minutes of a snow removal meeting held on 28 October 1996. At this meeting it was agreed, among other things, that, to allow good cooperation during storms and to speed up snow removal work, the head of maintenance was to be advised as soon as the active runway was available, and that care was to be taken to confirm whether authorization had been given to proceed along the whole length of the runway or with restriction. The ground controller concerned, and the maintenance supervisor had attended this meeting, and the maintenance supervisor had prepared and signed the agreed procedure. In the present case, Staff 22 did not see the need to request permission to proceed because the runway that he had just cleared was available again. Further, he thought that he could use its whole length without restriction.

The Air Traffic Control Manual of Operations (MANOPS) and the Airport Traffic Directives for the Operation of Vehicles on Airport Movement Areas (TP 2633) deal with ground traffic at airports and contain the standard phraseology to request and transmit traffic instructions to vehicles. These documents were amended following publication of an Air Traffic Services Directive (ATSD-015) issued on 16 April 1984. This directive pointed out that some phraseology was imprecise and could give rise to misinterpretations when associated with ground vehicle movements. To remedy this situation, the directive stipulated that in future the word “cleared” would be eliminated from the phraseology dealing with vehicle movements at airports and would be replaced with an executive type of authorization. The personnel concerned in this occurrence knew the contents of these documents.

Section 4.03 of TP 2633 stipulates that before proceeding onto manoeuvring areas on a controlled airport, the vehicle operator is to contact the ground controller for permission to proceed to a specific location by a specified route. Further, section 354.4 of the MANOPS stresses that air traffic personnel must be more vigilant during periods of restricted visibility to ensure that the runway is clear for use when required, and that they must remain aware of the location of ground traffic.

Analysis

During take-off, the flight crew of Flight ICN 1628 saw snow removal vehicles on the runway. The crew had not been informed of the presence of these vehicles because of the information available to the controllers on duty.

Personnel in the tower, and snow removal personnel were certified and qualified for the duties being performed, and they were current with existing procedures. In addition, the communication equipment used was operating properly, although the maintenance frequency was sometimes congested, as it was used by all airport vehicles. The frequency congestion was also made worse by use of the ground frequency.

When the vehicle convoy first proceeded onto runway 06 to begin snow removal, permission to proceed was requested and given in accordance with existing procedures. As the vehicles had to clear the runway to allow an aircraft to land, they proceeded onto the apron, where they continued snow removal work. When the ground controller shortly thereafter told the maintenance supervisor in charge of the convoy (Staff 22) that the runway was available, the six vehicles immediately proceeded onto the runway via taxiway Alpha, but without obtaining permission to proceed. The apron and the runways could not be seen from the control tower because of the restricted visibility.

The orders agreed on at the snow removal meeting prior to the winter season (in effect, that air traffic personnel were to advise maintenance personnel when the runway was available, and that everyone was to take care to confirm an authorization to proceed along the whole length of the runway, or with restriction) seemed clear and precise. In the incident, however, Staff 22 interpreted runway available as permission to proceed, because he had just cleared this runway. He also thought that he could use the whole length of the runway without restriction. These orders therefore caused confusion, because, before proceeding onto manoeuvring areas on a controlled airport, as stated in TP 2633, vehicle operators are to obtain permission to proceed to a specific location by a specified route.
While the vehicles were entering the active runway without permission, the shift supervisor, who was temporarily acting as ground controller, cleared ICN 1628 to proceed onto runway 06. The controllers on duty thought that the vehicles were still on the apron, because the lights indicated that runway 06/24 was clear and the progress strips indicated that the six vehicles were still at that location. However, as stressed in the MANOPS, because visibility was restricted, the ground and air controllers could have asked for the location of the vehicles before clearing ICN 1628 to proceed and take off, although that was not mandatory. Further, an ASDE might have detected the situation.

Two vehicle operators heard the communication for ICN 1628, but they were under the impression that the controller would warn them, if necessary, to clear the runway. The congestion of the maintenance frequency might also have contributed to the fact that Staff 22 did not hear this communication.

Subsequently, the snow removal convoy headed towards the right side of runway 24, without the controllers' being aware of their movements. In the middle of the runway, to the great surprise of everyone concerned, the aircraft in climb-out flew over the vehicle convoy. After the incident, the local authorities immediately took action to prevent a similar occurrence from happening again.

**Findings**

- The air traffic and snow removal personnel concerned were certified and qualified to perform their duties.
- The apron and the runway could not be seen from the control tower, because of the weather conditions.
- The airport is not equipped with Airport Surface Detection Equipment (ASDE).
- The maintenance frequency is used by all vehicles operating on the airport.
- The maintenance supervisor (Staff 22) and the snow removal vehicles left the apron and entered taxiway Alpha and the active runway without requesting permission to proceed.
- Both the strips used in the control tower for vehicles, and the warning lights, indicated that the vehicles were on the apron and that the active runway was clear.
- The air and ground controllers did not ask for the location of the snow removal vehicles before clearing ICN 1628 to proceed and take off.
- The air controller did not know that there were snow removal vehicles on the active runway when he cleared ICN 1628 for take off.
- The expression "runway available", from a local order, caused confusion and contributed to the fact that the snow removal vehicles were on the active runway without permission when an ATR 42 aircraft was taking off.

**Causes and Contributing Factors**

A dangerous situation occurred when an ATR 42 aircraft took off while there were six snow removal vehicles on the runway. The following factors contributed to this dangerous situation: visibility was considerably restricted; and the local snow removal orders caused confusion. As a result, the convoy of snow removal vehicles left the apron and was on the active runway without permission.

**Safety Action**

After the incident, the local authorities took the following actions:

- An operating bulletin was issued by the air traffic authorities to clarify the interpretation of the term "runway available" and to set out a new procedure to prevent any ambiguity.
- A plexiglass plate was added to the ground controller's position on which to write in grey pencil the active runway and the presence of vehicles on the airport's movement areas.
- An exchange program between air traffic personnel and airport vehicle drivers was established to promote better understanding of the duties and functions of the two groups, better communication between the parties, and better understanding of each others' work.
- A refresher course on airport traffic procedures and air traffic phraseology was given to all airport maintenance vehicle operators.
- The air traffic authorities carried out an on-the-job assessment and evaluated the phraseology used by their personnel under the System Quality Assurance Program (SQAP).

- The local air traffic authorities are trying again to obtain Airport Surface Detection Equipment (ASDE) for the airport, and are proposing alternative measures.

- A document was prepared by the maintenance service to obtain an additional working frequency exclusively for the use of snow removal crews.

This report concludes the Transportation Safety Board's investigation of this occurrence. Publication of this report was authorized on 29 July 1997 by the Board consisting of Chairman Benoit Bouchard and Members Maurice Harquail, Charles H. Simpson and W.A. Tadros.

Appendix A - Diagram of the Airport
## SUMMARY OF EVENTS

<table>
<thead>
<tr>
<th>No</th>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13:19 UTZ</td>
<td>Staff 22 - 5 on Ramp 1</td>
</tr>
<tr>
<td>2</td>
<td>13:24 UTZ</td>
<td>Staff 22 - 5 proceeds via Golf</td>
</tr>
<tr>
<td>3</td>
<td>13:24 UTZ</td>
<td>Staff 22 - 5 Runway 06</td>
</tr>
<tr>
<td>4</td>
<td>13:27 UTZ</td>
<td>Staff 22 - 5 in front of Hotel for Alpina</td>
</tr>
<tr>
<td>5</td>
<td>13:30 UTZ</td>
<td>Staff 22 - 5 clears Alpina for Ramp 1</td>
</tr>
<tr>
<td>6</td>
<td>13:31 UTZ</td>
<td>Staff 22 - 5 on Ramp 1 waiting &quot;runway available&quot;</td>
</tr>
<tr>
<td>7</td>
<td>13:36 UTZ</td>
<td>Staff 22 - 5 advised by ground that &quot;runway available&quot;</td>
</tr>
<tr>
<td>8</td>
<td>13:41 UTZ</td>
<td>IGN 1628 proceeds Bravo-Runway 30-Golf to Runway 06</td>
</tr>
<tr>
<td>9</td>
<td>13:41 UTZ</td>
<td>Transmits on board in two snow removal trucks</td>
</tr>
<tr>
<td>10</td>
<td>13:45 UTZ</td>
<td>IGN 1628 IDLS on Runway 06</td>
</tr>
<tr>
<td>11</td>
<td>13:46 UTZ</td>
<td>IGN 1628 takes off past intersection 12/24</td>
</tr>
<tr>
<td>12</td>
<td>13:46 UTZ</td>
<td>Staff 22 - 5 advised ground of presence of ATR</td>
</tr>
</tbody>
</table>

1. All times are EDT (Coordinated Universal Time (UTC) minus five hours) unless otherwise stated.

---

Updated: 2002-10-06
Air 1997

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 Occurrence Report In-Flight Breakup
Cessna A185F C-GCTI
Sept-Îles, Quebec 21 nm N
17 February 1997

Report Number A97Q0032

Summary
The ski-equipped Cessna A185F, serial No. 18502495, registration C-GCTI, took off at 1045 eastern daylight time (EDT) from Sept-Îles Airport, Quebec, on a visual flight to Wabush, Newfoundland. Shortly after reaching its cruise altitude of 4,500 feet above sea level (asl), at an indicated airspeed of approximately 145 mph, the aircraft pitched down sharply. The pilot immediately reduced power and pulled back on the elevator to stabilize the aircraft. The aircraft stabilized for about two seconds, then broke up.

The aircraft was flying over a wooded area with an average elevation of 1,000 feet asl and was found 14 nautical miles north of Sept-Îles Airport, broken up into several pieces. The pilot and the aircraft owner were seated in front and sustained fatal injuries at ground impact. Two passengers, seated in the rear, survived the fall of about 3,500 feet.

Ce rapport est également disponible en français.

Other Factual Information
The pilot had held a commercial pilot licence since 1991 and had over 2,900 flying hours. At the time of the occurrence, he was the chief pilot for an air carrier located in the region. There was no evidence that psychological or physiological factors affected the pilot's performance. Toxicology testing revealed nothing unusual.

Weather conditions at Sept-Îles were favourable for the flight as planned. The weather report issued at 1100(1) indicated a few clouds at 1,500 feet and visibility of 30 statute miles. The temperature was minus 22 degrees Celsius and the winds were from 270 degrees magnetic at seven knots. No pilots reported turbulence or high winds at altitude in the Sept-Îles area.

The aircraft was purchased from the manufacturer in April 1975 by the former operator. In December 1975, Airglas LW3600-180A skis were installed on the aircraft. In subsequent winters, the operator did not reinstall the Airglas skis because he had purchased another model of skis. When the current owner purchased the aircraft in November 1996, it had about 1,680 flying hours since new. The aircraft was purchased in float-equipped configuration, and the wheels and Airglas skis were included in the transaction.

In December 1996, an aircraft maintenance engineer (AME) removed the floats and installed the wheels. Approximately three hours were flown, and no vibrations or other irregularities that would have indicated a potential problem were observed on the aircraft. On 13 February 1997, the owner had the Airglas skis installed by the same AME. The AME observed nothing unusual during the installation. No research was done regarding the airworthiness directives (ADs) applicable to this type of aircraft; however, the entries in the technical logbooks and the amendment to the weight and balance report were made in accordance with existing regulations.

Section 605.84 of the Canadian Air Regulations (CARs) provides the following extract:

No person shall conduct a take-off, or permit a take-off to be conducted in an aircraft that is in the legal custody and control of the person, unless the aircraft is maintained in accordance with

b) the requirements of any airworthiness directives issued by the Minister pursuant to section 593.02; and . . .
Subpart 71 of Part V of the CARs provides that responsibility for complying with ADs rests with the aircraft owner. If the owner wants the AME to do research as a separate maintenance task, he must so indicate in a document specifying the agreements. Responsibility is thereby delegated.

On the morning of 17 February, the pilot and one passenger made a familiarization and test flight in preparation for the flight to Wabush planned for later that morning. They flew two circuits at Sept-Îles Airport. On returning from that flight, both were satisfied with the aircraft's performance. Shortly after the arrival of the aircraft owner and another passenger, the aircraft took off for Wabush.

The rear passengers reported that, while in flight at cruise altitude, they suddenly noticed that their legs were hanging in the air and they were descending in a turn. The fuselage had separated between the front and rear seats, and the engine had broken away. They tried to unfasten their seat-belts, but centrifugal force prevented them from doing so. The forward fuselage struck the snow-covered surface upside-down, penetrated through five to six feet of unpacked snow, and struck the ground. The pilot and front passenger, who were still attached to their seats in the forward fuselage, perished at impact. The rear of the fuselage, with the other two passengers, struck the ground on the left side. The passenger seated on the right was not injured, and he made a fire to protect his companion from the cold and to keep them both alive. Although the left passenger could not move around, he was able to call for help on his cellular phone one hour after the occurrence. About three hours later, they were rescued and transported to hospital for the usual examinations.

With the exception of the right landing gear, which was found on 20 May 1997, all major components of the aircraft were found in the first few days of the investigation. The aircraft was shipped to the TSB Engineering Branch for detailed analysis. The distribution of the parts on the ground and the lack of evidence of forward speed indicate that the aircraft broke up in flight. The wreckage distribution diagram is at Appendix A.

Examination of the aircraft showed the right wing had red and black transfer marks from the right ski. The marks on the wing extended from the leading edge to the main spar, and there were also marks on the wing strut. Aft of the wing spar, there were tears caused by instantaneous overload. The wing attachment was still fastened to the carry-through structure. The carry-through structure failed in overload. The left wing also failed in overload, and it carried with it the rest of the carry-through structure. The fuselage separated aft of the seats. Red marks were found on the vertical stabilizer and left elevator.

There were transfer marks of white paint on the right ski. The metal plate screwed to the ski tip and used to attach the bungee and steel cable was torn off. The bungee failed near the fitting at the ski tip. The steel cable presented a typical form of failure in overload.

The four engine mount brackets failed in instantaneous overload. One of the blades had two indentations near the tip. The first indentation, close to the blade tip, was deep and of a diameter consistent with that of the cable attached to the ski tip. The second indentation was consistent with the metal plate normally screwed to the ski tip. As a simulation, the engine was temporarily replaced in its normal position. This simulation established that the cable attached to the right ski tip was severed by the propeller.

On 21 September 1979, the manufacturer of Airglas skis issued a mandatory Service Bulletin (SB) LW3600-3. The purpose of the modifications outlined in the SB was to prevent the skis from rotating downward, which causes severe unbalancing of the aircraft and makes it hard to control. The bungees were to be replaced with a type that was more suitable for low temperatures. The bungee and forward steel cable attachment points were to be relocated near the windshield, and the aft steel cable attachments were to be relocated on the skis. As well, with the skis installed, the aircraft speed was to be limited to 160 KIAS, and a speed limit placard was to be installed on the instrument panel. On 12 May 1980, the Federal Aviation Authority (FAA) issued AD 80-10-01, directing owners to install a placard to limit speed to 160 KIAS with the skis installed, and to comply with Airglas Service Bulletin LW3600-3 within 50 hours time in service after the effective date of the AD, and thereafter any time that the skis are installed. On 21 July 1980, Transport Canada issued AD 80-18 which required that, before the next flight and, after that, whenever the skis are installed, Airglas SB LW3600-3 be complied with and that a placard be installed limiting speed to 145 KIAS when the skis are installed. That AD had not been completed on the accident aircraft.
The aircraft technical log-book contained a sheet of notes mentioning Cessna AD 80-10-01 with the description "ski, rotating tip down", and the notation "n/a to equipment installed". This note was written by the former operator's AME and was a reminder for him.

Figure 2 is a schematic of the installation of a landing gear leg on the Cessna 185. When the leg is not on the ground, the bolt is under tension, and at other times it serves as a locator to hold the assembly in position. On the right side of the aircraft, the upper part of the landing gear leg support bracket was torn away and the outboard lower part showed evidence of compression. The cabin floor area above the ski attachment angle was punctured by the tip of the landing gear leg. There is a hole to insert bolt AN-7 in the attachment angle. The interior surface of this bolt hole shows clear thread imprints on the inboard side. The number of threads matches that observed when the nut is engaged up to the fibre locking portion. The lower part of the attachment angle showed hexagonal imprints consistent with the shape of the nut. These nut and thread imprints were not observed on the left landing gear attachment angle.

Analysis

The pilot was qualified for the flight and the weather was favourable for the flight as planned.

At cruise altitude, as the aircraft speed increased, the angle of attack decreased and the right ski rotated downward. It is possible that this situation was aggravated because the nut (AN-7) was not tight enough, and the right ski was hanging lower than the left ski. The sudden increase in resistance when the ski rotated downward would have caused the aircraft to pitch down. The bungee stretched, probably resisted for a few seconds allowing the pilot to attempt to correct the attitude, then failed. (See Appendix B - In-Flight Breakup Sequence).

When the bungee failed, it allowed the ski to continue rotating. The bolts holding the metal plate on the ski tip...
failed in tension, allowing the steel cable to recoil and strike the propeller. The propeller plane of rotation was modified, and this produced excessive tension on the engine mount brackets, which failed, and the engine separated from the aircraft. At the same time, the ski continued to rotate rapidly toward its physical limit, exerting downward force on the landing gear leg. The nut on the AN-7 bolt failed and the floor was punctured.

When the engine separated, the aircraft pitched up as a result of aerodynamic forces and the shift in its centre of gravity. The ski then cut the right wing strut and the leading edge aft to the main spar. During this sequence, the forward carry-through structure was damaged, allowing the two wings to tear off. Finally, lacking a viable structure, the fuselage separated at the aft door pillar. Transfers of colour from the ski were also found on the vertical stabilizer and left elevator, suggesting that the fuselage rotated to the right after losing the right wing. After a descent of about 3,500 feet, the various pieces crashed on the ground.

When the skis were being installed, the AME did not research the ADs in effect, and did not notice that there was a note to that effect in the technical log-book. Consequently, AD CF-80-18 was not completed by the AME when the Airglas skis were installed. The CARs provide that the responsibility for complying with ADs rests with the person who has legal control of the aircraft unless that responsibility is specifically delegated in a document setting out the agreement.

The following laboratory reports were completed:

LP 034/97 - Structural Examination - In-Flight Breakup
LP 52/97 - Examination - Aircraft Engine & Propeller

Findings

- The pilot was qualified for the flight.

- Airworthiness Directive CF-80-18 relating to the installation of steel cables and bungees had not been complied with.

- The nut on bolt AN-7 that fastens the landing gear leg was incorrectly tightened when the skis were being installed, and the bolt failed in flight.

- The bungee on the right ski failed in flight and allowed the ski to rotate downward. The bracket tore off the ski and was thrown into the propeller causing the engine mounts to fail.

- The right ski and landing gear separated and struck the right wing of the aircraft.

- The aircraft broke up into several pieces in flight.

Causes and Contributing Factors

An incorrectly tightened bolt and non-compliance with an airworthiness directive allowed the right ski and landing gear to separate from the aircraft in flight and strike the right wing. The aircraft subsequently broke up and fell to the ground in pieces.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 04 February 1998.

Appendix A - Wreckage Distribution Diagram
The aircraft and pieces are not to scale

Appendix B - In-Flight Breakup Sequence
1 - Cruising at 145 mph, 4,500 feetasl.

2 - The right ski rotates downward, and the right gear leg rotates downward.

3 - The gear moves downward and aft. The bracket is torn off of the ski and thrown into the propeller disk.

4 - The propeller plane of rotation is changed and the engine mounts fail. The engine separates, the aircraft pitches up, the right ski strikes the wing, and the wing separates from the aircraft.

5 - The forward cabin separates from the rest of the fuselage, and the pieces fall to the ground.

1. All times are eastern daylight time (Coordinated Universal Time (UTC) minus four hours) unless otherwise stated.

Updated: 2002-10-06  

Important Notices
Air 1997

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 Occurrence Report
Controlled Flight Into Terrain Mountain
Cessna A185F Skywagon N4758E
Lac Morin, Quebec
14 June 1997

Report Number A97Q0118

Synopsis

The pilot and his two passengers flew to Lac Portneuf, Quebec, in the float-equipped Cessna A185F (serial number 18503864) on 9 June for a fishing trip and had planned to return home to Pittsfield, Maine, on 13 June. The aircraft took off as scheduled on 13 June with a planned refuelling stop at Lac Sébastien, 51 nautical miles (nm) to the southwest; however, about 45 minutes after takeoff, the pilot returned to Lac Portneuf because fog and low visibility prevented him from reaching his destination. The pilot decided to put off the departure until the next day. On 14 June, the takeoff was delayed again because of fog and rain. About 0845 eastern daylight time (EDT)\(^1\), the pilot and his passengers eventually departed from Lac Portneuf on a visual flight rules (VFR) flight to Lac Sébastien. About 0930, two men in the area of the Monts Valin, about three miles west of Lac Morin, heard the sound of an aircraft engine pass overhead westbound and then the sound of an impact a few moments later. The witnesses reported that they did not see the aircraft fly overhead because the visibility was restricted by thick fog. The aircraft did not arrive at its destination at the estimated time as filed on the flight plan, and searches were undertaken. The aircraft was found at about 1330 on the same day by Search and Rescue (SAR). It crashed at the 2,500-foot level of the east side of a mountain rising to 2,650 feet above sea level (asl) in straight-and-level flight on a magnetic heading of 250 degrees. The seaplane was destroyed by the impact and fire. The pilot and the two passengers were killed instantly.

Other Factual Information

The pilot and both passengers were sitting in their seats and wearing restraining devices. The belts gave way under the force of the impact,
and the three occupants were thrown from the aircraft. The deaths of the three men were attributed to the multiple injuries sustained in the accident. An autopsy was performed on the pilot's body; toxicological test results were negative. No trace of soot was observed in his respiratory tract; indicating no pre-crash fire. There was no evidence that incapacitation or physiological factors affected the pilot's performance. The pilot was certified and qualified for the flight in accordance with existing regulations. He had obtained his private pilot licence in the United States on 17 November 1993 and was authorized to fly day VFR only. He had successfully completed a checkout for single-engine seaplanes on 5 July 1995. His licence validation certificate (medical) was valid, and indicated prescription eyeglasses had to be worn in flight. Examination of the pilot's log book established that the pilot had approximately 386 hours total flying time, including 73 hours on seaplanes. The pilot had never flown in this area before.

The aircraft's journey log book was not found, but the technical log book was used to assess the airworthiness of the seaplane. Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The aircraft had a total of approximately 975 flying hours. The aircraft had been declared airworthy on 25 April 1997 following the annual inspection. The pilot installed the floats after the annual inspection; however, the installation of the floats was not documented in the aircraft's technical log books, as required by regulation. The pilot had not reported any deficiency during his trip or any specific problem since his departure. The weight and centre of gravity were within the prescribed limits.

The aircraft was equipped with the required instruments for flight in instrument meteorological conditions (IMC). Further, it was fitted with an autopilot that kept the wings level and with a global positioning system (GPS) navigation receiver. This navigation system is more efficient than traditional means of navigation and therefore reduces the pilot's workload. The GPS installed in this aircraft displays aircraft's geographical position, ground speed, time of arrival, distance, and track to programmed locations; it does not display ground elevation. The GPS receiver in the aircraft would indicate the bearing and distance to the destination at all times no matter where on earth the aircraft was physically located. Pilots tend to rely on this information and do not have to attend to where the aircraft is geographically located because they know they are not lost and they can always fly directly to their destination. The aircraft was not equipped with a radio altimeter or a ground proximity warning system (GPWS), nor was either required by regulation. An automatic fixed emergency locator transmitter (ELT) was installed in the tail of the aircraft and was in working order, but the signal was not received by any aircraft or the search and rescue satellite (SARSAT) because the antenna had broken off on impact. About 0800 on the day of the accident, the pilot observed a commercial aircraft flying southwest, so he telephoned a Lac Sébastien aircraft operator to obtain current meteorological information at his destination. He was informed that conditions were favourable for visual flight, and that the ceiling was 2,000 feet asl. At
0820, the pilot submitted a VFR flight plan to the specialist of the Roberval flight service station (FSS). The aircraft was to leave Lac Portneuf at 0845 and proceed direct to Lac Sébastien at an altitude of 2,500 feet asl. According to the flight plan, the estimated elapsed time of the flight was 45 minutes, with an endurance of 2 hours. The chosen flight route took the pilot over a heavily wooded area dotted with many lakes whose terrain consisted of mountains and valleys; the elevation of the summits ranged between 2,000 and 2,900 feet asl. The pilot did not request or receive any weather information relating to the planned route from the FSS.

Conditions at Lac Portneuf were favourable for VFR flight on take off. In the area where the accident occurred, visibility was very restricted or almost zero in fog. At the time of the crash, a bush pilot, who knew the area well was about six nm west of the accident site. He had departed Lac Sébastien flying north-eastbound and reported that the peaks of the mountains were concealed by clouds, and that to reach his destination, he had had to follow the valleys in order to keep the ground in sight. He added that, as the terrain was higher to the east, the area flown over by the occurrence aircraft was more conducive to conditions of poor visibility. Four hours after the accident, the pilot of the SAR helicopter observed localized low clouds in the area of the accident. While en route to the site, he had to navigate between the mountains because the mountain peaks were concealed by clouds.

The accident site is located in uncontrolled airspace on a magnetic bearing of 105 degrees magnetic, 14.5 nm from Lac Sébastien and 9 nm southeast of the direct flight route between the point of departure and the destination. The crash site is also 1 nm from a power transmission line running southwest. The east side of the mountain where the aircraft crashed has a steep slope and is densely wooded. The seaplane hit the ground, and then a rock face, in a slightly nose-up attitude with 5 degrees of left bank. The fuselage was lying a few feet from the point of impact. The wings broke off at impact and were lying, with the instrument panel, in front of the main fuselage to the left of the flight path. The cabin was heavily damaged by impact forces and a severe fire that broke out after the accident. The flaps were retracted. The flight control system was heavily damaged, and its continuity could not be confirmed. Examination of all the components recovered did not reveal any pre-impact failure or malfunction. All failures were attributed to overloads. Examination of the engine and the propeller at the site suggest that the engine was turning on impact; however, the examination could not determine the power that it was producing. The TSB Engineering Branch Laboratory conducted the metallurgical examination of the engine exhaust system. The examination of the sections of the exhaust system suggests that they were crushed at a temperature greater than a range of 600 to 800 degrees Fahrenheit. Examination of the wreckage did not produce any evidence suggesting that the aircraft had suffered a structural failure, flight control problems, electrical problems, power loss, or that fire broke out during flight.

The communication and navigation radios were tuned as follows: the very high frequency (VHF) radio on the Roberval mandatory frequency
of 126.7 megahertz and the VHF omni-directional range (VOR) receiver selected to the Saguenay VOR; the automatic direction finder (ADF) frequency selected was 348 kilohertz (kHz) (this frequency is not assigned to any navigation aid in the area, Roberval's frequency is 378 kHz). No radio communications were received from the pilot; however, because of the distance between the aircraft and the Roberval FSS station, the aircraft would have had to fly at an altitude of 3,000 feet asl to be able to establish two-way communication. A controlled flight into terrain (CFIT) accident is when an airworthy aircraft inadvertently strikes the terrain or water without the crew's suspecting the tragedy is about to happen. According to CFIT accident statistics collected by the TSB, the pilot had often tried to see the ground to fly VFR even though the flight was taking place in clouds, at night, in whiteout, or in other conditions that did not permit visual flight. More than half of such CFIT accidents occurred in VFR flight. More than a quarter of the aircraft were fitted with floats or skis, and half of the VFR accidents in instrument flight conditions (IMC) occurred in mountainous or valley areas. Canadian Aviation Regulations (CARs) state that for aircraft to fly VFR in uncontrolled airspace less than 1,000 feet vertically above ground or water, flight visibility must be at least 2 nm and the aircraft must be clear of cloud.

In 1995, the TSB recommended that the Department of Transport initiate a national safety awareness program addressing the operating limitations and safe use of GPS in remote operations. Transport Canada issued several special Aviation Notices since, which detailed the use of GPS in Canadian airspace and also published a number of articles on GPS in recent issues of the Aviation Safety Letter.

Analysis

The possibility of a failure of the aircraft's engine or systems was discarded because examination of the aircraft did not reveal any irregularity and no distress call was received from the pilot. There is no evidence that there was an emergency, or that the aircraft presented problems before impact.

On take-off from Lac Portneuf, the prevailing weather conditions at the points of departure and arrival were favourable for visual flight. The pilot could not have known that local conditions along the way were poor, as the area is largely uninhabited and weather information was not available. The pilot, who was unfamiliar with the area, planned to fly at a cruising altitude of 2,500 feet asl whereas the ceiling at Lac Sébastien was 2,000 feet asl. The chosen route was over mountainous terrain, with some mountain peaks concealed by the clouds; consequently, the pilot was unable to recognize the dangers that he was likely to encounter. He would have found himself in reduced visibility conditions in which he lost sight of the ground and would no longer have the visual references necessary to avoid collision with obstacles. Faced with deteriorating weather conditions, which made continuation of the flight hazardous, the pilot had to make a decision either to find a suitable lake for landing or to make a diversion. The pilot decided not to land, but to deviate from the direct route and try to reach his destination by veering southeast in order to fly in visual
meteorological conditions (VMC); he may have even tried to follow the power transmission line.

It is likely that the pilot was not aware of his true position in relation to the terrain and topography of the area and was relying on the GPS to get to his destination because the weather conditions required him to focus the greatest part of his attention on manoeuvring the aircraft to maintain VMC. In low-altitude flight, his field of view had to be very limited, and, because navigation charts are planform views whereas nothing is seen in planform at this height, the pilot would have difficulty in following the progress of the flight on the VFR navigation chart on which the elevation of the terrain appeared. Consequently, although the pilot knew where Lac Sébastien was located in relation to his aircraft, he did not know his exact position and was flying at an altitude lower than some of the surrounding terrain. The aircraft's attitude on impact suggests that the pilot was controlling the aircraft just prior to the accident. It is therefore conceivable that the pilot probably did not have the necessary visual references and did not see the ground in time to avoid it.

Why the pilot decided to continue the flight in adverse conditions could not be determined. It is likely that the nearness of the destination, and the pilot's reliance on the GPS, had an influence on his decision. As the return journey had already been delayed by one day because of adverse weather conditions, it is also possible that the desire of the pilot and the passengers to return home influenced the pilot's decision to undertake the flight.

Findings

- The pilot was certified and qualified for the flight in accordance with existing regulations and there is no evidence that incapacitation or physiological factors affected the pilot's performance.

- There was no evidence found of any airframe failure or system malfunction prior to or during the flight.

- The chosen route was over terrain whose high points were higher than the cloud ceiling and the pilot did not know the weather conditions along the route.

- The pilot decided not to land, but continued pressing toward his destination.

- In an attempt to remain VFR, the pilot probably relied on the GPS to navigate rather than map read when the weather conditions deteriorated.

- In the moments preceding impact, the pilot probably did not have the necessary visual references to avoid striking the mountain.

Causes and Contributing Factors

The pilot continued his flight in adverse weather conditions and probably did not have the necessary visual references to avoid hitting...
the steep slope of the mountain. Likely contributing to this occurrence was the pilot's reliance on GPS and not the navigation chart while attempting to maintain VMC.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 27 May 1998.

Updated: 2002-10-06
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 Occurrence Report
In-Flight Break-up
Cessna 210F C-FSEX
Milan, Quebec
28 July 1997

Report Number A97Q0158

Summary

The pilot of the Cessna 210F, serial number 21058753, with his wife and three children on board, was on an instrument flight rules (IFR) travel flight from Cornwall, Ontario, to Charlottetown, Prince Edward Island. At 1626, eastern daylight saving time, in level flight at 9000 feet above sea level (asl), the pilot advised the controller that he was about to enter rain showers. At 1636 the aircraft disappeared from the controller's radar screen in an area of significant weather returns. The aircraft broke up in flight in a thunderstorm. Search and Rescue services found the aircraft five hours later. The Cessna was destroyed; the five occupants perished in the accident.

*Ce rapport est également disponible en français.*

Other Factual Information

The pilot, who was employed by an airline, held a valid airline pilot licence and a Group 1 instrument flight rating. He had flown several types of single-engine and multi-engine aircraft; he had over 5000 flying hours, including 1300 hours under instrument flight rules (IFR). His employer considered him to be a safe pilot who did not hesitate to postpone or cancel a trip when he considered the weather unfavourable for a flight. The pilot had completed the Transport Canada company air safety officer course.

The pilot had rented a house on Prince Edward Island for a one-week family vacation starting 28 July 1997. He was to travel there in his private aircraft. At 0010 eastern daylight saving time (EDT) (1) on the day of the accident, the pilot received weather information for the flight from the London, Ontario Flight Service Station (FSS). A pressure
Trough was located north of New York State. Thunderstorms were forecast for the London area between 0200 and 0800. The storms were associated with a cold front extending from south of James Bay to north of Lake Huron. The frontal system, which was tracking east-southeast at 25 knots, was moving ahead of the flight along the pilot's intended route. The pilot correctly calculated that he would catch up with the cold front at Cornwall and be clear of it around Sherbrooke, Quebec. He also estimated that he would fly through the storm area south of Montreal, Quebec.

The pilot was hoping to reach Charlottetown before sunset; he therefore planned to take off from Tillsonburg Airport, Ontario, where his aircraft was parked, around 0900. At the airport, while preparing for the flight, the pilot told an attendant that he was anxious to depart, as he was already running late. However, it was only around 1230 that he took off for Charlottetown with stops planned at Brantford, Ontario, and Cornwall. The short flight to Brantford was without incident; on the ground the pilot had the aircraft's tires inflated and he borrowed some IFR charts. He seemed rested and fit, and especially glad to be going on vacation. He took off around 1300 for Cornwall to refuel.

At 1435, 35 minutes before landing at Cornwall, the pilot called the FSS specialist at Gatineau, Quebec, to advise that he planned to take off IFR from Cornwall around 1600 and to request en route weather. Visual meteorological conditions (VMC) were forecast for Charlottetown at 1600. Next, the specialist specifically mentioned that an area of active thunderstorms was over Montreal and vicinity and that a significant meteorological message (SIGMET) was issued at 1321 for the storm area. A SIGMET is issued only for the most dangerous phenomena of vital importance to aircraft of all types. The specialist transmitted to the pilot the following information from the SIGMET C2:

Thunderstorms were observed by weather radar and satellite photo on a line from 30 miles east of Québec to Trois-Rivières to 30 miles north of Montreal to 20 miles northeast of Ottawa. The maximum summit of the storm line is estimated at 40,000 feet causing visibility of two to five miles, thunderstorms and heavy rain showers, and a risk of hail and local gusting to 50 knots. Icing and severe turbulence are associated with the storm line. The storm line is moving east at 35 knots and gaining in intensity until 2015 UTC.

The specialist also reported that the storm line extended along the St. Lawrence River and heavy rain showers could be expected in the vicinity. He also read the following weather observation in effect at Dorval: winds from 310 degrees magnetic at 26 knots gusting to 44 knots, visibility one mile, moderate rain showers, storms and cloud layer at 100 feet broken. The pilot replied that he did not anticipate any problems because, according to him, the storm line was just north of his route.

