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 Fire
Royal Aviation Inc. Boeing 727-217 C-GRYC
Toronto/Lester B. Pearson International Airport, Ontario
18 July 1996

Report Number A96O0125

Summary

Royal Aviation flight 6192 departed from runway 24L at Toronto/Lester B. Pearson International Airport (LBPIA), Ontario, on a domestic flight to Deer Lake, Newfoundland. On board were 3 flight crew, 5 cabin crew, and 183 passengers. The flight, including push-back, engine starts, taxi, and take-off, was routine until the number 2 engine fire warning activated as the aircraft was climbing through 7,000 feet above sea level (asl) on departure. The flight crew carried out the appropriate checks and shut down the number 2 engine. Two fire bottles were discharged into the number 2 engine compartment; however, the fire warning light remained on. The captain declared an emergency with air traffic control and immediately returned to LBPIA for an overweight landing. The fire warning light extinguished as the aircraft returned to the airport. Emergency rescue services (ERS) were waiting as the aircraft landed on runway 24L. There was no fire evident as the aircraft landed and shut down. Inspection revealed that there was residual smoke and fire damage to the structure surrounding the number 2 engine. This is the centre engine, and it is embedded in the empennage structure. The aircraft flight controls were not affected.

Ce rapport est également disponible en français.

Other Factual Information

Approximately nine months prior to this occurrence, the aircraft's number 2 engine fire warning light illuminated on climb-out from Vancouver. The number 2 engine was shut down and the fire warning light extinguished. The aircraft returned to Vancouver for an uneventful landing. It was determined that the number 2 engine starter had failed.
The number 2 engine start control valve and starter were replaced, and the aircraft was returned to service.

The aircraft had a maintenance inspection (C-check) in June 1996. As part of the inspection, the starter was examined and its lubricating gear oil was found to be contaminated with metal particles. The starter was replaced. The aircraft had since been flown 243 flight hours.

When the aircraft was examined in Toronto, it was evident that the starter had failed. There was a two- by three-inch hole in the side of the starter gear case, and the air turbine had come out through the retaining screen. The air turbine hit and cut a constant speed drive (CSD) oil pressure line. Oil then sprayed around the engine compartment and onto a generator terminal block, and the oil ignited. Fire damage to the engine component wiring precluded any significant testing of the wiring harness.

Both the start valve and the starter were dismantled and examined. The start valve functioned normally with no significant anomalies. The starter was completely seized except for the clutch assembly, which was still functional. The damage to the planetary gear system and the air turbine bearings was consistent with a starter over-speed failure.

The engine start system is electrically controlled. Pressurized air, normally bleed air from the auxiliary power unit (APU), drives the starter. During the start sequence, air pressure is available to all three engine start valves, and flow control valves are closed, so air pressure is not available for other aircraft systems. During engine start, electrical power is supplied to the start valve to open it, allowing airflow to be directed over the air turbine which drives the starter. After the engine has started, electrical power is removed from the valve, which closes to stop the airflow, and the starter stops turning.

The engines are started individually. After all engines are operating, bleed air is made available to other aircraft systems by opening the flow control valves and closing the number 2 engine bleed air valves. When the aircraft is operating normally, the number 1 engine bleed air supplies air to the left air-conditioning pack and the number 3 engine bleed air supplies air to the right air-conditioning pack.

The number 2 engine bleed air system is isolated by closing the number 2 engine bleed air valves. There are two pressure transmitters, one located in the number 1 engine bleed air duct and the other in the number 3 engine bleed air duct. When the aircraft is operating normally, there is no bleed air pressure indication for the number 2 engine. When the flight crew are starting the engines, the first officer controls the engine start switch while the second officer monitors the bleed air duct pressure. A drop in duct pressure indicates that the start valve is open. When the start switch is selected back to the OFF position, the start valve closes, and the second officer confirms this by noting a rise in the duct pressure, which he did in this case. Duct pressure is the only cockpit indication of start valve position.

Engine starter failures resulting from open start valves were addressed
by Air Worthiness Directive (AWD) 83-01-05 in 1983. AWD 83-01-05 R2 refers to "undetected prolonged engine starter operation." The requirement of the AWD is to "provide a positive indication to the flight crew of the normal and unwanted operation of each engine starter." Alternative means of compliance with this AWD which provide an equivalent level of safety may be used with approval of the Federal Aviation Administration (FAA). There are two approved methods of compliance: the installation of a pressure switch downstream of each starter valve with an indicator light in the cockpit, or the installation of a starter valve master switch in the cockpit to power all three engine start valves. The second option, the engine start valve master switch, does not provide a positive indication to the flight crew of the start valve operation.

C-GRYC had been modified by the previous owner, Dan-Air Services Ltd, to incorporate an engine start valve master switch. The modification was accepted by Transport Canada when the aircraft was imported into Canada in 1992. The engine start valve master switch was put into the electrical circuit between the engine start switches and the start valve cutout switches on the engine starter. It provides protection for the start circuit up to the start valve cutout switch. Most of this portion of the start circuit is in the interior aircraft structure where it is protected from excessive vibration, temperature extremes, contamination, and physical damage. The switch does not provide any protection for the wiring between the start valve cutout switch and the start valve. The wiring between the start valve cutout switch and the start valve is entirely in the engine compartment, where it is subject to temperature extremes, vibration, oil and water contamination, and physical damage.

Analysis

All three engines started normally. The indications were that the number 2 engine start valve closed after the engine was started. Had it not closed, there would have been less airflow available to start the number 3 engine.

Examination of the starter indicated that it had failed because it had been rotating at too high a speed. Given that the clutch was functional, it is unlikely that the engine was driving the starter. The starter probably failed while it was being rotated by the air turbine, with no load on the starter. For this to occur, the start valve had to be in the open position with the engine running.

Since the start valve reportedly had closed following a successful number 2 engine start, as evidenced by the duct pressure, a new voltage must have been subsequently available at the start valve to re-open it sometime after the number 3 engine start. That voltage could have been the result of a short circuit of a power wire of some other engine component running in the same wiring harness. However, since the wiring harness was fire damaged, the source could not be determined.

The hazard associated with an engine fire caused by a starter failure
was recognized and addressed in AWD 83-01-05 R2. The previous owner's modification improved the start system circuitry but did not provide a positive indication of the start valve position. It also did not protect the circuit from a short circuit between the start valve cutout switch and the start valve.

After all engines of the B727 are operating, there is no bleed air duct pressure indication for the number 2 engine. If the start valve for either engine number 1 or engine number 3 re-opens, a very vigilant second officer may notice the decrease in duct pressure on either the left or right side. If the start valve for number 2 engine goes to the open position, there is no indication in the cockpit.

The number 2 engine is mounted in the aircraft tail. Because of the engine's proximity to the elevator and rudder control systems, a severe in-flight fire in the number 2 engine is potentially more serious than a fire in either the number 1 or 3 engine.

The following Engineering Branch report was completed:

LP 95/96 - FDR/CVR Analysis.

Findings

- It is probable that a short circuit in the engine wiring harness allowed the number 2 engine start valve to re-open, causing the number 2 engine starter to over speed and subsequently fail.

- The failure of the number 2 engine starter resulted in an engine fire.

- The previous owner of the aircraft installed an engine start valve master switch as an alternative means of complying with AWD 83-01-05 R2. Although approved by the FAA and Transport Canada (TC), the engine start valve master switch did not protect the complete circuit nor did it provide a positive indication to the flight crew of the normal and unwanted operation of each engine starter.

Causes and Contributing Factors

It is probable that a short circuit in the engine wiring harness allowed the number 2 engine start valve to re-open, causing the number 2 engine starter to over speed and subsequently fail, resulting in an engine fire. The FAA- and TC-accepted alternative means of complying with AWD 83-01-05 R2 did not protect the aircraft from the undetected and unwanted prolonged operation of the engine starter.

Safety Action

Royal Aviation has modified company aircraft so that all aircraft with a master start switch also have a start valve position light. The company has also modified its standard operating procedures (SOPs) so that when a start valve light indicates that the valve is open, the crew will
take the immediate necessary action to avoid unwanted, prolonged operation of the starter, given the potential consequences of an engine fire.

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.
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.

Tail Strike on Landing
Canadian Airlines International
Boeing 767-375 C-FOCA
Halifax, Nova Scotia
08 March 1996

Report Number A96A0035

Synopsis

The Boeing 767-375, Canadian Airlines International flight 48 (CDN48), was on a flight from Toronto, Ontario, to Halifax, Nova Scotia. During the landing at Halifax, the aircraft crossed the runway threshold about 20 feet above ground level (agl) and touched down 200 feet past the threshold. The tail of the aircraft struck the runway, causing substantial damage to the tail skid and rear fuselage.

The tail strike occurred because the crew responded to a visual illusion with an unwarranted power reduction between the minimum descent altitude and touchdown. The upslope illusion led both crew members to believe the aircraft was higher than it actually was, and the crew did not respond to visual cues from the precision approach path indicator, which showed the aircraft to be too low. Contributing to the accident were the captain's preoccupation with stopping on the slippery runway, and some loss of aircraft performance below 400 feet agl. Also contributing were the lateral navigation/vertical navigation procedures in use, and a higher than normal aircraft body angle, which was induced by a lower than normal approach speed and the aircraft's forward centre of gravity.

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1.0 Factual Information

1.1 History of the Flight

Canadian Airlines International (CAI) flight 48 (CDN48), a Boeing 767-375, departed Toronto, Ontario, at 1655 eastern standard time for Rome, Italy, with an en route stop at Halifax, Nova Scotia. This flight is normally a direct flight from Toronto to Rome; however, the aircraft was stopping in Halifax to pick up a special charter group of 197 people.

The cruise portion of the flight to Halifax was routine with the exception of a "pack trip" valve malfunction. The crew dealt with this problem by following the appropriate checklist, and, as a result, the air conditioning pack was isolated.

The captain was the "pilot flying" (PF). The active runway at Halifax was 06, and the crew received clearance for the non-precision localizer back-course approach for that runway. The crew was asked to maintain an airspeed of 170 knots to the Golf non-directional beacon (NDB) because of traffic behind them. During descent, the pilots noticed that the left engine bleed air light illuminated and that it was intermittently flickering on and off for the duration of the approach. The pilots discussed the consequences of the loss of left engine bleed air and what it would mean to their use of reverse thrust after landing.