After landing at Cornwall, the pilot refuelled and filed an IFR flight plan for the final eastbound leg. Shortly after take-off, just before making
and maintaining radio contact with the Montreal centre, the aircraft appeared on the radar screen at Montreal terminal at 1545. The controller first instructed the pilot to proceed on heading 075 degrees magnetic at 9000 feet asl to keep the aircraft to the north of some significant weather returns displayed on his screen. He then told him that he would be radar vectored to his destination because the route indicated on the flight plan ran right through an area of adverse weather.

The controller also advised the pilot to expect heavy weather, rain and storms all the way to near Millinocket, Maine, USA, and that the adverse weather over the St. Lawrence River had moved south of Montreal. The pilot then decided to divert to the north of the weather system instead of to the south as he had intended previously.

At 1604, about eight nautical miles west of Saint-Jean Airport, Quebec, radar vectoring terminated and normal navigation was resumed. The controller suggested to the pilot, given the position of the weather system, that he divert much farther to the north to get around the storm line. At 1607 the controller for the Granby, Quebec sector took charge of the flight. Between 1607 and 1613, the pilot modified his route three times due to adverse weather:

- At 1607 the pilot decided to head directly for the VHF omnirange at Sherbrooke, Quebec.
- At 1611 he requested to divert north to the VOR at Beauce, Quebec to avoid the weather.
- At 1613 he opted to head directly for Charlottetown: the controller had just advised him that, based on the radar sweep, the weather was more favourable to the east and toward Charlottetown than around the Beauce VOR. The controller also told the pilot he should be clear of the weather after Sherbrooke.

Subsequently, the controller gave the pilot some information on the locations of areas of heavy precipitation. The controller's duties include helping aircraft to avoid weather by advising them of alternate routes and providing information concerning very adverse weather conditions like SIGMETs to all aircraft in or about to enter the area. To accomplish this, the controller uses, among other things, air traffic services (ATS) radars and the Operational Information Display System (OIDS). However, data from weather radars and satellite photos cannot be displayed at the controller's workstation because no monitor is provided for that purpose.

The radars at Québec and Montreal, which provide data to the controller, showed a line of significant weather returns extending from Québec to south of Montreal. The line appeared to be unbroken except for a gap over the Sherbrooke area. The ATS radar indicated that the aircraft was headed toward the gap on a track that seemed largely free of weather returns. In fact, the pilot was about to fly through heavy rain that was not shown on the controller's screen. Satellite photos and the
Villeroy weather radar data for 1630 indicated several areas of heavy precipitation in the Sherbrooke area that had not been detected by the ATS radars.

The *Aeronautical Information Publication* (A.I.P. Canada) states that ATS radar, due to its inherent limitations, cannot always detect weather disturbances. A storm cell can be concealed if it is behind other radar contacts. In fact, during the flight, at the request of the controller, the pilot had to describe the weather he saw in front of him. Also, neither ATS radars nor weather radars can see turbulence.

At 1626 the pilot reported that he was "plowing through" some rain showers, even though it did not seem very safe to him. He also confirmed that he would continue the flight to Charlottetown. That was the last message received from the pilot. At that time the aircraft was at level flight at 9000 feet asl and a ground speed of 190 knots, and was 10 nautical miles south of the weather line observed by ATS radar. Abeam of the Sherbrooke VOR, about seven minutes before the in-flight break-up, the pilot made three heading corrections and headed toward an area of weather returns, where the aircraft disappeared from the radar screen at 1636.

Radar data obtained from ATS revealed that in the area of the Sherbrooke VOR, the changes in the aircraft's altitude had increased in frequency and scale; the vertical speed of the aircraft was fluctuating widely, with a climb rate often exceeding 600 feet per minute. The last returns indicated that the aircraft had climbed to 9400 feet asl when it started to lose altitude rapidly; its rate of descent reached 6000 feet per minute at an altitude of 7700 feet asl when its transponder ceased responding. Data from the Villeroy weather radar indicated that the aircraft was in an area of heavy precipitation when the break-up occurred. The A.I.P. Canada states that the intensity of turbulence is in proportion to the amount of rain that accompanies it. Severe turbulence like that reported in SIGMET C2 produces significant and sudden changes in altitude and/or attitude. It can also cause wide variations in indicated speed. The pilot might even lose control of the aircraft momentarily.

The dangers involved in operating near storms are known and extensively documented in several aeronautical publications. Section 2.7 of chapter AIR of the A.I.P. Canada deals with operations near thunderstorms: "the visible thunderstorm cloud is only a portion of a turbulent system of updrafts and downdrafts that often extend far beyond. Severe turbulence may extend up to 20 NM from severe thunderstorms. [...] No flight path, through an area of strong or very strong radar echos separated by 40 NM or less, can be considered free of severe turbulence".

After the SIGMET C2 was issued, the Montreal forecast centre issued two consecutive SIGMETs for the Montreal and Québec areas that were not relayed to the pilot. SIGMET C3 issued at 1501 to replace C2, and SIGMET C4, issued at 1553 to replace C3, repositioned the storm line moving east; they included warnings of potential dangers that were essentially the same as those contained in SIGMET C2. The aircraft
was in the Cornwall area when these SIGMETs were issued.

The aircraft broke up in flight over a wooded area and came to rest in brush near a logging road, 23 nautical miles east-northeast of the Sherbrooke VOR. Pieces of wreckage were scattered on both sides of the break-up trajectory, which was on a heading of 356 degrees magnetic. Although several pieces were spread over a distance of 2250 feet, the largest pieces were found in two main areas. The cabin and the left wing and stabilizer were found as one unit. The engine separated from the airframe after striking the ground. The flaps and landing gear were retracted. All engine cowls and doors were found at the point of impact. The right wing, fin and right horizontal stabilizer separated from the fuselage before the aircraft struck the ground. The right wing strut and part of the right wing skin were found about 2250 feet from the main point of impact, and the right horizontal stabilizer, fin and right wing were found about 500 feet farther north.

After the wreckage was examined at the accident site, it was transported to the Saint-Mathias Airport, Quebec, for further examination. The analysis of the aircraft was carried out by the TSB Engineering Branch. Examination of the flight control systems revealed no evidence of loss of continuity prior to the aircraft break-up. Both wings were partly shredded and showed similar deformations. They exhibited the effects of upward bending and rearward torsional moments. These substantial damages occurred in flight. Failure analysis suggests that the right wing fractured first, just inboard of the strut joint, then the wing struck the fin and the right horizontal stabilizer, which then failed.

There was no indication of a fire on board the aircraft or of a fuel tank explosion. The doors and cowls were attached to the fuselage at the time of ground impact. There was no indication of flutter or aeronautical flutter on the flight control surfaces. No signs of metal fatigue were observed. Examination of the debris revealed that all fractures were caused by either instantaneous overload or tearing.

There is every indication that the engine was serviceable and capable of producing power. Examination of the propeller revealed no pre-impact deficiencies that would have prevented it from operating normally.

The aircraft, which the pilot owned, was found airworthy on 05 June 1997 following an annual inspection. C-FSEX was certified, equipped and maintained in accordance with existing regulations and approved procedures. The available information indicates that the aircraft had approximately 2830 hours. The weight and centre of gravity were within the prescribed limits. The aircraft weight at the time of the accident was estimated at 2965 lb. Its service ceiling or maximum certified flight altitude was 19 900 feet. The aircraft was equipped for instrument flight. C-FSEX was also equipped with a global positioning system (GPS). It was not equipped with weather radar or a Stormscope storm detector; these instruments were not mandatory on this aircraft.

Weather radar is often the most effective means of avoiding adverse weather during IFR flight. The pilot did not report any deficiencies or
problems with the aircraft during the flight.

Based on the autopsy, toxicology and medical records, there was no indication that incapacitation or physiological factors affected the pilot's performance.

Analysis

Examination of the debris revealed no signs of fatigue or flutter. Also, the wreckage analysis determined that all fractures resulted from instantaneous overload. The available information suggests that the aircraft broke up in flight after entering a heavy rain shower, and that the turbulence normally associated with that weather phenomenon led to aerodynamic overloading of the wings.

Prior to take-off, the pilot obtained a full weather report as part of his flight planning. The weather prognosis, area forecasts, SIGMET C2 and specific reports on the locations of the areas of heavy precipitation were fairly representative of the conditions prevailing en route. Based on this information, supplied by FSS specialists and ATS controllers, the pilot would have been able to conclude that he would have to cross a cold front and a storm line to get to Charlottetown.

As the holder of an airline pilot licence and instrument rating, the pilot had the ability, knowledge and experience to recognize the dangers associated with flying near thunderstorms. By correctly calculating the movement of the cold front and where he would catch up with it, the pilot demonstrated that he clearly understood the weather system. Since the pilot could neither fly over the storm line, as he was limited to an altitude of 19 900 feet, nor fly around it, as it extended too far north-to-south, it would have been appropriate to wait on the ground until conditions improved. The investigation did not reveal why the pilot decided to take off from Cornwall and attempt to fly through adverse weather in an aircraft with no weather radar or a Stormscope storm detector. It was determined that there were no operational factors compelling him to continue the flight, since he had enough reserve fuel to wait or divert to another airport.

The ATS controllers performed their duties in accordance with established procedures and their assigned responsibilities. They provided radar vectoring to help the pilot avoid adverse weather and transmitted relevant meteorological information, except SIGMETs C3 and C4. As a result, the influence that these two SIGMETs might have had on the pilot's decision to continue the flight could not be evaluated. However, the pilot was aware of the dangers associated with the cold front because before arriving at Cornwall he had received SIGMET C2, which was essentially similar to C3 and C4. The investigation did not determine why the pilot was not advised of these SIGMETs or whether the controllers were advised on OIDS. Also, nine minutes before the crash, the Granby sector controller, acting in accordance with the rules, advised the pilot that the weather straight ahead appeared favourable, while in fact the aircraft was heading toward heavy showers. A specific display of the meteorological conditions was not available to the controller. The controller was therefore unaware of the areas of heavy
precipitation because he did not have the equipment needed to display data from the Villeroy weather radar. Consequently, the controller did not have the information or tools required to accurately inform the pilot of safer alternate routes.

Although it could not be determined why the pilot initiated and continued the flight, his decision may have been influenced by several factors. His and his family's apparent desire to land at Charlottetown before dusk on the first day of their one-week house rental may have caused him to take risks. The pilot may have overestimated the capabilities of ATS radar and the information provided by the controller on the position and movement of the areas of heavy precipitation. Still, the pilot must have been at least somewhat aware of the limitations of the radar system because the controller occasionally had asked him to describe the weather he observed in front of him. In any case, the pilot was entirely responsible for the aircraft, and he tried to squeeze between the storms despite the risks that he had recognized. He apparently made that decision in order to reach his destination by evading the storms. Whether he did not fully appreciate the limitations of the radar system or he did not have adequate meteorological information, the pilot did have sufficient information to determine that the weather near the cold front was hazardous, especially for an aircraft with no storm detection instruments. Moreover, the pilot must have known that the information provided by the radar controller was provided on an advisory basis and could be inaccurate, especially near areas of storm activity.

After penetrating the storm line, the pilot must have decided to maintain heading to get through as quickly as possible and avoid turns so he would not increase structural stresses on the aircraft.

The following laboratory report was completed:

LP 128/97 - Examination of Aircraft Structure In-flight Break-up.

**Findings**

- The pilot was certified, trained and qualified for the flight in accordance with existing regulations.

- Based on the autopsy and toxicology records, there was no indication that incapacitation or physiological factors affected the pilot's performance.

- The pilot knew that to reach his destination that day he had to go through heavy weather, rain and a thunderstorm area.

- The aircraft was not equipped with weather radar or a Stormscope storm detector.

- Approximately 10 minutes before the crash, the pilot reported
that he was “plowing through” rain showers, although it did not seem very safe to him.

- The aircraft broke up in flight as a result of penetrating an area of severe turbulence and heavy precipitation.

**Causes and Contributing Factors**

The aircraft broke up after the pilot attempted to fly through a storm line. The pilot's and his family's eagerness to start their vacation and the pilot's overestimation of the ability of ATS radar to detect areas of heavy precipitation likely contributed to the accident.

**Safety Action Taken**

*En Route Weather*

Transport Canada, in order to increase pilot awareness of Air Traffic Control limitations in providing current en route weather, will include additional questions in this area on the instrument rating and Airline Transport Pilot Licence written examinations.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 12 August 1999.*

1. All times are EDT (coordinated universal time [UTC] minus four hours), unless otherwise stated.
Air 1997

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.

Collision with Terrain
Cessna 180K C-GIGK
Aux Mélèzes River, Quebec
10 August 1997

Report Number A97Q0168

Synopsis

The pilot of the seaplane, serial number 18053048, accompanied by one passenger, took off from the du Gué River, in the extreme north of Quebec, to look for a good location to fish and set up a temporary camp. During the approach for a water landing on the aux Mélèzes River, the pilot executed a go-around. A short time later, the aircraft crashed on the south slope of the valley running alongside the river. The pilot and the passenger, who was seated in the right seat, were fatally injured. The aircraft was destroyed by the fire that started a few seconds after impact.

Other Factual Information

On 07 August 1997, C-GIGK and CF-RHI, two Cessna 180K aircraft, departed Montreal for a flight to the Ungava Bay region, in the extreme north of Quebec, for a fishing trip that was to last about 10 days. Each aircraft had one pilot and one passenger on board. On 10 August, the day of the accident, both aircraft took off from Lake Maricourt, Quebec, and proceeded north. Conditions were suitable for visual flight; visibility was over 15 miles, the temperature was 27 degrees Celsius, there was no precipitation, and the cloud layer was over 5,500 feet above sea level (asl).

The two aircraft first landed on the du Gué River. Around 1230 eastern daylight time (EDT)(1), the seaplanes took off again for the aux Mélèzes River, which they followed in a westerly direction, to find a suitable place to fish and set up a temporary camp. The floor of the valley is at an altitude of 300 feet asl, and the terrain on both sides of the river rises to at least 1,200 feet asl. The wind was from the west at approximately 20 knots; it was blowing partly parallel to the river, with a light south component.
During the flight, the pilots communicated with each other on a common VHF frequency. C-GIGK was a few miles ahead of CF-RHI at an approximate altitude of 1,000 feet asl. After finding a spot he considered suitable, just upstream from some rapids, the pilot of C-GIGK relayed the information to the other pilot so the latter could make an inspection overflight of the site. The pilot of CF-RHI overflew the suggested location, then made a water landing with no difficulty. A short time later, the pilot of C-GIGK initiated a final approach to land at the same spot, but before touchdown, the pilot initiated a missed water landing procedure. He then informed the pilot of CF-RHI that he was going to inspect more carefully the landing area. He had decided to fly another circuit because he was unsure of the strength of the current in the river. After advising the pilot of CF-RHI of his intentions, the pilot of C-GIGK did a go-around over the river to about 450 feet above ground level, followed by a 90-degree left turn to join the cross-wind leg. The aircraft levelled off and proceeded toward the south slope of the valley. About 30 seconds later, as C-GIGK had not yet turned parallel to the river and the upward-sloping terrain, for the downwind leg, and the seaplane was getting close to the rising terrain, the pilot of CF-RHI advised the pilot of C-GIGK to watch out for the mountain. A few seconds later, the aircraft pitched up without changing heading, then made two turns; the first turn was at a low bank angle to the right, upwind, and the second turn was steep and to the left, downwind. The aircraft started to lose altitude and pitched up gradually until it struck the trees, then struck the ground in a nose-down attitude. Four or five seconds after the impact, a fire started on the right side of the cabin. Thirty to sixty seconds elapsed between the pull-up and the accident.

The pilot of CF-RHI immediately took off to overfly the crash site to assess the situation and call for rescue. A helicopter arrived at the site 45 minutes later. The aircraft was still burning and the two occupants were seated in their seats in the cabin.
The accident occurred around 1330, during daylight, at 100 nautical miles southwest of Kuujuak, Quebec, in a partially wooded area approximately half a mile south of the aux Mélèzes River. The area is somewhat rough, with trees, mainly larch, of average size. The south side of the valley slopes upward at an angle of almost 20 degrees. The aircraft came to rest about 450 feet above the valley floor. The aircraft cut several trees over a distance of 50 feet before striking the ground. Based on the cut trees and the damage to the wings, the seaplane had a left roll attitude of 15 to 20 degrees, was nose-down, and on a heading of 113 degrees magnetic when it struck the ground. The damage attributable to the impact and the nose-down attitude of the wreck are consistent with a loss of control following a stall.

The aircraft appeared to be relatively intact right after the crash. The wings were still attached to the airframe; however, the aircraft was destroyed by the fire that started shortly after the ground impact. The fire spread to the vegetation over a distance of 40 feet in front of the aircraft. All of the fuselage, except the empennage and part of the left wing, was consumed by fire. The right side of the aircraft appears to have sustained the most damage from heat. The lock of the pilot door was engaged, but the passenger door lock was not recovered. The fuel selector switch was on "BOTH". The wings were burned in the area of the integral fuel tanks. A tree broke through the spar and underside of the right wing near the integral fuel tank and wing attachment bracket. The flaps were extended at 20 degrees. On a Cessna 180K, this is the flap setting normally used for a go-around.

The instrument panel melted in the intense heat of the fire; as a result, no determination could be made with regard to the condition and operational capabilities of onboard systems or their components, or the positions of any controls, switches or indicators. However, examination of all components recovered revealed no pre-impact failures or malfunctions. The flight control circuit sustained substantial damage, but continuity was confirmed.

All failures were attributed to overload. Examination of the engine and propeller at the accident site revealed that the engine was running at the time of impact and the propeller blades were at low pitch. The engine power could not be determined from the examination. However, the cuts in the surrounding trees indicate that the propeller was being driven by the engine at the time. Examination of the wreckage yielded no indication of any airframe failure, flight control problems, electrical problems, loss of power or in-flight fire. No messages were received from the pilot. The emergency locator transmitter (ELT) activated on impact and transmitted a signal that the pilot of CF-RHI was able to hear for a few seconds on the frequency 121.5 megahertz.

On the morning of the accident, the pilot appeared to be well rested. He was certified and qualified for the flight in accordance with existing regulations. He had held a private pilot (aeroplane) licence since 12 May 1984, and was authorized to fly in accordance with visual flight rules (VFR) by day and by night. He had his check on single-engine seaplanes on 27 May 1985. His licence validation certificate was valid. The pilot had about 1,850 flying hours; he flew about 150 hours a year. He had a reputation for being a safe pilot who knew the aircraft flight manual well and complied rigorously with the manufacturer's procedures and instructions.

The pilot was involved in two previous aircraft accidents. The first accident occurred at Saint-Jean Airport, Quebec, on 04 June 1984 when the Piper PA 28-140 he was flying left the runway after landing. The second accident happened on 02 July 1994 at Lake Louise, Quebec, where, shortly after take-off, downdrafts over mountainous terrain blew his Cessna 172 toward the ground; the pilot had then decided to land in the trees straight ahead. The two occupants were not injured, but the aircraft sustained substantial damage.

The passenger held a private pilot (aeroplane) licence since 06 September 1996. On the morning of the accident,
she seemed well rested. She had, nonetheless, been indisposed by motion sickness on the first flight of the day. She was sick after the landing on the du Gué River. There was no indication that she was flying the aircraft at the time of the crash; the pilot usually flew during the critical phases of flight. However, the pilot had occasionally let the passenger take the controls during level flight.

The aircraft belonged to the pilot. No journey log-book was found. It was probably destroyed by the post-crash fire. The technical log-book was used to assess the airworthiness of the seaplane. The aircraft had been declared airworthy on 04 June 1997 following the annual inspection. The records indicate that the aircraft was certified, equipped and maintained in accordance with existing regulations and approved procedures. The data available indicate that the aircraft had approximately 1,190 flying hours. A supplementary type certificate authorized the maximum allowable take-off weight to be increased from 2,950 to 3,190 pounds. The weight and centre of gravity were within the prescribed limits. The weight of the aircraft at the time of the accident was estimated at 2,965 pounds. There were no flammable liquids on board the aircraft or in the float compartments which could have caused the fire. The pilot did not mention any aircraft deficiencies or problems after departure. The witnesses stated that they noticed nothing unusual regarding the aircraft prior to impact.

Since the pilot had to abort his approach and go around while the aircraft was configured for a water landing, the recommended procedures for a missed water landing and the performance of the Cessna 180K were examined. The manufacturer recommends extending the flaps 20 degrees immediately after applying full power. Then the flaps are retracted gradually when the aircraft reaches a safe altitude and speed. The optimum theoretical rate-of-climb is 900 feet per minute; it is obtained in the following configuration: flaps up, full power, 2,400 rpm, cowl flaps open, indicated airspeed of 79 knots, weight of 2,950 pounds, altitude of 1,000 feet asl, and temperature of 30 degrees Celsius. This rate-of-climb corresponds to a climb gradient of approximately 6.5 degrees with no wind; the gradient is steeper with a headwind, and less steep with a tailwind. Climb performance is substantially reduced with the flaps extended or when the recommended speed is not maintained.

Just before it crashed, the aircraft pitched up gradually until it reached stall speed. The normal stall speed for a float-equipped Cessna 180K with a weight of 2,950 pounds, in level flight with the wings levelled, engine off, and 20 degrees of flap is about 50 knots. Stall speed increases with bank angle. In a turn with 30 degrees of bank, the stall speed is 53 knots; with 45 degrees, it is 58 knots; and at 60 degrees, the aircraft will stall at 69 knots. An audible alarm sounds to warn the pilot when the speed of the aircraft is 5 to 10 knots above the stall speed.

The electrical system is designed to be isolated, by turning off the master switch, from the battery located at the rear of the cabin. By switching off the electrical power and fuel supply before a forced landing, it is possible to greatly reduce the risk of fire.

The impact was survivable. The trees and the type of terrain helped to reduce the deceleration forces applied to the cabin structure. The cabin appears to have been only slightly buckled by the impact. Neither the occupants nor the cargo on board the aircraft were subjected to sufficient force to eject them from the cabin. The pilot's seat-belt was fastened and the passenger's was unfastened. The seat-belts were not fitted with shoulder harnesses. The seat locking mechanisms showed no indication of failure.

Based on the autopsy and toxicology testing, there was no indication that incapacitation affected the pilot's performance. The pilot was flying the aircraft from the left seat, and he survived the crash; he died as a result of the post-crash fire. The autopsy, however, did not determine whether he was conscious after ground impact. Furthermore, it was not possible to evaluate the injuries caused by the impact or deceleration forces. The passenger was seated in the right front seat; the heat generated by the fire was so intense that the cause of death could not be determined. It was also impossible to determine whether she was alive or conscious prior to the fire.

In some situations, a pilot's ability to estimate size, distance, speed, the direction to a slope, or even to identify objects can be seriously diminished. Pilots can be subjected to optical illusions when approaching a rising slope at right angles. When getting close to the ridge, the pilot may tend to maintain a constant angle between the extended cowl and the mountain peak; as a result, the pitch attitude of the aircraft increases and speed decreases. Consequently, aircraft performance decreases and vertical separation with the terrain decreases.

The proximity of the ground tends to hold the pilot's attention and, as a result, can affect the flying of the aircraft. The illusion of increasing speed in relation to the ground is easily noticeable, to the point where the pilot may be tempted to reduce speed.

**Analysis**

Examination of the aircraft revealed no deficiencies, no engine failure nor aircraft system failure. There is no indication of any emergency situation or aircraft problems prior to impact, and no distress calls were received.

The pilot decided to go around after informing the pilot of the other aircraft that he had doubts regarding the
suitability of the water landing area. The purpose of the manoeuvre was to fly a circuit and make another examination of the area so he could establish more clearly the characteristics and condition of the landing area. Consequently, the pilot's decision was justified from a safety standpoint, based on the information obtained during the approach.

The pilot's decision to fly a left-hand circuit was sound since he was sitting in the left seat and visibility was better on that side. Since the reconnaissance phase was to allow an examination of the surface of the water, it required that the flight be made at low level and low speed. The reconnaissance track was to be rectangular, or oval.

When the pilot turned onto the crosswind leg, he was over the river and, due to drift over the ground, the ground speed increased. Since the aircraft was nearly in level flight, it must have closed rapidly with the rising terrain. The pilot did not keep close to the north side of the valley before turning onto the crosswind leg, which did not allow him as much room as was possible, should he have needed it. As a result, not all the space available for the circuit was used to minimize the roll attitude of the seaplane in the turns and maximize the aircraft performance. The type of circuit chosen by the pilot reflected his intention to overly the landing area at low altitude.

Flying in mountainous terrain requires constant vigilance. Pilots must constantly compare their impressions with instrument readings. It could not be determined why the pilot continued flying at right angles to the ridge and did not try to avoid the mountain until the pilot of CF-RHI warned him. However, two possible explanations were identified to explain the pilot's delay in turning onto the downwind leg: the pilot may have been distracted and/or he may have been subjected to optical illusions.

On one hand, the pilot may have been preoccupied with either planning the water landing or an untimely event in the cabin. It is possible that, after the go-around, most of his attention was devoted to continuously examining the landing area to his left and slightly behind him rather than to flying the circuit. Similarly, a distraction on board the aircraft, such as the passenger being indisposed by motion sickness, could have had the same result.

On the other hand, while flying toward the rising slope, the pilot may have been subjected to optical illusions, which can be treacherous at low altitude and at near-stall speeds.

After the message from the pilot of CF-RHI warning him of the imminent danger of collision with the mountain, the pilot of C-GIGK seemed to have responded, but he had little time to react and his room to manoeuvre may have been so limited that a half-turn could have led to a stall in a turn. An assessment of the situation may have led the pilot to decide to end the flight quickly and make a forced landing in the best possible conditions on the slope of the valley, as he had done at Lake Louise in 1994. The pilot apparently did not have enough time to switch off the electrical power and the fuel and prepare for a quick evacuation from the cabin. The information gathered and the statements recorded did not reveal the causes of the accident.

Considering the light damage sustained by the cabin, the accident was survivable. However, the rapid onset and intensity of the post-crash fire gave the occupants no chance to evacuate the cabin in time. It could not be determined how the passenger's seat-belt was unfastened. It appears that no attempt was made to evacuate, since the pilot and passenger were found sitting in their seats and the pilot's door was still locked after the accident.

Damage to the right wing was serious enough to cause a fuel leak, which, on coming into contact with an ignition source, started the fire. Engine heat and electricity were the two possible sources of ignition. Although witness statements and the damage caused by the fire suggest that the fire started on the right side of the cabin, and the most likely source of ignition was electrical, the investigation could not determine the exact source of ignition. However, engine heat would have been the only possible source of ignition if the master electrical switch was selected off prior to impact.

Conclusions

1. The pilot was certified, trained and qualified for the flight in accordance with existing regulations.
2. Based on the autopsy and toxicology testing, there was no indication that incapacitation affected the pilot's performance.
3. The weight and centre of gravity of the aircraft were within the prescribed limits.
4. Records show that the aircraft was maintained in accordance with existing regulations.
5. There was no indication of any airframe or flight controls failures, or of any engine malfunction.
6. Weather conditions at the time of the accident were suitable for VFR flight, although the wind was moderate.
7. After executing a go-around in the aux Mélèzes River valley, the pilot turned left onto the crosswind leg to make
a reconnaissance circuit about 450 feet above the river and 450 feet below the ridge of the valley.

8. It seems that the pilot attempted to avoid the rising terrain after the other pilot warned him.

9. The pilot died as a result of the post-crash fire, which started about five seconds after the accident.

10. An unexplained distraction and/or the effects of an optical illusion may have contributed to distracting the pilot's attention from flying the circuit.

Causes and Contributing Factors

The cause of the accident was not determined.

Safety Action

Although the cause of this accident was not determined, the conditions associated with it were conducive to optical illusions, resulting from flying over rising terrain at low altitude. To increase pilot awareness of this hazard, Transport Canada will be publishing an article on the subject in a future issue of its Aviation Safety Letter.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles H. Simpson and W.A. Tadros, authorized the release of this report on xx xxxx 1998.

1. All times are EDT (Coordinated Universal Time (UTC) minus four hours), unless otherwise noted.

Updated: 2002-10-06
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 Occurrence Report
Wire strike on take-off
Piper Aztec PA23-250 C-GFNT
Squaw Lake, Quebec
22 August 1997

Report Number A97Q0183

Summary

The float-equipped Piper Aztec, serial number 274191, with three occupants on board, was on a private business flight from Squaw Lake, Quebec, to Dick Lake, Quebec, under visual flight rules. The pilot first tried to take off northward, but had to abort the take-off because a fuel tank cap was open. A few moments later, he began the take-off run southward; the aircraft travelled about 8,000 feet before becoming airborne. The aircraft did not attain a high rate of climb, but continued its flight at about 100 feet above the trees. The Flight Service Station (FSS) specialist, who was following the aircraft visually, noticed a brief power outage at his work station, then saw a cloud of smoke rising on the horizon. He tried unsuccessfully several times to contact the aircraft by radio. He then asked a helicopter flying over the area to go to the source of the smoke and check whether an accident had occurred. The helicopter pilot arrived a few minutes later, and confirmed that the aircraft had crashed after striking a high-voltage line.

An intense fire then erupted, and the aircraft sustained substantial damage. The pilot was able to evacuate the aircraft by the left forward door, passing through the flames and suffering serious injuries. The two passengers were unable to evacuate the aircraft, and they were fatally injured.

Ce rapport existe également en français.

Other Factual Information

The pilot was certified and qualified for the flight in accordance with existing regulations. He had approximately 13,000 flying hours, including approximately 3,000 hours on multi-engine aircraft and 800 hours on type.

According to the records, the aircraft was certified, equipped and maintained in accordance with existing regulations and approved procedures. There was no evidence of any airframe failure or engine or system malfunction on take-off. The aircraft had no known deficiencies before the flight.

The pilot had little rest in the 48 hours before the flight. He had been busy preparing his hunting camps for the season that was just opening. Logistics and monitoring his employees took a great deal of his time. He had slept for only about three hours on each of the two nights preceding the flight.

A person who does not get as much sleep as he needs will suffer from sleep deprivation and degraded performance. Cognitive tasks or those requiring alertness are especially affected. A person who is fatigued is also more willing to take risks: repeated lack of sleep and circadian disruption can lead to reduced alertness, degraded performance and mood impairment.\(^{(1)}\)
Section 602.02 of the *Canadian Air Regulations* states the following:

No operator of an aircraft shall require any person to act as a flight crew member and no person shall act as a flight crew member, if either the person or the operator has any reason to believe, having regard to the circumstances of the particular flight to be undertaken, that the person (a) is suffering or is likely to suffer from fatigue; or (b) is otherwise unfit to perform properly the person's duties as a flight crew member.

On the morning of the occurrence, the pilot left his home in Saint-Nicéphore, Quebec around 6 o'clock for Dorval Airport, Montreal, to take a commercial flight to Schefferville, Quebec. From Schefferville he was to fly his private aircraft to take two of his employees, who were cooks, to two different camps, with their personal effects, food and equipment for the camps. The clients, who were also going to the same camps, had already taken off and were en route to their destinations.

The weather observations taken by the FSS specialist at Squaw Lake at 1218, eastern daylight time, (2) a few minutes after the occurrence, were as follows: winds from 120° true at three knots, and visibility 15 miles. The cloud layer consisted of a few clouds at 3,000 feet, and the ceiling was estimated at 20,000 feet with broken clouds. The temperature was 18 degrees Celsius (°C), the dew point 4° C and the altimeter setting 30.20. The clouds were cumulus with an opacity of five eighths, and cirrus with an opacity of three eighths. According to the pilot, there was a light tail wind on the take-off toward the south.

The aircraft was loaded at the Air Saguenay dock. Both internal tanks were filled to capacity, while the level in the two external tanks was about one inch from the bottom. While the pilot was busy preparing the aircraft for the flight, two of his employees loaded the baggage on the aircraft. No baggage or cargo was weighed on the scale available on the Air Saguenay dock. According to the information obtained, two weight and centre of gravity estimates were calculated; they are appended. The first estimate was calculated using the weight as evaluated by the pilot; this evaluation shows that the aircraft was not overloaded and that the centre of gravity was within the envelope. The maximum zero fuel weight, which is 4,400 pounds, was exceeded by 113 pounds (see Appendix A). A second evaluation was done according to the statements of the employees who loaded the aircraft. According to that evaluation, the aircraft was overloaded by 322.5 pounds, and the centre of gravity was 5.97 inches aft of the aft limit, and outside the envelope. In that configuration, the maximum zero fuel weight was exceeded by 630.5 pounds (see Appendix B).

In an aircraft, the position of the centre of gravity plays a very important role in longitudinal stability. If the aircraft is loaded so that the centre of gravity is too far aft, the aircraft will tend to adopt a nose-up attitude rather than nose-down. Inherent stability will be lacking, and even though it is possible to correct this situation by moving the elevator down, longitudinal control of the aircraft will still be difficult, or impossible in some cases. Weight affects the aircraft's stall speed. Additional weight forces the aircraft to maintain a greater angle of attack to produce the lift necessary to sustain flight. Thus the critical angle of attack will be attained at a higher speed. The greater the angle of attack, the greater the drag will be. At a specific angle of attack, the aircraft enters the slow flying range. In the slow flying range, if the angle of attack is increased, lift does not increase further; on the contrary, it decreases, and drag increases. A slight increase in angle of attack may result in a stall. During initial training, pilots are trained to recognize the symptoms of slow flying, especially to avoid this phase of flight, and thereby to avoid a stall. There are several conditions where an aircraft may encounter the slow flying speed range. Some of these conditions are: take-off, landing, recovering from a misjudged landing, an overshoot, and an approach to a stall.

Squaw Lake is oriented northwest/southeast and is about two and a half miles long (see Appendix C). To the southeast, at the end of the lake, there is a valley between two hills. The elevation of the lake is 1,616 feet above sea level (asl), whereas the elevation at the first point of impact of the aircraft was 1,800 feet asl. The aircraft apparently covered about 8,000 feet before lifting off, and apparently flew for about 8,000 feet before striking the ground. The pilot stated that he realized that the aircraft was not achieving its usual performance during the initial climb. During the take-off run, the aircraft travelled for a longer than normal distance before taking off. The pilot attributed that situation to the tail wind. Normally, once the aircraft was flying, the pilot lowered its nose to retract the flaps and allow the aircraft to accelerate at the best rate of climb. In this case, the pilot could not
retract the flaps because of the shoreline and the obstacles that were quickly approaching. He pulled back on the controls and tried to gain altitude while maintaining a speed of approximately 80 mph, with the flaps still down 15 degrees. The pilot attempted to clear the obstacles on his flight path, but when the high-voltage wires appeared ahead, he could not take evasive action to clear the obstacle. The aircraft struck the high-voltage lines and a wooden pole, then went nose down and pivoted around the pole before crashing on the ground. An intense fire broke out after the aircraft came to rest.

According to the owner's manual for the Piper Aztec, the climbing speed recommended for maximum weight configuration is 120 mph. At that speed, the aircraft is capable of a rate of climb of 1,490 feet per minute. The speed at the best angle of climb, used to clear an obstacle at the end of the runway, is 107 mph.

According to an experienced pilot with many flying hours on the same float-equipped aircraft type, when loaded to the maximum weight of 5,200 pounds, with the flaps at 15 degrees, the aircraft requires a distance of about 3,000 feet for take-off. For example, on a lake a mile and a half long, if the aircraft does not lift off within the set limits, the loading must be revised to distribute the weight better, and the floats must be checked to make certain they do not contain any water. According to this pilot, the most critical factor is not to exceed the 150-pounds limit in the aft baggage hold, so as not to move the centre of gravity aft outside the envelope; that would cause the aircraft to be nose-up, both during the take-off run and when airborne.

Examination of the wreckage showed that the fuel on board the aircraft flowed toward the centre of the aircraft, helping the fire spread quickly and contributing to the almost total destruction of the aircraft. Due to the fire damage, no evidence could be found as to whether any of the aircraft systems malfunctioned in flight or there was a structural failure of the airframe or other aircraft components. It was impossible to confirm the flight controls integrity. However, the pilot confirmed that the aircraft had no known or suspected deficiencies before the flight.

The initial information suggested that there had been a loss or reduction in power in one of the engines during the initial climb; that would explain why the aircraft was unable to gain sufficient altitude to clear the obstacles. The damage observed to the engines and propellers is consistent with an impact at high power. The engines and propellers were sent to the TSB Engineering Laboratory for analysis. The results of the analysis showed that both engines were producing power; that was confirmed by the pilot.

**Analysis**

The pilot had not taken enough rest in preparation for the flight he was to undertake. He had not allowed enough time to prepare his camps for the hunting season, placing himself under pressure. He was highly stressed because of the very tight schedules he had set for himself. The pilot, pressed for time, did not check the cargo weight on the scale available on the Air Saguenay loading dock. He decided to take off with an aircraft that was overloaded and whose centre of gravity was too far aft. Knowing that his clients were already flying to the camps, and that the cooks had not yet arrived, led him to be determined to take off on his second attempt. The aircraft used a greater than normal distance before lifting off. At any time during this second attempt, the pilot could have aborted the take-off run and revised his load, but he decided to continue.

The aircraft took an abnormally long distance before rising out of the water because of its nose-up attitude, caused by the fact that the centre of gravity was outside the envelope and displaced aft, and because of the excess weight. This nose-up attitude of the floats in the water caused drag that prevented the aircraft from accelerating during the take-off run within the normal distance. After 8,000 feet of take-off run, which is over twice the distance normally required, the aircraft lifted off, partly due to the ground effects phenomenon. The observed behaviour of the aircraft on take-off suggests that the estimates of the aircraft's weight by the pilot and the employees were too low. Then the pilot, seeing the approaching obstacles on the shoreline, pulled back on the controls to try to clear them. The aircraft was travelling at 80 mph, which is well below the recommended climb speed of 120 mph, and even below the speed for the best climb angle of 107 mph. Due to its configuration, the aircraft stall speed was higher than normal. It can thus be concluded that the aircraft was in the slow flying range. The more the pilot pulled back the controls, the greater the drag. Thus the aircraft could not
attain a climb rate sufficient to clear the obstacles on its flight path, and it struck the high-voltage lines and a pole.

The following laboratory report was completed:

LP 138/97 - Engine & Propellers Examination, Aztec PA-23-250, C-GFNT.

Findings

- The pilot did not allow enough time to prepare his camps for the hunting season, thereby putting pressure on himself.
- The pilot was fatigued, because he did not take enough rest in preparation for the flight.
- The aircraft was overloaded, and the centre of gravity was outside the envelope.
- The aircraft covered a longer than normal distance before lifting off.
- The pilot did not abort the second take-off and decided to continue the flight rather than revise the loading in accordance with the recommended weight and centre of gravity.
- Just before the occurrence, the aircraft was in the slow flying range, and it therefore could not attain a rate of climb sufficient to clear the obstacles on its flight path.

Causes and Contributing Factors

Due to its excessive weight and its centre of gravity outside the envelope, the aircraft lifted off only after a long run, and it could not maintain a rate of climb sufficient to clear the obstacles on its flight path. Contributing to the occurrence were the pilot's stress, disorganization and fatigue.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles H. Simpson and W.A. Tadros, authorized the release of this report on 10 February 1999.

Appendix A - Weight and Centre of Gravity

(according to the pilot's data)

<table>
<thead>
<tr>
<th></th>
<th>Weight (lb.)</th>
<th>Arm (in.)</th>
<th>Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft empty weight</td>
<td>3,572</td>
<td>91.147</td>
<td>325,577.08</td>
</tr>
<tr>
<td>Rear seat (removed)</td>
<td>-45</td>
<td>157</td>
<td>7,065</td>
</tr>
<tr>
<td>Fuel</td>
<td>432</td>
<td>113</td>
<td>48,816</td>
</tr>
<tr>
<td>Row 1 - Pilot and Passenger</td>
<td>340</td>
<td>89</td>
<td>30,260</td>
</tr>
<tr>
<td>Row 2 - Passenger, Maps and HF radio</td>
<td>154</td>
<td>126</td>
<td>19,404</td>
</tr>
<tr>
<td>Row 3 - Cargo</td>
<td>422</td>
<td>157</td>
<td>66,254</td>
</tr>
<tr>
<td>2 outboard motor fuel tanks, Float compartment</td>
<td>10</td>
<td>92.58</td>
<td>925.8</td>
</tr>
<tr>
<td>Aft cargo position</td>
<td>60</td>
<td>183</td>
<td>10,980</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,945</strong></td>
<td><strong>100.132</strong></td>
<td><strong>495,151.9</strong></td>
</tr>
<tr>
<td>Mass without fuel</td>
<td>4,513</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (lb.)</td>
<td>Arm (in.)</td>
<td>Moment</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>Aircraft empty weight</td>
<td>3,572</td>
<td>91.15</td>
<td>325,587.8</td>
</tr>
<tr>
<td>Rear seat (removed)</td>
<td>-26</td>
<td>157</td>
<td>4,160.5</td>
</tr>
<tr>
<td>Fuel</td>
<td>492</td>
<td>113</td>
<td>55,596</td>
</tr>
<tr>
<td>Row 1 - Pilot and Passenger</td>
<td>362</td>
<td>89</td>
<td>32,218</td>
</tr>
<tr>
<td>Row 2 - Passenger</td>
<td>140</td>
<td>126</td>
<td>17,640</td>
</tr>
<tr>
<td>Row 3 - Cargo</td>
<td>688</td>
<td>157</td>
<td>108,016</td>
</tr>
<tr>
<td>Float compartments</td>
<td>10</td>
<td>92.58</td>
<td>925.8</td>
</tr>
<tr>
<td>Aft cargo position</td>
<td>285</td>
<td>183</td>
<td>52,155</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5,522</strong></td>
<td><strong>106.47</strong></td>
<td><strong>587,978.1</strong></td>
</tr>
</tbody>
</table>

Mass without fuel 5,030
Maximum mass without fuel 4,400
Overload 630
Maximum take-off weight 5,200
Overload 322
Centre of gravity position -0.37 within the envelope
Appendix C - Topographical Map of Squaw Lake, Quebec


2. All times are EDT (coordinated universal time (UTC) minus four hours), unless otherwise stated.

Updated: 2002-10-06
Air 1997

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 Occurrence Report
Crash on Take-off
Piper Malibu PA-46-350P C-FLER
St-Mathieu-de-Beloeil Airport, Quebec
22 October 1997

Report Number A97Q0222

Summary

A Piper Malibu Mirage, registration C-FLER, serial number 46-36090, was preparing for an instrument flight rules (IFR) private business flight from St-Mathieu-de-Beloeil Airport, Quebec, to Burlington, Vermont, USA, with two persons on board. The pilot/owner and passenger moved the aircraft out of the hangar and did the usual preparations and checks. After doing the run-up, the pilot listened to the automatic terminal information system (ATIS) message from Saint-Hubert, Quebec, and requested IFR clearance. When the tower advised him that there would be a delay of about 10 minutes, the pilot taxied back to position the aircraft on the threshold of runway 15. At that time, heavy snow had been falling for over two hours. After waiting 11 minutes, the pilot received IFR clearance and initiated take-off. The aircraft lifted a few feet off the ground, then bounced and came to rest in a cornfield several hundred feet from the runway end. The pilot shut off electrical power, fuel and the magnetos, and the two occupants evacuated the aircraft. There was no post-impact fire. The occupants sustained minor injuries, and the aircraft sustained substantial damage.

Ce rapport est également disponible en français.

Other Factual Information

The pilot was certified and qualified for the flight in accordance with existing regulations. He was the owner of the aircraft and had about 1,600 flying hours at the time of the occurrence, including about 850 hours on type. He had held a private pilot's licence since 1994, with multi-engine rating, night flying rating, and group 3 (single-engine) instrument flight rating since November 1996. The pilot had 300 IFR flying hours at the time of the occurrence.
Examination of the aircraft log books indicated that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The aircraft had about 200 hours of flight since it was built in March 1997, and was in compliance with all airworthiness directives. The aircraft had flown about five hours since its last 100-hour inspection, and it had no known deficiencies before the flight. The weight and centre of gravity were within the prescribed limits.

The pilot received a full weather briefing from Dorval Flight Service Station (FSS) at 2000, eastern daylight time (EDT),\(^{(1)}\) on the evening before the flight. The next morning, snow began to fall about two and a half hours before the start of the flight and accumulated at a rate of approximately four centimetres per hour. The Environment Canada report for the Saint-Hubert area at 0800 indicated a sky obscured at 300 feet, visibility three quarters of a mile in light snow, temperature 0 degrees Celsius, and dew point minus 1 degree Celsius. The winds were from 350 degrees magnetic at 3 knots.

The aircraft was stored in an unheated hangar when not in use. On the morning of the flight, the pilot checked the aircraft and fuel before moving the aircraft out. He reported that wet snow was falling. The pilot indicated that despite the snow accumulation on the runway he had no particular problem taxiing into position for take-off.

About 20 to 25 minutes elapsed between the time the aircraft was moved out of the hangar and the take-off from runway 15. Part of the delay was the 11 minutes it took to receive IFR clearance from the Saint-Hubert control tower. During that time, the pilot noticed that snow had accumulated on the wings. However, the pilot stated that it dissipated as he increased and decreased power while taxiing. When he received IFR clearance, the pilot initiated the take-off run with 10 degrees of flap. At 60 knots, the pilot noticed that the snow had blown off the wings. He used three quarters of the runway length, as he normally did.

The aircraft lifted off only a few feet, and the pilot heard engine misfires and dull thuds and felt the whole aircraft shaking. The engine was not producing enough power to take off, and the aircraft struck the ground with the main gear, bounced a few feet, then struck the ground again, causing the main gear to separate. The aircraft continued its course and came to rest in a cornfield, 450 feet from the end of the runway. The passenger reported feeling severe vibrations two or three seconds after take-off. He said he also heard an audible warning and saw a warning light at the same time.

The aircraft sustained substantial damage in the crash sequence. The wings remained attached to the fuselage. The flaps were extended 10 degrees. The landing gear was down but the wheels had separated from the oleo shock struts and the main gear doors were torn off. The fuel tanks were full and undamaged. Flight control continuity was established, including the engine and propeller controls.
Various static checks were done on the systems and engine components. Dynamic engine testing was done at 800 to 2,500 rpm with an intake pressure of 25 inches of mercury (Hg). The checks performed on the engine and accessories revealed no technical deficiencies that could have affected take-off performance. However, the engine air filter was saturated with water to over three quarters of the thickness. Atmospheric conditions were conducive to the accumulation of water in the air filter but, based on discussions with pilots experienced on this type of aircraft and with Piper representatives, it was concluded that water accumulation in the air filter is not a common problem on this type.

For operating requirements, the engine breathes in air via either the primary system or the alternate system. The pilot selects one of the two systems using a control on the centre console just below the engine controls. The primary system filters the air before directing it into the engine; the alternate system does not filter the air. The Pilot's Operating Handbook for the Malibu states that "alternate air should never be used during ground operations, except for checking its operation," because the engine could ingest debris and be damaged.

The TSB Engineering Branch was asked to do a theoretical analysis to estimate the minimum runway length required to take off in the weather conditions at the time of the accident, since that information is not provided in the Pilot's Operating Handbook. For the purposes of the analysis, the Engineering Branch assumed that taking off on a runway covered with two inches of wet snow is as unfavourable as taking off on a runway covered with long grass. The analysis showed that just to reach take-off speed the aircraft would need 1,900 feet on a short-grass runway and 2,500 feet on a long-grass runway. The runway at St-Mathieu-de-Beloeil is 2,200 feet long.

Airworthiness Notice No. B017, Edition 1 issued by Transport Canada regarding the clean aircraft concept, states that "test data indicate that frost, ice or snow formations having a thickness or roughness similar to medium or coarse sandpaper, on the leading edge and upper surface of a wing, can reduce wing lift by as much as 30% and increase drag by 40%. The changes in lift and drag significantly increase stall speed, decrease controllability and alter aircraft flight characteristics. Thicker or rougher frozen contaminants can have increasing effects." In addition, subsection 602.11(4) of the Canadian Aviation Regulations states:

> Where conditions are such that frost, ice or snow may reasonably be expected to adhere to the aircraft, no person shall conduct or attempt to conduct a take-off in an aircraft unless (a) the aircraft has been inspected immediately prior to take-off to determine whether any frost, ice or snow is adhering to any of its critical surfaces.

The Transport Canada study and reference guides for instrument flight qualification list several subjects which pilots must be taught during theoretical courses. These subjects include icing, surface contamination, the clean aircraft concept, cold-soaked aircraft phenomena, pre-take-off inspection, aircraft operations in winter, and
the effects of snow, ice and frost on the take-off run and landing.

Analysis

The pilot was certified and qualified for the flight in accordance with existing regulations. The aircraft was airworthy and had no known deficiencies before the flight, and the engine was capable of producing maximum power.

The pilot stated that the engine misfired as the aircraft left the ground. The actual causes of the engine misfires could not be determined, but the atmospheric conditions at the time of the accident were conducive to the formation of frost or ice. The filter in the engine air intake system was found to be saturated with water to over three quarters of its thickness, it is possible that the filter froze during the take-off run and blocked the supply of air to the engine. The pilot did not select the alternate air intake system when the engine misfired because the Malibu Pilot's Operating Handbook does not suggest that this be done while operating on the ground.

On the day of the flight, snow had begun to fall two hours before the aircraft took off. The runway was contaminated with wet snow. Although the pilot did not notice any impediment on the manoeuvring areas and he said he executed the rotation at the usual location, a contaminated runway will in all cases extend the take-off run.

Between 20 and 25 minutes elapsed from the time the pilot moved the aircraft out of the hangar to the take-off. When initiating the take-off, the pilot did not inspect the critical surfaces of the aircraft as prescribed in the Canadian Aviation Regulations. He supposed that if the snow dissipated from part of the wings when he accelerated on the ground the same thing would happen on all other critical surfaces.

Immediately after leaving the ground, the entire aircraft shook severely and an audible alarm and warning light activated. These indications show that the aircraft had not attained the speed necessary to sustain flight, even in the ground effect, and it stalled. The pilot was in a situation where the outcome was unavoidable due to the runway length available.

Findings

- The pilot was certified and qualified for the flight.
- Examination of the aircraft log books indicated that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.
- The weight and centre of gravity were within the prescribed limits.
- The air intake filter was contaminated by water to three quarters of its thickness.
- The runway was contaminated by a two-hour accumulation of wet snow.

- The pilot initiated the take-off without checking if the critical surfaces were contaminated by wet snow.

- The aircraft stalled on take-off just after the rotation.

Causes and Contributing Factors

The aircraft was not producing sufficient lift to sustain flight and it stalled immediately after the rotation for take-off. The following factors may have contributed to the accident: a runway contaminated by wet snow; an aircraft contaminated by precipitation; and engine misfires, which may have been caused by a filter saturated with water.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 18 May 1999.*

1. All times are EDT (coordinated universal time (UTC) minus four hours) unless otherwise noted.

Updated: 2002-10-06
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 Occurrence Report
Mid-Air Collision
between Cessna 172M C-GEYG
of Cargair Ltd.and Cessna 150H C-FNLD
Mascouche Airport, Quebec
07 December 1997

Report Number A97Q0250

Summary

Following a pleasure flight in the area of Saint-Hubert, Quebec, the Cessna 150H, registration C--FNLD, serial number 15068912, joined the left-hand circuit downwind for Runway 29 at Mascouche Airport, Quebec, to come to a complete stop. At the same time, a Cessna 172M, registration C-GEYG, serial number 17266418, took off from Runway 29 for touch-and-goes on the runway following a left-hand circuit. The two aircraft collided in flight on the final leg for Runway 29 and crashed on the highway by an overpass abreast of Mascouche Airport. There were two occupants on board each aircraft, and all four suffered fatal injuries.

Ce rapport est également disponible en français.

Factual Information

The pilot of Cessna 172 C-GEYG held a Class 3 Instructor Licence - Aeroplane Category. He had begun his training in August 1991 and had accumulated over 2500 hours' flight time at the time of the occurrence. The instructor was to review exercises in the circuit before letting the student pilot make a solo flight. The student pilot had a little over 21 hours' flight time. The pilot of Cessna 150 C-FNLD had owned the aircraft since April 1997 and held a Private Licence. He had begun his training in September 1994 and had accumulated over 200 hours' flight time. He had brought a passenger with him.

The autopsies were performed at the Laboratoire de médecine légale de Montréal. The reports indicate that the crews sustained severe, irreversible injuries in the occurrence, and that the deaths were due to multiple traumatic injuries sustained in the accident. Toxicological testing was conducted at the Centre de toxicologie du Québec. Toxicological test results were negative for the crews of both aircraft.

According to the meteorological data for 1400 eastern standard time at Mirabel Airport, there was a first, broken cloud layer at 2300 feet, and another layer at 4500 feet. Visibility was 25 statute miles, and the winds were blowing from 280 degrees true at seven knots; these conditions favoured the use of Runway 29.
Both aircraft were maintained in accordance with existing regulations. No irregularity was identified.
The weight and centre of gravity were within the manufacturer-prescribed limits for both aircraft.

Both aircraft had joined a left-hand circuit for Runway 29 at Mascouche (meaning all turns in the
circuit were to the left). Another aircraft, C-GADU, was preceding them, but it was on the ground,
clear of the runway, by the time of the accident. The circuit is composed of several parts, as shown in
Figure 1. The arrows on the upwind side indicate how aircraft can join this side from different
directions before entering the circuit as such.

Data gathered from radar at the Montreal control centre made it possible to reconstruct the following
information (Appendix A).

1420:51 Cessna 150 C-FNLD, arriving from the Saint-Hubert area, made a long detour
northwards to approach Mascouche Airport on the upwind side of the circuit as
Cessna 172 C-GEYG took off from Runway 29.

1421:49 When Cessna 150 C-FNLD joined the left-hand downwind leg for Runway 29, it was
preceded by another aircraft that would be first in the landing sequence. At that time,
Cessna 172 C-GEYG began its turn for the crosswind leg.

1423:11 Cessna 150 C-FNLD stretched its downwind leg while the aircraft ahead of it turned
on the final leg. This aircraft would come to a complete stop. Cessna 172 C-GEYG
began the left-hand downwind leg for Runway 29.

1424:38 Cessna 150 C-FNLD was now established on the final leg about 5.8 nautical miles
(nm) from the end of the runway while Cessna 172 C-GEYG was established on the
base leg.

1425:17 When Cessna 172 C-GEYG turned on the final leg, it was 4 nm from the end of the
runway. Cessna 150 C-FNLD was ahead of it, but at a lower altitude. The approach
speed of Cessna 172 C-GEYG was higher than that of Cessna 150 C-FNLD.

1426:00 The radar identified only one target and then none.

The radar data revealed that the circuit followed by each of the aircraft was similar to that followed by
several other aircraft that had preceded them during the day.

The Lachenaie police department has equipped its patrol vehicles with a camera that activates as
soon as the vehicle is started. At the time of the occurrence, a patrol car was eastbound on Highway
640 less than one kilometre from the exit for Mascouche Airport. The camera captured images of the
collision showing that, shortly after the initial impact, the two aircraft adopted a high nose-up, almost
vertical attitude. The aircraft appeared to become entangled and then separated again just before hitting the ground. When they separated, there was insufficient altitude available for either aircraft to effect a recovery. The report from the TSB Engineering Branch Laboratory in Ottawa indicates that the camera captured 12 seconds of the occurrence: five seconds before the collision, the collision and the fall to the ground. Measurements taken from the videotape's digitized images show that the aircraft were at an altitude of 450 feet above ground level at the time of impact. The images confirm that the Cessna 172 was higher than the Cessna 150. The images also confirm that the Cessna 172's landing light was on at the time of the mid-air collision while that of the Cessna 150 was off.

In the AIR section of the Aeronautical Information Publication (A.I.P. Canada), Transport Canada states that more and more operators have been using a landing light when flying at the lower altitudes, both during daylight hours and at night, because they have confirmed that the use of the landing light greatly enhances the probability of the aircraft's being seen. Transport Canada therefore recommends that pilots use the landing light during the take-off and landing phases and when flying below 2000 feet within terminal areas or control zones.

The two aircraft crashed by the bridge crossing Highway 640 at the exit for Mascouche Airport, 2000 feet from the runway threshold. After the final impact, both aircraft came to rest on their backs. After the accident, the Cessna 150's cabin space was considerably reduced. There were several laceration marks—caused by a propeller--on the top of the cabin, such that the aircraft's structure was very damaged. The Cessna 172 showed evidence of impact with the ground and traces of colour transfer from the collision.

The two aircraft used two-way VHF communication radios, which allowed them to communicate on the frequency employed by crews using Mascouche Airport. Mascouche Airport does not have a control tower or a two-way communication recording system.

Canadian Aviation Regulations (CARs) 602.101 concerning joining the circuit at an uncontrolled airport lying within a mandatory frequency (MF) area specifies that:

The pilot-in-command of a VFR aircraft arriving at an uncontrolled aerodrome that lies within an MF area shall report
  (a) before entering the MF area and, where circumstances permit, shall do so at least five minutes before entering the area, giving the aircraft's position, altitude and estimated time of landing and the pilot-in-command's arrival procedure intentions;
  (b) when joining the aerodrome traffic circuit, giving the aircraft's position in the circuit;
  (c) when on the downwind leg, if applicable;
  (d) when on final approach; and
  (e) when clear of the surface on which the aircraft has landed.

CARs 602.102 specifies for aircraft flying continuous circuits that:

The pilot-in-command of a VFR aircraft carrying out continuous circuits at an uncontrolled aerodrome that lies within an MF area shall report
  (a) when joining the downwind leg of the circuit;
  (b) when on final approach, stating the pilot-in-command's intentions; and
  (c) when clear of the surface on which the aircraft has landed.

The information gathered indicates that the crews established radio communication on entering the circuit, on the downwind leg and on the final leg as prescribed in the regulations. Neither aircraft appears to have reported its position on the base leg, and was not required to do so. Just before the collision, a third aircraft tried to communicate with the two aircraft on the final leg to advise them of the dangerous situation they were in, but it was already too late.

During the period from April to November 1994, Transport Canada set up a mobile control tower at Mascouche Airport. The working group involved says in its report that this experiment helped to make many pilots aware of the importance of complying with standards and procedures. During the period from April to November 1995, Transport Canada tried the experiment again, and also set up an awareness program.

NAV CANADA has a detailed policy on the delivery of air navigation services. The policy defines a set of assessment criteria and an Aeronautical Study process. One of the criteria for installing a control
tower is that the annual movements must be equal to or greater than 60,000. This standard is not rigid and must be assessed in the light of other criteria, including the traffic mix and the level of risk defined by an aeronautical study. For the period from April to November of 1994 and 1995, the number of movements at Mascouche Airport stayed between 47,000 and 51,000. Mascouche Airport for the most part serves a population consisting of flying schools and resident and itinerant private pilots. The traffic is considered relatively homogenous and should remain so given the physical characteristics of the runway (length and width). Since the occurrence, no formal request for the installation of a control tower has been received by NAV CANADA or Transport Canada.

Visual flight is limited by the ability to see and be seen. Several factors can alter a pilot's chances of seeing and being seen, such as the aircraft appearance, the environment and the crew attention. Without being exhaustive, the main criteria that affect appearance are aircraft size, colour and shape, while the difficulty of seeing an aircraft in its environment seems to depend on brightness and background. The fuselage of Cessna 150 C-FNLD was red, and that of Cessna 172 C-GEYG was blue. Both aircraft had white wings. In several places on the circuit, the aircraft were in a position to see each other.

Crew attention is a determining factor in collision avoidance. Good scanning technique is required, as well as looking outside the cockpit as often as possible. Close attention to radio communications helps forming a mental image of the surrounding traffic and reducing the risks of collision.

CARs 602.19 deals with right of way. It specifies that the pilot-in-command of an aircraft that is approaching an aerodrome for the purpose of landing shall give way to any aircraft at a lower altitude that is also approaching the aerodrome for the purpose of landing. CAR 602.21 deals with collision avoidance and simply states that no person shall operate an aircraft in such proximity to another aircraft as to create a risk of collision.

**Analysis**

The flight crews were certified and qualified for the flight in accordance with existing regulations. The weight and centre of gravity of each aircraft was within prescribed limits, and each was maintained in accordance with existing regulations.

Although the Cessna 150's pilot was arriving from the south, he had bypassed the airport in a long detour to the east in order to approach the airport on the north side to join the Runway 29 circuit. He thus followed in every respect the procedure for joining the circuit of an uncontrolled aerodrome, just as the Cessna 172 was following the procedure for continuous circuits. Furthermore, the aircraft reported where they were supposed to as set out in CARs 602.101 and 602.102.

The pilot of Cessna 150 C-FNLD knew that another aircraft was ahead of him and probably decided to stretch out his downwind leg to give this aircraft time to touch down and clear the runway. The crew of Cessna 172 C-GEYG did not stretch their downwind leg to follow the aircraft ahead; the crew may have confused the Cessna 150 C-FNLD, still in the circuit, with the traffic that had just landed, or else was not attentive to the communications that would have allowed them to know what aircraft were ahead.

The crew of each aircraft could have seen the other aircraft at several places in the circuit. The pilot of Cessna 150 C-FNLD could have seen Cessna 172 C-GEYG at turning on the base leg and after his turn on the final leg. The pilot of Cessna 172 C-GEYG could have seen Cessna 150 C-FNLD while C-GEYG was on the downwind leg and during its descent on the base leg. Several factors, such as the appearance of the aircraft, the environment, a lack of attention or operation of the radios, could explain the collision, but no single factor could be identified in the investigation. The lack of evasive action by either aircraft indicates that neither aircraft had noticed the other.

The landing light of Cessna 172 C-GEYG was on, thereby increasing the possibility of its being identified by Cessna 150 C-FNLD during certain phases of flight. This advantage, however, proved useless when the aircraft were on the final leg, because Cessna 172 C-GEYG was behind and above the Cessna 150.

The aircraft collided in flight at an altitude of 450 feet on the final leg for Runway 29 at Mascouche.
and crashed, although, just before the collision, a pilot on the ground tried to warn them of the danger. The video sequences show that when the aircraft separated there was insufficient altitude available to effect a recovery.

Findings

- Both flight crews were certified and qualified for the flight in accordance with existing regulations.
- Both aircraft seem to have followed the joining, circuit and communication procedures in effect for an uncontrolled aerodrome.
- Neither aircraft seems to have reported its position on the base leg, and was not required to do so under existing regulations.
- Several factors such as the appearance of the aircraft, radio reception, the environment and the lack of crew attention were assessed, but none was identified as a determining factor in the accident.
- The aircraft collided in flight at an altitude of 450 feet on the final leg for Runway 29 at Mascouche.
- No evasive action was taken to avoid collision, indicating that neither pilot was aware of the other aircraft's presence.
- The Cessna 172's pilot does not seem to have taken the presence of the Cessna 150 into consideration when planning his circuit.

Causes and Contributing Factors

For an undetermined reason, the crew of the Cessna 172 did not maintain safe separation by stretching the downwind leg of the circuit to take the presence of the Cessna 150 into consideration. Several factors such as a failure of the radio equipment, the appearance of the aircraft, the environment and a lack of attention, may have contributed to the occurrence.

Safety Action

Since the accident in Mascouche, Transport Canada has delivered several presentations on the subject of circuit procedures at uncontrolled aerodromes. The presentations emphasize the importance of communication to ensure aircraft separation and the use of landing lights to increase the probability of being seen.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 01 March 2000.

Appendix A - Aircraft Position Data, from Radar
Air 1997

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 Occurrence Report
Damage to Aircraft - Over-Stress
Department of Transport Aircraft Services
Bell 206B JetRanger (Helicopter) C-FDOE
Nordegg Recreational Campground, Alberta
09 July 1997

Report Number A97W0130

Summary

After landing the Bell 206B JetRanger helicopter, serial number 381, at a private campground near Nordegg, Alberta, the pilot rolled the throttle to idle, tightened the cyclic and collective friction controls, and briefed the fixed-wing pilot who was sitting in the left seat to hold the left-side dual controls steady. The helicopter pilot then exited the helicopter, without shutting down the engine, and ran approximately 150 feet to a recreational trailer. As he was returning to the helicopter, he stopped briefly to talk to the campground caretaker who was standing approximately 100 feet to the left of the helicopter. Immediately, thereafter, a clunking sound similar to that of an out-of-balance washing machine was heard and the helicopter began to rock fore and aft on the skids. The main rotor disc was observed to be tilted to the extreme forward position. The pilot ran back to the helicopter, ducked under the main rotor disc from the left side, ran around the front of the helicopter, and climbed into the right seat. He immediately attempted to stabilize the helicopter by applying collective and increasing rotor speed. The oscillations diminished initially and then increased dramatically when the weight was reduced on the skids. The pilot then lowered the collective and shut down the engine. When he applied the rotor brake after shutdown a loud “clunk” was heard before the rotor blades stopped turning. Examination determined that the swashplate drive collar set and both main rotor pitch links were fractured. None of the four occupants on board the helicopter sustained injury.

Ce rapport est également disponible en français.

Other Factual Information
Good visual meteorological conditions existed at the time of the occurrence, with clear skies, unrestricted visibility, and light southerly winds. Witnesses estimated the temperature to be 22 degrees Celsius.

The purpose of the flight was to transport two Transport Canada officials and a dependent from the Edmonton City Centre Airport to the Edmonton International Airport to Nordegg to Rocky Mountain House to Red Deer and to Cooking Lake, Alberta to visit general aviation operators.

The flight from the Edmonton City Centre Airport to the Edmonton International Airport and to Nordegg was uneventful. The pilot and passengers reported that the helicopter had a discernable one-to-one vertical vibration in forward flight; however, no other discrepancies were noted. The pilot considered the vibration to be unusual for this helicopter; however, he did not consider the magnitude of the vibration to be cause for concern.

In addition to inspecting a helicopter company that was operating from Nordegg, the pilot decided to stop at the Nordegg Recreational Campground. The private campground was located about two miles north of the town site and consisted of numerous trailer lots that were situated on the perimeter of the old, abandoned town airstrip. The grass airstrip was approximately 1,500 feet long and 300 feet wide. As the flight was behind schedule due to an extended stop at the Edmonton International Airport, the pilot determined that he would save time by landing at the campground rather than driving or walking from the town site to the campground after landing in Nordegg.

After landing, the pilot consulted with the passengers to determine if it was necessary to shut down. Since none of the passengers expressed a desire to get out of the helicopter at the campground, the pilot decided he would not shut down, as it would require only a short time to conduct his personal business and there was an experienced fixed-wing pilot in the left seat.

A simulation of the occurrence determined that the pilot had taken approximately 20 seconds to tighten the friction controls and brief the fixed-wing pilot, and that he was out of the helicopter for approximately 50 seconds. It was estimated that the pilot would have required approximately seven minutes to shut down, conduct business, and restart the helicopter.

The helicopter pilot held a valid Airline Transport Pilot Licence (ATPL), and was certified and qualified for the flight in accordance with existing regulations. He had acquired approximately 6,760 hours of flight experience, including 4,700 hours in rotorcraft, and 943 hours in the Bell 206 type helicopter. He had commenced his flying career with the Canadian Armed Forces and had instructed on helicopters for several years. He reported that as an instructor, he had frequently exited helicopters prior to shutdown on training flights in order to let the student complete the shutdown alone. He had flown Transport Canada helicopters for approximately six years, and related that he was used to having a qualified helicopter pilot occupy the left seat on Transport
Canada flights, as Transport Canada helicopter pilots frequently conducted training and other flights in pairs. He had received Transport Canada Crew Resource Management (CRM) training, and had provided CRM and decision making instruction to commercial pilots in the past. He reported that he had not previously exited a Transport Canada helicopter without first shutting down the helicopter's engine.

The fixed-wing pilot held a valid ATPL, and had accumulated approximately 12,000 hours of fixed-wing flying experience. He had attended Transport Canada CRM training. He had never received helicopter training and, prior to this flight, had not ridden in a Bell 206 for approximately 10 years. He reported that he had pushed the cyclic forward, after the helicopter started to oscillate, in order to prevent the helicopter from becoming airborne.

Part 602.10 of the Canadian Aviation Regulations (CARS) states that, no person shall leave an engine of an aircraft running, unless a pilot's seat is occupied by a person who is competent to control the aircraft. The regulation permits a pilot to leave an aircraft with an engine running provided that there are no passengers on the aircraft, that precautions have been taken to prevent the aircraft from moving, and that the aircraft is not left unattended. Exiting a running helicopter during ground operation is considered an acceptable practice by some helicopter pilots.

The Transport Canada Aircraft Services Directorate Helicopter Flight Operations Manual states, "Except during authorized flight training, no person other than a qualified Department of Transport pilot shall manipulate the flight controls during flight." The Operations Manual did not address the manipulation of the flight controls while the helicopter was on the ground with the rotors turning. On 10 August 1993, an Operational Memorandum pertaining to "Changing Crew Seats" was issued and stated that, "At least one crew seat equipped with flight controls must be occupied by a qualified pilot at all times that the helicopter is running." This memorandum did not define pilot qualifications.

The pilot filed a visual flight rules (VFR) flight itinerary with the Edmonton Flight Service Station (FSS). The flight itinerary was completed using an outdated Transport Canada Flight Plan/Notification form. The pilot did not indicate any intermediate stops on the flight itinerary, and did not include Nordegg in the route information. The nearest town to Nordegg to be referenced in the flight itinerary was Rocky Mountain House, Alberta; which is located approximately 50 miles to the east. The estimated elapsed time; which must include the time for the planned stops, was recorded as three hours and thirty minutes. It was estimated that the flight, including the planned stops, would have required approximately nine hours to complete.