The aircraft touched down at 1941 Atlantic standard time (AST), 200 feet past the threshold, with a vertical acceleration of 2.2 g. During the landing roll, the first officer noticed that the tail skid light was illuminated. After arriving at the boarding gate, the captain examined the tail skid and discovered that there was substantial damage to the tail skid and aft fuselage. The two flight attendants who occupied the aft cabin positions reported that they had heard a bang when the aircraft touched down and that the landing had seemed very rough. Although the flight crew indicated that the landing had been firm, the aircraft had not seemed very nose-high to them, and they were surprised the aircraft was damaged. The aircraft was removed from service.

1.2 Injuries to Persons

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1.3 Damage to Aircraft

The Boeing 767 is equipped with a tail skid that extends and retracts with the landing gear. A tail skid light illuminates if the tail skid position disagrees with the extended or retracted position of the landing gear. During the touchdown, the tail skid contacted the runway surface with sufficient force to shear the tail skid hydraulic actuator attachment pin and drive the actuator upward, striking the stabilizer ball screw assembly. This caused the tail skid light to illuminate. The damage required the replacement of the tail skid hydraulic actuator, the left and right tail skid housings, and all hydraulic lines and hoses common to the actuator. There was also some minor damage to the stabilizer position switches and their associated mounting brackets.

After the tail skid actuator failed, the lower skin on the tail section of the aircraft contacted the runway surface, causing multiple scrapes and buckles to the skin between stations 1417 and 1540 and stringers 36 right and 36 left. The skin in this area, five frames, and numerous stringers and stiffeners were replaced before the aircraft was returned to service.
1.4 Other Damage

There was no other damage.

1.5 Personnel Information

<table>
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<th>First Officer</th>
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1.5.1 Aircraft Captain

The captain was licensed and qualified for the flight. At the time of the incident, the captain held a valid class 1 medical with the restriction that glasses must be available. He was described by some as being a nervous individual and a heavy smoker. The captain had not had crew resource management (CRM) training.

A review of the captain's company training file revealed that he had displayed satisfactory performance. However, the captain had experienced difficulties with back course approaches on two successive pilot proficiency checks (PPCs), performed by company check pilots, three years before this occurrence. These were assessed as minor difficulties that were corrected by the simulator instructor. The captain had not been retested on localizer back course approaches during subsequent PPCs, but he had been required to demonstrate other non-precision approaches, which he did successfully.

The captain last flew a non-precision, back course localizer approach at Montreal several years prior to this occurrence. This was a night approach during a winter snowstorm and had been conducted using the aircraft's autoflight capability. The captain was uncomfortable with the approach in that, when visual reference with the runway was established, the aircraft was lower than he had anticipated, and he had to manoeuvre the aircraft to land on the runway. Almost all of the captain's recent flying was to large airports with instrument landing system (ILS) approaches and runways generally longer than runway 06 at Halifax.

1.5.2 First Officer

The first officer was licensed and qualified for the flight, and has been a first officer with the company for over 20 years on the Boeing 737, 767, and the DC10. He was described as being a quiet person and not assertive. Prior to the occurrence, he had never attended a CRM course.

At the time of the incident, the first officer held a valid class 1 medical with the restriction that glasses or contact lenses must be worn.

1.6 Aircraft Information

1.6.1 General
According to the Boeing 767 Flight Crew Training Manual, a normal aircraft body attitude during approach at a speed of $V_{\text{REF}}30 + 5$ is 3°. Landing flare body attitude at the same speed is given as 5° to 6°. Information provided by the manufacturer indicated that a five-knot decrease in approach speed will increase the body attitude by 1°.

The aircraft's tail skid will contact the runway when the aircraft has a 10° body attitude with the main landing gear oleos extended. Tail skid contact will occur at a body attitude of 8° if the main landing gear oleos are compressed.

### 1.6.2 Flight Management System

The Boeing 767 is equipped with Flight Management System (FMS), which is an integration of subsystems designed to aid crews in controlling the aircraft's lateral (LNAV) and vertical (VNAV) flight path. These flight-path subsystems contain submodes, including those to track a front course localizer (LOC), and a back course localizer (B/CRS and LOC - two switches selected). The selector buttons for the various modes are found on the Mode Control Panel (MCP), which is located on the glare shield between the two pilots. Either pilot is able to make mode selections.

### 1.6.3 Weight and Balance

The aircraft departed Toronto with a centre of gravity (C of G) of about 13% mean aerodynamic chord (MAC), which is in the forward portion of the allowable  C of G range. The C of G moved further forward as fuel was burned during the flight. The C of G on landing was at about 12% MAC, which was within the company's specified forward limit of 11.1% MAC (the certificated forward C of G limit is 7%). The landing weight was about 276,000 pounds, with the maximum allowable landing weight being 320,000 pounds.

The landing C of G was forward of the usual values because of freight in the forward hold and a small passenger load. The aircraft's body attitude on approach is increased the further forward the C of G is located. The increase in aircraft body attitude between a mid-range C of G and a forward C of G is about three quarters of a degree.

When the aircraft's C of G is near the forward limit as opposed to being aft, approximately three degrees of additional elevator deflection is required to compensate for ground effect and flare. The additional elevator deflection and associated increase in control column force are small and not readily apparent to the pilot. The captain indicated that the control column force seemed lighter than usual during the landing.

### 1.6.4 Landing Distance

The Federal Aviation Administration approved Flight Manual landing distance for the Boeing 767-300, from a threshold crossing height (TCH) of 50 feet, is 5,400 feet for a wet runway.
Runway 06 at Halifax is 8,800 feet long. There were no charts available to the crew to correct the landing distance for James Brake Index (JBI) values. In the past, charts existed to calculate the effect of JBI on landing operations, but these were no longer in use. Other Boeing 767-300 pilots with the airline indicated that, for the reported JBI of .36, and based on their experience, there should have been adequate stopping margin. The CDN48 flight crew indicated that the aircraft decelerated well; the aircraft turned off the runway at taxiway "D", which is about 6,500 feet from the runway threshold.

The aircraft is equipped with an automatic brake system, with five landing brake settings, 1 to 4 plus MAX AUTO. The normal setting for a wet runway would be 3 or 4. On this flight, the captain instructed the first officer to select MAX AUTO for landing, a selection almost never considered necessary by pilots who fly the Boeing 767, apparently because of passenger comfort considerations. There is no specific guidance in the aircraft manuals as to the brake settings when operating on icy runways.

### 1.7 Meteorological Information

The area forecast for Halifax, issued at 1330 Coordinated Universal Time (UTC) on 08 March 1996, predicted an overcast cloud layer based between 1,000 and 2,000 feet above sea level (asl) and topped at 24,000 feet asl. Frequent snow ceilings of 400 to 800 feet asl would result in visibility between one-half and two miles in snow, light snow, and blowing snow. The precipitation was forecast to become light freezing rain and ice pellets in the vicinity of Halifax, which was near a warm front. Moderate rime icing was forecast in cloud between 7,000 and 11,000 feet asl, with moderate to severe clear icing below 4,000 feet asl in the freezing rain and ice pellets.

The terminal forecast for Halifax for the time of the occurrence predicted scattered cloud at 800 feet agl with an overcast ceiling of 2,000 feet agl and visibility four miles in light snow. There would be occasional obscured ceilings of 900 feet agl with the visibility one mile in light freezing drizzle, light snow, and fog.

The 2300 UTC weather, a regular special observation, was: partially obscured, clouds 300 feet overcast, visibility one and one-half miles in light freezing drizzle and fog, temperature -3.7° Celsius (C) and dew point -4.5°C, wind of 070° true at 7 knots, and an altimeter setting of 29.15 inches Hg (mercury).

A special observation taken at 2328 UTC, 13 minutes before CDN48 landed, was as follows: clouds 300 feet overcast, visibility one and one-half miles in very light freezing drizzle and fog, and wind of 080° true at 7 knots.

The 2346 UTC special weather observation for Halifax, four minutes after the occurrence, was as follows: clouds 300 feet overcast, visibility one and one-half miles in light freezing drizzle and fog, temperature -3.7°C, dew point -4.5°C, and wind 090° true at 6 knots.

Automatic terminal information system information "Papa" for Halifax was first broadcast about 1922 AST, 19 minutes before CDN48 landed. The information was as follows:

Halifax International Airport information Papa, 2300 Zulu weather - Partially obscured, measured 300 foot overcast, visibility one and a quarter mile in light freezing drizzle and fog, temperature minus four, dew point minus five, wind 090 at 5 to 10 knots, altimeter is two niner one three. IFR (instrument flight rules) approach localizer back course runway 06, landing and departures runway 06. Runway 06 has been reported 160 feet wide, and that portion was 10 per cent bare and dry, 20 per cent light snow, 10 per cent compact snow, 60 per cent ice, outside of that is 100 per cent dry snow. Was sanded at one niner one five. JBI runway 06 temperature minus four, decimal 36 at 2304.

The crews of several aircraft that landed before and after CDN48 were contacted and asked if
they had encountered icing conditions that evening in the vicinity of Halifax. Their responses varied from encountering no ice at all to a moderate accumulation in cloud. The crew of CDN48 reported that they had not observed any accumulation of ice on their aircraft during the descent. Although the aircraft engine anti-ice was selected on during the descent, the crew did not select the wing anti-ice on. According to CAI procedures, wing anti-ice can be used as a de-icer or anti-icer, and the primary method is to use it as a de-icer by allowing ice to accumulate before turning wing anti-ice on. Ice accumulation on the cockpit front window frames, windshield centre post, windshield wiper post, or side windows can be used as indication of airframe icing conditions and the need to turn on the wing anti-ice system.

Several Halifax ramp personnel were asked to comment about any ice accumulation they had observed on aircraft arriving that evening. Many had not noticed any ice and some had observed slight ice buildup on the landing gear and radomes of a few aircraft. The pilot of a Boeing 737 aircraft reported that he had observed an ice buildup of 3/8 inches on his aircraft's stabilizer during a walkaround after arriving at Halifax that evening.

1.8 Aids to Navigation

The approach to runway 06 at Halifax uses a localizer back course signal and the Golf NDB located 4.8 nautical miles from the runway threshold. It was determined that the localizer and Golf NDB were operating normally at the time of the occurrence. (See Appendix A.)