The helicopter had been manufactured as a Bell 206A in 1969 and had been upgraded to a Bell 206B JetRanger II. Logbook entries indicated the helicopter had been maintained and certified in accordance with existing regulations. The swashplate drive collar set attaches to a splined area of the mast and forms part of the swashplate drive link.
assembly. The mast assembly had been replaced approximately 15 hours prior to the occurrence. No maintenance or material preoccurrence discrepancies were identified during a detailed examination of the mast, the swashplate, and the collar set. The transmission isolation mount, the transmission mount plate and support, and the transmission pin assembly sustained overload damage that was consistent with severe mast bumping. The pitch horns on the rotating upper swashplate had sustained damage due to cowling contact, and the collar set and pitch link fractures were overload in nature.

The Bell 206B helicopter is fitted with an underslung, semi-rigid, teetering, two-blade main rotor system. The teetering design allows the main rotor blades to flap to compensate for asymmetrical lift during flight. One static stop is mounted on either side of the main rotor hub to physically limit the amount of blade flapping. A condition known as mast bumping occurs if the static stops contact the mast, due to excessive blade flapping, during ground operations or in flight. During ground operations with the rotor turning, the main rotor may be affected by wind gusts and flap to its limits resulting in a light static stop to mast contact. In such an event, mast bumping may manifest itself as a light shudder felt throughout the helicopter. The more extreme the flapping, the more severe the shudder. Mast bumping will also occur during ground operation, if the cyclic is incorrectly positioned or is moved sufficiently to tilt the rotor disc to an extreme position. If the static stop to mast contact is severe, pronounced helicopter oscillations may develop and the helicopter can sustain substantial damage. The appropriate corrective action is to immediately reposition the cyclic, toward or near the neutral position so that the rotor disc resumes a flat position. On the ground, at idle RPM, the rotor disc is less stable and more susceptible to larger deviations due to flapping.

The Bell 206 is also fitted with cyclic and collective friction controls that allow the pilot to set the force required to move the flight controls, in order to reduce the tendency for pilot induced oscillation or collective creep in flight. The cyclic and collective friction controls are not intended to be used as control locks. The pilot had left the hydraulics selected on prior to leaving the helicopter, and testing determined that five to six pounds of force was required at the grip to move the cyclic from a neutral to a forward position with the cyclic friction control tightened and hydraulic power applied.

The transition from fixed-wing to helicopter flying requires the acquisition of new skills and fixed-wing responses may not accomplish the desired reaction in a helicopter. The helicopter cyclic is the equivalent of the fixed-wing control wheel; however, cyclic response is extremely sensitive and rapid in all flight regimes; whereas, control wheel response diminishes at low airspeeds. A fixed-wing pilot may hold a control wheel fully forward during ground operation, in strong winds, in order to keep the aircraft firmly on the ground.

Information regarding two similar Bell 206B occurrences was obtained during the investigation. In one case the helicopter was being run up by a student pilot. At about 80% N1, the helicopter began to bounce and
vibrate, and the rotor disc was observed to be tilted in an extreme forward position. The helicopter eventually bounced approximately 120 degrees to the right, and a line supervisor ran to the cockpit and shut the engine down. Examination determined that the transmission isolation mount, the support plate, and the pin assembly had sustained substantial damage, and that the collar set had fractured due to overload. The second incident occurred when a trainee pilot was being checked out by a company check pilot. The trainee pilot had conducted a landing at a remote staging area and the check pilot had exited the helicopter to recover some sling gear that had recently been left at the site. When the check pilot was approximately 100 feet away, the helicopter began to rock violently fore and aft. As the check pilot ran back to the helicopter, he observed that the tip path plane was in the full forward position. The check pilot entered the cockpit and immediately shut the helicopter down. Examination identified that the transmission isolation mount, the support plate and the pin assembly had sustained substantial damage. In both cases, it was determined that the cyclic had been moved to an extreme forward position.

Decision making is the process of choosing between alternatives, by selecting or rejecting the available options. The process is mostly subjective and is often error-prone. The quality of decision making is affected by factors such as knowledge, cognitive heuristics (mental rules of thumb), stress, training, motivation, and attention level. According to normative approaches, optimal decision-making involves identifying all possible courses of action, evaluating the risks and benefits of each course of action, assessing the likelihood of those risks and benefits, and selecting the best course of action based on the integration of all information. In fact, decision-making is affected by a number of cognitive heuristics and biases in human logic; which can degrade the process.

One such heuristic is called a framing bias. Research has shown important differences between the way people make risky decisions with positive and negative outcomes. When people must make a choice between two actions where either outcome is expected to be positive, people tend to avoid the riskier choice. Conversely, if the choice is expected to result in somewhat negative outcomes, people tend to take the riskier choice. Government regulations and company procedures are often formulated to prevent predictable human actions or decisions that compromise safety.

Analysis

The helicopter was maintained and certified in accordance with existing regulations and there was no evidence that a pre-occurrence mechanical discrepancy contributed to the occurrence. The abandoned airstrip was large enough for a Bell 206 landing and departure, and good visual meteorological conditions, with light winds, existed at the time of the occurrence. The analysis will therefore discuss the decision by the pilot-in-command to leave the helicopter engine running with a pilot who was not qualified on helicopters at the controls, and on the effect of applying fixed-wing knowledge to helicopter operation.
The pilot's decision to land at the private recreational campground was based on his desire to conduct some business at his trailer. After landing, the pilot had two options with regard to exiting the helicopter. In both cases the possible outcomes were negative. One choice was to shut the helicopter down, as required by existing regulations, and lose approximately seven minutes of time. This was the less risky choice; however, the flight was already behind schedule, and the known outcome was a further loss of time. The second choice was to leave the helicopter running, have the fixed-wing pilot monitor the controls, and thereby lose less time. This was more risky in that the outcome could be far more disastrous; however, the risk probabilities were unknown. Considering that the entire trip, including stops, would have required approximately nine hours to complete, the additional time that would have been lost by shutting down was relatively insignificant.

Given that this was personal rather than official business, and that the real purpose of the flight was to visit operators, it is probable that the pilot wished to minimize any inconvenience to the other two Transport Canada officials. The fixed-wing pilot (and the other Transport Canada official) had sufficient aviation experience to encourage a multi-person decision-making environment; however, they were relatively unfamiliar with helicopters. As well, an atmosphere of cooperation and congeniality existed and the decision to leave the helicopter running was never challenged. The pilot had the final authority in the decision making process and while he may have realized that option one was safer, he chose option two, because the perceived outcome was more desirable. His decision to leave the helicopter in the care of the fixed-wing pilot may have been reinforced by his previous experiences of exiting a running helicopter to permit students to shut down on their own, with no adverse consequences, and by the willingness of the fixed-wing pilot to accept the responsibility of holding the flight controls. The pilot overestimated the fixed-wing pilot's helicopter skills and underestimated the likelihood of a negative outcome.

It could not be determined why the helicopter initially began to oscillate; however, it is probable that the condition occurred due to a combination of factors, including the excessive flapping of the main rotor due to a wind gust, and/or an inadvertent movement of the cyclic from the centre position. The fixed-wing pilot responded by moving the cyclic forward; which induced severe mast bumping. This action was the misapplication of a normal fixed-wing corrective action. The mast bumping was sufficiently intense to damage the transmission isolation mount, the transmission mount plate and support, and the transmission pin assembly, and to permit the rotating swashplate pitch horns to contact the surrounding cowling. When the swashplate rotation was restricted due to pitch horn interference with the cowling, the collar set failed in overload. The main rotor pitch links subsequently failed due to overload when the flailing drive link assembly jammed and further restricted the swashplate rotation.

Had a search been required in order to locate the helicopter, the search effort may have been hampered because pertinent information was missing from the flight itinerary.
Findings

- The helicopter was maintained and certified in accordance with existing regulations.
- The fixed-wing pilot who occupied the left seat was not qualified on helicopters.
- After the helicopter began to oscillate, the fixed-wing pilot applied an inappropriate corrective action, and induced severe mast bumping, by moving the cyclic control forward.
- The swashplate collar set failed in overload, because of swashplate to cowling contact.
- The pilot did not provide the correct information on the flight itinerary.

Causes and Contributing Factors

Because the pilot-in-command decided to leave the helicopter running with an unqualified pilot at the controls, the helicopter was damaged when the unqualified pilot applied inappropriate cyclic control inputs to counteract excessive flapping of the main rotor blades.

Safety Action

Following this occurrence, the operator issued a directive to all its helicopter pilots which requires that a crew seat equipped with flight controls must be occupied by a qualified helicopter pilot at all times that the helicopter is running. Unless these conditions are met, the pilot-in-command may not disembark from the helicopter while it is running. This new directive is particularly explicit about the necessary qualifications of the pilot at the controls.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 07 July 1998.

Updated: 2002-10-06

Important Notices
Air 1997

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 Occurrence Report
Engine Failure
Fireweed Helicopters Ltd.
Bell 206B (Helicopter) C-FNIQ
Dawson, Yukon 60 nm North
24 July 1997

Report Number A97W0142

Summary

The pilot of the Bell 206B helicopter (serial number 1743) had departed an exploration camp after delivering supplies, and was going to pick up two workers at a site about three miles west of the camp. In cruise flight, at an altitude of about 100 feet above ground level (agl), the engine (Allison 250C20) suddenly failed. During the autorotation the pilot stretched the glide in order to cross a creek to a level landing area. The rotor rpm decreased resulting in a loss of lift, and at touchdown the left skid dug into the ground and the helicopter rolled onto its right side. The pilot reported that the engine had failed without any unusual noises or instrument indications, and that there was adequate fuel on board. There were no injuries, but the helicopter was substantially damaged.

Ce rapport est également disponible en français.

Other Factual Information

The weather at the time of the accident was an overcast ceiling of 300 feet agl, visibility of 8 miles, temperature of 15 degrees Celsius, and light winds. Weather was not considered to be a factor in this occurrence.

The pilot was certified and qualified for the flight in accordance with existing regulations. He had about 8,000 hours total flying time, and about 6,000 hours on the Bell 206.

Records indicate that the helicopter was maintained in accordance with existing regulations. A 300-hour inspection had been completed 29.3 air hours prior to the occurrence. During the inspection, the fuel nozzle
was replaced because it was time-expired, and the tail rotor was re-balanced. There were no reported unserviceabilities at the time of the occurrence.

When the engine quit, the helicopter had about 39 U.S. gallons of Jet B fuel on board. The fuel tank was ruptured at impact by the rear landing gear cross-tube, and ground evidence at the scene indicated spillage of a considerable quantity of fuel. All fuel lines and filters were intact, and contained fuel with no visible contaminants.

Field examination of the wreckage found no evidence of pre-impact failure of any structure or systems, with the exception of the engine driven fuel pump (EDP). The EDP drive shaft could be rotated, but did not drive the pumping gears. This drive shaft disengagement was a result of excessive wear of the splines on the drive shaft and the splines in the drive gear.

The EDP (Model No. MFP263, Part No. 113300-01A1, Serial No. AKV0216), was manufactured by Chandler Evans Control Systems Division of Coltec Industries (CECo), and installed on this engine on 15 November 1995. Total time since new (TTSN) and total time in service (TTIS), at the time of failure, was 6,55.5 hours. The recommended time between overhauls (TBO) is 3,500 hours.

The EDP model MFP263 is one of a new family of pumps which have been in production since 1993, and were placed in service by Allison Engine Company on their 250 series engines in late 1994. CECo has reported that none of the MFP 263 pumps had accumulated 3,500 hours TTIS as of the occurrence date.

This occurrence was one of three failures of the same model pump reported to CECo within the period of about one week, all with the same problem of the shaft-to-gear disengagement due to spline wear. The other two aircraft were on the ground when the pumps failed at around 800 and 850 hours TTSN respectively, and were not reported as occurrences.

The pump was disassembled and all components examined at CECo, with TSB investigators, Federal Aviation Authority (FAA) inspectors, and Allison Engine Company (Allison) representatives in attendance. Components of the pump met all of the physical and metallurgical specifications, with the exception of the drive shaft and driver gear spline wear. A reddish powder deposit was found coating the passages and shaft seal; it was determined that the powder matched the specification of the spline material and had oxidized. Small sections of the splines which had previously broken away were also found in the high pressure fuel filter downstream of the fuel pump, after having passed through the pump bypass, inlet, and the pumping gears. It was not determined what caused the wear of the splines.

Several reports from operators in the field have indicated that the MFP263 pumps have a higher level of vibration and roughness during operation than equivalent pumps from other manufacturers on the same engines, and that the MFP263s are much noisier when operated
on Jet B fuel than on Jet A fuel.

Material specifications indicate that Jet B fuel has a higher percentage of naptha to kerosene than Jet A, and therefore would have lower levels of lubricity. Jet B is blended for superior low temperature combustion properties, and is more widely available in colder climates. Initial certification endurance test information regarding fuels used and times run were not available, but both fuels are approved for use.

In normal operations, fuel from the tank is delivered to the EDP by electric boost pumps at a pressure of about 15 to 20 pounds per square inch (psi). The EDP then increases the fuel pressure for delivery to the fuel nozzle in the combustion chamber. A minimum operating pressure of 30 psi is required to open the metering valve in the nozzle to initiate a primary flow condition for starting, a minimum pressure of 150 psi is required to open the valve to a secondary flow position for idle and flight power, and the maximum pressure required at full throttle is about 600 psi. Failure of the EDP will cause the fuel pressure to drop to boost pump pressure, resulting in the closure of the metering valve, and shutting down of the engine.

Analysis

It was concluded that the engine stopped when the engine driven fuel pump failed due to the disengagement of the drive shaft splines from the driver gear splines. Because of the suddenness of the failure, the pilot had no warning that a problem existed.

The pilot was transiting at 100 feet agl when the power loss occurred, which reduced the number of landing sites available for an autorotation landing. Stretching his glide to cross a creek resulted in a decrease in rotor rpm, which affected the pilot's ability to reduce the helicopter's forward speed and rate of descent prior to touchdown. As a result, the left skid dug into the ground and the helicopter rolled onto its right side. Many factors play a role in the ability of the pilot to carry out an autorotation without damage to the helicopter. In this case cruising at a higher altitude may have eliminated the need to stretch the glide, and allowed the pilot to maintain rotor rpm to control the landing.

Findings

- The engine stopped due to fuel starvation caused by the failure of the engine driven fuel pump.

- The engine driven fuel pump failed due to excessive wear of the splines of the drive shaft and the driver gear.

- It could not be determined what caused the excessive wear of the splines.

- The pilot was flying at an altitude which reduced his choices of landing sites for the autorotation.
Causes and Contributing Factors

The engine lost power because the engine driven fuel pump failed. The cause of the pump failure was disengagement of the drive shaft splines from the driver gear splines due to excessive wear.

Safety Action

The Chandler Evans Control Systems Division is continuing to investigate a number of possible external causes of the premature and excessive wear of the splines, such as misalignment in the pump or engine gearbox, fuel contamination, harmonic vibrations, flow rate through the splines, and fuel lubricating qualities.

On 30 July 1997, Chandler Evans Control Systems Division initiated the collection of most of the 567 model MFP263 pumps that had been delivered at the time of this occurrence, for tear-down examination of the drive splines. It is reported that several pumps were found to have abnormal wear on the splines.

Allison Engine Company issued a Commercial Engine Bulletin on 21 August 1997, requiring removal and inspection of the affected fuel pumps for drive shaft backlash, which would be an indication of wear. Initial inspection is to be accomplished within 25 operating hours from receipt of the bulletin, with recurring inspections every 100 hours thereafter until further notice.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 18 June 1998.*
Air 1996

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 Occurrence Report
Collision with Terrain
Yellowhead Helicopters Limited
Bell 206B II (Helicopter) C-GWXJ
Gordondale, Alberta 8 nm SW
20 October 1997

Report Number A97W0227

Summary

The Alberta Department of Environmental Protection, Lands and Forests division, chartered the Bell 206B helicopter, serial number 1791, to conduct aerial timber management inspections. In the morning, cut blocks south of Grande Prairie, Alberta, were inspected, and areas northwest of Grande Prairie were being inspected in the afternoon. The afternoon flight reported airborne from Grande Prairie at 1338 mountain daylight time (MDT)\(^1\), and there was no further radio contact. Beginning at 1455, several attempts were made to establish radio contact with the helicopter, but there was no response. A local search helicopter, with three forestry officers on board, was dispatched at 1545, and, at 1700, they reported that they had spotted the missing helicopter. As a precautionary measure, a second helicopter was dispatched with a forestry officer and two paramedics on board to provide medical aid, if required.

The helicopter crashed approximately 52 miles northwest of Grande Prairie, in the vicinity of the cut blocks that were being inspected. The helicopter descended into the trees in a steep right-bank and steep nose-down attitude. The helicopter was destroyed by the impact and by the post-impact fire. The pilot and the two forestry officers sustained fatal injuries.

Ce rapport est également disponible en français.

Other Factual Information

Records indicate that the pilot was certified and qualified for the flight in accordance with existing regulations. He had approximately 8 280 total
flying hours, of which 6,057 hours were on the Bell 206B. He had been
with the company since the spring of 1995. Company representatives,
forestry officials, and other clients reported the pilot to be very
conscientious, capable, and safety conscious.

On 25 September 1997, a charter group arrived at the airport with an
extra passenger that the pilot had not planned for while calculating the
fuel load for the trip. To accommodate the extra passenger and remain
at or below the maximum allowable gross take-off weight, the pilot
siphoned fuel from the helicopter by inserting a hose into the
helicopter's fuel tank and siphoning into a container on the ground.
During the siphoning process, the pilot inhaled some jet fuel. After the
trip, at the end of the day, he became ill and received medical
treatment from a family physician for jet fuel aspiration and chemical
pneumonia. The pilot described his experience in a letter to Transport
Canada System Safety, Prairie and Northern Region, for distribution to
pilots. After reporting the incident to the company, he was scheduled off
flying status for ten days.

The occurrence pilot had one flight each day on the 6th and 7th of
October and did not fly again until the day of the accident. The forestry
officer who accompanied him on the morning flight reported that the
pilot was in good spirits and was his normal self. He had flown with the
occurrence pilot on approximately 12 occasions during the past year.

The logbooks and maintenance records indicate that the helicopter was
certified and equipped in accordance with existing regulations and
approved procedures. A review of company records revealed no
reported deficiencies before the flight. The main rotor hub and tail rotor
systems were undamaged by the fire and showed evidence of being
powered at the time of impact.

Damage from the impact and the post-crash fire precluded the
examination of the engine accessories and components. The engine
and the flight control components were examined at the TSB
Engineering Branch. The engine power turbine output coupling was
sheared in a manner consistent with a torsional overload. An analysis
of the metal splattered on the first stage compressor turbine blades and
on the nozzle revealed an aluminum alloy composition consistent with
the aluminum coating on the inside of the compressor scroll. The flight
control hydraulic servos were sectioned and examined, and no
indication of pre-impact damage or malfunction was found. Examination
of the hydraulic fluid drained from the servos did not reveal any
significant contamination or deterioration. Laboratory examination of the
annunciator panel revealed that no warning lights were illuminated at
impact. The emergency locator transmitter (ELT) was not found; it is
possible that it was destroyed by fire.

Tree strikes at the crash site indicate that the helicopter descended in
an approximate 90-degree right-bank and 50-degree nose-down
attitude. The first tree top was broken 35 feet above ground level and
31 feet before the impact point on the ground. Two trees, closer to the
location of the final impact with the ground, were broken in multiple
pieces. The first blade of the main rotor to strike the ground penetrated the soil 28 inches and fractured. The second blade was embedded 18 inches and remained attached to the rotor mast. The intense fuel-fed fire that erupted at impact, from the ruptured fuel tanks, burned grass and trees over an area of 50 feet by 60 feet. The two passengers were ejected from the helicopter on impact, and the pilot remained in the cockpit area.

Environment Canada's recorded weather for Grande Prairie, 52 miles southeast of the crash site, was at 1400: scattered clouds at 14 000 feet above ground level (agl), an overcast ceiling at 25 000 feet agl, a visibility of 25 miles, a temperature of 10 degrees Celsius, and the winds calm. The Dawson Creek weather, 24 miles west of the crash site, was at 1400: high broken cloud, 20 miles visibility, temperature 10 degrees Celsius, and the wind from the west at 14 miles per hour. Neither station reported a significant change in the weather pattern in the following hour. Personnel at a gas transmission plant, near the crash site, reported no unusual weather pattern during the day of the occurrence.

The Canadian Aviation Regulations (CAR) 404.04(3) states that the Minister may:

(a) request the holder of a medical certificate to undergo, before a specified date, any medical tests or examinations or provide any additional medical information, as necessary to determine whether the holder continues to meet the medical fitness requirements specified in the personnel licensing standards; and
(b) suspend, or refuse to renew, the holders' medical certificate if the holder fails to comply with the request referred to in (a) before the specified date.

CAR, Part IV 404.06(1) states the following:

...no holder of a permit, licence or rating shall exercise the privileges of the licence or rating if

(a) one of the following circumstances exists and could impair the holders' ability to exercise those privileges safely:

(i) the holder suffers from an illness, injury or disability,
(ii) the holder is taking a drug, or
(iii) the holder is receiving medical treatment.

There was no record found to indicate that the pilot had been reexamined by an aviation medical examiner after the jet fuel exposure.

Based on the postmortem examination, all three occupants died of multiple blunt injuries. The pilot had an atherosclerotic coronary heart disease with up to 75 percent stenosis of the left anterior descending and left circumflex coronary arteries. The disease was of a degree that could produce sudden unconsciousness due to abnormal heart beats also called cardiac arrhythmia. Microscopic examination of the lungs revealed no residual incapacitating changes from his jet fuel exposure.
The pilot's aviation medical reports and electrocardiograms did not reveal the presence of coronary artery disease.

Analysis

Because of the almost complete destruction of the helicopter by the crash and fire, it could not be determined whether any pre-impact failure or system malfunction contributed to this accident; however, none was identified.

The evidence gathered at the crash scene was similar to that of a weather-related accident where the pilot becomes disoriented and loses control of the helicopter due to the lack of visual cues. However, the reported weather from persons in the local area provides no supporting evidence that unusual weather patterns were present on the afternoon of the occurrence.

There is insufficient medical information available to determine the influence of the 25 September 1997 jet fuel inhalation incident and the subsequent toxic effects which may have acted on the liver, the respiratory, cardiovascular, and immune systems.

The possibility that atherosclerotic coronary artery disease caused the pilot to lose consciousness and/or to be disorientated and, subsequently, to lose control of the helicopter could not be conclusively ruled out.

The following Engineering Branch reports were completed:

- LP 170/97 - Instrument Examination
- LP 171/97 - Helicopter Components Examination
- LP 176/97 - Engine Components Examination

Findings

- Records show that the pilot was certified and qualified for the flight in accordance with existing regulations.

- Records show that the helicopter was certified and equipped in accordance with existing regulations and approved procedures.

- Most of the helicopter was destroyed by the impact forces and the post-crash fire.

- Examination of the components revealed no mechanical deficiencies that would have contributed to the accident.

- The engine was determined to be developing substantial power at impact.

- Postmortem examination revealed no residual effects from the aspiration-type chemical-induced pneumonia resulting from jet
- The pilot had advanced coronary artery disease.

**Causes and Contributing Factors**

The cause of the loss of control of the helicopter that led to a steep right-bank and nose-down descent to the ground could not be determined.

*This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 16 September 1998.*

1. All times are MDT (Coordinated Universal Time minus six hours) unless otherwise noted.

---

**Updated:** 2002-10-06  

**Important Notices**
Air 1997

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 Occurrence Report
Main Rotor Blade Separation in Flight
Rupert's Land Operations Inc.
Hughes 369D (Helicopter) C-FDTN
Provost, Alberta, 14 km N
10 December 1997

Report Number A97W0254

Summary

At about 1400 hours mountain standard time (MST)\(^{(1)}\), the pilot of the Hughes 369D helicopter, serial number 370102D, was slinging a rack of seismic equipment bags on a 50-foot lanyard. The pilot had positioned one bag and was entering a hover at about 100 feet above ground level to release another bag. The cyclic control suddenly began to vibrate violently, and the nose of the helicopter pitched down. In an attempt to level the helicopter, the pilot applied full aft cyclic, but the machine descended and struck the ground heavily in a nose-down, left-side-low attitude. The helicopter came to rest laying on its left side, breaking the left cross tubes and left skid tube. The tail boom had separated in flight, and the main rotor blades were curled from ground contact. The fuel tank ruptured and was leaking into the cockpit. Seismic workers called for medical assistance for the pilot, who was dazed, and helped remove him from the wreckage. The pilot was taken by ambulance to a local hospital. Later, seismic workers located a main rotor blade about 1,200 feet south of the accident site. Ce rapport est également disponible en français.

Other Factual Information

The Hughes 369D helicopter is equipped with five main rotor blades (Part No. 369D21100-517), which were installed as a set on 17 July 1995. The colour of paint on the blade attachments nuts indicates the respective blade installation location. At the time of the occurrence, the accumulated flight time of the blade assembly was about 2,461 hours, except that the blue blade had 86 hours less because it was out of service for abrasion strip repairs. The blades have a normal service life of 3,530 hours.
The recovered blade (serial no. 009999-H709), referred to as the green blade, had failed and separated from the helicopter because of chordwise cracking just outboard of the lower blade attachment fitting. The spar, blade skin, and doubler exhibited indications typical of a fatigue-related failure. TSB Engineering Branch examination of this rotor blade revealed that the crack had initiated in the lower inboard doubler and propagated in a chordwise direction through the blade skin and spar. Investigation revealed that a batch of doublers used for production blade assembly were initially rejected as non-conforming yet were subsequently used. The nature of the non-conformance was a break or increase in the curvature of the doubler relative to the blade skin. Such a defect would allow variations in the thickness of the adhesive layer and possible regions of poor bonding during the assembly. In addition to the reduction in load transfer brought about by the adhesive disbonding, stress analysis has shown that the non-conforming doubler can introduce significant residual stresses in the doubler skin following blade assembly.

During the field examination, a similar crack was found in the same location on the blue blade (serial no. 009999-H706). Subsequent examination of the remaining blades by the TSB Engineering Branch revealed that all of them had cracks in the same location; the white blade (serial no. 009999-H708) had a half-inch crack, and the red and yellow blades (serial nos. 009999-H705 and -H707) had microcracking.

Examination of the wreckage showed that the metal surface of the pilot's seat pan was displaced downwards, and that the instrument pedestal had broken away from its base mounting and was laying against the remains of the pilot's rudder pedals and the left forward doorpost. The engine continued to run after impact and singed the exposed grass in the area below the exhaust tail pipes. The pilot's door was torn off its hinges, and the left upper plexiglass windsheild was broken during the ground impact. There was no indication found that the main rotor blades had struck the tail boom. The manufacturer's representative indicated that, in previous occurrences involving severe main rotor imbalance, lateral vibration had resulted in failure of the tail boom structure.

Records indicate that the helicopter was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The helicopter's weight and balance was within limits, and the centre of gravity was within the normal range. Entries in the aircraft logs indicate that Airworthiness Directive (AD) 96-10-09, requiring the examination of the root end fitting, had been carried out during the last 100-hour inspection on 26 November 1997, with no cracks found.

The pilot was certified and qualified for the flight in accordance with existing regulations, and had flown a total of 1,554 hours, of which 1,452 were on a Hughes 369D. The pilot was wearing a helmet and used the full seat-belt and shoulder harness available. He was occupying the left seat, as is normal in a Hughes 369D helicopter. The pilot was hospitalized with a collapsed left lung, minor abrasions to both
ankles, and chemical burns to his lower torso and left arm from fuel leakage. He also experienced a sore neck and tail bone.

The occurrence site is located in a rolling, grassy pasture area with occasional small trees and brush. The automatic weather observation system (AWOS) report for Coronation, Alberta, (50 nm southwest of Provost) at the time of the occurrence was sky clear below 10,000 feet, visibility 9 miles, wind from 270 degrees true at 7 knots, temperature -3 degrees Celsius, and dew point -7 degrees Celsius. The weather was not considered a factor in the occurrence.

Analysis

The main rotor blade failed in fatigue and separated from the helicopter under normal service loading. It is likely that the combination of a reduction in load transfer, brought about by the adhesive disbonding, and the significant residual stresses in the doubler skin following blade assembly, caused the onset of the fatigue failure.

The pilot's injury pattern was consistent with the helicopter landing heavily on the left skid. Despite the use of the complete available harness and a helmet, the pilot was subjected to severe left lateral and vertical forces, as evidenced by the downward displacement of the seat pan and damage to the pilot's door. When the helicopter came to rest, the pilot was unable to extricate himself from the wreckage without assistance.

The following TSB Engineering Branch report was completed:

LP 190/97 - Main Rotor Blade Examination

Findings

- A main rotor blade (green) failed in fatigue, likely because of non-conforming doublers, and separated from the helicopter.

- Severe vibration from the loss of the main rotor blade resulted in separation of the tail boom.

- After the tail boom separated, the pilot was unable to maintain control of the helicopter, and it landed heavily.

Causes and Contributing Factors

The pilot lost control of the helicopter when a main rotor blade failed in fatigue and separated from the helicopter, resulting in a severe vibration causing the tail boom to separate.

Safety Action

Examination of the failed main rotor blade parts by the manufacturer resulted in the issuance of two Mandatory Service Bulletins (MSB);

SB 369D-194, on 24 December 1997, requiring visual
inspection of the root fitting area at 25-hour intervals on blades that have 1,500 or more hours of operation.

SB369D-195R1, on 23 January 1998, requiring visual inspection of the root fitting area at 25-hour intervals on specific model and serial number blades that have operated 600 or more hours.

The FAA issued two priority letters:

AD 98-01-13, on 31 December 1997, mandating compliance with the inspection requirements of SB 369D-194.

AD 98-03-15, on 29 January 1998, mandating compliance with the inspections requirements of SB 369D-195R1.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 10 June 1998.

1. All times are MST (Coordinated Universal Time minus seven hours) unless otherwise noted.
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 Occurrence Report
Collision with Terrain
Cessna 172M C-GDTK
Liverpool, Nova Scotia 2 nm West
15 December 1998

Report Number A98A0184

Synopsis

The pilot and passenger departed the Shearwater airport in a Cessna 172M aircraft, on a night visual flight rules (VFR) flight to the Liverpool airport. The flight was to include a touch-and-go at Liverpool before a return to Shearwater. About 2 ½ hours after flight departure, the Moncton Area Control Centre (ACC) was advised that an emergency locator transmitter (ELT) signal was being received by other aircraft. A search was initiated and the wreckage site was found early the next morning. The aircraft had crashed in heavily wooded terrain two nautical miles (nm) west of the Liverpool airport. The two occupants were fatally injured, and the aircraft was destroyed.

The Board determined that, during the overshoot from the approach to the airport, the pilot probably lost situational awareness as a result of spatial disorientation, and unintentionally flew the aircraft into the ground.

Ce rapport est également disponible en français.

Table of Contents

1.0 Factual Information

1.1 History of the Flight
1.2 Injuries to Persons
1.3 Damage to Aircraft
1.4 Other Damage
1.5 Personnel Information
1.5.1 General
1.5.2 Pilot Experience and Training
1.6 Aircraft Information
1.7 Meteorological Information
At 1843 Atlantic standard time (AST)\(^{(1)}\) the 25-year-old pilot and his 19-year-old brother departed the Shearwater airport on a time-building flight in preparation for the pilot's upcoming commercial flight test. The flight was to include a touch-and-go at the Liverpool airport before returning to Shearwater.

At 2112, the Moncton ACC received pilot reports of an ELT signal. A search was initiated that included the Canadian Forces, the Rescue Coordination Centre (RCC) Halifax, the Royal Canadian Mounted Police (RCMP), and the Halifax flight service station (FSS), as well as personnel from the Queens County volunteer ground search and rescue unit. The geographic location of the ELT signal was confirmed at 2235. The terrain was heavily wooded, and flares were dropped to aid in locating the aircraft. The ground search team reached the wreckage site about 0625 the next morning. The pilot and passenger had been fatally injured, and the aircraft was destroyed.

The aircraft was equipped with an altitude reporting transponder. A review of the radar data indicated that the aircraft approached the Liverpool airport from the east, turned south across runway 25/07 and

---

\(^{(1)}\) Atlantic standard time (AST)
joined the circuit left-hand downwind for runway 25. The aircraft disappeared from radar at 1100 feet above sea level (asl) while on final to runway 25 and reappeared on radar at the same altitude just west of the airport one minute and 27 seconds later; radar coverage continued for another 47 seconds. During this phase it climbed to 1300 feet, levelled off, and then descended to 1100 feet asl before disappearing from radar.

1.2 Injuries to Persons

<table>
<thead>
<tr>
<th></th>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>1</td>
<td>1</td>
<td>--</td>
<td>2</td>
</tr>
<tr>
<td>Serious</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Minor/None</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>1</td>
<td>--</td>
<td>2</td>
</tr>
</tbody>
</table>

1.3 Damage to Aircraft

The aircraft was destroyed.

1.4 Other Damage

Ground damage was restricted to mature trees in an unpopulated area.

1.5 Personnel Information

1.5.1 General

<table>
<thead>
<tr>
<th></th>
<th>Captain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>25</td>
</tr>
<tr>
<td>Pilot Licence</td>
<td>PPL</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
<td>March 1999</td>
</tr>
<tr>
<td>Total Flying Hours</td>
<td>187</td>
</tr>
<tr>
<td>Hours on Type</td>
<td>45</td>
</tr>
<tr>
<td>Hours Last 90 Days</td>
<td>39.4</td>
</tr>
<tr>
<td>Hours on Type Last 90 Days</td>
<td>39.4</td>
</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
<td>2.5</td>
</tr>
<tr>
<td>Hours Off Duty Prior to Work Period</td>
<td>5.5</td>
</tr>
</tbody>
</table>

1.5.2 Pilot Experience and Training

The pilot enrolled in the aviation flight training program with the Career Academy School of Aviation (CASA) in February 1997. He completed his private pilot training, received his licence in April 1998, and continued towards a commercial pilot licence rating until CASA closed their operation in August 1998. The Nova Scotia Department of Education facilitated the continuation of flight training for the CASA
students in October 1998 through a Nova Scotia Community College aviation diploma program, with the Shearwater Flying Club providing the required flight training portion of the syllabus.

The pilot was issued his night endorsement in July 1998 and, at the time of the occurrence, had about 187 hours total flight time. His pilot logbook showed 13.5 hours dual night instruction, 12.9 hours (night) pilot-in-command, 10.1 hours instrument (hood) training, and 3.3 hours flight simulator time. He had flown to the Liverpool airport on four previous occasions within the past six weeks. Three of the flights were conducted at night with either an instructor or another licensed pilot on board; the accident flight was the first night flight without another pilot on board. The pilot had about 45 hours total flight time in the Cessna 172 aircraft and all of this time was within the five months preceding the accident. The Canadian Aviation Regulations (421.42) require, in part, a minimum of 10 hours dual instrument time for a night endorsement.

The pilot flew with his instructor on the morning of the occurrence, booked the aircraft for the night flight to Liverpool, and returned home early in the afternoon. He slept several hours before having supper and departing for the Shearwater airport. The pilot was reported to have been well rested and in good spirits when he left home. Interviews with his instructors did not identify the presence of any attitude, judgement, or piloting deficiencies other than those expected as part of the student-pilot training environment. The pilot was considered conscientious and one who took a keen interest in all flying-related subjects.

1.6 Aircraft Information

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Cessna Aircraft Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and Model</td>
<td>C172M</td>
</tr>
<tr>
<td>Year of Manufacture</td>
<td>1976</td>
</tr>
<tr>
<td>Serial Number</td>
<td>172 - 66720</td>
</tr>
<tr>
<td>Certificate of Airworthiness</td>
<td>28 April 1977</td>
</tr>
<tr>
<td>(Flight Permit)</td>
<td></td>
</tr>
<tr>
<td>Total Airframe Time</td>
<td>1820.1</td>
</tr>
<tr>
<td>Engine Type (number of)</td>
<td>Lycoming O 320 -E2D (1)</td>
</tr>
<tr>
<td>Propeller/Rotor Type (number of)</td>
<td>McCauley 1C160 DTM - 7553 (1)</td>
</tr>
<tr>
<td>Maximum Allowable Take-off Weight</td>
<td>2300 lbs</td>
</tr>
<tr>
<td>Recommended Fuel Type(s)</td>
<td>80/87, 100LL</td>
</tr>
<tr>
<td>Fuel Type Used</td>
<td>100LL</td>
</tr>
</tbody>
</table>

The aircraft's last maintenance inspection was a 200-hour scheduled inspection carried out on 13 November 1998. A 50-hour inspection was due following the completion of the occurrence flight. There had been no aircraft unserviceabilities or unscheduled maintenance action recorded in the aircraft journey log or aircraft technical log since completion of the 200-hour inspection. The aircraft had 1820 hours
total time since new, and the engine had 504 hours time since overhaul in 1996. The aircraft had been flown by the occurrence pilot and his instructor earlier on the day of the occurrence, and there were no deficiencies identified at that time. A review of the aircraft's technical records indicated that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The computed aircraft weight at the time of the occurrence was 2049 pounds, and the centre of gravity was within limits.

1.7 Meteorological Information

1.7.1 Weather Observation Stations

There are two aviation weather observation stations near the Liverpool airport: Greenwood, 42 nm north, and Yarmouth, 60 nm southwest. There is also a marine automatic weather station at Western Head, 17 nm to the southeast, and a provincial highway weather station at Bridgewater, 22 nm to the east.

On 15 December 1998, the weather observations for 2000 were as follows:

Greenwood--reported surface winds 230 degrees true at 9 knots, visibility 15 statute miles (sm), temperature 4 degrees Celsius, dew point 0 degrees Celsius, and altimeter setting of 29.82.

Yarmouth--reported surface winds 240 degrees true at 14 knots gusting to 23 knots, visibility 12 sm, sky clear, temperature 6 degrees Celsius, dew point 3 degrees Celsius, and altimeter setting 29.92.

Western Head--reported winds 240 degrees true at 13 knots, temperature 4.5 degrees Celsius, dew point minus 1 degree Celsius.

Bridgewater--reported surface winds 292 degrees magnetic at 9 knots gusting to 12 knots, temperature 4 degrees Celsius, dew point 3 degrees Celsius.

1.7.2 Weather Interpretation

An interpretation of available weather information shows that, at the time of the occurrence, the Liverpool area was under clear skies with no restrictions to visibility. The surface temperature was 5 degrees Celsius and the winds were 15 knots with gusts to 25 knots. The freezing level was at 10 000 feet with no possibility of icing at lower levels. The presence of moderate mechanical turbulence was expected from the surface to 4000 feet above ground level (agl); this was supported by several pilot reports (PIREP) of weather conditions in flight, which indicated low-level turbulence that day. There was no indication of windshear.
The moon was positioned 50 degrees below the horizon at the time of the accident, and pilot reports indicated that dark sky conditions existed; there would have been fewer visual cues than would have been present during his previous flights to Liverpool.

1.8 Aids to Navigation

The Liverpool airport has a non-directional beacon.

1.9 Communications

The pilot had contacted the Halifax FSS at 1852 to confirm that the aircraft's flight plan had been activated. At that time the pilot was provided with the Yarmouth and Greenwood altimeter settings, 29.92 and 29.82 respectively, and the Yarmouth surface winds of 240 degrees magnetic at 17 knots gusting to 24 knots.

Several local residents, who had frequency scanning equipment for recreational purposes, had been listening on their scanners about the time of the accident. They reported hearing a pilot transmit his intentions to fly across the active runway and join the circuit downwind for a touch-and-go on runway 25 at the Liverpool airport. One of the listeners had been a commercially licensed pilot and, as an avid scanner user, recognized the pilot's voice as a previous visitor to the Liverpool airport. The listener remarked that the occurrence flight was the only air traffic that had broadcast to land at Liverpool that night. The listener also remarked that there was no inflection in the pilot's voice to suggest the pilot was experiencing difficulty with the flight. There was no known other communication from the pilot.

1.10 Aerodrome Information

The Liverpool airport (CYAU) is a regional, certified aerodrome operated by Queens Municipality, is 314 feet asl, and has a paved runway 3937 feet long and 75 feet wide oriented 250/070 degrees magnetic. The runway lighting system was Aircraft Radio Control of Aerodrome Lighting (ARCAL) type J, and could be remotely activated on the Liverpool UNICOM frequency by keying the microphone five times within five seconds; once activated, the lights remain on for 15 minutes unless keyed again by the pilot.

1.11 Flight Recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder, nor was either required by regulation.

1.12 Wreckage and Impact Information

1.12.1 General

The aircraft descended into mature trees about 2 nm beyond the departure end of runway 25 at Liverpool, on a magnetic heading of 270 degrees. The aircraft was 44 feet above the ground in a wings-level, 30-degree descent angle when the right wing struck trees, leaving wing
structure and a partial section of aileron lodged in the trees. Further tree impact displaced the left wing aft along the fuselage, and the aircraft came to rest in a nose-down, 45-degree right-bank attitude. The impact ruptured both wing fuel tanks, spilling the contents onto the ground. There were several propeller strike marks on trees along the wreckage trail; the marks were consistent with the propeller being powered at impact.

The fuselage was extensively damaged, which compromised the cabin integrity. The floor structure, including the seat tracks, had buckled, and the rudder pedals and surrounding floor/firewall structure were crush damaged. The engine separated from the fuselage, and the propeller and propeller flange separated from the engine crankshaft. The engine and propeller came to rest several feet forward of the fuselage. The wing flaps were retracted at the time of impact.

The cockpit controls were positioned as follows: engine mixture control full rich; throttle control displaced at a near idle position; carburetor heat full cold; engine primer in and locked; magnetos on both; and, fuel selector on both. No reliable information could be derived from the electrical switch positions due to the nature of the impact damage. The elevator trim tab position was consistent with a slight nose-down trim setting, normal for final approach for a touch-and-go landing. An aircraft established in the climb phase would normally have the elevator trim reset to a slightly nose-up trim position; however, this trim position would not have affected the aircraft's controllability and, therefore, was not considered a factor in the occurrence.

1.12.2 Engine and Propeller

The engine was examined at the TSB regional wreckage examination facility in Dartmouth, NS, with personnel from the TSB, the engine manufacturer, the aircraft manufacturer, and the Shearwater Flying Club in attendance. The engine had substantial impact damage to all of the accessories; however, continuity of the accessory gear drives and engine internal components was confirmed. There was no indication of pre-impact, mechanical failure.

Spalling was observed on the intake tappet bodies of cylinders number 3 and 4 as well as on the corresponding cam lobes that action both these tappet bodies. It could not be determined to what extent, if any, this wear affected engine performance. There were no pilot reports of degraded engine performance during any of the preceding flights.

The carburettor was disassembled and the only anomaly observed was that the metal floats were compressed from the nominal dimension. This anomaly is frequently associated with a fuel system rupture during impact where a brief increase in static pressure is often sufficient to compress the metal floats.

Propeller blade damage and twist were consistent with considerable power being produced at the time of impact.
1.12.3 Exhaust Stacks

The engine exhaust stacks were sent to the TSB Engineering Branch for metallurgical testing and analysis. The metallurgical analysis determined that the exhaust stack material was crushed while above the 600 to 800 degree Fahrenheit temperature range, an indication that the engine was operating at impact.

1.12.4 Instruments and Light Bulbs

The aircraft flight and engine instruments and all undamaged light bulbs were examined by the TSB Engineering Branch. The engine tachometer showed a needle impact mark at 1200 revolutions per minute (rpm). The indicated airspeed (IAS) indicator needle left a witness mark on the glass face, indicating 125 miles per hour (mph). There was insufficient damage to the vacuum-driven horizon gyro to give any valid information concerning its operation at impact. The aircraft overhead instrument flood light, cabin dome light, compass light, and the tail navigation light bulbs were retrieved from the wreckage. With the exception of the dome light, the remaining bulbs would normally be illuminated during a night flight. The analysis determined that the instrument flood light bulb was illuminated at impact. The remaining lamps were either off at impact or had not received sufficient force to distort the filament.

1.12.5 Navigation Equipment

The aircraft was equipped with a Trimble model TNL 1000 global positioning system (GPS), which was sent to the component manufacturer for flight data retrieval. The last two seconds of GPS data identified that the aircraft was descending at about 4000 feet per minute (fpm) at 111 knots. The GPS recorded geographic coordinates corresponding to the occurrence site, about 2 nm west of the Liverpool airport. The last time recorded by the GPS was 15 seconds after the aircraft had disappeared from radar.

1.13 Medical Information

The pilot received an aviation medical (Category 3) in February 1997, and, as a private pilot, was due for his next medical in March 1999. In preparation for the Category 1 medical requirements for a commercial pilot licence, the pilot had received a medical examination on December 14, the day before the occurrence, and no health concerns were identified at that time. The pilot's autopsy results did not identify the presence of any pre-existing medical condition, and toxicology tests for alcohol/drugs were negative for both individuals. Blood analysis identified the presence of a low level of carbon monoxide (less than 10 per cent saturation). Both the pilot and passenger were smokers, and the carbon monoxide levels were consistent with levels observed in smokers.

1.14 Fire
There was no evidence of fire either before or after the occurrence.

1.15 Survival Aspects

The pilot and passenger were wearing their seat-belts and associated shoulder harnesses. They had received multiple injuries due to the high "g" force at impact, which compromised the cabin integrity and rendered the accident non-survivable.

1.16 Tests and Research

The TSB conducted a representative night flight to the Liverpool airport in a rented Cessna 172 at a time when light and sky conditions were similar to those of the occurrence night. The purpose of the flight was to identify the visual references available to a pilot when flying a runway 25 approach and departure/go-around.

The airport is located in a sparsely populated area where there is little peripheral lighting. The runway lights were observed clearly on approach and during the go-around phase, and the aircraft passed over a road about 1.5 miles west of the airport, where there was some street lighting in an area of houses. Beyond the road there were few external visual cues, and the horizon was not easily discernable.

The TSB flight was recorded on radar, allowing a comparison between the occurrence flight and TSB flight radar data. The TSB flight included four approaches to runway 25, with two touch-and-go landings and two go-arounds. The aircraft's altitude when passing over the road was between 1100 and 1300 feet asl, depending on whether the climb phase had followed a touch-and-go or a go-around, respectively. A comparison of elapsed time during a touch-and-go versus a go-around indicated that the pilot of the occurrence flight had conducted a go-around. Time and distance information was used to estimate that the occurrence aircraft had averaged a ground speed of 78 knots during the last 47 seconds of flight. The reported winds from the west would have provided a headwind component during the approach and go-around phase of flight, resulting in the air speed being greater than 78 knots. The estimated airspeed during the go-around was consistent with a speed at which the aircraft was controllable.

1.17 Organizational and Management Information

The Shearwater Flying Club has been in operation since 1967 and is located at Canadian Forces Base Shearwater. A general manager oversees the club's operations and reports to a Board of Directors who are elected and serve a two-year term of appointment. The club has a good working relationship, but is not affiliated, with the military base.

1.18 Additional Information

1.18.1 Witness Observations at Liverpool

The Liverpool airport was not staffed at the time of the occurrence, and no one had observed an aircraft land. An individual who was working
near the airport reported having seen an aircraft descending towards the airport and had driven there with his son to observe it land, but they were too late. He reported that the runway lights were illuminated and that he observed a flashing red light in the sky, to the west of the airport.

1.18.2 Spatial Disorientation

The most accurate sensory information available to a pilot about aircraft attitude and motion are the visual cues provided by the earth's horizon, the aircraft's flight instruments, or both. When this information is not available, such as when the horizon is obscured by darkness or weather, or when the pilot's attention is distracted from the attitude instruments for a short time, the pilot's sense of orientation may be taken over by the inner ear, a very inaccurate source of sensory information during flight. Spatial disorientation occurs when a pilot's sense or "orientation percept" of the position, motion, or attitude of his aircraft or himself with respect to the earth's surface and the gravitational vertical is based on incorrect or misinterpreted sensory information. Pilots with limited instrument flight time are most susceptible to spatial disorientation.

One form of spatial disorientation is the false climb illusion. This illusion can occur during acceleration when a pilot loses or is uncertain of visual references and relies on the inner ear rather than on the instruments. Because the inner ear cannot distinguish between gravity and horizontal acceleration, forward acceleration can generate the same perception as backward tilt (i.e., a climbing aircraft). This illusion can be experienced by pilots operating low- or high-performance aircraft.

In low visibility a pilot may attempt to counteract a perceived climb by lowering the aircraft's nose until the downward pitch of the aircraft counterbalances the apparent backward tilt caused by the acceleration, often resulting in flight into terrain. Furthermore, if the false climb illusion is reinforced by the presence of a false visual horizon (such as a shoreline or other extended cluster of lights with ocean or unlighted terrain beyond) receding under the aircraft, the pilot's compulsion to push the nose down can become overwhelming.

Knowledge and experience are the key determinants of a pilot's susceptibility to disorientation. Pilots with little instrument time are particularly susceptible to spatial disorientation when they are confronted with limited external visual attitude references. A pilot's only defence against spatial disorientation is to develop the ability to suppress natural vestibular responses through training and practice (vestibular suppression), and to always use visual information from the instruments to maintain spatial orientation (instrument discipline) and, consequently, his or her situational awareness.

2.0 Analysis

When the pilot broadcast his intentions to conduct a touch-and-go on
runway 25 there was no indication of any in-flight mechanical difficulty. The radar data time comparisons showed that following the last approach the pilot conducted a go-around rather than the planned touch-and-go. The decision to go-around normally is taken if a pilot assesses that a safe landing cannot be accomplished. Analysis of the radar data during the aircraft's climb phase on the go-around also indicated that the flight path and estimated airspeed were consistent with a normally operating aircraft in controlled flight. The aircraft was at 1100 feet asl (about 800 feet agl) when it disappeared off radar. About 15 seconds later, following a 4000 fpm rate of descent, the aircraft struck the terrain. There was no indication of a mechanical failure or pilot incapacitation.

The environmental conditions on the night of the occurrence and the limited outside visual ground references in the vicinity of the Liverpool airport were elements conducive to spatial disorientation. During the go-around, false horizon and false climb illusions were both possible. A pilot's response to a false horizon illusion can result in incorrect flight control inputs for the real situation; false climb illusion can result in forward pressure on the control column and subsequent aircraft nose-down pitch attitude. At low altitude there is minimal time for a pilot to recognize an illusion and take the appropriate corrective action. The impact angle of the aircraft appeared to be more consistent with the nose-down pitch attitude associated with the false climb illusion.

The complex skill set that a pilot requires to recognize and counter the effects of spatial disorientation are developed through flight instrument training, experience, and practice. The occurrence pilot, although appropriately licensed, had minimal instrument experience; consequently, he did not have the opportunity to fully develop the skills necessary to deal with the onset of spatial disorientation. Therefore, it is probable that the pilot experienced spatial disorientation that he could not overcome, lost situational awareness, and flew the aircraft into the ground.

3.0 Conclusions

3.1 Findings

- The pilot was appropriately licensed to conduct the night VFR flight and was apparently medically fit.

- There was no indication of pilot incapacitation, and toxicology tests for drugs and alcohol were negative for both individuals.

- Blood analysis identified the presence of a low level of carbon monoxide (less than 10 per cent saturation) in both individuals; these values were consistent with levels observed in smokers.

- Records indicate that the aircraft had been maintained in accordance with existing regulations.
The pilot transmitted his intentions to carry out a touch-and-go on runway 25 at the Liverpool airport.

From a comparative analysis of radar data from the occurrence flight and the TSB representative flight, it was determined that the pilot conducted a go-around rather than a touch-and-go landing.

The aircraft's engine and flight control configuration at impact were consistent with settings used during a go-around phase of flight.

Metallurgical analysis of the engine exhaust stacks indicated that the engine was operating at impact.

The propeller blade damage and propeller cuts observed on trees along the wreckage trail indicate that the engine was developing power at impact.

There was no mechanical anomaly identified that would account for the descent into the terrain.

Conditions necessary for visual and vestibular illusions were present at the time of the occurrence.

Spatial disorientation can lead to a loss of situational awareness, which in turn can result in an inappropriate control input.

The pilot had minimal instrument experience.

The impact angle of the aircraft was consistent with the nose-down pitch attitude associated with the false climb illusion.

3.2 Causes

During the overshoot from the approach to the airport, the pilot probably lost situational awareness as a result of spatial disorientation, and unintentionally flew the aircraft into the ground.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Jonathan Seymour, Charles Simpson, W.A. Tadros and Henry Wright, authorized the release of this report on 14 January 2000.

Appendix A--List of Supporting Reports

The following TSB Engineering Report was completed:

LP 12/99--Exhaust Stack Analysis Temperature Determination
This report is available upon request from the Transportation Safety Board of Canada.

Appendix B--Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC</td>
<td>Area Control Centre</td>
</tr>
<tr>
<td>agl</td>
<td>above ground level</td>
</tr>
<tr>
<td>ARCAL</td>
<td>aircraft radio control of aerodrome lighting</td>
</tr>
<tr>
<td>asl</td>
<td>above sea level</td>
</tr>
<tr>
<td>AST</td>
<td>Atlantic standard time</td>
</tr>
<tr>
<td>CASA</td>
<td>Career Academy School of Aviation</td>
</tr>
<tr>
<td>ELT</td>
<td>emergency locator transmitter</td>
</tr>
<tr>
<td>fpm</td>
<td>feet per minute</td>
</tr>
<tr>
<td>FSS</td>
<td>Flight Service Station</td>
</tr>
<tr>
<td>g</td>
<td>G load factor</td>
</tr>
<tr>
<td>GPS</td>
<td>global positioning system</td>
</tr>
<tr>
<td>IAS</td>
<td>indicated airspeed</td>
</tr>
<tr>
<td>lbs</td>
<td>pounds</td>
</tr>
<tr>
<td>mph</td>
<td>miles per hour</td>
</tr>
<tr>
<td>nm</td>
<td>nautical miles</td>
</tr>
<tr>
<td>PIREP</td>
<td>pilot report of weather conditions in flight</td>
</tr>
<tr>
<td>PPL</td>
<td>Private Pilot Licence</td>
</tr>
<tr>
<td>RCC</td>
<td>Rescue Coordination Centre</td>
</tr>
<tr>
<td>RCMP</td>
<td>Royal Canadian Mounted Police</td>
</tr>
<tr>
<td>rpm</td>
<td>revolution per minute</td>
</tr>
<tr>
<td>sm</td>
<td>statute mile(s)</td>
</tr>
<tr>
<td>TSB</td>
<td>Transportation Safety Board of Canada</td>
</tr>
<tr>
<td>UNICOM</td>
<td>a private advisory station located at an uncontrolled aerodrome</td>
</tr>
<tr>
<td>VFR</td>
<td>visual flight rules</td>
</tr>
</tbody>
</table>

1. All times are AST (coordinated universal time minus four hours) unless otherwise stated.
Air 1998

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
Collision with Trees
Knighthawk Air Express Limited
Dassault-Breguet Falcon 20D C-GTAK
St. John's, Newfoundland
30 December 1998

Report Number A98A0191

Synopsis

Knighthawk flight 8073, a Falcon 20D aircraft, serial number 197, was a cargo flight from Gander, Newfoundland, with two pilots on board. The aircraft was on an instrument approach to runway 16 at St. John's, Newfoundland. During the approach, severe turbulence and wind shear were encountered. This resulted in a sudden loss of altitude and impact with the tops of trees. The crew executed a wind shear recovery, declared an emergency, and then carried out a second uneventful approach to the same runway. The aircraft sustained substantial damage to the left wing; there were no injuries to the crew.

Ce rapport est également disponible en français.

Table of Contents

1.0 Factual Information
  1.1 History of the Flight
  1.2 Injuries to Persons
  1.3 Damage to Aircraft
  1.4 Other Damage
  1.5 Personnel Information
  1.6 Aircraft Information
  1.6.1 Weight and Balance
  1.7 Meteorological Information
  1.7.1 Area Forecast (FA)
  1.7.2 Aerodrome Forecast (TAF) and Aviation Routine Weather Reports (METAR)
  1.7.3 Winds Aloft
  1.7.4 Mechanical Turbulence
  1.7.5 Low Level Wind Shear

1.7.5 Low Level Wind Shear

1.7.6 Downdrafts

1.8 Aids to Navigation

1.9 Communications

1.10 Aerodrome Information

1.11 Flight Recorders

1.12 Wreckage and Impact Information

1.13 Medical Information

1.14 Fire

1.15 Survival Aspects

1.16 Tests and Research

1.17 Organizational and Management Information

1.18 Additional Information

1.18.1 Altimeter Error

1.18.2 Crew Training

2.0 Analysis

2.1 Introduction

2.2 Weather Information

2.3 Crew Decision Making

2.4 Crew Information and Preparedness

2.5 Aerodrome Information

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

3.2 Other Findings

4.0 Safety Action

4.1 Action Taken

4.1.1 Safety Memo

4.1.2 Aviation Safety Advisories

4.1.3 Cautionary Information

5.0 Appendices

Appendix A - Glossary

1.0 Factual Information

1.1 History of the Flight

Knighthawk flight 8073 was being operated by Knighthawk Air Express Limited in a cargo configuration. The aircraft departed Gander for St. John's at 1445 Newfoundland standard time (NST). En route, the crew was informed that the glide slope for the instrument landing system (ILS) to runway 16 and the wind speed indicator (anemometer) at the airport were unserviceable. The crew was given an estimated wind of 150 degrees magnetic at 10 knots, gusting to 25 knots. Although the ceiling was reported below landing minima for the localizer approach to runway 16, the crew decided to attempt the approach after receiving a pilot report (PIREP) from an aircraft which had just landed on runway 16. The PIREP did not contain any comment on turbulence.
At approximately 20 nautical miles (nm) from the airport, the aircraft was cleared for the localizer approach for runway 16. During the initial part of the descent into St. John's, only light turbulence was encountered. At about 3000 feet above sea level (asl), the captain, who was the pilot flying, reduced the descent rate and speed. At about this time, a marked increase in turbulence occurred followed shortly thereafter by a rapid increase in airspeed and drift. The crew members were not overly concerned by the turbulence as they had flown into St. John's several times in the previous week and had encountered similar conditions. The crew configured the aircraft for landing and had begun a correction toward the localizer when the turbulence became severe. Shortly thereafter, there was an uncontrollable and rapid loss of altitude. The first officer believed that, during the rapid descent, he saw the ocean followed quickly by the presence of terrain. He also believed he shouted "terrain" to the captain. The captain initiated a wind shear recovery by applying maximum power and increasing the pitch attitude until the stall warning was heard. At about this time, the aircraft descended into the trees at 1515. After clipping several trees, the aircraft began to climb, the crew discontinued the approach, and an emergency was declared. During vectors for a second approach, the glide slope became serviceable and an uneventful ILS approach and landing were carried out.

1.2 Injuries to Persons

<table>
<thead>
<tr>
<th></th>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Serious</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Minor/None</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>

1.3 Damage to Aircraft

The left wing sustained the following damage: approximately three feet of the outboard droop leading edge was torn loose and curled under the wing; the outboard wing extension lower skin was twisted; and the aileron and outboard flap panel exhibited minor damage. The left wing inboard droop and fixed leading edges exhibited several substantial impact marks.
1.4 Other Damage

Ground damage was restricted to several black spruce trees in an unpopulated area. The six- to seven-foot tall trees had been broken off three to four feet above the ground.

1.5 Personnel Information

<table>
<thead>
<tr>
<th></th>
<th>Captain</th>
<th>First Officer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>27</td>
<td>35</td>
</tr>
<tr>
<td>Pilot Licence</td>
<td>ATPL</td>
<td>ATPL</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
<td>01 October 1999</td>
<td>01 September 1999</td>
</tr>
<tr>
<td>Total Flying Hours</td>
<td>4591</td>
<td>4905</td>
</tr>
<tr>
<td>Hours on Type</td>
<td>750</td>
<td>600</td>
</tr>
<tr>
<td>Hours Last 90 Days</td>
<td>195</td>
<td>140</td>
</tr>
<tr>
<td>Hours on Type Last 90 Days</td>
<td>195</td>
<td>140</td>
</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Hours Off Duty Prior to Work Period</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

1.6 Aircraft Information

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>Dassault-Breguet</td>
</tr>
<tr>
<td>Type and Model</td>
<td>Falcon 20D</td>
</tr>
<tr>
<td>Year of Manufacture</td>
<td>1969</td>
</tr>
<tr>
<td>Serial Number</td>
<td>197</td>
</tr>
<tr>
<td>Certificate of Airworthiness (Flight Permit)</td>
<td>3 January 1996</td>
</tr>
<tr>
<td>Total Airframe Time</td>
<td>20 252</td>
</tr>
<tr>
<td>Engine Type (number of)</td>
<td>General Electric CF-700-2D (2)</td>
</tr>
<tr>
<td>Maximum Allowable Take-off Weight</td>
<td>28 660 lb</td>
</tr>
</tbody>
</table>
1.6.1 Weight and Balance

The weight and centre of gravity were within the prescribed limits.

1.7 Meteorological Information

1.7.1 Area Forecast (FA)

The FA received by the crew from their dispatch prior to departure was FACN33 CYQX. However, this forecast was for the Flemish Region which did not include the area around St. John's. The appropriate FA for the St. John's region was FACN31 CYQX, issued at 1130 and 1730 UTC. FACN31 forecast moderate to severe mechanical turbulence below 3000 feet due to strong gusting surface wind.

1.7.2 Aerodrome Forecast (TAF) and Aviation Routine Weather Reports (METAR)

Before departure, the crew received a TAF for St. John's Airport, issued at 1631 UTC, which indicated that the weather for the period from 1700 to 2000 UTC would be as follows:

Surface winds 110 degrees true at 25 knots gusting to 35 knots, visibility 0.5 statute mile (sm) in light freezing rain and fog, vertical visibility 200 feet, temporarily 3 sm in light freezing rain, light snow pellets and light freezing drizzle, 1000 feet overcast.

Also received was the following METAR for St. John's Airport valid at 1800 UTC:

Surface winds 140 degrees true at 15 knots gusting to 25 knots, visibility 1 sm in light freezing rain and mist, runway 16 visual range 5000 feet, vertical visibility 100 feet, temperature zero degrees Celsius, dewpoint minus one degree Celsius, altimeter setting 29.51, remarks: fog 8 octas, present surface wind speed is estimated, pressure falling rapidly.

NOTE: The surface wind speed was estimated because the anemometer was not functioning, probably due to the freezing precipitation. A frozen anemometer was a finding in a previous report (A97H0003) and the subject of a TSB Aviation Safety Advisory circular (A970044). Over the winter of 1999/2000, Environment Canada had carried out performance evaluations of heated anemometers; however, further tests are needed to complete the evaluation.
1.7.3 Winds Aloft

The wind at 3000 feet in the St. John's area was forecast to be 180 degrees true, 39 knots. The forecast surface wind at St. John's for the landing period was 110 degrees true at 25 knots, a directional difference of 70 degrees.

1.7.4 Mechanical Turbulence

Mechanical turbulence is caused by friction between the ground and moving air (wind). In areas of relatively flat, even ground, this effect is minimal; however, if the surface of the ground is uneven, the probability and severity of turbulence increase with the asperity of the terrain and strength of the wind. Both the terrain and the wind conditions around St. John's Airport were conducive to severe mechanical turbulence.

Severe turbulence, and the wind shear and downdrafts that can be associated with it, are often contained in a relatively small area. Aircraft operating adjacent to an area of reported turbulence may experience little or no turbulence at all.

1.7.5 Low Level Wind Shear

Wind shear is defined as a change in wind speed and/or direction in a short distance resulting in a tearing or shearing effect; it can exist in a horizontal or vertical direction, and occasionally in both. The flight crew reported a significant and rapid change in drift and airspeed just before the sudden loss of altitude which were conditions typical of a wind shear encounter.

1.7.6 Downdrafts

When strong winds blow over precipitous terrain, severe downdrafts can occur on the leeward side of the terrain. Aircraft entering this area of descending terrain may encounter downdrafts of such severity that the climb performance of the aircraft is insufficient to overcome the descent. The type of terrain along the approach path to several runways at St. John's Airport, including runway 16, is conducive to these downdrafts; at least two previous accidents\(^2\) at St. John's have been attributed to this phenomenon.

1.8 Aids to Navigation

As the glide slope was unserviceable, the crew attempted a straight-in non-precision localizer approach for runway 16. The crew was using an instrument approach procedure chart effective 26 February 1998, from the Air Canada route manual.

The Canada Air Pilot (CAP) approach plates for St. John's Airport formerly contained a cautionary note which stated "Dangerous downdrafts all runways especially Runway 16 with south winds". This cautionary note was amended on 25 June 1992 and now states
"Moderate to severe turbulence may be anticipated".

The cautionary note in the Air Canada approach plate used by the crew stated:

**WARNING**

**MODERATE TO SEVERE TURBULENCE MAY BE ANTICIPATED.**

In the aerodrome/facility directory of the Canada Flight Supplement (CFS), several airport listings contain information on the probability of moderate to severe turbulence in high-wind conditions. No information in the CFS listing for St. John's Airport informs pilots of the existence of these conditions.

1.9 Communications

Communication between the aircraft and air traffic control was maintained throughout the flight.

1.10 Aerodrome Information

The field elevation at St. John's Airport is 461 feet asl. Steep cliffs and headlands rise sharply out of the ocean to the east, southeast, and northwest of the airport. The localizer approach to runway 16 extends to the northwest of the airport.

During the intermediate portion of the localizer approach for runway 16, aircraft may descend from 2000 feet asl at the initial approach fix (IAF), down to 1600 feet asl and must maintain a minimum of 1600 feet asl until over the final approach fix (FAF). While transiting from the IAF to the FAF, an aircraft crosses over cliffs which rise approximately 900 feet from the ocean. The minimum obstacle clearance altitude for the intermediate approach segment is determined by these cliffs. In this case, obstacle clearance approach design criteria found in Transport Canada's (TC) TP 308, *Criteria for the Development of Instrument Procedures*, only require the altitude on the intermediate approach to be 1500 feet asl; however, other design criteria raised the altitude to 1600 feet asl.

Section 323 of TP 308, "Minima Adjustments", states the following:

Raising the minimum descent altitude (MDA) or decision height (DH) above that required for obstacle clearance may be necessary under the following conditions:

- Precipitous Terrain. When procedures are designed for use in areas characterized by precipitous terrain, in or outside of designed mountainous areas, consideration must be given to induced altimeter errors and pilot control problems which result when winds of 20 knots or more move over such terrain. Where these conditions are known to exist, required obstacle clearance in the final approach segment should be increased. Procedure designers and
approving authorities should be aware of such hazards involved and make appropriate addition, based on their experience and good judgement, to limit the time in which an aircraft is exposed to lee-side turbulence and other weather phenomena associated with precipitous terrain. This may be done by increasing the minimum descent altitude over the intermediate and final approach fixes so as to preclude prolonged flight at low altitudes. User comments should be solicited to obtain the best available local information.

Discussions with approach designers indicated that the intermediate approach altitude of 1600 feet could be increased to as much as 1900 feet and still meet the maximum gradient for the approach.

1.11 Flight Recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder, nor was either required by regulation.

1.12 Wreckage and Impact Information

The aircraft struck the tops of trees on a 920-foot hill, slightly right of the approach path, 2 nm from the final approach fix, and 5.5 nm from the threshold of runway 16.

1.13 Medical Information

There was no indication that incapacitation or physiological factors affected the crew's performance.

1.14 Fire

There was no fire before or after the occurrence.

1.15 Survival Aspects

The timely application of wind shear recovery techniques likely prevented more serious and potentially fatal consequences.

1.16 Tests and Research

No tests or research were conducted.

1.17 Organizational and Management Information

The operator holds a valid air operator certificate issued under Part VII, "Commercial Air Services", of the Canadian Aviation Regulations (CAR). The main operating base is at Ottawa Airport and sub-bases are maintained at Toronto/Lester B. Pearson and Calgary airports. The Falcon 20 is operated under CAR 704, Subpart 4, "Commuter Operations".

1.18 Additional Information
1.18.1 Altimeter Error

The flight crew reported that the lowest indicated altimeter reading observed during the occurrence was 1300 feet asl, and the lowest observed altitude on radar was 1200 feet asl. As the aircraft struck the trees at 920 feet asl, this indicates a likely altimeter error of at least 280 feet. Altimeter errors as much as 2500 feet have been recorded in downdrafts. The aircraft altimeters were tested by the operator after the occurrence and found to be within prescribed limits.

1.18.2 Crew Training

The crew had undergone wind shear recovery training in an approved Falcon 20 flight simulator.

2.0 Analysis

2.1 Introduction

The aircraft was determined to have been serviceable for the flight and there was no indication of impairment in crew performance. Consequently, the analysis will deal with the following factors: weather information available to the crew, crew decision making, crew information and preparedness, and aerodrome information at St. John's.

2.2 Weather Information

Approximately seven minutes before the accident, the flight crew received the latest surface wind conditions at the airport which indicated the wind speed to be 15 to 25 knots estimated. The wind speed was estimated due to the fact that the wind speed indicator at the airport was unserviceable. According to the aerodrome forecast, the wind speed was expected to be 25 knots gusting to 35 knots. The area forecast indicated wind speeds of as much as 25 to 35 knots gusting to 50 knots. Based on the forecasts and the conditions encountered on approach, it is probable that the wind encountered on approach was much stronger than that which was reported to the flight crew. The forecast and actual weather conditions at St. John's were conducive to turbulence, wind shear, and downdrafts.

2.3 Crew Decision Making

The flight crew members decided to continue to their destination after they were advised that the weather was going to be below the landing minima for the only available approach. This decision was based on a PIREP relayed from an aircraft which landed safely approximately 18 minutes before the accident; the PIREP had given no indication of turbulence.