The last flight inspection to check the calibration of the localizer for runway 06 had been completed on 27 November 1995. During this inspection, it was found that the facility met all operational requirements and that the localizer signal was within the approved technical tolerances.

1.9 Communications Communications between the crew of CDN48 and Air Traffic Control (ATC) were normal throughout the flight.

During the approach, the captain was advised by ATC that braking action "looks like it's not good" and that an Airbus was having difficulty exiting the runway at taxiway Delta. The captain of CDN48 did not ask for a current braking action report from the Airbus, apparently because it would have added to the workload of the crew of CDN48.

1.10 Aerodrome Information

1.10.1 General

Halifax International airport, located at 44°52' North and 63°30' West, is a certified aerodrome operated by Transport Canada. The field elevation is 477 feet asl.
Runway 06/24, which is oriented 056/236° magnetic, measures 8,800 feet long by 200 feet wide. The first quarter of runway 06 has a 0.77% upslope. At taxiway Charlie, the runway begins to slope down by 0.5% to about the runway halfway point. The remainder of the runway is basically level. There is no information contained in the aviation publications about the overall slope for runway 06. The slope of a runway is published by the Canada Air Pilot (CAP) when the average slope is 0.3% or greater. For example, the average slope for runway 33 at Halifax is 0.55% down, which is significant enough to be noted on the CAP approach plates for that runway.

Jeppesen approach charts were used by CAI, and those charts do not provide runway slope information. To determine the slope, a crew member would have to determine the difference between the two threshold heights, which are provided if known to Jeppesen, and divide by the runway length. Occasionally the Jeppesen charts do provide narrative information regarding unusual conditions such as visual illusions. No such narrative was provided on the Jeppesen charts for Halifax.

According to TP312, Aerodrome Standards and Recommended Practices Standard 3.1.2.3, the maximum upslope in the first quarter of the runway with a length of 8,800 feet (runway code number 4) is 0.8%.

1.10.2 Runway 06 Instrument Approach

The CAP non-precision localizer back course approach to runway 06 at Halifax has a beacon crossing altitude of 1,700 feet asl over the Golf NDB, final approach fix, with a minimum descent altitude (MDA) of 760 feet asl or 298 feet agl. The touchdown zone elevation is 462 feet asl. The Jeppesen approach plates used by CAI use the same altitudes as the CAP approach plates.

The standard method of conducting the runway 06 back course approach would be to cross the approach beacon at or just above 1,700 feet asl, descend to the MDA and level off, and proceed until visual reference with the runway is established or until the estimated time to the missed approach point has expired. If adequate visual reference were established, a pilot would continue the approach and use the PAPI (precision approach path indicator) for glide path guidance. This method, although more difficult than using a constant rate descent provided by a glide path has been used safely and successfully for many years. Operators of FMS-equipped aircraft have exploited the capability of the onboard systems to generate a pseudo 3-degree flight path by adjusting the crossing altitudes of the final approach fix.

It had been many years since either crew member had flown to Halifax, and neither one could recall ever having flown the back course approach for runway 06.

1.10.3 Runway 06 Visual Approach Aids

An omni-directional approach lighting system (ODALS) is installed for runway 06. The ODALS consists of a 1,500-foot row of bright, non-variable, sequenced strobe lights, with a strobe light at each corner of the threshold. In addition, there are green threshold lights, white runway edge lights, and white runway centre line lights, all with variable intensity. It could not be determined what setting the lights were on when CDN48 landed; however, the captain reported that all the other lights seemed dimmer than the threshold strobe lights. The captain did not recollect seeing the lead-in strobe lights. The area approaching runway 06 is devoid of any ground lighting.

The runway is served by a type 3 PAPI, suitable for aircraft with an eye-to-wheel height of up to 45 feet (Boeing 747 and smaller). The PAPI consists of four light units in a wing bar, located on the left side of the runway, 1,307 feet from the threshold, and provides a 3° glide path to
the touchdown zone. A pilot's on-slope indication is two white lights and two red lights visible. If four red lights are visible, the aircraft is too low.

The Boeing Flight Crew Training Manual, in describing PAPI, states that "PAPI may be safely used with respect to threshold height, but may result in landing further down the runway."

It was determined that all visual approach aids were functioning normally at the time of the incident. In the fall of 1994, Transport Canada (TC) received several complaints from pilots regarding poor vertical reference on runway 06 at Halifax with the ODALS in operation. In response, on 19 October 1994, TC inspectors conducted a number of night approaches to runway 06 in visual flight conditions, and found that approaches made with reference to the PAPI provided the desired glide path. Transport Canada, in its 10 January 1995 report regarding the complaints and the testing carried out, indicated that it solicited comments from pilots who used the airport frequently. According to the Transport Canada report, the pilot comments ranged from "comparable to any other ODALS system" to "the worst black hole approach in Canada." The 10 January report concluded that no further action was required.

The captain indicated that he was less experienced with PAPI indicators than with VASIS (visual approach slope indicator system) indicators, and that he preferred the older VASIS indicators. He reported that, on final approach, he noticed that the PAPI indicated mainly red but he believed that the landing could be continued safely. The captain also believed that, by following the approach slope indications of the PAPI, the aircraft would touch down beyond the 1,000-foot runway marks, and it was his intention to touch down near the 1,000-foot marks. The first officer indicated that he did not observe the PAPI.

1.11 Flight Recorders

1.11.1 General

The digital flight data recorder (DFDR) and cockpit voice recorder (CVR) were removed from the aircraft and sent to the TSB Engineering Branch for analysis.

The CVR was a Loral A100, model number 93A100-30, which recorded the crew and cockpit area microphone channels on a 30-minute continuous loop. Aircraft electrical power continued to be supplied to the CVR for several hours after the aircraft's arrival at the boarding gate, which resulted in the incident data being overwritten.

The DFDR, model number 980-4100-AXUS, was manufactured by Allied Signal. The DFDR was played back without removal of the tape, and the entire 25 hours of data was retrieved using the TSB's Recovery, Analysis, and Presentation System. A computer animation of the flight was developed to assist in the analysis of the incident. Radar data supplied by the Moncton Area Control Centre were used to verify the accuracy of the ground track derived from the recorded flight data.

1.11.2 DFDR Flight Reconstruction
The following information has been extracted from TSB Engineering Report LP 36/96 - FDR/CVR Analysis, Boeing 767-375, C-FOCA, 08 March 1996.

As the aircraft turned on to final for runway 06, descent was initiated from 2,200 feet asl and the aircraft was slowed to approximately 178 knots indicated airspeed (KIAS). The autopilot pitch and roll modes were selected to VNAV and LNAV respectively, with the auto-throttles selected to the speed mode.

Just after the crew reported by the Golf NDB inbound, the aircraft's landing gear was extended and the flaps were set first to 20°, then 30°. Airspeed decreased to the approximate "Flaps 30" reference speed plus 5 knots (VREF30+5) of 139 KIAS as the flaps were fully extended. The descent rate averaged about 560 feet per minute (fpm) on a glide path of 2.3°, and the engine power averaged about 67% N1. Aircraft body attitude averaged about 4°.

The crew indicated that they saw the runway environment at minimum descent altitude (760 feet asl). At about 730 feet asl, the autopilot pitch mode changed to altitude capture, and, approaching 700 feet, the aircraft began to level off. Aircraft body attitude increased from 4.5° to 6.3° and engine power increased to 80% N1. The autopilot was then disengaged as the flight director went into altitude hold at about 700 feet. Four seconds after autopilot disengagement, the auto-throttles were disengaged.

After auto-throttle disengagement, the aircraft's nose lowered to 5.3°, the engine power was reduced to 70% N1, then further reduced to 50% N1 at about 150 feet agl. The descent rate, which had been steady at about 550 fpm, increased to approximately 850 fpm. LNAV had been in use, placing the aircraft slightly right of the actual localizer centre line, and, simultaneously with the reducing pitch, a slight turn to the left was initiated, followed by small turn to the right.

The aircraft crossed the runway threshold at approximately 20 feet agl, the engine power was increasing through 58% N1 (to 72% N1 at touchdown), body attitude was increasing through 5.8°, and the aircraft was descending at 800 fpm. In the last 10 seconds before touchdown, the N1 averaged about 8% lower than the previous steady value during the approach, which equates to about 20% less thrust. Airspeed had decreased to 134 KIAS (VREF30). The aircraft touched down, without slowing its descent, about 200 feet beyond the threshold, 40 feet left of the centre line, with a peak vertical acceleration of 2.2G (load factor)and peak pitch attitude of 8.1°.

DFDR data indicated that the use of reverse thrust and auto braking was discontinued within 30 seconds of touchdown, and that the aircraft was capable of stopping within about 4,000 feet.

### 1.12 Wreckage and Impact Information

There was no wreckage, and the applicable impact information is contained in section 1.3, Damage to Aircraft.

### 1.13 Medical and Pathological Information

Not applicable.

### 1.14 Fire

There was no evidence of fire before or after the occurrence.

### 1.15 Survival Aspects

Not applicable.
1.16 Tests and Research

1.16.1 Performance Evaluation

DFDR data for the time of the incident were sent to the aircraft manufacturer for analyses on an engineering simulator. A comparison of theoretical aircraft performance with actual aircraft performance in Halifax was done. Also, flight data for a previously recorded landing in Hawaii, in atmospheric conditions non-conducive to ice accretion and in relatively smooth and stable flight, were used for comparison.

Aircraft performance was considered to be normal until descent through about 400 feet agl, at which time theoretical simulations suggested a loss in aircraft performance (increased drag and decreased lift). The reason for the performance loss in the final portion of the approach could not be determined; however, possible explanations include partial speed brake deployment, ice accretion, and/or wind shear.

Speed brake handle position and spoiler control surface position are not recorded DFDR parameters on this aircraft(1), but speed brake deployment and retraction were evident from changes in other DFDR data earlier in the descent. During the latter portion of the approach, where the performance loss became evident, there was no evidence that the speed brakes were fully extended, and the crew indicated that there were no indications of speed brake extension.

According to the manufacturer, the aircraft was designed so that flight in icing conditions should not affect its control, trim, or handling. The horizontal tail, with no de-icing capability, was designed to minimize its susceptibility to the accumulation of ice. The size of the horizontal tail was designed to allow it to operate at tail lift levels at or below the levels where leading edge ice would affect the tail’s ability to generate the required lift.
The CAI Boeing 767 Operations Procedure, which discusses the effect of wing ice contamination, indicates that lift decreases and drag increases at high angles of attack. The manufacturer indicates that there is no lift loss attributable to ice contamination until the wing angle of attack increases above 15°. The angle of attack reached a peak of 12° during the accident flight as the aircraft descended through 50 feet agl. The CAI Operations Procedure also indicates that during take-off, wing contamination would cause the aircraft to behave as if it were trimmed in a nose-up direction; no trim information is provided for the approach phase.

The recorded DFDR data indicate that the aircraft encountered some turbulence during the approach, and the surface wind reported by the tower was 100° magnetic at five knots. Other flights did not indicate the presence of windshear at the point of landing.

1.16.2 Simulator Tests

Simulator trials were conducted at the CAI facility in Vancouver to review company procedures, study approach profiles, and assess available visual cues, performance degradation, and aircraft handling techniques. The trials were conducted during two 3-hour sessions in the Boeing 767-375 simulator, set up to simulate the conditions of aircraft weight, C of G, and weather encountered on the occurrence flight.

Halifax is not one of the airports in the simulator's data base so a generic airport with the same basic runway configuration was used. The simulator was not able recreate approach-end runway slope or the same lighting, and the simulator runway display had a PAPI indicator on each side of the runway, not just on the left side of runway as is the case for runway 06 at Halifax. The following observations were made during the trials:

- Workload during a non-precision approach was assessed as higher than that during precision approaches;

- Simulator "aircraft" body attitudes during the approach above MDA were consistent with those predicted by the manufacturer;

- When an NDB crossing altitude of 2,050 feet asl was used to produce a 3° VNAV glide path, the transition to visual flight for the landing was easier and smoother than with a 2.3° glide path;

- When the simulator was "flown" at the 2.3° glide path (using an NDB crossing altitude of 1,700 feet asl), the PAPI at MDA showed a below-slope indication (four red lights). After raising the NDB crossing altitude to 2,050 feet asl, the PAPI at MDA showed an on-slope indication (two red and two white lights);

- With the MDA set on the MCP window and the autopilot engaged, the approaches became unstable in pitch and thrust when the autopilot began to level the aircraft;

- While conducting the simulator tests, partial speed brake extension was demonstrated, and below 800 feet agl the following indications were observed:

  - SPEED BRAKE EXT message on engine indicating and crew alerting system (EICAS)
  - The SPEED BRAKE caution light is illuminated
  - Both master caution lights are illuminated
  - A level-B aural caution sounds
  - Because of simulator design, it was not possible to effectively simulate the effect of airframe
icing; and,

- Only one instance of simulator "aircraft" body attitude high enough to produce a tail strike was noted, and unnatural pitch control inputs were required to produce it.

1.16.3 Main Gear Touchdown Point

When using the location of the PAPI at runway 06 at Halifax, but not accounting for the runway upslope, the main gear touchdown point can be determined using the approximately 30-foot difference between eye-level path and gear path for the Boeing 767-300, as depicted in figure 4. Assuming no flare, the main wheels would contact the runway at about 700 feet. With normal flare and round out, a touchdown could be expected at about 1,000 feet.

1.17 Organizational and Management Information

1.17.1 General

Aspects of the airline's management which might have influenced the crew's performance as well as the dispatch of the flight were examined in more detail.

1.17.2 Company Training

CAI conducts bi-annual recurrent pilot training in their Boeing 767 simulator located in Vancouver. A training session is followed by a PPC. The training includes emergency procedures, crew coordination, and approach procedures for both precision and non-precision approaches. The airport locations used in the training alternate between Vancouver, various European stations, and Toronto, giving the flight crews approaches for both North America and Europe every year. In many cases, the training for non-precision approaches is scripted so as to result in a missed approach and/or an engine failure, thus the transition to landing would not be practised as often as a precision approach such as ILS.

CAI training emphasizes that their pilots use the VNAV capability on non-precision approaches for vertical guidance and use the localizer back course approach (B/CRS and LOC) mode for lateral guidance rather than LNAV. VNAV allows the pilots to fly the approach with a constant glide path in the same way they would follow a glide slope on an ILS approach. LNAV provides the flight crew with lateral guidance in a way similar to that of the localizer on an ILS; however, LNAV is inherently not as accurate as tracking the localizer using LOC or B/CRS and LOC. Crews tend to use LNAV to intercept the localizer, because it will perform a smoother intercept. LNAV can then be engaged to track the localizer. During training, flight crews are instructed to set the missed approach altitude in the MCP window shortly after passing the final approach fix.

CAI teaches their pilots that using the above procedures should allow them to reach the visual
reference point at MDA during a non-precision approach provided the weather is sufficient. The pilot must then follow the visual vertical guidance provided by a PAPI or VASIS. There is no specific information to indicate that the aircraft may require adjustment to the visual flight path after completing a VNAV approach. The importance of not flying below the proper glide path (described in some literature as "ducking under") in a wide body aircraft is discussed with the pilots.

### 1.17.3 Flight Crew Operating Manual

The CAI Flight Crew Operations Manual (FCOM) in use at the time of the occurrence contained information regarding the completion of non-precision approaches using the autoflight system. In Volume 1 of the FCOM, commencing at page 02.07.04, the pilot flying (PF) is told to use LNAV or heading select to track the approach or to establish an intercept course for a back course approach. This FCOM section then indicates that the PF is to select B/CRS and LOC for the back course approach. At the final approach fix, the pilot not flying (PNF) is to set MDA or the next lower 100-foot level on the MCP. The PF is to use VNAV (or select V/S mode and appropriate vertical speed) to descend to MDA. Approaching MDA, the PF is to allow the engagement of ALT HOLD mode (or select ALT HOLD when using V/S). The PNF is directed to then set the missed approach altitude on the MCP. The PF is to disengage the autopilot when descending below MDA and to disengage the auto-throttle prior to landing. The Boeing Flight Crew Training Manual describes the procedure for a non-precision approach and landing in a similar manner.

### 1.17.4 Standard Operating Procedures

Also contained in the CAI FCOM is an insert labelled "Standard Operating Procedures" (SOP), dated 23 December 1991, with a subject of "V-Nav Non-Precision Approach (AFDS)." The CAI SOP under "general" states that "the approach may be conducted in LNAV/VNAV when conditions permit, or in any other suitable roll and pitch mode." The SOP does not contain any explicit instruction for crews to select B/CRS and LOC during the approach, and in one section implies that LNAV could be used unless there is a disagreement between the map display and the "raw" navigational data.

The SOP, in a section entitled "Final Approach," provides guidance regarding the selection of gear and flaps. It states that, at approximately 30 seconds or 1.5 miles before the final approach fix, the landing gear down and flaps 20 should be selected. Landing flaps are to be selected at the final approach fix and speed is to be reduced to the final approach speed. The SOP indicates that the aircraft should arrive at, or near, the visual descent point by MDA. Crews are told to set the missed approach altitude in the MCP window when "approaching MDA" and to be prepared to land or go-around at MDA.

A preamble to the CAI SOP on page 02A.07.3 states that, "....Standard Operating Procedures supersede and take precedence over the Boeing Operations Manual, Vol. 1, Chapter 2, Normal Procedures."

### 1.17.5 Pre-Flight Considerations

The captain had been watching the weather patterns for the east coast of Canada for several days prior to the occurrence flight. On the day of the occurrence, he was concerned about the weather and reported for duty an hour earlier than usual. He told CAI personnel that he was concerned about operating through Halifax with the slippery runway conditions, and he recommended to CAI Operations that the passengers be flown from Halifax to Toronto. The captain would then fly them direct to Rome. Because of logistical limitations in getting the passengers to Toronto, it was decided instead that an extra pilot would board the flight in Halifax. This would permit a longer crew day in the event of a requirement to make an
intermediate stop in the flight from Halifax to Rome. Possible weight limitations on departure, due to the slippery runway, could have created a need for an intermediate stop.

Alternate airports were further than normal from Halifax because the eastern seaboard weather was below alternate limits, but adequate fuel reserves were on board to allow for a diversion.

1.18 Additional Information

1.18.1 Approach Procedures

The crew of CDN48 had never flown together before. Prior to the flight, they took time to discuss crew coordination and company standard operating procedures.

CAI policy is for the PF to initiate the descent for the final approach. During the approach to runway 06, the captain selected VNAV, but the system went to altitude hold because 2,300 feet was still set in the MCP. The first officer (the PNF) reset the altitude to 700 feet and then initiated the final descent on VNAV. Standard procedure is to lower the gear and select flaps 20 between 1½ and 2 miles prior to the final approach fix (FAF). In this incident, the DFDR data show that flaps 20 and gear down were selected just after NDB (FAF) passage. The crew indicated that the late selection of gear and flaps was related to resetting the speed in the speed intervention window, as called by the first officer, and because of dealing with the numerous "left bleed" EICAS messages. The captain had briefed the use of the B/CRS and LOC functions; however, LNAV was used.

With 1,700 feet, the minimum height at the FAF, set on the MCP, the glide path was approximately 2.3° from the FAF to the touchdown zone. Because of his concerns about going too low on approach, the captain instructed the first officer to add 10 feet to the 48-foot TCH given by the aircraft's data base for the approach to runway 06.

Another Canadian air carrier uses company-designed approach plates for non-precision approaches, including one for runway 06 at Halifax. When setting up the VNAV for runway 06, the pilots input a final approach fix (NDB) altitude of 2,050 feet to produce a glide path coincident with the 3° PAPI indication. A note on the approach plate advises that the lowest NDB crossing altitude is 1,700 feet asl.

After crossing the FAF, the crew set 700 feet, the next lower 100-foot level below the MDA of 760 feet, on the MCP window. When the aircraft reached about 730 feet, the autopilot began to capture the altitude and the auto-throttles added power to maintain the selected speed. At this time, the captain disconnected the autopilot, then the auto-throttles, reduced power manually, and lowered the nose of the aircraft.

CAI policy is that, if the first officer notices an unsafe condition, he or she should immediately and, if necessary, forcibly, bring this to the captain's attention. The first officer stated that he did not observe the PAPI and at no time did he feel the landing was unsafe. The first officer observed the 800 to 900 fpm descent rate during the final stage of the approach, but did not call out the rate of descent to the captain, nor was he required to do so by the company SOPs. Rates of descent of 1,000 fpm or greater are to be called out by the pilot not flying. The captain indicated that at no time did he feel the landing was unsafe.