On the approach, the crew was not concerned with the presence of the moderate turbulence during the initial stages because they had flown into St. John's several times in the previous week and encountered similar conditions. However, they were not prepared for the presence of
the wind shear and the severe downdraft which followed.

**2.4 Crew Information and Preparedness**

The predominance of information regarding severe downdrafts is generally associated with thunderstorms or mountainous regions. Flight crews are provided with information, strategies, and/or training for managing their flights safely when such conditions may be encountered. However, available awareness training or information is limited for the circumstances which this crew faced in St. John's; no thunderstorms were present, and the terrain is not generally considered to be mountainous. The only weather advisory existed on the approach plates, and it provides a warning of turbulence in strong wind conditions.

The fundamental strategy for operating safely in conditions where severe weather exists is avoidance. This strategy can only be implemented if the crew has the correct information for the area in which the flight will be conducted. The FA included in the weather package that the crew had received prior to departure was not the correct forecast for the St. John's area and only forecasted light to nil turbulence.

The crew response and recovery action when the downdraft occurred were considered appropriate.

**2.5 Aerodrome Information**

The only advisory of the presence of potentially adverse conditions on approach to St. John's Airport is provided on the approach plates. A cautionary note warns pilots that they may anticipate moderate to severe turbulence; however, in previous issues of the charts, pilots were advised that dangerous downdrafts could exist on the approaches. The more appropriate warning is that which advises of the potential for dangerous downdrafts.

Pilots who approach the St. John's Airport under visual flight rules (VFR) may not have reference to the instrument approach procedure charts. As there is no mention of turbulence in the CFS, VFR pilots may be unaware of turbulence hazards around the airport.

Section 323 of TP 308, *Criteria for the Development of Instrument Procedures*, would allow for an increase in the intermediate approach altitude and FAF crossing altitude for runway 16. This increase in the minimum altitude would help to position aircraft above downdrafts and would help to limit the amount of time that aircraft would be exposed to the hazards associated with lee-side phenomena associated with precipitous terrain. It would also provide the aircraft with more terrain clearance in the event of an inadvertent encounter with a downdraft; the altitude could be increased from the present 1600 feet to as much as 1900 feet. Had this buffer been applied, it is possible that the aircraft would not have struck the trees.

**3.0 Conclusions**
3.1 Findings as to Causes and Contributing Factors

- The weather conditions on the approach at St. John's Airport were conducive to severe turbulence, wind shear, and downdrafts.

- The aircraft encountered severe turbulence and downdrafts which caused a sudden loss of altitude and subsequent impact with the trees.

- The pilot applied the correct wind shear recovery techniques.

3.2 Other Findings

- The flight crew members were certified, qualified, and trained to operate the aircraft in accordance with existing regulations.

- The weight and centre of gravity of the aircraft were within the prescribed limits.

- The cautionary note warning of downdrafts in the instrument approach procedures charts for St. John's airport was removed.

- The listing for the St. John's Airport in the CFS did not contain information which warns of the existence of severe turbulence, wind shear, and downdrafts.

- The obstacle clearance altitude on the intermediate approach does not take into account the precipitous terrain criteria contained in TP 308, *Criteria for the Development of Instrument Procedures*.

4.0 Safety Action

4.1 Action Taken

4.1.1 Safety Memo

Within days after the accident, the operator issued a safety memo to all company personnel informing them of the circumstances surrounding the accident and the potential wind shear hazard at St. John's.

4.1.2 Aviation Safety Advisories

Two aviation safety advisories have been sent to TC. One advisory has identified the absence of consideration for the wind conditions and precipitous terrain at St. John's in obstacle clearance height determination. The other advisory identified the inadequacy of pilot information regarding the potential hazardous weather/wind conditions. Both advisories suggested that these circumstances could be present at other airports in Canada.
In its response to the advisories, TC indicated that both TC and NAV CANADA concur with the subject of the advisories. Furthermore, NAV CANADA has indicated to TC that on the "Publication of Turbulence Advisories", they will implement procedures to ensure that information is available to pilots regarding potential hazardous weather/wind conditions; on the "Obstacle Clearance Criteria - Precipitous Terrain" advisory, NAV CANADA has indicated to TC that they will examine the modalities of its application at St. John’s.

4.1.3 Cautionary Information

After being informed of the lack of information on turbulence, windshear, and downdrafts in the CFS, NAV CANADA is initiating action to include this information in the CFS.

TC is also advising the regional managers of Aerodrome Safety to be vigilant in ensuring that relevant cautionary notes on approach plates are also provided in the appropriate sections of the CFS.

*This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board authorized the release of this report on 07 June 2000.*

Appendix A - Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>asl</td>
<td>above sea level</td>
</tr>
<tr>
<td>ATPL</td>
<td>airline transport pilot licence</td>
</tr>
<tr>
<td>CAP</td>
<td>Canada Air Pilot</td>
</tr>
<tr>
<td>CAR</td>
<td>Canadian Aviation Regulations</td>
</tr>
<tr>
<td>CFS</td>
<td>Canada Flight Supplement</td>
</tr>
<tr>
<td>DH</td>
<td>decision height</td>
</tr>
<tr>
<td>FA</td>
<td>area forecast</td>
</tr>
<tr>
<td>FAF</td>
<td>final approach fix</td>
</tr>
<tr>
<td>IAF</td>
<td>initial approach fix</td>
</tr>
<tr>
<td>ILS</td>
<td>instrument landing system</td>
</tr>
<tr>
<td>lb</td>
<td>pound(s)</td>
</tr>
<tr>
<td>MDA</td>
<td>minimum descent altitude</td>
</tr>
<tr>
<td>METAR</td>
<td>aviation routine weather report</td>
</tr>
<tr>
<td>nm</td>
<td>nautical mile(s)</td>
</tr>
<tr>
<td>NST</td>
<td>Newfoundland standard time</td>
</tr>
<tr>
<td>PIREP</td>
<td>pilot report of weather conditions in flight</td>
</tr>
<tr>
<td>sm</td>
<td>statute mile(s)</td>
</tr>
<tr>
<td>TAF</td>
<td>aerodrome forecast</td>
</tr>
<tr>
<td>TC</td>
<td>Transport Canada</td>
</tr>
<tr>
<td>TSB</td>
<td>Transportation Safety Board of Canada</td>
</tr>
<tr>
<td>UTC</td>
<td>coordinated universal time</td>
</tr>
<tr>
<td>VFR</td>
<td>visual flight rules</td>
</tr>
</tbody>
</table>
1. All times are NST (Coordinated Universal Time (UTC) minus 3.5 hours) unless otherwise stated.

2. Occurrence numbers A85A4048 and A91A0044

Updated: 2002-10-06

Important Notices
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
Loss of Control
Air Satellite Inc.
Britten-Norman BN2A-26 C-FCVK
Pointe-Lebel, Quebec
07 December 1998

Report Number A98Q0194

Synopsis
Air Satellite's Flight 501 was scheduled to fly from the airport at Baie-Comeau, Quebec, to Rimouski. After a five-hour delay because of adverse weather conditions, the Britten-Norman aircraft, serial number 2028, took off at 1109 eastern standard time. Eight passengers and two pilots were on board. The reported ceiling was 800 feet, the sky was obscured, and visibility was 0.5 statute mile in moderate snow showers. Shortly after take-off, the aircraft, which was climbing at approximately 500 feet above sea level, pitched up suddenly and became unstable when the flaps were retracted while entering the cloud layer. The pilot-in-command pushed the control column down to level the aircraft. After deciding that the aircraft could not safely continue the flight, he began turning left to return to Baie-Comeau. While turning, the aircraft rolled rapidly to the left and began to dive. The aircraft crashed into the St. Lawrence River approximately 0.5 nautical mile from shore and less than 1 nautical mile from the airport. Four passengers were fatally injured in the crash. Two passengers died while awaiting rescue, which came 98 minutes after take-off. The body of the co-pilot was carried away by the current and has not been recovered. The pilot-in-command and two passengers sustained serious injuries.

Ce rapport est également disponible en français.

Table of Contents
1.0 Factual Information
1.1 History of the Flight
1.1.1 Pre-flight Planning and Activities
1.1.2 Startup and Taxiing
1.1.3 Take-off and Flight
1.2 Injuries to Persons
1.3 Damage to Aircraft
1.4 Other Damage
1.5 Personnel Information
1.5.1 General
1.5.2 Pilot-in-Command
1.5.3 Co-pilot
1.5.4 Pilot and Co-pilot Training
1.5.4.1 Initial Company Training
1.5.4.2 Flight and Stall Training
1.5.4.3 Wind Shear Training
1.5.4.4 Surface Contamination Training
1.5.4.5 Crew Resource Management and Pilot Decision-Making Training
1.6 Aircraft Information
1.6.1 General
1.6.2 Aircraft Information
1.6.3 Weight and Balance
1.6.4 Flight Controls
1.6.5 Electrical System
1.6.6 Anti-icing and De-icing System
1.6.7 Flight Instruments
1.6.8 Stall Warning System
1.6.9 Seat Belts
1.6.10 Emergency Locator Transmitter
1.6.11 Engines and Propellers
1.6.11.1 Engines
1.6.11.2 Propellers
1.6.12 Technical Records and Airworthiness
1.6.13 Take-off Performance
1.6.14 Flight Characteristics During a Stall
1.6.15 Operational Considerations in Case of Snow or Ice on Critical Surfaces
1.7 Meteorological Information
1.7.1 Area Forecasts
1.7.2 Aerodrome Forecasts
1.7.3 Regular Weather Reports
1.7.4 Analysis of Weather Conditions by Environment Canada
1.7.5 Other Information
1.8 Aids to Navigation
1.9 Communications
1.10 Aerodrome Information
1.11 Flight Recorders
1.12 Wreckage and Impact Information
1.13 Medical Information
1.14 Survival Aspects
1.14.1 Evacuation of Occupants
1.14.2 Lifejackets
1.14.3 ELT Signal Received by Search and Rescue Satellite
1.14.4 Nav Canada Procedure
1.14.5 Baie-Comeau Airport Emergency Plan
1.15 Tests and Research
1.16 Organizational and Management Information
1.16.1 General
1.16.2 Management Organization and Company Operation
1.16.3 Maintenance Department
1.16.4 Flight Operations
1.16.5 TC Safety Overview
1.16.5.1 Regulatory Audit of Maintenance Department
1.16.5.2 Regulatory Audit of Flight Operations Department
1.17 Additional Information
1.17.1 De-icing Regulations
1.17.2 Aerodynamic Effects of Icing
1.17.3 Air Satellite's Procedure in Case of Contamination of Critical Surfaces
1.17.4 Stall
1.17.5 Air Satellite's SOP Manual
1.17.6 ELT Model 406

2.0 Analysis

2.1 General
2.2 Flight Planning
2.2.1 Weather Conditions
2.2.1.1 Turbulence and Wind Shear
2.2.1.2 Type of Precipitation While the Aircraft was Outside
2.2.1.3 Crew's Decision Not to Remove Snow From Aircraft
2.2.1.4 Weather Conditions in Rimouski and Mont-Joli at Take-off
2.2.2 Aircraft Load
2.2.3 Pre-flight Check
2.2.3.1 Engines and Electrical System
2.2.3.2 Co-pilot's Shoulder Harness
2.2.3.3 Stall Warning System
2.3 The Flight
2.3.1 Taxiing
2.3.2 Choice of Take-off Runway
2.3.3 Take-off Roll and Flight
2.3.4 Stall and Impact
2.4 Survival Aspects
2.4.1 Emergency Message and Distress Signal
2.4.1.1 Emergency Message and Communications
2.4.1.2 ELT Operational Condition
2.4.2 Installation of ELT
2.4.3 Stations Capable of Receiving ELT Signal From Accident Site
2.4.4 Lifejackets
2.4.5 Baie-Comeau Airport Emergency Plan
2.4.6 Nav Canada Procedures
2.5 Flight Crew
2.5.1 Pilot-in-Command
2.5.2 Co-pilot
2.6 Company Management
2.6.1 Maintenance
2.6.2 Operations
2.7 Transport Canada Regulatory Control

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors
3.2 Findings as to Risk

4.0 Safety Action

4.1 Action Taken

5.0 Appendices

Appendix A: Weights Used for the Flight and Weights Estimated
1.0 Factual Information

1.1 History of the Flight

1.1.1 Pre-flight Planning and Activities

On 07 December 1998, the Britten-Norman BN2A-26, registration C-FCVK, operated by Air Satellite, was to take off at 0615 eastern standard time\(^{(1)}\) for a scheduled flight (ASJ501) between Baie-Comeau and Rimouski, Quebec. The departure was delayed until an area of freezing rain, which was causing severe clear icing, left the Baie-Comeau and Rimouski areas.

The pilot-in-command arrived at the company's premises at the Baie-Comeau airport at approximately 0445 to conduct a walkaround inspection of the aircraft and carry out the pre-flight preparation. While the aircraft was in the Air Satellite hangar, where the aircraft had been placed the night before, the pilot-in-command checked all the systems described in the flight manual. No irregularities were found. At about 0900, the door of the hangar was opened to allow the aircraft to reach the outside temperature. This was done to prevent the snow that was falling from turning to ice on contact with the warm surfaces of the aircraft.

After receiving the relevant weather information, the pilot-in-command filed an instrument flight rules (IFR) flight plan with the flight service station (FSS) in Québec. The plan specified a flying time of 30 minutes to Rimouski and a flight endurance of four hours.

C-FCVK was brought out of the hangar between 1000 and 1015. The pilot-in-command and the co-pilot performed the runup and completed the usual inspection of the aircraft's systems, including the carburettor heat. After being informed that there would be eight passengers, the pilot-in-command asked Air Satellite's flight monitoring attendant to enter 500 pounds of fuel on the Air Satellite weight and balance sheet.

At about 1030, the pilot decided to fill the tanks up with 800 pounds of fuel in case landing would be impossible due to the adverse weather in Rimouski and the marginal conditions in Mont-Joli. The pilot-in-command decided that it was not necessary to de-ice the aircraft. He noticed a very light layer of snow on the wingtips, but the wing surfaces in general, and particularly behind the engines, looked clean. At about 1045, the passengers boarded the aircraft, and the baggage was loaded. At 1048, the co-pilot received the latest weather conditions for Baie-Comeau and Mont-Joli.

1.1.2 Startup and Taxiing
The pilot-in-command gave the passengers a safety briefing, then taxied to taxiway Delta, where he stopped on the apron. At 1058, the co-pilot, who was in the right-hand seat, contacted the Mont-Joli FSS to request IFR clearance to Rimouski. The FSS specialist first asked the co-pilot to keep clear until five snow removal vehicles had left the runway, then informed her that the preferred runway was Runway 28 and that the wind was calm. He then informed the crew that, after take-off from Baie-Comeau, they would have to proceed to the MIWAK waypoint fix, where they could expect to wait 5 to 10 minutes before continuing the flight to Rimouski. To avoid the expected delay, the pilot-in-command decided to take off from Runway 10, as suggested by the specialist. Finally, at 1103, the pilot-in-command was informed that no delay was expected at the MIWAK fix and that he could take off from Runway 10 or 28. After observing from the wind sock covered with ice that the wind, although calm, was favourable for Runway 28, the pilot-in-command decided to take off from Runway 10.

At 1104, snow removal vehicles cleared the runway and taxiway Delta. Mont-Joli FSS issued a take-off clearance to ASJ501 for a MIWAK One standard instrument departure on Runway 10. The aircraft taxied onto taxiway Delta and turned left onto the runway, taxied toward the threshold of Runway 28, then turned around to taxi to the threshold of Runway 10.

1.1.3 Take-off and Flight

Before taking off, the pilot-in-command briefed the co-pilot on the division of tasks, critical speeds, and the procedure in case of problems. It was agreed that the pilot-in-command was the pilot flying and that the co-pilot would be responsible for air traffic control (ATC) communications, monitoring the instruments, and reporting any irregularities. The selected rotation speed was 65 knots. It was also agreed that, if a failure occurred in IFR meteorological conditions, the pilot-in-command would continue the flight under IFR rules and would return to Runway 10 for an approach using the instrument landing system (ILS). The appropriate communication and navigation frequencies were set accordingly. The pilot-in-command also started the propeller de-icing unit, the stall warning system, the pitot heating, and the windshield heat panel. This procedure is the appropriate procedure for the prevailing weather conditions.

The aircraft, flaps extended 25°, was aligned on the runway centreline, and the pilot-in-command advanced the throttle to full throttle. At 70 knots, he pulled back on the control column for take-off. At 1109, the co-pilot told the Mont-Joli FSS that they had taken off from Runway 10. Forty seconds later, she read back the instructions received from the FSS specialist to contact the Montréal Area Control Centre (ACC) on 134.65 MHz. This transmission was the last received from Flight ASJ501. Shortly after take-off, the pilot-in-command reduced engine power to a climb setting. The aircraft climbed on a runway heading at a climb rate of approximately 500 feet per minute and a speed of approximately 100 knots. At 500 feet above sea level (asl), the airplane turned right to intercept radial 182 outbound of the
Baie-Comeau VOR (very high frequency [VHF] omnidirectional radio range), toward the MIWAK waypoint fix, in accordance with the MIWAK One standard departure procedure.

After initiating the turn but before entering the cloud layer, the pilot-in-command retracted the flaps. According to the after take-off checklist, flaps should be retracted before climbing power is set. Almost immediately, the nose of the aircraft pitched up suddenly; the aircraft's general stability seemed greatly reduced. The pilot observed that the aircraft's speed dropped to approximately 70 knots. In response to the aircraft's behaviour, he immediately extended the flaps to 25\(^\circ\), then lowered the nose of the aircraft. He could see the ground through the left window. While making a slightly banked left turn to land on Runway 28, he informed the co-pilot that he was returning to Baie-Comeau immediately. Shortly after beginning the turn, the left wing tilted toward the water, and the aircraft pitched downward. The pilot pulled on the control column and turned the control wheel to the right to level the aircraft. The aircraft crashed into the St. Lawrence River approximately 1 nautical mile (nm) from the end of Runway 10, 0.5 nm from shore. The accident occurred at 1111, in less than two feet of water, during a rising tide. C-FCVK was found at noon by a child watching the river. A helicopter arrived at the crash site at 1236 and had to make two trips. Three people were found on top of the cabin. The last survivors were evacuated at 1247. The three survivors were suffering from hypothermia and had serious injuries.

### 1.2 Injuries to Persons

<table>
<thead>
<tr>
<th></th>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Missing</td>
<td>1*</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Serious</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Minor/None</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>8</td>
<td>-</td>
<td>10</td>
</tr>
</tbody>
</table>

* Missing and presumed drowned.

### 1.3 Damage to Aircraft

The TSB's investigators had to wait until the police search was completed three days after the accident before they were allowed to examine the crash site. The fuselage forward of the wing, including the cockpit and the first row of passenger seats, was bent 20\(^\circ\) to the right of the cabin. The tail, immediately aft of the wing, was almost broken off. The skin of the aircraft was torn behind the rearmost passenger seat, leaving a large hole measuring approximately 60 cm in the left fuselage. The tail remained attached to the main body of the wreckage by the control cables and by some 20 cm of the roof's skin. The tail was bent 30\(^\circ\) to the right of the cabin. The wings and the carry-through structure, above the second and third rows of the cabin, had collapsed, crushing the side panels of the fuselage. The floor was crushed.
upward, with heavy hydraulic deformation.

The two main landing gears tore off on impact and could not be found because they were washed away by the tides and the current. The left stabilizer was bent about 90°. The antenna of the emergency locator transmitter (ELT) was intact. The left wingtip was completely torn off. The right aileron was torn at the inboard end of the wing. The doors were not found.

1.4 Other Damage

An unknown quantity of motor oil was released into the St. Lawrence River when the fill tubes broke on impact.

1.5 Personnel Information

1.5.1 General

<table>
<thead>
<tr>
<th></th>
<th>Pilot-in-Command</th>
<th>Co-pilot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>40</td>
<td>24</td>
</tr>
<tr>
<td>Pilot Licence</td>
<td>Commercial</td>
<td>Commercial</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
<td>April 1999</td>
<td>November 1999</td>
</tr>
<tr>
<td>Total Flying Hours</td>
<td>1098</td>
<td>679</td>
</tr>
<tr>
<td>Hours on Type</td>
<td>234</td>
<td>68</td>
</tr>
<tr>
<td>Hours Last 90 days</td>
<td>82</td>
<td>66</td>
</tr>
<tr>
<td>Hours on Type Last 90 days</td>
<td>82</td>
<td>34</td>
</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
<td>6.4</td>
<td>6</td>
</tr>
<tr>
<td>Hours off Duty Prior to Work Period</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

The crew was certified and qualified for the flight in accordance with existing regulations. The pilots flew regularly between Baie-Comeau and Rimouski, twice a day, five days a week.

1.5.2 Pilot-in-Command

The pilot-in-command obtained his commercial pilot's licence in February 1993. He passed the flight test for his instrument rating on his fourth try, in February 1996. At that point, he had completed 115 hours' instrument time: 57 hours' dual instrument time and 58 hours' instrument ground time, in a flight simulator. Transport Canada (TC) requires a minimum of 40 hours' instrument time, of which not more than 20 hours may be instrument ground time. The following table summarizes the pilot's first three flight tests.

<table>
<thead>
<tr>
<th>Date of IFR Flight Tests</th>
<th>Evaluation</th>
<th>Comments by Transport Canada Examiner</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 December 1994</td>
<td>Failed</td>
<td>Failed Tracking off centre during</td>
</tr>
<tr>
<td>Date</td>
<td>Result</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>9 May 1995</td>
<td>Failed</td>
<td>Did not follow holding pattern entry procedures.</td>
</tr>
<tr>
<td>7 June 1995</td>
<td>Failed</td>
<td>Failed During an engine fire exercise in the holding pattern, the pilot shut off and feathered the wrong engine.</td>
</tr>
</tbody>
</table>

From April 1996 to August 1996, the pilot worked for Patrouille aérienne du Québec as a Cessna R182 pilot. In April 1998, he began working for Air Satellite, where he completed just over 20 hours' flying time on the BN2A-26 during his line indoctrination. This was the first time he had been employed to fly multi-engine aircraft. It was also the first time he flew professionally in IFR conditions and with a co-pilot. He passed his pilot proficiency check (PPC) on the BN2A-26 on 12 May 1998; however, the TC inspector felt that seven exercises called for SBs (satisfactory with briefing). The pilot-in-command had difficulty performing six of the exercises because he did not follow the checklist and the appropriate procedures. Among other things, deficiencies were noted during four IFR approach exercises and two emergency (power loss) exercises. Coordination of the BN2A-26's crew is not evaluated during a PPC for this category of aircraft. After completion of the PPC, the TC examiner mentioned to Air Satellite's operations manager that the pilot-in-command was a rather weak pilot.

Review of the pilot-in-command's training record for flights completed from May 1998 to the end of November 1998 and the information gathered revealed that he had difficulty with IFR flying and did not follow approved checklist procedures rigorously. The pilot-in-command seemed to be unusually nervous in icing conditions. However, during a training flight on a Cessna 335 on 25 November 1998, the company's chief pilot felt that the pilot-in-command's performance was satisfactory.

The data available indicate that, at the time of the accident, the pilot-in-command had nearly 1000 hours' total flying time, including approximately 400 hours on the BN2A. A crosscheck between the aircraft logbook and the weather information shows that the pilot's commercial experience in IFR conditions amounted to about 50 instrument hours, including 30 hours with the occurrence co-pilot. According to the documents available, he had no previous winter experience. His total experience in snow conditions was four days: 20, 26, and 27 November 1998 and 04 December 1998.

The pilot-in-command had obtained his flying instructor and ground-school instructor ratings on the BN2A-26 on 29 September 1998. He received training on contamination of critical surfaces on 03 October 1998. He had not flown since 04 December 1998. On the day of the accident, he got up around 0400.

**1.5.3 Co-pilot**
The co-pilot began her flight training in February 1996. She received her IFR rating in May 1997, on her second attempt. From June 1997 to September 1997, she worked for Dynamair as an instructor. In September 1997, she was hired by Air Satellite as an instructor and a charter pilot; this was the first time she was employed to fly multi-engine aircraft. It was also the first time she had worked as a commercial pilot in IFR conditions and on an aircraft with a minimum of two pilots. Her PPC on the BN2A-26 took place on 19 June 1998. An SB was entered on the flight test report; the TC check pilot advised her to avoid losing altitude during the stall approach exercise.

She acted as co-pilot on the BN2A-26 when IFR conditions prevailed or as pilot-in-command when the conditions were visual flight rules. In September 1998, the chief pilot made an SB on the co-pilot's last line check for the pre-flight inspection and briefing. On the day of the accident, the co-pilot woke up at 0130 and 0515 to obtain the weather information from the Mont-Joli FSS.

1.5.4 Pilot and Co-pilot Training

1.5.4.1 Initial Company Training

The company required all new crew members to take a three-hour introductory course. The course was supposed to include such topics as flight planning and standard operating procedures (SOPs), wind shear, aircraft icing and other meteorological training relevant to the area of operations, anti-icing and de-icing procedures on the ground, and weight and balance control procedures. No documents indicated that either crew member had taken this course.

1.5.4.2 Flight and Stall Training

As with most small, piston-powered multi-engine aircraft, there is no flight simulator for the BN2A. Training was conducted on the particular aircraft type. During these flights, the aircraft was light and its balance was close to the middle of the prescribed range; these conditions favoured good stall characteristics. In-flight training was conducted in accordance with existing regulations.

1.5.4.3 Wind Shear Training

The dangers associated with wind shear and the recommended procedures when its presence is observed are described in the company operations manual, Aeronautical Information Publication (A.I.P. Canada), and the BN2A-26 flight manual. Because wind shear is a natural meteorological phenomenon, pilots who do not practise on a flight simulator can have only a theoretical understanding of wind shear or an understanding derived from in-flight simulations. The recovery procedure recommended in A.I.P. Canada and in Air Satellite's operations manual is to apply maximum power and the attitude corresponding to the maximum angle of attack. The investigation revealed that, although the pilot had received this training,
he did not know the recommended procedures for wind shear.

1.5.4.4 Surface Contamination Training

On 03 October 1998, the crew took a course on aircraft surface contamination. One part of the course used material developed by TC. The information from the course was included in the company operations manual and specified the following:

- In frost or snow conditions, no pilot shall begin a flight unless the aircraft has been inspected to determine whether frost, ice, or snow is adhering to its surfaces.

- The performance of an aircraft may be seriously affected by frost, ice, or snow accumulating on the wings and the control surfaces, primarily because such accumulation disrupts the regularity and uniformity of the airflow over those surfaces.

- Frost or ice on a wing increases the stall speed and reduces the rate of Climb.

- When an aircraft has been de-iced in a heated hangar and pushed outside in below-zero temperatures, the pilot should be particularly attentive to freezing of wet surfaces, formation of frost, and sublimation of water vapour into ice crystals.

- When an aircraft taxis through slushy or wet conditions, the crew should be particularly vigilant for contamination of the wheel wells, the lower surface of the aircraft, and the control surfaces.

1.5.4.5 Crew Resource Management and Pilot Decision-Making Training

Neither the pilot nor the co-pilot had taken TC-recognized courses on pilot decision making (PDM) or crew resource management (CRM). Although CRM and PDM training are known to improve air safety, Air Satellite's pilots were not required to take these courses.

1.6 Aircraft Information

1.6.1 General

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Britten-Norman Ltd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and Model</td>
<td>BN2A-26</td>
</tr>
<tr>
<td>Year of Manufacture</td>
<td>1986</td>
</tr>
<tr>
<td>Serial Number</td>
<td>2028</td>
</tr>
<tr>
<td>Certificate of Airworthiness</td>
<td>27 October 1988</td>
</tr>
<tr>
<td>Total Airframe Time</td>
<td>9778</td>
</tr>
<tr>
<td>Engine Type (number of)</td>
<td>Lycoming O-540-E4C5 (2)</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Propeller Type (number of)</td>
<td>Hartzell HC-C2YK-2CFU (2)</td>
</tr>
<tr>
<td>Maximum Allowable Take-off Weight</td>
<td>6600 pounds</td>
</tr>
<tr>
<td>Maximum Allowable Landing Weight</td>
<td>6300 pounds</td>
</tr>
<tr>
<td>Recommended Fuel Type(s)</td>
<td>Avgas 100 LL</td>
</tr>
<tr>
<td>Fuel Type Used</td>
<td>Avgas 100 LL</td>
</tr>
</tbody>
</table>

### 1.6.2 Aircraft Information

The Britten-Norman Islander is a high-wing twin-engine aircraft that can carry eight passengers and two pilots. The tops of the horizontal surfaces are more than six feet above the ground. The aircraft was certified for flight in known icing conditions. Because the aircraft did not have an autopilot system, the minimum crew for IFR flight was two pilots. The aircraft has three doors that are also used as emergency exits.

A 100-hour inspection was done on 23 November 1998, approximately 26 flight hours before the accident. The maintenance records indicate that all components were functioning on the morning of the accident. All irregularities indicated in the logbook had been corrected, except a high oil temperature reported on 23 November 1998.

### 1.6.3 Weight and Balance

The maximum allowable take-off weight was 6600 pounds, and the maximum allowable landing weight was 6300 pounds. Air Satellite's flight monitoring attendant completed the weight and balance form and the load sheet, both of which indicated a total weight of 6368 pounds. The weight of the occupants was based on the approved standard summer weights, without carry-on baggage, given in the company operations manual. According to regulations, summer weights may be used until December 14, unless it is obvious that the actual weights are higher.

<table>
<thead>
<tr>
<th></th>
<th>Summer Weight</th>
<th>Winter Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man</td>
<td>174 pounds</td>
<td>180 pounds</td>
</tr>
<tr>
<td>Woman</td>
<td>127 pounds</td>
<td>133 pounds</td>
</tr>
</tbody>
</table>

The baggage of the passengers (three women and five men) was weighed at the company's counter. The weight of the pilots' baggage was not entered on the load sheet, however; nor was it calculated on the weight and balance form. According to the company's form, the aircraft's weight and balance were within the prescribed limits for take-off from Baie-Comeau and for the scheduled landing in Rimouski 30 minutes later.

To determine whether the aircraft's weight and balance could have
affected the BN2A's flight characteristics and performance, the actual weights and their distribution on board the aircraft were estimated. The weight of the occupants was obtained from autopsy reports, information gathered, and medical reports. An additional 8 pounds per person was added, because the weights indicated did not include the weight of clothing. *A.I.P. Canada* indicates that, based on a survey, at least 8 pounds should be added to the summer weight and 14 pounds to the winter weight. The baggage could not be weighed after the accident because it was lost in the tide before the aircraft was salvaged. For weight and centre of gravity calculations, the TSB used the baggage weight as given by the company, that is, 180 pounds. An additional 20 pounds was added for the crew's baggage. This weight is conservative because no weight was entered for the total weight of the passengers' carry-on baggage.

The company's fuelling log indicates that the pilot added 233 L (380 pounds) of fuel to the aircraft's tanks before boarding. Given that the aircraft's fuel capacity was approximately 780 pounds, it may be concluded that 400 pounds of fuel was on board the aircraft before fuelling. Existing regulations required the pilot to take off with enough fuel for a flight lasting 1 hour 55 minutes. Because hourly fuel consumption was 200 pounds, the flight needed 385 pounds of fuel.

According to the TSB's estimates, the aircraft's actual weight at take-off was 6813 pounds. This estimate varies from the weight calculated by the flight monitoring attendant because of two significant discrepancies: the weight of the occupants and the weight of the fuel. It can be concluded that the aircraft was overweight at take-off and that it would have been overweight if it had landed at Rimouski after a 30-minute flight, as intended by the pilot.

Another factor that influenced the aircraft's performance at take-off was the snow accumulation on the aircraft before take-off, because the aircraft spent an hour outside while moderate snow, with a relatively high water content, was falling.

1.6.4 Flight Controls

Witness marks on the aileron hinge points and the hydraulic deformations that they sustained on impact indicate that the aileron controls were set to bank the aircraft to the left. The elevator was not damaged, except for a slight upward deformation on the left. Its servo tab was set to exert upward pressure on the elevator. The tail fin was not damaged. The recommended flap settings are 56° for landing, 25° for take-off, and flaps up for the best rate of climb. The flaps were extended 25°.

The control system was significantly damaged, but its integrity was confirmed. Examination of all components recovered showed no pre-impact failure or malfunction.

1.6.5 Electrical System
After the aircraft was salvaged, examination of the circuit-breaker panel showed that the circuit breakers for the engine revolution indicator and the audio system were open. Examination of the cables revealed no irregularities. Because no defects were reported by the pilot, it was concluded that the impact blew the breakers.

Functional testing of the two alternators was not possible because of the extent of the damage from corrosion caused by prolonged immersion in the river. Examination of the components revealed that the four alternator brushes were severely worn. The brushes, which measure 0.500 inch, are normally replaced when wear reaches the witness mark at 0.250 inch. The four brushes were worn to 0.220 inch, 0.242 inch, 0.090 inch, and 0.140 inch, respectively. According to the company's inspection program, the alternator and its belt were supposed to be checked at the 100-hour inspections. No irregularities were detected during the last inspection, performed on 23 November 1998.

1.6.6 Anti-icing and De-icing System

The anti-icing and de-icing system included a heating plate in the windshield in front of the pilot-in-command, electrically heated de-icing strips on the two propellers, de-icing boots on the wings, tail fin, and stabilizer, and a heating element for the pitot heat and the stall warning system. The switches for the pitot/stall warning system and the propeller system were switched to "on"; the other two were in the "off" position. The integrity of the electrical system was established.

1.6.7 Flight Instruments

The basic flight instruments—namely the attitude indicator, airspeed indicator, altimeter, turn and bank indicator, vertical speed indicator, and horizontal situation indicator—were in front of the pilot, on the left side of the instrument panel. The radio panel and the stall indicator were in front of the co-pilot, on the right side of the instrument panel. Because of corrosion, examination of the flight instruments did not reveal any relevant information.

1.6.8 Stall Warning System

The stall warning system includes a stall indicator that gives an audible and a visual warning, a lift sensor vane in the leading edge of the left wing, and an electrical circuit connecting the sensor to the indicator. Examination of the wreckage revealed that the right screw and nut attaching the lift sensor to the wing were missing. Although analysis of the sensor showed that the screw was not in place before the accident, it was not possible to determine how long the screw had been missing. On the ground, the system functioned normally; but in flight, the housing for the detector could pivot around the left screw and prevent the vane from closing the circuit when the aircraft approached a stall. The stall warning alarm did not sound during stall exercises performed shortly before the accident. The missing screw was not recorded in the
1.6.9 Seat Belts

The passengers were in their seats with their seat belts fastened at the time of impact. The crew members were wearing a lap belt and a diagonal harness that are part of a common system, a shoulder harness, that cannot be separated. The shoulder harness was attached to an inertia reel mounted on either side of the internal partition, close to the door mounts.