1.18.2 Channelized Attention

Channelized attention is the focusing of one's attention on a particularly limited area to the exclusion of other areas or cues. The phenomenon can be exacerbated by fatigue, lack of knowledge, excessive motivation, or the novelty of the situation.

1.18.3 Effects of Smoking
Smoking can affect the health of individuals, but it can also directly interfere with some aspects of flying aircraft because of its visual and psychomotor effects.

It is well known that night vision is degraded by hypoxia. The vision loss is about 5% per 2,000-foot increase in altitude. Inhaling carbon monoxide as a result of smoking increases carboxyhemoglobin (COHb) and results in hypemic hypoxia (degradation of the oxygen transport mechanism). A smoker will often have between 5% to 12% COHb, versus 1% for a non-smoker; 5% COHb has the same effect as being about 8,000 to 10,000 feet above sea level.

At least one study carried out in a vehicle simulator indicates that smokers and non-smokers do not differ in terms of tracking and vigilance errors. However, deprived smokers made more tracking and vigilance errors. It was concluded that nicotine withdrawal constitutes a form of physiological stress(2). The captain indicated that he combatted nicotine withdrawal while flying by using Nicorette gum.

1.18.4 Visual Illusions

Deviating below the proper glide path can be an intentional action if the pilot deliberately wants to land short on the runway. In other cases, a pilot can believe that a good glide path is being maintained while unintentionally deviating below the glide path. The flatter the glide path, the more difficult it is to visualize changes in the descent rate.

Given the correct set of circumstances, a pilot's perception of the aircraft's position relative to the proper glide path may be significantly impaired, regardless of the pilot's experience or visual ability. An obscuring phenomenon that reduces the brightness of the threshold and runway lights, threshold and runway lights that are on a dim setting, or an up-sloping runway surface can contribute to the illusion that the aircraft is higher than it really is. According to material published by Transport Canada,(3) a normal approach to a runway that has even a small uphill slope will create an illusion that the aircraft is too high, causing pilots to descend to make the runway visual image compatible with the one they are used to. There is a strong tendency in these conditions for the pilot to fly low on the approach and to delay the flare. The illusion is usually increased as visibility decreases and fewer visual references are available to the pilot. The reported visibility when the crew of CDN48 established visual reference with runway 06 was 1½ miles. The illusions are known to "affect even the most experienced pilots...". The Transport Canada document provides guidance to pilots to counteract the effects of runway illusions. Three of these procedures are as follows:

- In your planning, find out the length and width of the runway so as to anticipate any illusions. Do the same with runway slope.

- Initiate your descent at the same point and establish the pitch and power settings that produce a constant airspeed and rate of descent.

- If an approach slope indicator system is in operation, visual illusions are easily countered by keeping on the glide slope.

2.0 Analysis

2.1 Introduction

The analysis discusses the events leading up to landing at Halifax, including company operations, crew procedures, the flight path flown and the deviations below the normal flight path, the actions of the captain in landing the aircraft, and aircraft performance. Also discussed are the runway environment, the activity of the crew, and influences upon the actions of the
2.2 Dispatch of the Flight to Halifax

The flight to Halifax did present some challenges to the crew. The runway was slippery, which created difficulties for the landing at Halifax and the planned departure from Halifax to Rome. Company Operations had addressed the concerns expressed by the captain regarding the departure from Halifax at a heavy aircraft weight. Operations had arranged for another pilot to join the crew in case a decision was made to lighten the fuel load, thereby necessitating an intermediate stop which would have extended the crew day. The landing distance required for CDN48, given the runway condition at Halifax, was expected to be less than the runway available. The amount of runway actually used by CDN48 during the landing, less than 6,500 feet, supports the conclusion that the landing distance available was adequate.

The weather in Halifax was forecast to be above approach limits for the estimated time of arrival, and the surface winds were not forecast to be a factor. However, icing conditions were forecast in cloud and freezing precipitation. Alternate airports were further than normal from Halifax, but sufficient fuel was on board to allow for a diversion if necessary.

Because of the weather conditions, the crew was justified in taking extra care in planning for the flight to Halifax and Rome, but there does not appear to have been an operational reason to cancel their flight.

2.3 Approach Design

The airline's procedures for completing non-precision approaches, like the back course procedure to runway 06, call for the use of FMS VNAV for descent guidance. The procedure is intended to place the aircraft below cloud in good position for a visual landing. CAI, like other airlines operating FMS-equipped aircraft, have adjusted their approach procedures to allow the approach to be flown using FMS vertical guidance.

The approach for runway 06 was set up by the crew using a beacon crossing altitude of 1,700 feet asl, in accordance with the company's procedures, which produced a virtual glide path angle of about 2.3°. The extra 10 feet added to the threshold crossing altitude, by request of the captain, had a negligible effect on the glide path angle. The approach, as programmed in the FMS, created the situation where the approach would become unstabilized at MDA, where the crew would transition to visual flight to make the landing using the 3° PAPI glide path. There was no training provided to the crew indicating that there would be a difference in flight paths when transitioning from VNAV to visual conditions for landing. The calculation of the data required to produce a constant 3° glide path, although possible, would have represented a significant challenge to most flight crew, and was outside of the scope of the airline's procedures or training. Other operators addressed this problem by providing crews with beacon crossing altitudes that produced a glide path angle of 3.0°, which reduces the problems in transitioning from the instrument approach to visual landing.

The use of a beacon crossing altitude that produces a shallower than normal (or optimal) 3° glide path angle can create problems for crews when transitioning to visual flight. However, during the accident approach, the autoflight selections led to the autopilot levelling the aircraft at about 700 feet asl, which caused the flight path angle to change unexpectedly. Thus, the 2.3° virtual glide slope did not directly cause the approach of CDN48 to become unstabilized; nonetheless, the procedures regarding the use of VNAV were flawed, and led to unexpected changes in the flight path that initiated the perception by the captain that he may have been too high and or going too high.

2.4 Procedural Deviations

During the investigation, it was noted that the crew did not always follow standard procedures
in conducting the approach to Halifax. In some cases, it was difficult to determine exactly what procedure should have been followed. Some of the deviations were unintentional and were followed by prompting or correction by the co-pilot. The landing gear and 20°-flap selection were made later than normal; the selection of 30°-landing flaps was made slightly below the normal altitude given by the CAI FCOM, and the aircraft was configured properly for the landing. The late gear and flap extension caused an increase in the crew's workload at the time the aircraft crossed the beacon.

The use of LNAV on final approach instead of B/CRS and LOC, which appears to have been unintentional, resulted in the aircraft being positioned slightly right of the runway centre line as the runway became visual. The initiation of a left turn as the captain assessed his vertical references would have added to his workload and contributed to the approach becoming unstabilized.

There is a difference between the method taught by the airline to conduct back course localizer approaches and that contained in the CAI FCOM, CAI SOP, and the Boeing Flight Crew Training Manual. Crews that follow the procedures outlined in the manuals could be prone to difficulties such as having the approach become unstabilized or becoming very workload intensive if the weather is close to the approach limits.

2.5 Landing and Performance

As the captain acquired visual reference with the runway environment at MDA, the autopilot began to level the aircraft at about 700 feet asl, as a consequence of the VNAV procedures used. The engine thrust increased, the body attitude increased, and the flight path angle decreased. This caused the engine power to increase above approach value, disturbed the stable descent path, and initiated problems in the captain's landing of the aircraft. It would be reasonable to expect that, when the captain disconnected the autopilot, he had sensed that the aircraft was levelling out and that engine power was increasing. This would have given him the impression that the aircraft was going above the glide path that he wanted; he therefore reduced power and pitch angle. The power reduction to below the nominal approach value in the last 10 seconds of the flight resulted in a higher-than-normal rate of descent. As a result, the aircraft deviated below the normal glide path and the approach became unstable in pitch and power.

The aircraft came close to landing short of the runway, which was potentially very hazardous. The captain's decision to ignore the PAPI was not justified, and his allowing the aircraft to go below the glide path created the situation leading to the tail strike. By transitioning to and using the on-slope PAPI indications, a good thrust/lift relationship would have been maintained, and the likelihood of a tail strike would have been reduced. An analysis of reported braking action and landing distance calculations indicate that, even if the aircraft had touched down 1,500 feet from the runway threshold, it could have been stopped safely on the remaining runway. However, the crew did not have a chart or table available to indicate that there was adequate stopping distance, based on the reported JBI.

At the last instant before landing, the captain pulled back on the control column, causing the aircraft body attitude to increase; the rate of descent, however, did not appear to decrease. The captain noticed that the controls seemed lighter than normal. This may have been a perception stemming from the apparent lack of aircraft response; however, in light of the observed performance loss, the possibility of altered control forces cannot be discounted. The aircraft landed hard, which compressed the oleos, with the body attitude increasing. The tail struck the ground at the peak body attitude of 8.1°, close to the value for the tail skid contact angle of 8.0°, with oleos compressed, given in the B767 Flight Crew Training Manual.

Because of the forward C of G position, the minimum airspeed flown on the approach and the flatter than normal approach path, the margin between the pitch angle on approach and the
angle required to strike the tail was reduced by about two degrees. Given the dynamics of the last few seconds of the flight, it is not possible to conclude that a further aft C of G would have prevented the tail strike. However, the crew was not aware of the pitch-angle increase.

Engineering analysis indicated that, in the last 400 feet of the approach, the accident aircraft exhibited a loss of lift and an increase of drag when compared to theoretical data. This loss of performance may have contributed to the captain's inability to arrest the descent rate during the landing flare. Performance tests and DFDR data indicate that speed brakes were not extended. It could not be determined whether wind shear or ice accretion may have influenced the performance loss. Pilot reports and the reported wind conditions do not indicate the presence of any wind shear. Wing anti-ice was not used, but the manufacturer indicated that such a performance loss could not be attributed to leading-edge ice accretion in the range of angle-of-attacks recorded by the DFDR during the approach and landing. There is no direct evidence of ice being observed on the aircraft wings or tailplane after landing. The crew did not observe ice accretion near the cockpit windows during the approach. Missing DFDR parameters (speed brake) and the sampling rate of other parameters, such as angle-of-attack, contributed to the uncertainty of the origin or the magnitude of the performance loss.