The pilot-in-command's nylon harness was partly frayed and showed signs of air friction heating. This damage probably occurred as the strap rapidly deployed and then suddenly stopped. These signs indicate that the shoulder harness functioned correctly, preventing the pilot from striking the instrument panel.

The co-pilot's shoulder harness was replaced on 21 April 1996. The inertia reel was not installed in accordance with Britten-Norman's installation standards. The reel, which was mounted vertically, was firmly attached to the door post, and the strap was turned backward. The reel should have been mounted horizontally and left free to pivot around the attachment point, and the strap should have been turned upward. Consequently, the strap was not able to stop correctly on impact and did not keep the co-pilot in place. Examination of the co-pilot's shoulder harness did not show any damage characteristic of rapid deployment and sudden stopping.

1.6.10 Emergency Locator Transmitter

The ELT (Artex 00-10-99, Narco Avionics, serial number 47005) was installed on 24 October 1988 on a mounting plate attached to the flooring behind the baggage hold bulkhead, at station 309.8. The ELT met regulatory requirements. Its housing was not water resistant. Its battery was due for replacement in November 1999. The force of the impact bent the floor upward, deforming the ELT mounting plate. Consequently, the ELT was ejected from its position and landed on the floor. The ELT was on "arm" so that it would activate automatically on impact. The ELT was capable of functioning for a short time before being damaged in the salt water. Tests have shown that a short circuit occurs when the antenna connection contacts the water surface. The antenna, on the roof of the empennage, was attached to the ELT and sustained no damage. There was no switch for the ELT in the cockpit, even though, according to Britten-Norman, the pilot should have been able to turn the ELT on from the cockpit by means of a concealed switch. Functional testing of the ELT was not possible because of extensive corrosion. However, no irregularities were seen upon examination.

Modification Instruction NB-M-676, Part D, issued by Britten-Norman, recommends installing the ELT as far up the left wall of the baggage hold as possible, at station 255.25. Because an impact generally causes less deformation to the walls than to the floor, a wall mount
lessens the risk that the ELT will be damaged or ejected in an accident. According to Britten-Norman, the recommended installation ensures the integrity of the control cables on the floor of the aircraft and facilitates access to the ELT.

The *Canadian Aviation Regulations Standards* (CARs Standards) give a general description of the ELT location. CARs Standard 551.104(c)(2)(v) states that "ELTs shall be located and mounted so as to minimise the probability of damage to the transmitter and antenna by fire or crushing as a result of crash impact." The ELT installation was approved by a TC inspector.

### 1.6.11 Engines and Propellers

The pilot-in-command did not observe any engine irregularities before or during the flight. Examination of the wreckage showed that the engine controls were locked on a power setting of approximately 75 per cent.

#### 1.6.11.1 Engines

The engines were maintained according to an on-condition maintenance program. Because of impact damage, examination of the engines had to be limited to the mechanical integrity of the assemblies. The two engines were functioning on impact. However, the examination could not determine how much power they were producing.

Examination of the left engine revealed the following irregularities:

- The gasket for the oil tank had been repaired with sealant.
- The rocker arms for cylinder No. 6 had been reversed at installation.
- Cylinders Nos. 2, 4, 5, and 6 showed signs of significant blow-by.
- The compression rings for pistons Nos. 1, 2, and 4 were broken.
- Two of the six cylinders showed signs of blow-by and had broken compression rings.

Blow-by and/or broken compression rings may result in high oil consumption and loss of power.

Examination of the right engine revealed the following irregularities:

- The model used for piston No. 3 was incorrect; a low-compression model had been installed instead of a high-compression one.
- Pistons Nos. 1, 2, 4, 5, and 6 showed signs of significant blow-by.
Pistons Nos. 1, 2, 4, 5, and 6 showed signs of significant blow-by.

- The compression rings on pistons Nos. 1, 4, 5, and 6 were broken.
- The head of piston No. 5 was punctured.
- The wear on piston No. 6 exceeded the manufacturer's standards.
- Piston No. 6 was cracked on the bottom of the forward scallop.

Normally, these irregularities would lead to a decrease in power and engine vibrations, although no vibration or power loss was reported.

A significant increase in consumption of motor oil was noted in the aircraft logbook on 01 December 1998. Average hourly consumption by the left engine increased from 0.23 L to 0.80 L, while that of the right engine rose from 0.30 L to 0.88 L.

According to the maintenance schedule, one cylinder in each row should have been removed to allow internal examination of the engines. This examination should have been entered in the engine log. No documentation indicating that this work had been done was found in the aircraft technical records.

1.6.11.2 Propellers

Both propellers showed similar damage. The impact left two marks on the right propeller's pre-load plate, corresponding to blade angles of 12° and 18°. Because blade angle tends to decrease on impact, it may be concluded that the blade angle was 18° before the crash. A blade angle of 18° is typical of an aircraft flying at low speed with a moderate to high engine setting. The right propeller had no impact marks. Neither propeller showed any sign of pre-impact failure. The condition of the two propellers and the similarity of the damage indicate that they were producing an equivalent amount of thrust at impact.

1.6.12 Technical Records and Airworthiness

The TSB reviewed the aircraft's technical records and found the following irregularities:

- There was no technical record for the on-condition maintenance program for the engines. No technical entries were found regarding the condition of the engines or the inspection required under the program approved by TC. The engine inspection program had not been followed.

- Airworthiness Directive CAA 008-10-96 was entered in the technical logs in September 1998, whereas it should have been
entered in October 1997.

- **Airworthiness Directive CAA 009-10-97** was carried out in September 1998, whereas the prescribed limit was October 1997.

- **Airworthiness Directive CAA 011-10-97** was carried out in September 1998, whereas the prescribed limit was October 1997.

- **Airworthiness Directive CAA 009-05-95** was not carried out between September 1995 and November 1998. This directive should have been carried out after 500 hours' flying time.

- The two magnetos were replaced on the left engine; no technical entry was made in the engine log, and the serial numbers of the magnetos were not entered in the technical log.

- No action had been taken regarding the "Oil temp high" defect recorded in the aircraft logbook on 23 November 1998.

To maintain an aircraft's airworthiness, the following conditions must be met:

- Maintenance of the aircraft must be performed according to an approved maintenance program and maintenance schedules.

- Any irregularities discovered must be rectified immediately, unless they are deferred according to the company's maintenance control manual (MCM).

### 1.6.13 Take-off Performance

It was reported that the aircraft lifted off immediately before taxiway Delta, after a take-off roll of some 3700 feet. The manufacturer calculated that, with flaps extended 25° and a weight of 6850 pounds at take-off, the distance required for the aircraft, without any accumulation of snow or ice, to take off from a paved, dry runway was approximately 1200 feet. According to Britten-Norman, the difference between the observed ground roll and that calculated may be attributed to a combination of all or some of the following factors: tailwind component greater than reported, aircraft weight greater than 6850 pounds, snow-covered runway, snow or ice on aircraft surfaces, and decrease in engine power. In fact, the manufacturer calculated that, even at a weight of 7500 pounds, the take-off roll for a BN2A-26 would be 3000 to 3500 feet on a runway covered with 2 cm of snow and with a tailwind component greater than 8 knots, as reported at the time of the accident.

### 1.6.14 Flight Characteristics During a Stall
According to Britten-Norman, the aircraft's stall is smooth in all configurations. For this reason, the stall warning system, which gives a visual and an audible warning, activates well before a stall. If the recovery procedure is implemented without delay, the aircraft loses little altitude. According to reports on flight tests conducted by Britten-Norman, in case of stall, the BN2, at a weight of 6600 pounds, has never lost more than 100 feet of altitude, the change in pitch attitude has never exceeded 30°, and yaw and bank attitude have never exceeded 15°. The aircraft's stall characteristics were unchanged at a weight of 6900 pounds. During power-on stalls, the nose-up angle was high and could reach 35 to 40°. The aircraft's stall speed, at a weight of 6850 pounds and with engines on, was approximately 49 knots.

1.6.15 Operational Considerations in Case of Snow or Ice on Critical Surfaces

The certification of the BN2A-26 prohibits take-off when frost, ice, or snow has accumulated on the wings, control surfaces, propellers, stabilizers, or vertical tail surfaces. The manufacturer does not have any aerodynamic performance data for the BN2A-26 when the surfaces are contaminated. However, Britten-Norman believes that the presence of snow or ice may displace the centre of gravity to the aft limit, abnormally lessening the control forces load. Normally, the aircraft noses down slightly when the flaps are up, and force must be applied on the control column to offset this tendency. If an equivalent force is applied when the surfaces are contaminated and when the aerodynamic load on the controls is low, the aircraft will suddenly pitch up.

1.7 Meteorological Information

Atmospheric environment service (AES) weather reporting stations are located at the Baie-Comeau and Mont-Joli airports, but not at the Rimouski airport. The AES station closest to Rimouski is Mont-Joli, 14 nm to the northeast. The pilots used weather information from Baie-Comeau and Mont-Joli to plan the flight to Rimouski.

1.7.1 Area Forecasts

The area forecast, valid on 07 December 1998 from 0600 to 1800, was issued at 0630 by the AES station in Mont-Joli. In summary, a cold front was east of Baie-Comeau and heading southwest. After the passage of the cold front, the forecast called for ceilings at 3000 feet asl and visibility reduced to 4 statute miles (sm) in rain and mist. Convection clouds were forecast, with rain showers that might reduce visibility to 1 to 3 sm. Precipitation north of the frontal wave would change to snow. Ceilings of 400 to 1200 feet were forecast for the area of precipitation. The wind was blowing out of the west at around 20 knots gusting to 30 to 35 knots.

Light to moderate rime icing was in clouds above the freezing point, which was at or near ground level. Moderate mixed icing was expected in the convection clouds. Moderate mechanical or wind shear
turbulence, changing to strong at times, was forecast below 5000 feet, particularly near the cold front. Convection turbulence was also expected near convection clouds.

At 0621, the Québec FSS specialist told the pilot to expect wind shear turbulence and strong wind when the cold front passed through Baie-Comeau at about 1100.

1.7.2 Aerodrome Forecasts

The morning of the accident, the actual conditions were systematically worse than stated in the aerodrome forecasts. During the 0820 and 0912 weather briefings, the Québec FSS specialist specifically warned the pilot that the aerodrome forecasts were somewhat inaccurate and that conditions would be worse than anticipated. The pilot-in-command used the Mont-Joli forecasts to select the Mont-Joli airport as an alternate aerodrome.

The Mont-Joli aerodrome forecast, issued at 0917 and valid from 0900 to 1800, was as follows: wind 040º true at 10 knots, visibility 1 sm, light ice pellets in mist, and overcast ceiling at 300 feet. Between 0900 and 1000, a temporary fluctuation: visibility 4 sm in light freezing rain and mist, and overcast ceiling at 1500 feet. At 1000, a permanent change: wind 240º true at 12 knots, visibility more than 6 sm in mist, and overcast ceiling at 3000 feet. Between 1000 and 1100, a temporary change: visibility 1 sm in light snow, ice pellets and mist, and overcast ceiling at 1500 feet. At 1100, a permanent change: wind 280º true at 20 knots gusting to 30 knots, visibility more than 6 sm and broken ceiling at 3000 feet. Between 1600 and 1800, a temporary change: scattered clouds at 3000 feet. These forecasts were available to the crew before departure from Baie-Comeau.

After the accident, a new forecast was issued at 1121 for the Mont-Joli airport, valid from 1200 to 2400. Between 1200 and 1300, the following conditions were expected: wind 280º true at 10 knots gusting to 20 knots, visibility 0.5 sm, and moderate snow showers reducing visibility and ceiling at 200 feet.

1.7.3 Regular Weather Reports

Regular weather reports are usually prepared and issued every hour. During the morning, frequent meteorological changes required special weather observations for both airports. The following pertinent weather reports were issued at Baie-Comeau:

- Baie-Comeau, corrected at 1000: Wind calm, visibility ½ sm, moderate snow, sky obscured and vertical visibility of 1000 feet above ground level (agl), temperature 0ºC, dew point 0ºC, and altimeter setting 29.35 inches of mercury (inHg). Remarks: snow covering sky 8/8, snow accumulation 3 cm (after passage of the cold front at about 0830).

- Baie-Comeau, Special observation at 1029: Wind calm, visibility
¾ sm, light snow, sky obscured and vertical visibility of 1000 feet agl. Remarks: snow covering sky 8/8, recent moderate snow.

- Baie-Comeau, Special observation corrected at 1035: Wind calm, visibility ¼ sm, light snow, overcast ceiling at 1500 feet agl. Remarks: snow covering sky 2/8, stratus 6/8, recent moderate snow.

- Baie-Comeau, 1100: Wind calm, visibility ½ sm, moderate snow, sky obscured and vertical visibility of 800 feet agl, temperature 0ºC, dew point 0ºC, altimeter setting of 29.35 inHg. Remarks: snow covering sky 8/8, snow accumulation 4 cm (after passage of the cold front around 0830).

The corrected special observation issued at 1035 was the last the crew received from Baie-Comeau. According to subsequent reports, 5.4 cm of snow fell between 0830 and 1300, and 1 cm fell between 1000 and 1100. Although the 1100 report indicated a temperature of 0ºC, the actual temperature was -0.2ºC. Conditions remained marginal until 1237 with ceilings at 200 feet agl. During the morning, equipment for measuring the wind could not be used because of the freezing rain. At 1129, based on the position of the wind sock, the observer estimated the wind to be 230º true at 7 knots. However, the cloth cone on the wind sock was covered with ice, increasing its weight.

The following pertinent weather reports were issued at Mont-Joli:

- Mont-Joli, 1000: Wind 10º true at 4 knots, visibility 1½ sm, light snow and ice pellets in mist, overcast ceiling at 400 feet agl, temperature -1ºC, dew point -1ºC, altimeter setting of 29.35 inHg. Remarks: stratus 8/8.

- Mont-Joli, Special observation at 1014: Wind 290º true at 5 knots, visibility ¾ sm, runway visual range 5000 feet for Runway 06, light snow, obscured sky and vertical visibility of 300 feet agl. Remarks: snow covering the sky 8/8.

The special observation issued at 1014 was the last received from Mont-Joli by the crew. The two subsequent reports indicated a visibility of ½ sm and a ceiling of 200 feet until 1156.

**1.7.4 Analysis of Weather Conditions by Environment Canada**

Environment Canada analyzed the area forecast, the aerodrome forecasts, and the data from the weather reports. According to Environment Canada, the most probable conditions at about 1100 near the Baie-Comeau airport are as follows: wind 230º true at 5 to 8 knots, snow showers reducing visibility to nearly ½ sm, and snow ceilings varying between 400 and 800 feet. The snow had a high water content that could result in significant icing conditions on cold objects. The reduction in visibility to ½ sm in moderate snow suggests the presence of convection clouds in the immediate area of the airport. These clouds could have generated downdrafts, causing turbulence near the ground.
Moderate wind shear was probable under 3000 feet.

1.7.5 Other Information

A Cessna 310 left Air Satellite's hangar a few minutes before C-FCVK. Approximately 20 minutes later, after refuelling, the pilot of the Cessna 310 decided to brush the snow off the aircraft with a broom. The aircraft was covered with approximately 1 cm of wet snow that was sticking "a little" to the surfaces. The aircraft took off from Baie-Comeau on Runway 28 at 1039. At about 1055, the pilot of the Cessna 310 informed the crew of C-FCVK that he had observed a little rime icing on the leading edge of the wings while climbing at 4000 feet.

1.8 Aids to Navigation

Runway 10 at the Baie-Comeau airport was served by an ILS that allowed Category I approaches. The ILS decision height was 200 feet above the touchdown zone.

The Rimouski airport was served by the Mont-Joli VOR/DME (VOR / distance-measuring equipment) and by a nondirectional beacon (NDB). These navigational aids allowed circling approaches on runways 07 and 25. Because the aircraft was not equipped with a DME, only the NDB A approach was allowed. The minimum descent altitude was 640 feet asl.

The Mont-Joli airport was served by a VOR/DME, an NDB, and an ILS. The pilot could make a precision approach on Runway 06, which had a decision height of 392 feet asl (250 feet above the touchdown zone).

The BN2A-26's equipment included two NAVCOM radios. The pilots could switch between the active and standby frequencies by pushing a button. The frequencies were set for the planned flight and, in case of emergency, a return to Runway 10 at the Baie-Comeau airport. The aircraft also had a transponder, two ADFs, and a global positioning system. The flight took place below radar coverage, which starts around 6000 feet in the Baie-Comeau area.

1.9 Communications

The pilots wore communication headsets. A pushbutton on the control column was used to operate the VHF radio. All communication equipment was functioning normally. Examination of the radio communications revealed no technical irregularities in the radio equipment. Communication between the flight crew and the FSS specialist was normal and followed established rules. The co-pilot was responsible for communication with ATC. However, the pilot decided to communicate directly with the Mont-Joli FSS to establish the expected delay at the MIWAK fix.

The VHF radio transmitter-receivers were operating and set for the following frequencies:

<table>
<thead>
<tr>
<th>Radio</th>
<th>Active Frequency</th>
<th>Standby Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMM No. 1</td>
<td>118.30 MHz (Mont-Joli FSS)</td>
<td>134.65 MHz (Montréal ACC)</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>COMM No. 2</td>
<td>131.95 MHz (Air Satellite)</td>
<td>126.70 MHz (en route)</td>
</tr>
</tbody>
</table>

The COMM selector on the audio panel was on COMM No. 1. The Montréal ACC frequency had not yet been activated even though, after take-off, the co-pilot had agreed to a request from the Mont-Joli FSS to contact the Montréal ACC.

### 1.10 Aerodrome Information

The Baie-Comeau airport is in the municipality of Pointe-Lebel and is operated by the Regional Municipality of Manicouagan County. It is certified by TC and meets the CARs requirements. The airport has been an uncontrolled airport since TC closed the control tower in 1995; that is, the airport no longer has airport controllers to control ground traffic and local air traffic. However, a control tower is still adjacent to the terminal building. The control tower is in front of taxiway Delta, 0.5 nm from the end of Runway 10 and approximately 1.3 nm from the accident site.

The airport is served 24 hours a day by FSS specialists at the Mont-Joli FSS. The FSS specialists use a remote communications outlet (RCO) to provide flight information to aircraft flying near the Baie-Comeau airport.

When the tower was closed, all radio transmitter-receivers were removed, including the one tuned to the emergency frequency of 121.5 MHz. Consequently, the Baie-Comeau RCO could not relay the ELT signal to the Mont-Joli FSS. There are no standards or regulations requiring installation of the emergency frequency at airports served by an RCO. Shortly after the accident, Nav Canada installed the 121.5 MHz frequency at the Baie-Comeau airport.

The tower, which gives an unobstructed view of the runway and the approaches, was not occupied at the time of take-off. At about 1150, the airport manager went to the tower to try to locate the aircraft, but was not successful. The TSB investigation established that a controller would not have been able to see the aircraft after the crash, even from the roof of the control tower, because of trees obstructing the view.

The Baie-Comeau airport is 71 feet asl. Runway 10 is asphalted and is 6000 feet long by 150 feet wide. Its slope is negligible. The runway had been partly cleared immediately before the aircraft taxied onto it. A surface report was done approximately four minutes after the accident; a strip 100 feet wide had been cleared along the centre of the runway, and the runway was completely covered with an uneven layer of snow that was up to 7.6 cm deep in some areas.

### 1.11 Flight Recorders

The aircraft was not equipped with flight recorders, nor were any required.
1.12 Wreckage and Impact Information

The aircraft crashed into the St. Lawrence River approximately 1 nm from the end of Runway 10, 0.5 nm from the shore. The tide had been rising since 1000, and the water temperature was 1°C. Using data provided by the Canadian Hydrographic Service of Fisheries and Oceans Canada, the water depth at the accident site was estimated as follows:

<table>
<thead>
<tr>
<th>Time</th>
<th>Water Depth (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1111 (accident)</td>
<td>20</td>
</tr>
<tr>
<td>1200 (aircraft found)</td>
<td>41</td>
</tr>
<tr>
<td>1236 (first rescue)</td>
<td>51</td>
</tr>
<tr>
<td>1247 (second rescue)</td>
<td>56</td>
</tr>
</tbody>
</table>

From this information it can be determined that the water in the cabin was at most 50 inches deep. The damage to the wings and the stabilizer indicates that the aircraft was banked 19° to the left when it struck the surface of the water. Examination of the floor of the aircraft and the tail skid revealed that the aircraft had a nose-up angle of approximately 3° at the time of impact. The tail fin was intact; there was no sign of the deformation or distortion normally associated with a violent impact. The damage to the landing gear indicates that the aircraft was side-slipping to the left at the time of impact.

1.13 Medical Information

The crew members had valid medical certificates. The co-pilot's body was not found. Autopsies were performed on the victims.

1.14 Survival Aspects

The pilot gave a pre-flight passenger briefing. In addition, passenger information cards on the aircraft identified, by means of pictograms and text, the emergency exits, the location of the ELT, the brace posture, and the operation of the safety belts. All the occupants were seated and their seat belts were fastened. When the pilot decided to return to Baie-Comeau, the crew was not able to prepare the passengers and give the necessary safety instructions. Immediately before the aircraft nosed down toward the river, the passengers seated in the first row, behind the crew, realized the imminence of the danger and leaned forward, adopting the brace posture. Appendix B gives a chronological outline of the emergency response.

1.14.1 Evacuation of Occupants
The aircraft had three rows of two seats and a two-seat bench at the rear. The pilot, the co-pilot, and the passengers in seats 1A, 1B, 4A, and 4B survived the initial impact.

Upon impact, the floor buckled upward and the wing collapsed. This destroyed the survival space of the passengers in seats 2A, 2B, 3A, and 3B, resulting in asphyxiation due to compression and drowning. The co-pilot sustained a serious facial injury and was unconscious after the crash. The pilot and the passengers in 1A and 1B freed the co-pilot from her seat and brought her up on top of the wreckage, where they awaited assistance.

The passengers in 4A and 4B, who sustained multiple injuries, were unable to move and remained seated and secured to the rearmost seat. The tide rose, bringing water up to their waists. Because of their injuries and resulting incapacity, the survivors on top of the cabin were unable to help those passengers out of the wreckage. While the pilot and the passenger from 1A held onto the co-pilot, the passenger from 1B, lying on the roof, held the head of the passenger in 4B out of the water; he did so until water submerged the cabin between 1200 and 1215. The passenger in 4A never regained consciousness after the crash and also drowned.

Shortly after the water covered the wreckage, the survivors, who were suffering from hypothermia, could no longer hold onto the co-pilot, who was carried away by the water at about 1230.

1.14.2 Lifejackets

C-FCVK flew between Baie-Comeau and Rimouski almost exclusively, making the trip twice a day, five days a week. The flight path was almost entirely over the St. Lawrence River; it was 41 nm from Baie-Comeau to Rimouski and 35 nm from Baie-Comeau to Mont-Joli.

The BN2A-26 was capable of maintaining flight in case of engine failure and did not fly more than 50 nm from the shore. Therefore, in accordance with existing regulations, the company's management did not equip the aircraft with lifejackets. The company had lifejackets in its hangar, however.

1.14.3 ELT Signal Received by Search and Rescue Satellite

No ELT signal was received, heard, or reported during the search. The ELT on board C-FCVK could broadcast a signal on the 121.5 MHz and 243 MHz frequencies. This signal could be detected by the SARSAT (search and rescue satellite-aided tracking) and COSPAS orbital satellites, or by any aircraft or radio tuned to those frequencies. However, this model of ELT was restricted to line-of-sight range.

The SARSAT system did not report any valid events for the Baie-Comeau area. A few minutes after the aircraft was found, the Rescue Coordination Centre (RCC) in Halifax, Nova Scotia, examined the
SARSAT database. Analysis of the SARSAT data revealed that an ELT signal with a very weak confidence level, 1 out of 4, was recorded by the system at 1119. The SARSAT system does not validate events with a confidence level less than 3. The recorded signal had a high intensity. According to the data, recording of the signal began at 1111 (the time of the accident) and stopped at 1115. However, the length of a recording is not precise and may differ from the actual duration of an ELT signal’s reception. The signal’s geographic position, as calculated by SARSAT, was 111 nm from the accident site. It cannot be definitely concluded from the SARSAT data that the signal detected came from C-FCVK’s ELT.

1.14.4 Nav Canada Procedure

When aircraft need aid, the Air Traffic Services (ATS) division of Nav Canada alerts the appropriate agencies, including search-and-rescue teams, ambulances, doctors, and other emergency services.

Because the required routine contact had not been established with C-FCVK and no information indicated that the aircraft had crashed, the ACC controller in Montréal and the FSS specialist assumed that the aircraft had experienced a communication failure. They therefore followed the emergency procedures for communication failure. In accordance with Part 6, "Emergencies", in the Air Traffic Control Manual of Operations, the ATS separated other aircraft from C-FCVK, blindly transmitted a description of the ATC’s actions and the weather conditions at the destination and alternate airports, tried to locate the aircraft, performed a communications search, and, finally, took the necessary measures at the airports concerned.

ATS activated the Baie-Comeau airport's emergency plan by declaring a Code White alert 18 minutes after take-off. The Montréal ACC informed the RCC that C-FCVK was in an uncertainty phase and transmitted information on the aircraft 39 minutes after a position report was to have been received. According to the Air Traffic Control Manual of Operations, the Montréal ACC should have informed the RCC after 30 minutes.

1.14.5 Baie-Comeau Airport Emergency Plan

The airport's emergency procedures manual (EPM) contains the procedures to follow in case of emergency, the responsibilities of the public and private agencies concerned, and a directory of regional agencies and resources available. Response procedures are organized by codes (Code White, Code Yellow, and Code Red). Code White, which precedes Code Yellow, is declared only when deployment of airport emergency units and the alerting of outside agencies are required. A Code White was declared 16 minutes after the crash and remained in effect almost until the aircraft was found. As soon as he was advised of the situation, 8 minutes after the crash, the airport manager began conducting his own search operation at the airport and in the surrounding area. When the wreckage was found in the St. Lawrence River, the procedure for an aerodrome within 8 km of a large
body of water was followed. In the event of a crash in the water, the EPM stated that if the crash occurred in the St. Lawrence River, assistance was to be requested from helicopter companies, such as Hydro-Québec and the Canadian Coast Guard, that have float-equipped helicopters. The EPM also provided the necessary information to reach local boat operators.

At 1210, 10 minutes after C-FCVK was found, the Sûreté du Québec (Quebec police) informed Héli-Manicouagan of the accident and asked that a helicopter be dispatched to the site. Although none of the operator's helicopters were equipped to perform a water rescue, the company's owner sent a ski-equipped Bell 206 with a pilot and an aircraft maintenance engineer on board. Because all the pilots had gone out for lunch, the helicopter did not take off until 17 minutes after the call. Héli-Manicouagan was the only helicopter operator in the Baie-Comeau area. The TSB investigation revealed the following:

- No helicopter operators were listed in the EPM.

- A crash in the water was the only emergency situation requiring the assistance of a helicopter operator.

- The possibility of a crash in the water was not included in the Code White and Code Yellow alerts.

- As early as 1205, emergency personnel tried to locate a boat and dispatch it to the site. Because of a combination of unfortunate circumstances, the difficult access to the water, the distance to be covered in rough water, and adverse environmental conditions, the first boat arrived at the scene of the accident at 1311, 21 minutes after the survivors were evacuated by helicopter.

1.15 Tests and Research

The following tests were performed:

- to determine whether the Mont-Joli FSS or another VHF station was able to receive an ELT signal from the accident site

- to define the conditions needed for reception of an ELT signal by the Mont-Joli FSS and other VHF stations at the Baie-Comeau airport

- to assess the operation of an ELT in contact with water

- to compare the data recorded by the SARSAT satellite at the time of the accident with the test results

At the accident site, an ELT was turned on for four minutes at a time. Because the RCO was now able to relay an ELT signal, Nav Canada was asked to stop its operation during some of the tests. The results of
The tests were as follows:

- The signal received by the SARSAT satellite had a confidence level of 1 and, consequently, the information was not relayed to the RCC.

- The Mont-Joli FSS did not receive the ELT signal when the 121.5 MHz frequency was not in operation at the Baie-Comeau RCO.

- The Mont-Joli FSS received the ELT signal when the 121.5 MHz frequency was in operation at the Baie-Comeau RCO.

- A VHF radio in the Baie-Comeau tower received the ELT signal.

- The ELT stopped transmitting a signal as soon as the antenna connection contacted the surface of the water.

- The ELT signal was not received at the Baie-Comeau harbour where the Canadian Coast Guard vessel was berthed.

1.16 Organizational and Management Information

1.16.1 General

Operation of C-FCVK was subject to Section 703 of the CARs, "Air Taxi Operations". At the time of the accident, Air Satellite was operating a fleet of 17 aircraft, with 10 different types, mainly single-engine and piston-powered twin-engine aircraft carrying less than 10 passengers. The company had only one BN2A-26. Air Satellite operates from its main base at Baie-Comeau and from secondary bases at Havre-Saint-Pierre, Sept-Îles, and Rimouski.

1.16.2 Management Organization and Company Operation

Air Satellite's vice-president is also the company's general manager and operations manager. She is responsible for strategic and routine management of the company. As general manager, she is the immediate superior of the maintenance manager and, as operations manager, she is the immediate superior of the chief pilot. According to the company operations manual, the operations manager must ensure that flights are conducted safely, in accordance with State rules and regulations and in accordance with the standards, practices, procedures, and specifications specified in the company operations manual.

1.16.3 Maintenance Department

Air Satellite maintained its aircraft according to a maintenance schedule approved by TC. The maintenance manager was responsible for all of
the company's maintenance activities. He also performed all administrative functions relating to maintenance: chief inspector, production manager, and head of quality control. Five apprentice aircraft maintenance engineers worked under his supervision. Three of them had four to six months' experience; the other two had two years' experience. It was not possible to determine the apprentices' training because the company did not keep records on maintenance staff.

1.16.4 Flight Operations

Like many Level 3 air carriers, Air Satellite had difficulty recruiting and keeping qualified personnel, including filling the chief pilot position. In July 1998, Air Satellite's chief pilot accepted to work for another company. He accepted to act as Air Satellite's chief pilot part-time until the position was filled permanently. Air Satellite reported the situation to TC in July 1998. After this notice, as prescribed in the procedures, TC forwarded a notice to Air Satellite advising that the company had 30 days to hire a new chief pilot on a permanent basis and that, after that date, the failure to do so might result in suspension of the company operating certificate. In September 1998, a new permanent chief pilot began employment with Air Satellite.

The chief pilot was responsible for matters relating to professional standards for the flight crews under his responsibility. Among other things, he was required to develop SOPs, develop and implement all approved training programs required for the operator flight crews, and, as necessary, provide directives, instructions, and supervision to flight crews. In addition, he had to fly regularly to assess the pilots' performance. At the time of the accident, the chief pilot did not have a PPC for the BN2A-26 and, consequently, could not be a crew member on C-FCVK. He could, however, perform a training flight in visual flight rules conditions.

Air Satellite used a pilot self-dispatch system, under which the pilot had sole responsibility for the preparation, planning, and execution of a flight. The pilot had to ensure that the flight was conducted according to existing regulations and company procedures as outlined in the operations manual. In November 1998, Air Satellite's management reviewed the experience of its pilots. The company concluded that the pilots' flight times were adequate (1000 to 2000 hours) but that the pilots had little experience in IFR and winter conditions. Consequently, the management decided that each IFR flight would have to be authorized by the chief pilot or the operations manager.

1.16.5 TC Safety Overview

Company audit frequency depends on TC's previous findings. According to TC, every air carrier holding a Canadian aviation document will be audited on a periodic cycle of 6 to 36 months or in accordance with the policy document on inspection frequency. However, a carrier may be subject to additional audits, special audits, or more frequent audits if risk management indicators are identified.
1.16.5.1 Regulatory Audit of Maintenance Department

TC conducted regulatory audits of Air Satellite's maintenance department in February 1987, September 1991, May 1993, June 1995, and September 1998. During the last audit, 21 out of 31 maintenance areas were audited. Area 3.5.7, "De-Icing Procedures and Equipment", was not audited. Several of the irregularities identified by the inspectors involved updating maintenance documents but did not compromise aircraft airworthiness. However, TC also identified irregularities relating to airworthiness of some aircraft. TC noted the following:

- The maintenance procedures manual (MPM) and the MCM did not reflect the current status of the company's activities. Many audit observations revealed irregularities needing correction.

- The company did not keep its regulatory and technical publications up to date.

- No records were kept showing that maintenance personnel received training on the company's policies and procedures. The company did not follow the programs outlined in the MPM and the MCM.

- The procedures outlined in the MCM for recording and control of important maintenance events were not followed.

- The operator deferred the correction of defects essential to the airworthiness of some aircraft.

- Inspection of the company's different aircraft revealed a number of irregularities requiring immediate action by the company that had not been reported to the maintenance organization.

- Maintenance schedules were not followed. Planned inspections were not performed within the tolerances specified by the approved programs. Special inspections were not conducted in accordance with the specifications outlined in the programs.

- Airworthiness directives were not carried out at the prescribed times, and aircraft were returned to service that should not have been.

After this regulatory audit, TC's audit manager established an audit frequency of 18 months. Air Satellite drew up a corrective plan to be implemented over several months. TC accepted all proposed corrective measures. The aircraft airworthiness deficiencies have since been corrected.

1.16.5.2 Regulatory Audit of Flight Operations Department

The last two regulatory audits of Air Satellite's flight operations were
conducted by TC in September 1991 and September 1998. The 1991 audit revealed a number of irregularities, all of which were corrected to TC's satisfaction. In September 1998, the inspectors found various deficiencies related to the responsibilities of the operations manager and the chief pilot. For example, the training program was incomplete, the pilot training records contained many errors and omissions, pilots acted as crew members when they did not have the required qualifications, and no training for flight monitoring personnel was planned. TC's evaluation of these irregularities did not reveal a direct link with factors compromising flight safety. TC's audit report concluded that "[Translation] There are obvious problems with respect to the operational management of Air Satellite Inc." The report identified the source of the problems as follows: "[Translation] Due to the size of the company's operations, required by the area, staff must be qualified and regularly trained. Frequent turnover in the chief pilot position has clearly been a source of the problems identified in the regulatory audit. The operations manager, who has a degree in business administration from a recognized university and is trained in aircraft maintenance, is investing considerable time, energy, and effort in the company, but cannot manage the company's operations by herself." The report recommended close supervision of Air Satellite by TC inspectors and an increase in the frequency of routine inspections and regulatory audits.

After this audit, Air Satellite drew up a corrective plan to be implemented over several months. TC accepted all the proposed corrective measures. After the accident, while a TC inspector was on his way to Baie-Comeau to suspend the company operating certificate, Air Satellite surrendered the certificate voluntarily and stopped its operations for 15 days. This time allowed the management to support the investigation, supervise company personnel, and take the corrective actions required by TC, including PDM training for company pilots.