2.6 Influences on Crew Actions

At several points during the approach and landing, the crew's performance was degraded by external and self-generated difficulties. It should be noted that an exact analysis of the flight events was precluded by an absence of CVR information.

The captain was concerned about making the flight to Halifax because of the runway condition and weather. He had suggested that the passengers be flown to Toronto to eliminate the Halifax stop. Events during the flight would have added to his concern. The weather had deteriorated to less than that forecast. While on approach, a bleed air malfunction occurred which had the potential of affecting reverse thrust. The localizer back course approach to landing was a type of approach that he had not flown often in the airline's B767 routes or during simulator training. The captain did not have good experiences in conducting actual back course approaches, he demonstrated difficulties during training involving these approaches, and now he had to complete this type of approach in minimum weather. There are several indications that the captain was overly concerned about the runway condition, leading to a condition of channelized attention, and a loss of situational awareness.

The captain reported an hour earlier than usual to begin flight planning, which is not a problem, but was inconsistent with his concerns about an extended crew day in the event that an intermediate stop had to be made after departure from Halifax. The captain's selection of the brakes to MAX AUTO, a selection almost never considered necessary, also indicates the extent of the captain's concern. The last aircraft to land prior to CDN48 had difficulty exiting the runway because of slippery conditions in the vicinity of taxiway Delta, and this information was passed to the crew of CDN48. The captain did not ask ATC to get a braking action report from the crew of that aircraft, which could have given him a better indication of actual runway braking conditions. This suggests that the captain's plan of action for dealing with what he anticipated would be a very slippery runway was already well developed.

Runway 06 has an upslope of 0.77% in the first portion of the runway, which is close to the normal limit specified by TP312. The illusion created by the upslope is that the aircraft is higher than it should be, and a reaction to correct for this perceived problem causes the aircraft to deviate below the proper path. There was nothing on the approach chart to indicate that the first portion of the runway was sloped up. Also, there does not seem to be any way for the crew to have determined that runway 06 had an upslope in the first portion of the runway. Only average slope is provided if the average runway slope exceeds 0.3%. The visibility present during the landing would limit the amount of runway that could be seen, which would have made the first portion upslope more of a visual illusion problem. It appears that both pilots
were unaware of, and affected by, the visual illusions presented by the runway and approach lights, causing them to believe that the aircraft was higher than it actually was. An absence of published information in the form of a cautionary note, or a slope indication on an approach chart, deprived the crew of a possible strategy in overcoming the runway illusions present. This could explain why the power was reduced to 50% N1 by the captain, leading to an unstabilized approach as the aircraft descended through 150 feet agl. A call of the 800 to 900 fpm descent rate, even though it was not required by company SOPs, might have been helpful to the captain. The lack of a call may indicate that the first officer was affected by the visual illusions and failed to appreciate the unfolding situation. The PAPI provided information that would have assisted the captain in maintaining the proper visual glide path to landing. However, he discounted these visual cues. Ignoring the PAPI is consistent with his preoccupation with the possibility of overrunning the runway, and contributed directly to the deviation below the desired glide path.

At certain points in the approach, deviations from procedures led to increased crew workload. A serious problem appears to be the unexpected partial levelling of the aircraft near MDA because of the VNAV procedures used. The ability to successfully cope with workload demands varies from one individual to another, and can also vary for an individual based on his or her state of mind. There is no doubt that the captain's capacity to deal with the increased workload was degraded by his concern about the possibility of being unable to stop on the runway.

3.0 Conclusions

3.1 Findings

1. The flight crew was certified and qualified in accordance with existing regulations.

2. The CVR recording of the accident was over written after the aircraft was parked because power to the CVR was not removed.

3. The aircraft was loaded within approved weight and balance limits but near the forward limit, and was flown at minimum airspeed, resulting in a higher than normal body attitude on approach.

4. The weather conditions at Halifax were conducive to ice accretion on aircraft during the approach.

5. Wing anti-ice was not used during the approach, nor was it required by SOPs.

6. The aircraft flew a 2.3° glide path on the approach to runway 06 because of the NDB crossing altitude selected as per company SOPs.

7. After reaching MDA in visual conditions, the captain flew the aircraft below the visual glide path angle indicated by the PAPI.

8. Theoretical flight simulations indicated that there was a loss in aircraft performance below 400 feet agl. The reason for the performance loss could not be determined.

9. The captain used the aircraft’s LNAV for lateral guidance during the approach instead of B/CRS and LOC.

10. In following LNAV, the aircraft was displaced slightly to the right of the runway centre line at MDA, which required last-minute corrective action by the captain.

11. The aircraft began levelling off unexpectedly at MDA because of VNAV procedures used by the crew.
12. Procedures used in the operator's training for LNAV/VNAV approaches differed from the operator's published procedures for flying the approach.

13. The captain had previously experienced difficulties performing localizer back course approaches during his recurrent training.

14. The captain had not performed an actual localizer back course approach for several years.

15. There was limited training regarding landing from non-precision VNAV approaches and the change of VNAV flight path to visual flight path near MDA.

16. Neither the captain nor the first officer had received formal CRM training.

17. The first officer did not observe the PAPI or notice any unsafe condition during the approach.

18. The first officer did not call out the rate of descent during the approach, nor was he required do so by company SOPs, because the rate of descent was less than 1,000 feet per minute.

19. The first quarter of runway 06 at Halifax has a 0.77% upslope, which is not noted on instrument approach charts.

20. Visual illusions during the approach caused both crew members to believe that the aircraft was higher than it actually was, leading to an unwarranted thrust reduction 10 seconds before touchdown.

21. There were no charts available to the crew to indicate the adequacy of the runway length for the runway surface conditions.

3.2 Causes

The tail strike occurred because the crew responded to a visual illusion with an unwarranted power reduction between the minimum descent altitude and touchdown. The upslope illusion led both crew members to believe the aircraft was higher than it actually was, and the crew did not respond to visual cues from the precision approach path indicator, which showed the aircraft to be too low. Contributing to the accident were the captain's preoccupation with stopping on the slippery runway, and some loss of aircraft performance below 400 feet agl. Also contributing were the lateral navigation/vertical navigation procedures in use, and a higher than normal aircraft body angle, which was induced by a lower than normal approach speed and the aircraft's forward centre of gravity.

4.0 Safety Action

4.1 Action Taken

4.1.1 VNAV Procedures for Non-Precision Approaches

On 14 May 1996, CAI issued a Flight Operations Bulletin (B767-10-96) entitled 3 Degree Glide Path Conversion Chart. The stated purpose for the chart is "to provide B767 crews conducting non-precision approaches with a smooth transition at the minimum descent altitude to the visual airport vertical guidance system." The chart enables pilots to calculate the beacon (FAF) crossing altitude to produce a 3° glide path using VNAV, with a TCH of 50 feet. The chart provides a height value (in feet), based on the distance of the FAF from the runway, to be added to the runway threshold height to produce a revised FAF crossing altitude.

Subsequently, the TSB forwarded an Aviation Safety Advisory to Transport Canada (TC) on
the use of ad hoc VNAV procedures for non-precision approaches. The advisory suggested that TC consider publishing guidelines on the use of VNAV for non-precision approaches, and consider amending non-precision approach charts to facilitate the use of VNAV systems. It was further suggested that TC encourage operators which use VNAV for non-precision approaches to establish applicable Standard Operating Procedures (SOPs) and associated training. In response TC identified their intention to establish an internal working group to study the issue and recommend the publication of appropriate guidance material and the establishment of Standard Operating Procedures and associated training.

The International Civil Aviation Organization (ICAO) Programme for "The Prevention of Controlled Flight Into Terrain" is considering requirements for the design of non-precision instrument approach procedures to take into account the need for a stabilized approach technique with a minimum glide path angle of 3°.

4.1.2 Preservation of CVR Recording

CAI has taken steps to ensure that, when there is an occurrence during the final portions of the flight, crews pull the CVR circuit breakers immediately after the aircraft has parked at the gate or has come to a final stop, in order to preserve the CVR recording of the event. The item was discussed at a company flight safety meeting and the pilot union representative agreed to remind members to take steps to preserve the CVR.

4.1.3 CRM Training

The first officer completed CRM a few weeks after the occurrence. The airline is conducting CRM training at a rate of two courses per week. The CRM training that has been provided has been reviewed and the airline intends to place increased emphasis on the assertiveness portion of future CRM training. The Canadian Air Regulations (CARs) which came into force on 10 October 1996 require that airlines which operate large aircraft (generally 20 or more passengers) have an approved CRM training program.

4.1.4 JBI Charts

The Board determined that the accident occurred, in part, because of the crew’s preoccupation with stopping on the slippery runway. Subsequent to the accident, CAI issued a Flight Operations Information Circular which allows Boeing 767 crews to determine, for a specific runway and JBI, the maximum landing weight which will facilitate a safe stopping distance. This Information Circular contains a table that would have indicated to the crew that adequate landing performance was available for the existing aircraft weight and runway JBI.

4.1.5 Provision of Runway Slope Information

In June 1997, the TSB forwarded another Aviation Safety Advisory to TC concerning the availability of information on "abnormal" slope conditions existing in runway approach environments. It was suggested that the provision of such information would allow pilots to better assess and adapt their final approaches to landing, thereby reducing the risk of flight path errors caused by visual illusions. In the Advisory, the TSB suggested that TC consider establishing criteria for the inclusion of information and/or cautionary statements concerning sloped runway environments in the Canada Flight Supplement and the Canada Air Pilot, and encourage the provision of such information in similar documents used by Canadian operators.

In response, TC stated that this is the first observation regarding this matter and by itself it does not document a threat to safety caused by the current method of providing runway slope information. Transport Canada further stated that Canada's methodology is consistent with the requirements agreed to through ICAO and that they would reserve further analysis until the
accident report was received.

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 November 1997.

Appendix A - Localizer Back Course Approach

Appendix B - List of Supporting Reports
The following TSB Engineering Branch Report was completed:

LP 36/96 - FDR/CVR Analysis, Boeing 767-375, C-FOCA, 8 March 1996.

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

Appendix C - Glossary

AFDS - autopilot flight director system
gl - above ground level
asl - above sea level
AST - Atlantic Standard Time
ATC - air traffic control
ATIS - automatic terminal information system
ATPL - Airline Transport Pilot Licence
B/CRS - back course
C of G - centre of gravity
CAI - Canadian Airlines International
CAP - Canada Air Pilot
CDN48 - Canadian Airlines International flight 48
COHb - carboxyhemoglobin
CRM - crew resource management
CVR - cockpit voice recorder
DFDR - digital flight data recorder
EICAS - engine indicating and crew alerting system
FAF - final approach fix
FCOM - Flight Crew Operations Manual
FMS - flight management system
fpm - feet per minute
hr - hour(s)
ICAO - International Civil Aviation Organization
ILS - instrument landing system
JBI - James Brake Index
KIAS - knots indicated airspeed
LNAV - lateral navigation
LOC - localizer
MAC - mean aerodynamic chord
MCP - mode control panel
MDA - minimum descent altitude
N1 - low-speed rotor speed
NDB - non-directional beacon
ODALS - omni-directional approach lighting system
PAPI - precision approach path indicator
PF - pilot flying
PNF - pilot not flying
PPC - pilot proficiency check
SOP - standard operating procedure
TC - Transport Canada
TCH - threshold crossing height
TSB - Transportation Safety Board of Canada
UTC - Coordinated Universal Time
VASIS - visual approach slope indicator system
VNAV - vertical navigation
' - minute(s)
° - degree(s)
% - percent
1. Other B767 aircraft do record speed brake handle and control surface positions.


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
Runway Overrun
Kelowna Flightcraft Air Charter Ltd.
Boeing 727-172C C-GKFT
Moncton, New Brunswick
03 April 1996

Report Number A96A0047

Summary

The aircraft, operating as Kelowna Flightcraft (KFA) 280, was on a scheduled night cargo flight from Hamilton, Ontario, to Moncton, New Brunswick. After landing on runway 06 in Moncton, the aircraft overran the end of the runway by 154 feet. There were no injuries to the crew, and there was no damage to the aircraft.

Ce rapport est également disponible en français.

Other Factual Information

The flight crew members of KFA 280 were aware before leaving Hamilton that the runway conditions in Moncton would be a concern because of an ongoing snowstorm in the Moncton area. Snow was accumulating at a rate of about two centimetres per hour in gusty winds, with a steady temperature between zero and minus one degrees Celsius. Runway 06/24 at Moncton, which is 6,150 feet long, was being kept open throughout the night by five airport vehicles doing ploughing and sweeping. The crew added sufficient fuel to the aircraft in order to use Quebec City as an alternate; the weather in Quebec City was clear.

At 0349 Atlantic standard time (AST), 26 minutes prior to touchdown, the flight crew contacted Moncton Air Traffic Control Centre (ACC) and were given the latest weather, runway surface condition, and braking action reports. The weather special at 0335 AST was passed as follows: partially obscured, 200 feet overcast ceiling, visibility 1/2 mile in snow, temperature zero, dew point zero. The runway visual range (RVR) was reported as 3,500 feet with the lights on strength three
(before the aircraft landed, the RVR improved to over 6,000 feet with the lights on strength five). The runway surface condition report issued at 2330 AST (4 hours and 45 minutes prior to landing) for runway 06/24 was passed to the crew as follows: 140-foot centre line, 100% snow covered between zero and 1/2 inch in depth, remainder 100% slush between 3 and 18 inches in depth. Braking action reports were passed to the flight crew as follows: various braking action reports through the evening--a McDonnell Douglas DC9, a Boeing 737, and a Convair 580--reported braking action as poor (these aircraft had landed between three and four hours prior to the arrival of the incident aircraft); the latest report was from a second Convair 580 that landed "about an hour ago" and reported braking action as "fair for the type" (this aircraft had landed at 0238 AST).

After the second Convair 580 landed, the crew were asked by the Moncton tower controller for any comments on the braking action. They replied "we were mostly reverse thrust... as far as the amount we used it was fair braking". The tower controller relayed this to Moncton ACC by stating "Braking action fair for the Convair". The Convair 580 crew then relayed further information to Moncton tower, indicating that on the backtrack of runway 06 they "found a few icy patches where it was extremely slippery for the turn-off". The tower controller asked if this was close to the intersection of taxi Delta and runway 06, and the Convair 580 crew replied "That's affirmative, very poor action with numerous ice patches". The tower controller relayed this additional information to Moncton ACC as follows: "The Flightcraft adds that on the backtracking for the taxiway numerous ice patches where its very slippery". This information was not relayed to the crew of KFA 580. Taxiway Delta is located 3,537 feet from the threshold of runway 06.

At 0401 AST, 14 minutes prior to touchdown, the flight crew of KFA 280 contacted Moncton tower for an updated runway surface condition report and any braking action reports. The tower controller asked the flight crew to monitor Moncton ground frequency and listen in while he obtained a report directly from the field maintenance foreman, who was in one of the vehicles on the runway. The following information was given:

"We got a hundred and twenty foot centre line swept at this time and we are sweeping and ploughing it, it's a hundred per cent snow covered up to a half inch, it's wet snow or slush and outside of that we got snow banks up to three feet."

A review of the Moncton Tower tape revealed that this radio transmission was somewhat garbled. The words "wet snow or slush" were not heard by the flight crew, nor did the crew realize that they had missed part of the transmission. The vehicle operator was not aware that he was being monitored by an aircraft on final approach.

After listening to the above runway condition report from the field maintenance foreman, the tower controller gave the flight crew the following braking action report:
"The last braking action we have was from a ah, that was a Navajo about half an hour ago reported braking action fair, before him was a Gulfstream, a G159 reported braking action fair as well."

When air traffic controllers relay braking action reports given by flight crews, they are required by their manual of operations (MANOPS) to state both the type of aircraft and the time of the report. No times were passed for any of the braking action reports relayed to the occurrence aircraft.

The Navajo referred to by the Moncton tower controller landed at 0307 AST, 1 hour and 6 minutes before the tower controller relayed the information to the incident aircraft, and 1 hour and 14 minutes prior to the landing by the incident aircraft. It was reported to the flight crew that the Navajo had given a braking action report of "fair"; however, the Navajo pilot had not passed a braking action report.

The Gulfstream G159 referred to by the tower controller had landed at 0251 AST, 1 hour and 10 minutes before the tower controller relayed the information to the incident aircraft, and 1 hour and 24 minutes prior to the landing by the incident aircraft. The G159 pilot, replying to a request from the tower controller for a comment on the braking action, had given a one-word comment, "fair".

The field maintenance foreman had determined that, because of the wet snow/slush condition of the runway, it would not be possible to obtain an accurate James Brake Index (JBI) reading on the runway. This information was not passed to the flight crew of KFA 280, nor did the flight crew request a JBI report. There is no requirement for air traffic controllers to inform flight crews that a JBI report has not been issued.

The flight crew used the B727 landing performance chart for wet runways and calculated that the aircraft was more than 40,000 pounds below its theoretical maximum landing weight for the runway length available. They did not attempt to factor in any additional landing distance for a contaminated runway.

Before landing, the flight crew had briefed that, on touchdown, they would do a very quick assessment of the braking action before selecting reverse thrust. If the braking action appeared to be unsatisfactory, they would apply take-off power and not attempt to stop. The approach was stable and the target speeds were met. Although the official weather observation at 0400 AST indicated a ceiling of 200 feet overcast with a visibility of 3/4 mile in light snow, the approach and runway lights were visible to the flight crew at about 200 feet above approach minimums. The main wheels touched down 1,972 feet from the runway threshold. The first officer, who was the pilot flying, thought that the aircraft had touched down closer to the threshold. He attributed the extra distance before touchdown to the fact that he had to align the aircraft in the crosswind conditions, which were 70 degrees to the left of the runway heading at 20 knots.
After touchdown, the flight crew's quick assessment of the braking action was that it was satisfactory. The crew immediately applied full brakes, deployed the spoilers, and selected reverse thrust. As the aircraft slowed, both the captain and the first officer applied brakes (this is acceptable for the aircraft type). It appeared to all three crew members that the aircraft was slowing normally. In accordance with standard procedures, at 70 knots, control of the aircraft was transferred to the captain, and engines one and three were placed in idle reverse. The crew then assessed that the aircraft was no longer slowing normally and they re-applied full reverse thrust and full brakes. The aircraft stayed in this configuration until it came to a stop in the snow off the end of the runway. As the aircraft exited the end of the runway, it was at "jogging speed" and was no longer slowing. The flight crew reported that the "roll-out" end of the runway appeared to be more slippery than the touchdown portion. That end of the runway also has a slight downslope. When they exited the aircraft, they observed that the ground under the aircraft (in the overrun area) was covered with wet snow over glare ice.

The flight crew reported that all aircraft systems, including the anti-skid system, had functioned normally. No information was available from the cockpit voice recorder (CVR) as the unit was left powered after the occurrence and the tape was recorded over. The aircraft was equipped with a five-parameter foil-type flight data recorder (FDR). There was no information available from this unit because, although such FDRs remain legal for use in Canadian aircraft, there are no longer any FDR readout facilities in North America that have the operational capability to read them.

There are no performance charts in the Boeing 727 Aircraft Flight Manuals to allow flight crews to calculate landing distances on contaminated runways. There is no guidance in the company operating manual to inform flight crews of company policies or procedures for operations on contaminated runways. Tables are available in the Transport Canada Aeronautical Information Publication (AIP) to allow pilots to estimate the additional landing distance required for given JBI numbers. A separate table contains average JBI equivalent values for reported runway surface conditions when JBI numbers are not available. This table does not attempt to give equivalent values for runways contaminated with wet snow or slush, as it is not possible to obtain JBI values under such conditions. After the occurrence, the flight crew reported that, had they been aware that the runway was contaminated with wet snow or slush, they would not have attempted the landing.

Analysis

No mechanical discrepancies were found with the aircraft that could have contributed to the occurrence. Also, there was no evidence to indicate that the flight crew members were under any external pressure to attempt the landing. This analysis will focus on the general lack of complete and explicit communications, the flight crew decisions and actions, and the lack of company guidance and aircraft performance information for contaminated runways available to the flight crew.
When the flight crew made their decision to continue with the landing, their assessment of the suitability of the runway was based on incomplete and inaccurate information. There had been numerous opportunities for more complete and accurate information to be collected and passed on; however, for the most part, these opportunities were negated by poor communications. Also, the flight crew did not appreciate that, given that there was a constant snowfall with the temperature near the freezing point, contamination with wet snow or slush was a distinct possibility. There were several instances where poor communications contributed to this occurrence. When the Moncton ACC controller passed the braking action reports to the flight crew 26 minutes before the occurrence, he did not provide the landing times for the DC-9 and the B737. These aircraft had reported the braking action as poor. Even though these aircraft had landed three to four hours earlier, their assessment of the braking action should have been more applicable to the incident crew than the assessments of aircraft that landed later, particularly given their similarity to the incident aircraft in size and weight, and given that the weather and runway clearing efforts had not changed appreciably in the interim. The low-key manner in which the information from these two aircraft was passed to the flight crew contributed to their dismissing the information as not applicable, so much so that, after the occurrence, they did not even remember these aircraft being mentioned by the controller.