1.17 Additional Information

1.17.1 De-icing Regulations

No person shall take off or attempt to take off in an aircraft that has frost, ice, or snow adhering to any of its critical surfaces. In addition, the Air Satellite operations manual states that, where conditions are such that frost, ice, or snow may reasonably be expected to adhere to the aircraft, no person shall take off or attempt to take off in an aircraft unless the aircraft has been inspected immediately before take-off to determine whether any frost, ice, or snow is adhering to any of its critical surfaces. The risks associated with icing are known and documented in many publications and letters that TC sends to pilots.

1.17.2 Aerodynamic Effects of Icing

Experimental data indicate that the formation of frost, ice, or snow of a thickness and roughness comparable to that of medium or coarse sandpaper on a wing's leading edge and upper surface can reduce a wing's lift by up to 30 per cent and increase drag by 40 per cent. The
lift loss comes largely from contamination of the leading edge. Consequently, aerodynamic stall of a contaminated wing may occur before the stall warning system activates.

1.17.3 Air Satellite's Procedure in Case of Contamination of Critical Surfaces

Section 3.3, "Contamination of Critical Surfaces", of the company operations manual reiterates the requirements of the CARs:

[Translation]

Frost or snow adhering to any lift or control surface must be completely removed before take-off.

If it is impossible to clean the aircraft before departure, the only solution is to delay the flight until acceptable conditions prevail.

No pilot shall begin or continue a flight into known or expected icing conditions if the accumulation of frost on the aircraft may compromise the flight safety. At all times, the pilot-in-command assumes full responsibility for deciding whether or not to undertake a flight in icing conditions.

Air Satellite's pilots could remove surface contamination by placing the aircraft in the hangar, applying hot water to the contaminated surfaces, using de-icing liquid from a portable tank kept in the company's office in the terminal building, or by using a broom.

1.17.4 Stall

The symptoms of an impending stall include sluggish control surfaces (loss of effectiveness), airframe vibration, and activation of the stall warning system. Pilots must decrease the angle of incidence and minimize the loss of altitude. To do so, they must apply full throttle and take an attitude close to cruising attitude. Extending the flaps improves lift by increasing part of the wing's camber and decreases the stall speed. However, while increasing lift, the flaps increase drag. To maintain the same flight regime, pilots must increase engine thrust to compensate for the increased drag.

1.17.5 Air Satellite's SOP Manual

Air Satellite had an SOP manual for the Embraer 110, the Cessna 402, the Cessna 310, and the BN2A. According to the BN2A SOP manual, the pilot-in-command was responsible for performing all tasks, making standard announcements, and assuming all responsibilities. The SOP manual did not assign any specific responsibilities to the co-pilot.

1.17.6 ELT Model 406
In 1979, an ELT model that transmits on the 406 MHz frequency was put into service. The digital signal is received by a geostationary satellite that partially processes it and relays the information to a ground station. Although TC does not specify a particular model to be installed, this model offers significant advantages in comparison with the 121.5/243-MHz model:

- global coverage;
- almost instantaneous reception and relay of the ELT signal;
- more specific identification of the ELT’s geographic position;
- complementary information from the coded digital message, such as the device’s country of origin, the aircraft’s registration, and the derived position of a navigation system on board the aircraft;
- elimination of false signals.

2.0 Analysis

2.1 General

No irregularities were noted during the flight or during previous flights. Examination of the wreckage and the individual components did not reveal any indication of a structural defect, control malfunction, or loss of power that could have caused the accident.

2.2 Flight Planning

2.2.1 Weather Conditions

2.2.1.1 Turbulence and Wind Shear

The area forecast in effect at the time of the accident and the 0618 briefing from the FSS specialist indicated moderate to strong wind shear turbulence below 5000 feet asl associated with the passage of the cold front through Baie-Comeau at about 1100. Consequently, the information received by the pilot-in-command should have made the crew aware that sudden changes of attitude and significant variations in speed could occur during the flight to Rimouski.

2.2.1.2 Type of Precipitation While the Aircraft was Outside

The ambient temperature was near the freezing point (-0.2°C), creating wet snow. Environment Canada reported that the snow had a high water content, and a pilot observed wet snow on his aircraft at about 1030. The 1000 and 1100 weather observations indicated moderate snow, whereas those of 1029 and 1035 reported light snow. Between 1000 and 1100, 1 cm of new snow fell. The aircraft took off nine minutes later, during moderate snow. Therefore, it may be concluded
that more than 1 cm of snow fell while the aircraft was outside and that
snow accumulated on the aircraft's surfaces.

2.2.1.3 Crew's Decision Not to Remove Snow From Aircraft

The upper surface of the wings, cabin, stabilizer, and elevator were
more than six feet above the ground. Therefore, the pilot-in-command
could not inspect the horizontal surfaces without a stairway. The pilot-
in-command could only inspect the upper surface of the aircraft's
horizontal surfaces when he refuelled the aircraft during a lull in the
weather (the weather observations indicated light snow), 40 minutes
before take-off. Based on this observation and the fact that snow was
not adhering to the windshield while taxiing, the pilot-in-command
concluded that the surfaces were not contaminated; he relied on
obsolete or insufficiently representative information. Because the crew
could not see the aircraft's surfaces from the cockpit, the pilot-in-
command should have asked another staff member to assist him by
inspecting the surfaces.

It seems that the surface contamination training did not assist the pilot-
in-command in identifying the weather conditions conducive to aircraft
surface contamination.

2.2.1.4 Weather Conditions in Rimouski and Mont-Joli at Take-off

Given the proximity of the weather station, it was reasonable to think
that weather conditions at the Rimouski airport were fairly similar to
those observed at the Mont-Joli airport. The 1014 observation from
Mont-Joli and the 0917 Mont-Joli aerodrome forecast would have led
the pilot-in-command to expect the ceiling at Rimouski to change from
300 feet agl to 3000 feet agl after 1100 and visibility to increase from
¾ sm to 6 sm. Consequently, the decision to undertake the flight with a
view to completing an approach was in accordance with regulations,
because the Rimouski airport was not subject to an approach ban. The
decision to select Mont-Joli as the alternate airport was consistent with
the relative weather requirements. However, examination of the Mont-
Joli weather observations should have confirmed the warnings from the
Québec FSS specialist regarding the unreliability of the Mont-Joli
aerodrome forecast.

Because the flight was to last 30 minutes, the available information led
the crew to believe that, in all probability, the ceiling and the visibility
would be below the approach minimums in Rimouski and the alternate
airport in Mont-Joli. The lowest minimum descent altitude at which the
crew could descend, if they had not established the necessary visual
references, was 640 feet asl. The likelihood of seeing the runway at the
end of the approach was therefore rather poor. Because the crew could
expect not to land at their destination 30 minutes later, and the flight
had been delayed five hours because of the weather, the decision to
take off for Rimouski in such conditions, although consistent with
regulations, was marginal.

2.2.2 Aircraft Load
As permitted by regulations, the pilot-in-command used the approved standard summer weights to calculate the aircraft's weight and balance. However, the actual weight of each occupant exceeded the average weight used. Consequently, the total weight of the occupants was underestimated. Given the winter weather conditions, use of the standard winter weights, although not mandatory, would have been appropriate. Moreover, to determine the weight of the occupants more accurately, the true weight of the occupants and their carry-on bags should have been used.

The pilot-in-command asked the flight monitoring attendant to enter 500 pounds of fuel on the weight and balance form. However, once he arrived at the fuelling pit, the pilot-in-command refuelled to full tanks (780 pounds), as indicated in the flight plan filed one hour before. The pilot-in-command signed the weight and balance form without amending the fuel weight. According to the form, the sum of the standard summer weights for the occupants, the weight of the passengers' luggage, the weight of the fuel, and the empty weight of the aircraft were within the prescribed limits for take-off and for landing at Rimouski. The pilot-in-command should have known that the weight of the aircraft at the time of the final load report exceeded the allowable take-off weight, because he knew that there were 280 pounds of fuel more than expected. In addition, he should have known that the weight of the aircraft would have exceeded the allowable weight for landing at Rimouski. Although the difference between the weight registered and the actual weight of each of the elements seems negligible, the total discrepancy probably contributed to a decrease in performance; when the aircraft took off, it was overweight by more than 200 pounds.

2.2.3 Pre-flight Check

2.2.3.1 Engines and Electrical System

The pre-flight inspection would not have detected the internal irregularities in the engines and the electrical system (excessive wear of alternator brushes). The significant increase in oil consumption indicated that some of the engine's internal components were defective, but the pilot-in-command was not qualified to diagnose the deficiencies. No operational irregularities had been reported before the flight.

2.2.3.2 Co-pilot's Shoulder Harness

The co-pilot's shoulder harness did not function correctly because it was not installed properly. This could have been detected by pulling rapidly on the diagonal strap to ensure that it would stop. It seems unlikely that no pilot, maintenance personnel, or TC inspector had performed this simple check since the belt's installation in 1996. Consequently, it is possible that the company's staff and TC's inspectors had incorrectly assessed the importance of proper shoulder harness installation and the consequences of an improper installation in an accident.
2.2.3.3 Stall Warning System

The lift sensor for the stall warning system is in the leading edge of the left wing, six feet from the ground. It was therefore possible to detect that a screw was missing. However, confirmation that the audible and visual alarms were working suggested, incorrectly, that the system was functioning properly. Even if the lift sensor had been attached properly, the alarm would not have activated, because the aircraft stalled approximately 20 knots over the stall speed.

2.3 The Flight

2.3.1 Taxiing

The aircraft had to wait in the manoeuvring area for clearance to use taxiway Delta. Normally, from taxiway Delta, the aircraft should have turned right onto the runway to taxi to the threshold of Runway 10. For undetermined reasons, once the aircraft reached the runway, it turned left and backtracked onto Runway 28 before turning around. It is possible that the crew were distracted or that the aircraft rolled onto taxiway Delta before receiving clearance and then had to backtrack onto Runway 28 to let the snow removal equipment go by.

2.3.2 Choice of Take-off Runway

When the Mont-Joli FSS informed the crew that departure from Runway 28 would probably lead to a wait at the MIWAK waypoint fix, the pilot-in-command agreed to take off from Runway 10. He chose to continue waiting on the ground and take off with a tailwind rather than risk in-flight icing in the holding pattern at the MIWAK fix. When the expected wait at the MIWAK fix was cancelled and Runway 28 was again available, the pilot-in-command still chose, for undetermined reasons, to take off from Runway 10, despite the advantages of taking off from Runway 28. It would have made sense to take off from Runway 28: taking off with a headwind would have allowed the shortest ground roll, the slowest ground speed, a more open angle of climb, and, because the threshold of Runway 28 is 3000 feet closer to taxiway Delta, less surface contamination. The take-off on Runway 10 was conducive to snow accumulation on the critical surfaces, degrading the aircraft's performance.

2.3.3 Take-off Roll and Flight

The take-off roll was approximately three times longer than it should have been. According to Britten-Norman, the take-off roll was longer than the distance required by a BN2A-26 weighing 500 pounds more than C-FCVK, on a runway covered with nearly 7.6 cm of snow, and a tailwind component exceeding 8 knots. The degree of contamination of the aircraft is the only variable that was not factored into the calculation. Consequently, contamination of the critical surfaces must have been an important factor in increasing the take-off roll and affecting the aircraft performances. Because the aircraft did not show
any adverse effects related to contamination after rotation, until suddenly pitching up at just over 500 feet asl, it is unlikely that enough snow accumulated on the critical surfaces during the climb of about 60 seconds to cause a stall above 70 knots.

As during his training flights, the pilot-in-command did not follow the checklist sequence and reduced power before retracting the flaps. The change in sequence decreased thrust without reducing drag. If the pilot had not reduced power before retracting the flaps, the aircraft would have been operating with full thrust and a higher speed at the time of the sudden pitch-up.

Airspeed decreased by more than 25 knots and lateral stability was affected at approximately the same time as the flaps were retracted and the aircraft entered the cloud base. The rapid decrease in speed indicates that the aircraft climbed into a wind shear area. The flaps were retracted just before the aircraft pitched up, so, when the aircraft entered the wind shear area, the pilot-in-command was probably pulling on the control column to compensate for the aircraft's natural tendency to nose down. The combination of wind shear and flap setting would then have amplified the rate at which the nose rotated upward and contributed to the rapid loss of speed. The pilot-in-command probably did not realize that the aircraft was crossing a wind shear area. However, even if he had realized it, he was not familiar with the recommended recovery procedure.

The pilot's immediate challenge was to recognize the aircraft's attitude and speed. Because the aircraft was set to climbing power, it was imperative to increase thrust by applying full throttle, take the attitude corresponding to the maximum angle of attack, and keep the aircraft straight and level to avoid stalling.

After the aircraft pitched up, the pilot-in-command lowered the aircraft's nose, maintained power, extended the flaps after the aircraft's speed decreased to 70 knots, and initiated a left turn, during which the aircraft stalled. The pilot-in-command appears to have considered the situation serious enough to turn back for a visual flight rules approach on the closest runway (Runway 28) in conditions that required constant monitoring of the flight instruments, instead of following the plan established during the pre-flight briefing. Although extending the flaps increased lift, it also increased drag and probably decreased airspeed. The combined effects of contamination of the critical surfaces and the turn increased the stall speed. The stall may thus be attributed to a combination of all these factors, which eliminated the difference between the aircraft's speed and the stall speed.

### 2.3.4 Stall and Impact

The general instability of the aircraft at 70 knots is characteristic of an aircraft approaching stall speed. The fact that the left wing dropped first and that the nose pitched down corresponds to a loss of control after a stall in a level or descending turn.
The stall must have occurred about 500 feet asl because it happened very soon after the start of the turn. According to Britten-Norman, the aircraft could lose at most 100 feet, in normal conditions, if the stall recovery procedure was begun immediately. It is possible that the element of surprise kept the pilot from immediately lowering the nose of the aircraft and delayed stall recovery.

Examination of the damage and the slightly nose-up attitude of the aircraft indicate that the aircraft was no longer in a stall. In theory, a stall recovery can be made in about 100 feet of altitude. In the circumstances, however, there was likely insufficient altitude available to recover from the stall before striking the water.

2.4 Survival Aspects

2.4.1 Emergency Message and Distress Signal

Because there were no witnesses to the accident and no emergency messages or signals, Nav Canada could not know that the aircraft had crashed into the St. Lawrence River. The crew did not send an emergency message in flight and no ELT signal was recognized and confirmed, delaying implementation of emergency procedures. If Nav Canada had been made aware of C-FCVK's situation as soon as it crashed, analysis of the information available at that time would likely have allowed identification of the area where the accident occurred.

2.4.1.1 Emergency Message and Communications

When the aircraft became unstable, the pilot-in-command assessed that continuing would compromise the flight. When he decided to return to the Baie-Comeau airport, he informed the co-pilot of his intentions. The co-pilot, whose main responsibility was to conduct air-ground communications, should have informed the Mont-Joli FSS at that time. This responsibility, although hers, could have been shared with the pilot-in-command. If the aircraft was in distress, the pilot-in-command could have contacted ATC directly to explain the situation. In fact, the pilot-in-command did contact ATC directly, a few minutes before the accident, to obtain details regarding the expected delays at the MIWAK waypoint fix. However, the crew did not transmit an emergency message. A number of factors, including the following, might have contributed to the co-pilot and the pilot-in-command not communicating their intentions on the air-ground frequency:

- The time and the circumstances probably did not allow the crew to contact ATC.

- The origin of the problem was linked to the manoeuvrability of the aircraft rather than to an aircraft system. Consequently, the co-pilot might not have had the same impression of urgency as the pilot-in-command.

- The crew's little experience in CRM was not favourable for good
coordination.

- The pilot-in-command might have focused all his attention on maintaining control of the aircraft.

- The co-pilot's role was not clearly defined in the company's SOPs.

- The pilot-in-command and the co-pilot had not received training in effective communications; this training is not mandatory.

### 2.4.1.2 ELT Operational Condition

The SARSAT system recorded a low-reliability event at the exact time of the crash. Nevertheless, it cannot be concluded with certainty that the signal received was from C-FCVK. Tests demonstrated that a signal can be recorded without being validated if its duration is insufficient for an acceptable level of reliability. Given that no ELT irregularities were reported before the accident, that examination by the TSB did not reveal any defects other than those caused by corrosion, and that its battery was not due for replacement until a year later, it is reasonable to believe that the ELT was functioning before the flight. Therefore, it may be concluded that the ELT, which was switched to "arm", activated on impact. The emergency signal probably stopped when the ELT was ejected from its mounting plate on impact and/or when a short circuit occurred due to contact with the salt water.

### 2.4.2 Installation of ELT

Britten-Norman believed that the rear wall was less likely to sustain deformation after an accident. Therefore, the wall mount was the best way to ensure that the ELT could emit a signal after a crash. The impact seriously damaged the floor of the aircraft, whereas the rear wall sustained little damage. The wall mount would have greatly increased the likelihood that the ELT would remain out of the water, attached to its support, and capable of emitting an emergency signal. The ELT had not been installed according to the instructions specified in Modification Instruction NB-M-767, Part D, issued by Britten-Norman. It is TC's position that the installation did not meet regulatory requirements; however, despite regular inspections, this fact was not noted or otherwise commented on by TC inspectors. The TSB also concluded that the installation did not comply with the regulations.

### 2.4.3 Stations Capable of Receiving ELT Signal From Accident Site

It was reported that the Mont-Joli FSS was the only ground station in the crash area that was listening to the 121.5 MHz emergency frequency. Because of the range-of-sight limitations (distance and obstacles) of VHF frequencies, this station could not receive the ELT signal from C-FCVK. The tower at the Baie-Comeau airport was within
range of the ELT. However, there was no transmitter-receiver tuned to
the 121.5 MHz emergency frequency at the airport because there was
no regulatory requirement to that effect. Aircraft categories, type of
flight, and density of traffic around the airport are not factors
considered in the decision to equip an RCO with an emergency
frequency. When TC closed the tower in 1995, the RCO was equipped
with frequencies useful for operation of the airport only. The Mont-Joli
FSS, which offered an alerting service to aircraft under its control, could
not receive an ELT signal transmitting from the vicinity of the Baie-
Comeau airport.

According to tests conducted by the TSB, if the Baie-Comeau RCO
had had the 121.5 MHz frequency, the Mont-Joli FSS would have
known, when the ELT activated, that C-FCVK was in distress rather
than experiencing a communication failure. Consequently, it is probable
that the rescue time would have been reduced.

The ELT signal was too short for the SARSAT system to validate it and
determine the location of C-FCVK.

2.4.4 Lifejackets

The regulations do not provide for emergencies requiring an immediate
water landing or events leading to an unexpected water landing.
According to the regulations, an aircraft on a regular flight conducted
almost entirely over the water, as with Flight ASJ501, is not required to
have lifejackets on board. Because the river is approximately 35 nm
wide between Baie-Comeau and Rimouski, C-FCVK was never more
than 18 nm from the shore when flying between the two airports.

There were two groups of survivors: the passengers in 4A and 4B, who
were trapped in the cabin, and the four occupants seated at the front,
who were found on top of the cabin. The passengers in 4A and 4B
were seriously injured. Even if they had been wearing lifejackets, they
would not have been able to evacuate the cabin before the tide
submerged the wreckage. Three of the survivors who were found
outside the cabin could partially move. It took all their energy to hold
onto the unconscious co-pilot for nearly 1 hour 20 minutes, in extremely
difficult conditions. Out of strength and suffering from hypothermia, they
were unable to hold onto the co-pilot when the tide submerged the
cabin, about 10 minutes before help arrived. In those circumstances, it
is reasonable to think that if the co-pilot had worn a lifejacket, it would
have been easier for the survivors to hold onto her. The availability of
lifejackets on board an aircraft increases the occupants' chances of
survival in case of an emergency water landing.

2.4.5 Baie-Comeau Airport Emergency Plan

The emergency response before the aircraft was found suggests that
all agencies concerned thought that the aircraft had probably crashed.
The ground search began 22 minutes after take-off, even though the
Code White that had been in effect for 3 minutes required these
agencies only to be on standby. It seems that the assistance of a
helicopter was not requested until the aircraft was found because this procedure was described only in the section "crash landings in water" in the airport's emergency plan. Because the company, Héli-Manicouagan, was not advised of the situation earlier, there were no pilots available at the company's base when the company was informed of the crash. Consequently, the Héli-Manicouagan helicopter took off 27 minutes after being informed of the accident, 17 minutes after the Sûreté du Québec asked Héli-Manicouagan to go to the accident site. The emergency response time was longer than it could have been.

2.4.6 Nav Canada Procedures

The Montréal ACC informed the RCC 9 minutes after the time lapse stipulated in the operations manual. The Hercules and the Griffon dispatched by the Halifax RCC arrived at the scene 59 minutes and 86 minutes, respectively, after the rescue. It may therefore be concluded that the survival of the occupants would not have been affected had the RCC been informed when the Code White was declared, 21 minutes earlier, or at the time stipulated in the operations manual.

2.5 Flight Crew

2.5.1 Pilot-in-Command

The pilot-in-command met the statutory requirements for a commercial pilot's licence, but his difficulty qualifying for his IFR rating, his reluctance to follow procedures and checklists, his previous attitude in icing and IFR conditions, and the fact that a TC inspector had described him as a rather weak pilot indicate that he had difficulty flying.

2.5.2 Co-pilot

Because the co-pilot was a flight instructor, it can be assumed that she knew the recommended procedures in case of sudden pitch-up of the aircraft and wind shear. However, for undetermined reasons, she did not take any action during those critical moments. It is probable that the following factors contributed to inhibiting the co-pilot:

- The pilot-in-command did not clearly communicate his concern or ask for assistance.
- The SOPs did not clearly define her responsibilities as co-pilot on the BN2A.
- The lack of flight instruments on the right side of the instrument panel: it was difficult to read and interpret the flight instruments in front of the pilot-in-command.
- Neither of the crew members had been trained in effective crew coordination.
2.6 Company Management

TC indicated that the company had experienced some problems at the operations management level. To solve this problem, Air Satellite had hired a production manager shortly before the accident. This person was not yet performing the duties of production manager at the time of the crash, but Air Satellite had implemented the remedial plan it had proposed to TC.

2.6.1 Maintenance

The deficiencies identified after the accident, including the defective lift sensor of the stall warning system, the incorrect shoulder harness installation, and the condition of the engines and the alternators, showed that C-FCVK's certificate of airworthiness did not meet the regulatory requirements. If the procedures outlined in the inspection program and the maintenance manuals had been followed, the aircraft's deficiencies would have been identified and corrected. The fact that the aircraft took off with several deficiencies and that many maintenance irregularities were noted indicates a lack of supervision by the company. It seems that it was not possible for the maintenance manager to assume all the responsibilities associated with his various management positions.

2.6.2 Operations

The crew was composed of two pilots who had little experience in adverse conditions; consequently, they had difficulty making effective decisions before and during the flight. In the circumstances, it would have been reasonable for the company's management to designate a pilot-in-command and a co-pilot with shared flying experience who could form a more experienced team.

Although Air Satellite uses a pilot self-dispatch system, the existing conditions and both pilots' lack of experience in those conditions and in IFR would have justified close operational control. In addition, the pilot's limited experience as pilot-in-command on a twin-engine, commanding a crew, and flying in IFR and winter conditions fully justified close supervision of his flights.

The inexperienced crew decided to take off in difficult conditions, with a snow-covered, overloaded aircraft, for an airport at which the weather conditions offered little chance of landing. One can therefore conclude that the management supervision was inadequate.

2.7 Transport Canada Regulatory Control

High turnover of flight personnel and the repeated changes in the position of company chief pilot were a risk indicator easily identifiable by TC's main inspector. This indicator would normally decrease the time between regulatory audits to less than 36 months. If TC had complied with its established audit standards, the many deficiencies in training and operations might have been identified well before the accident.
TC approved Air Satellite's recovery plan, even though the audit report indicated that the carrier's management was inadequate. This approval suggests that TC deemed that the deficiencies were minor and did not compromise flight safety. However, the fact that TC was en route to suspend the company's operating certificate after the accident suggests that TC reassessed the deficiencies identified previously and decided that they did jeopardize aviation safety. Therefore, it seems that TC had underestimated the company's problems.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

- The aircraft took off with contaminated surfaces, without an inspection by the pilot-in-command. This contamination contributed to reducing the aircraft's performance and to the subsequent stall.

- At take-off, the aircraft was more than 200 pounds over the maximum allowable take-off weight. This added weight contributed to reducing the aircraft's performance.

- During the initial climbout, the pilot-in-command did not follow the recommended procedure when he entered an area of wind shear. Consequently, the aircraft lost more speed, contributing to the stall.

- Insufficient altitude was available for the pilot to recover from the stall and avoid striking the water.

- The co-pilot's shoulder harness was not installed properly. The co-pilot received serious head injuries because she was not restrained.

3.2 Findings as to Risk

- The crew's lack of experience in the existing conditions was not conducive to effective decision making during the pre-flight planning and the flight.

- The stall warning system was defective and, in other circumstances, could not have alerted the crew of an impending stall.

- The crew did not transmit an emergency message after the pilot-in-command decided to return to Baie-Comeau for landing. This lack of a message delayed the rescue operation.

- The emergency signal was not received by the Mont-Joli Flight Service Station because the Baie-Comeau remote communications outlet (RCO) was not equipped with the 121.5 MHz emergency frequency. The RCO was not required to be
equipped with the emergency frequency.

- The emergency locator transmitter (ELT) was not installed in accordance with Britten-Norman's instructions. The ELT’s installation on the floor of the aircraft increased the risk of damage.

- Transport Canada did not comply with its established audit standards for regulatory audits of the operator, thus increasing the risk that training and operational deficiencies would not be identified.

- The emergency signal probably ceased after the ELT was ejected from its mounting plate and the antenna connection contacted the water. The ejection contributed to reducing the signal and prevented the SARSAT (search and rescue satellite-aided tracking) system from validating the signal.

- One of the occupants might have had a greater chance of survival had lifejackets been on-board the aircraft. Existing regulations did not require lifejackets to be carried on board.

- The aircraft had numerous mechanical deficiencies that should have been detected by Air Satellite's staff.

- According to the Baie-Comeau airport emergency plan, a helicopter could be used only after confirmation of a crash in water. The emergency response time was therefore longer than it could have been.

- The configuration of the instrument panel made it difficult to read and interpret the flight instruments from the co-pilot's seat.

- Air Satellite's manual of standard operating procedures did not promote effective crew coordination.

- The pilot-in-command and the co-pilot had not taken courses in crew resource management or pilot decision making. These courses would have promoted effective crew coordination but were not required under existing regulations.

- The high turnover of flight personnel and the repeated changes in the position of company chief pilot did not allow adequate supervision of operations.

4.0 Safety Action

4.1 Action Taken

The TSB's report underlines the fact that some aircraft that are certified
for single-pilot operations do not have instrumentation at the co-pilot seat. When flying from the co-pilot position, the aircraft must therefore be flown without the benefit of a full instrument panel. To correct this deficiency in the regulations, Transport Canada (TC) has issued a notice of proposed amendment to the Canadian Aviation Regulations (CARs). This deficiency, identified by the TSB, will be eliminated when the amendment is incorporated into the CARs.

The report uses data observed by the weather specialists and states that, during the morning, the equipment for measuring the wind could not be used because of the freezing rain. Based on the position of the wind sock, an observer estimated the wind to be 230° true at 7 knots. However, the cloth cone on the wind sock was covered with ice, increasing its weight. Moreover, information gathered during the investigation indicates that the wind speed might have been much higher than that observed. To correct this deficiency in the regulations, TC issued a notice of proposed amendment to the CARs. This deficiency, identified by the TSB, will be eliminated when the amendment is incorporated into the CARs.

On 25 July 2002, the TSB issued Aviation Safety Advisory A010052-1 to TC concerning the problems with the improper installation of the emergency locator transmitter (ELT). C-FCVK's ELT had been installed directly on the aircraft metal covering. This installation offered less rigidity and was thus not in accordance with the aircraft manufacturer's instructions. Furthermore, the ELT was mounted to a plate that was attached to the flooring behind a bulkhead, making access difficult. Finally, its sensitive axis was 12°, which is 2° more than the 10° maximum limit prescribed by the ELT manufacturer. Following this advisory, TC may wish to consider reviewing the CARs to add more precise installation criteria to ensure that this regulation cannot have multiple interpretations.

Air Satellite has implemented some measures since the accident. These measures include improved flight supervision and hiring a licensed aircraft maintenance engineer and a safety officer. The company has also ensured that crews will receive pilot decision-making training.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 13 August 2002.*

Appendix A: Weights Used for the Flight and Weights Estimated by the TSB

<table>
<thead>
<tr>
<th></th>
<th>Weights used by pilot (pounds)</th>
<th>Weights estimated by TSB (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty Weight of Aircraft</td>
<td>4136</td>
<td>4136</td>
</tr>
<tr>
<td>Occupants</td>
<td>1552</td>
<td>1717</td>
</tr>
<tr>
<td>Luggage</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Fuel</td>
<td>500</td>
<td>780</td>
</tr>
<tr>
<td>------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Take-off Weight</td>
<td>6368</td>
<td>6813</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Landing Weight</td>
<td>6288</td>
<td>6743</td>
</tr>
</tbody>
</table>

Maximum take-off weight: 6600 pounds

Maximum landing weight: 6300 pounds

### Appendix B: Chronological Outline of Emergency Response

<table>
<thead>
<tr>
<th>Time elapsed after take-off at 1109</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>About 2 minutes</td>
<td>The aircraft crashed into the river.</td>
</tr>
<tr>
<td>3 minutes</td>
<td>The Montréal Area Control Centre (ACC), the Mont-Joli Flight Service Station (FSS), and some aircraft in flight tried to contact Flight ASJ501. A communications search was then undertaken by various agencies.</td>
</tr>
<tr>
<td>10 minutes</td>
<td>The Mont-Joli FSS informed the Baie-Comeau airport that Air Traffic Services (ATS) had lost contact with Flight ASJ501 after take-off.</td>
</tr>
<tr>
<td>18 minutes</td>
<td>The Mont-Joli FSS, which thought that Flight ASJ501 had experienced a communication failure, declared a Code White alert. Code White is used to deploy the personnel of the airports concerned and to put outside agencies on alert. The Baie-Comeau airport emergency coordination centre became operational.</td>
</tr>
<tr>
<td>22 minutes</td>
<td>One airport maintenance attendant at the Baie-Comeau airport went to the apron with a direction finder to see if he could receive an emergency locator transmitter (ELT) signal. A second airport maintenance attendant searched the runway.</td>
</tr>
<tr>
<td>24 minutes</td>
<td>Pointe-Lebel firefighters and various police departments were put on standby.</td>
</tr>
<tr>
<td>26 minutes</td>
<td>The emergency coordination centre asked that a search be conducted on Garnier Street, which runs along the river just east of Runway 10.</td>
</tr>
<tr>
<td>38 minutes</td>
<td>The Baie-Comeau airport manager expanded the ground search southwest of the runway.</td>
</tr>
<tr>
<td>41 minutes</td>
<td>The Baie-Comeau airport manager tried to locate the aircraft from the control tower.</td>
</tr>
<tr>
<td>42 minutes</td>
<td>The Rescue Coordination Centre (RCC) in Halifax, Nova Scotia, was notified.</td>
</tr>
<tr>
<td>Time</td>
<td>Event Description</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>45 minutes</td>
<td>The Canadian Coast Guard (CCG) was notified. The CCG had a vessel, the <em>Pearks</em>, berthed at the Baie-Comeau harbour.</td>
</tr>
<tr>
<td>47 minutes</td>
<td>The Halifax RCC dispatched a Hercules from Canadian Forces Base (CFB) Trenton, Ontario, to the area to begin the search.</td>
</tr>
<tr>
<td>48 minutes</td>
<td>The CCG decided to dispatch the <em>Pearks</em> to search for the aircraft.</td>
</tr>
<tr>
<td>50 minutes</td>
<td>The Mont-Joli FSS declared the aircraft missing and moved onto Code Yellow and the alerting phase. All stakeholders were informed.</td>
</tr>
<tr>
<td>51 minutes</td>
<td>A citizen reported seeing C-FCVK in the river.</td>
</tr>
<tr>
<td>61 minutes</td>
<td>The Sûreté du Québec (Quebec police) asked Héli-Manicouagan, a commercial operator based in Baie-Comeau, to dispatch a helicopter to the site of the accident.</td>
</tr>
<tr>
<td>65 minutes</td>
<td>The Halifax RCC dispatched a helicopter from CFB Bagotville to the scene to rescue the victims.</td>
</tr>
<tr>
<td>78 minutes</td>
<td>A ski-equipped Bell 206 helicopter left the Héli-Manicouagan base for the accident scene with a pilot and an aircraft maintenance engineer on board.</td>
</tr>
<tr>
<td>98 minutes</td>
<td>The Bell 206, which was not equipped with floats or a winch, hovered over the wreckage. The aircraft maintenance engineer helped a survivor aboard. The survivor was then brought to emergency personnel on shore.</td>
</tr>
<tr>
<td>100 minutes</td>
<td>The Bell 206 returned to the scene and rescued the other two survivors.</td>
</tr>
<tr>
<td>121 minutes</td>
<td>The first boat arrived at the scene.</td>
</tr>
<tr>
<td>159 minutes</td>
<td>The Hercules arrived at the scene.</td>
</tr>
<tr>
<td>186 minutes</td>
<td>The Griffon helicopter arrived at the scene.</td>
</tr>
</tbody>
</table>

**Appendix C: List of Laboratory Reports**

The following TSB Engineering Laboratory reports were completed:

- LP 145/98 Wreckage Analysis
- LP 2/99 ELT Analysis
- LP 51/99 Stall Warning Analysis

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

**Appendix D: Glossary**

- ACC: area control centre
- ADF: automatic direction-finder
AES  atmospheric environment service  
agl  above ground level  
*A.I.P.*  Aeronautical Information Publication  
*Canada*  
asl  above sea level  
ATC  air traffic control  
ATS  Air Traffic Services  
CARs  Canadian Aviation Regulations  
CCG  Canadian Coast Guard  
CFB  Canadian Forces Base  
CRM  crew resource management  
cm  centimetre(s)  
DME  distance-measuring equipment  
ELT  emergency locator transmitter  
EPM  emergency procedures manual  
FSS  flight service station  
IFR  instrument flight rules  
ILS  instrument landing system  
inHg  inches of mercury  
L  litre(s)  
LL  low lead  
MCM  maintenance control manual  
MHz  megahertz  
MPM  maintenance procedures manual  
NDB  nondirectional beacon  
nm  nautical mile(s)  
PDM  pilot decision making  
PPC  pilot proficiency check  
RCC  Rescue Coordination Centre  
RCO  remote communications outlet  
SARSAT  search and rescue satellite-aided tracking  
SB  satisfactory with briefing  
sm  statute mile(s)  
SOP  standard operating procedure  
TC  Transport Canada  
TSB  Transportation Safety Board of Canada  
VHF  very high frequency  
VOR  VHF omnidirectional radio range  
°  degree(s)  
°C  degree(s) Celsius  

1. All times are EST (Coordinated Universal Time [UTC] minus five hours). See Appendix D for a glossary of acronyms and abbreviations.