The second Convair 580 that was reported to the flight crew as having landed "about an hour ago" had passed information to the tower controller about very poor braking action and icy patches on the runway where it was extremely slippery. Once again, poor communications kept vital information from reaching the incident flight crew. The information that eventually was relayed to the incident flight crew concerning the Convair 580 (fair for the type) did not accurately reflect either the actual runway conditions or the intent of the message given to the tower controller by the Convair 580 flight crew. What the Convair 580 flight crew had intended to reflect was that they had used only minimal braking and, therefore, could not provide an accurate assessment of braking action, and that the runway was extremely slippery in spots.

Fourteen minutes prior to touchdown, the tower controller attempted to ensure that the incident flight crew had the most current and accurate information possible by having them monitor a report directly from the maintenance foreman who was working on the runway. During this report, the maintenance foreman stated that the runway was covered with up to 1/2 inch of snow, and that it was being swept and ploughed. He then stated that the snow cover was wet snow or slush. This part of the transmission was heard and understood by the tower controller, but the quality of the transmission was such that these key words were not picked up by the flight crew. A review of the tower tape shows that it is unlikely that the flight crew would have realized that they had missed or misunderstood some of the transmission; therefore, they would not have had reason to ask for the information to be repeated.

The final information passed to the flight crew prior to their landing
(braking action "fair" reports from the G159 and the Navajo) served to reconfirm to them that they were landing on a suitable runway. In fact, neither of these reports should have had any relevance to the incident flight crew. In the case of the Navajo, a braking action report had never been made, and in the case of the G159, the braking action report was simply a one-word afterthought by the pilot, with no mention of whether brakes were even used during the landing.

No FDR readout was available to confirm the amount of reverse thrust selected by the flight crew after landing; however, they reported that they used close to maximum, if not maximum, values. By not aggressively targeting to touch down closer to the threshold at the bottom of the glide path (at the 1,000-foot markers), and by taking engines one and three out of full reverse at 70 knots, the flight crew used more runway to stop than they would have had they used all available deceleration devices to their maximum limits. There are no performance charts available for the B727 to accurately determine a landing distance for the runway conditions that were present during the incident landing. Therefore, it could not be determined if a successful landing would have been possible if the flight crew had used a more aggressive landing/stopping technique.

The flight crew's intention to test the braking action after touchdown before selecting reverse is not an approved and trained procedure for the aircraft. In this case, it is unlikely that their test of the braking action caused any significant delay in applying reverse thrust. However, by having such a procedure as an "out", flight crews could be influenced to attempt landings on runways of questionable suitability.

The following Engineering Branch report was completed:

   LP 45/96 - Flight Recorder Analysis.

Findings

- Available equipment does not allow accurate measurement of braking action in conditions of wet snow or slush.

- Incomplete and non-standard communications prevented vital information on the runway condition from reaching the flight crew.

- Previous landing aircraft did not give detailed braking action reports.

- ATC MANOPS procedures were not followed when braking action reports were relayed to the flight crew.

- The flight crew did not adequately assess the potential for contamination on the runway, and did not use all information available to them to make an accurate assessment of the runway conditions.
- The landing technique used by the flight crew was not consistent with the type of landing technique normally associated with landing on a potentially contaminated runway.

- Aircraft flight manuals for the B727 aircraft do not provide sufficient information for flight crews to be able to calculate landing distances on contaminated runways.

- The company operations manual did not provide guidance to flight crews concerning operations on contaminated runways.

- Information was lost to the investigation because the FDR was old and there was a lack of facilities to read it, and because there was no CVR data available.

**Causes and Contributing Factors**

Incomplete and inexplicit communications led the flight crew to believe that the runway condition was suitable for landing when it was not. Contributing factors include the flight crew not obtaining and assessing all of the information available to them, and a lack of aircraft performance information and company guidance for operations on contaminated runways.

**Safety Action Taken**

The company has taken the following safety actions:

- Supporting documentation and approvals have been obtained to start the change-over of the two remaining foil-type FDRs in their fleet to the newer digital FDRs.

- A memo to all flight crew has been issued requiring the pilot-in-command to ensure that the CVR and FDR circuit breakers are pulled after landing following an accident or reportable incident. Also, a formal Flight Operations Manual revision covering this subject has been approved and will be issued once it is printed.

- A memo (96-018) was issued that instructs flight crew to request runway condition reports and JBI readings for all operations on contaminated runways and to ask specific questions of the appropriate agency to ensure that they have an accurate picture of the existing conditions.

- Memo 96-018 also instructs flight crew, when landing on a contaminated runway, to fly the aircraft firmly to the runway at the aiming point (1,000-foot markers), and, once on the runway with the stopping effort begun, to not attempt a go-around, to use all deceleration devices to the allowable limits, and to not discontinue reverse thrust until a full stop is assured.
Memo 96-018 also contains further information on calculating the landing distance required on contaminated runways.

The company is actively researching a quick reference type of required landing distance chart.

Transport Canada has taken the following safety action:

- Transport Canada Civil Aviation has taken the necessary action to ensure that the company’s operations manual has been amended to provide guidance to flight crews concerning operations on contaminated runways.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail and W.A. Tadros, authorized the release of this report on 24 October 1996.

Updated: 2002-10-06

Important Notices
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
Take-off/Landing Event
Air Canada
Canadair CL 600-2B19
Fredericton, New Brunswick
08 April 1996

Report Number A96A0050

Summary

The Canadair Regional Jet landed on runway 15 at Fredericton, New Brunswick, at 2229 Atlantic daylight saving time (ADT). During the after-landing roll, at low speed, the aircraft yawed left and exited the runway about 5,500 feet beyond the threshold. The aircraft came to a stop when its nose gear sunk into the soft ground adjacent to the runway surface. There were no injuries to the crew or passengers and there was no damage to the aircraft.

Ce rapport est également disponible en français.

Other Factual Information

The captain had an airline transport pilot licence (ATPL) and 12,200 hours total flight time, of which 535 hours was as pilot-in-command on the aircraft type. The first officer had an ATPL and 8,500 hours total flight time, with about five hours on the aircraft type.

The aircraft weight and centre of gravity were within limits. There were no aircraft system deficiencies reported by the flight crew or identified by maintenance during the inspection following the incident.

The aircraft, operating as Air Canada flight 646 (ACA646), was cleared by Moncton Area Control Centre (ACC) for a straight-in instrument landing system (ILS) approach to runway 15 at Fredericton. Runway 15 is 6,000 feet long and 200 feet wide. The crew contacted the Fredericton Flight Service Station (FSS) when 100 miles west of the airport and requested the runway surface condition (RSC). The FSS specialist advised ACA646 that there was no James Brake Index (JBI) report, that the sweepers would be on the runway until about five
minutes before their arrival, and that an updated RSC report would be
given to the crew prior to their landing. About six minutes before
touchdown, the flight crew received the following RSC: runway 15/33
100-foot centre line, 60% bare and wet, 20% light slush and 20% light
snow, outside the centre line one inch of slush and snow mixed.

The actual surface weather record issued by Environment Canada at
2200 ADT (29 minutes before ACA646 landed) was as follows:
precipitation ceiling 800 feet obscured, visibility 3/4 mile in light snow,
temperature 0°C, dew point -1°C, and wind 030° true at 10 knots. The
actual surface weather recorded at 2248 ADT, 19 minutes after
ACA646 landed, was unchanged. About four minutes before
touchdown, ACA646 was advised that runway 15 runway visual range
(RVR) was 6,000 feet with light setting strength five. Two minutes
before touchdown, the wind was reported to the flight crew as 060°
magnetic at 10 knots.

During the after-landing roll, the aircraft yawed left as the indicated
airspeed (IAS) was decreasing through 40 knots. To counteract the
yaw, the pilot flying (PF) reduced reverse thrust and then stowed the
reversers on both engines, while braking and maintaining full right
rudder. The reversers were unintentionally stowed before the engines
had spooled down to idle reverse. As a result, the aircraft transitioned
to forward thrust with a higher than idle thrust setting. The left engine
reverser, then the right engine reverser, was redeployed, with the left
engine thrust increasing above idle(1); the aircraft continued to the left
and exited the runway.

The aircraft stopped when the nosewheel tire sunk into the soft ground.
After the aircraft had stopped, left engine forward thrust was selected in
an unsuccessful attempt to return the aircraft to the runway. The aircraft
was shut down, and arrangements were made to transport the
passengers to the terminal.

The flight data recorder (FDR) and cockpit voice recorder (CVR) were
sent to the TSB Engineering Branch. TSB investigators had requested
that the CVR circuit breaker be pulled after the occurrence; however,
by the time the CVR was disabled, crew conversations prior to the
runway excursion were recorded over and not available.

FDR data indicated that the aircraft approach and touchdown speeds
were normal for the aircraft weight and landing configuration, and that
the ground spoilers deployed at touchdown. Thrust reverse deployed
after touchdown for 24 seconds and was maintained at 84% N1 for 17
seconds. Aileron and rudder inputs were applied to counteract the left
crosswind.

The runway surface condition reported to the flight crew about six
minutes prior to landing did not exceed the recommended runway
surface condition limitations for the aircraft type. A JBI reading for the
runway was not produced because the runway surface was
contaminated with water and slush. The flight crew reported that the
runway was 100% snow-covered when the aircraft landed.
The aircraft's maximum demonstrated crosswind component for landing or taking off is 24 knots, which is not considered to be limiting (dry runway). The operator's Airplane Operating Manual (AOM) states that another runway should be considered when the crosswind on a wet or slippery runway exceeds 15 knots. The crosswind component was 10 knots when ACA646 landed. Although Canadair recommends that reverse thrust be at less than 30% N1 at speeds below 60 knots to reduce the possibility of foreign object damage to the engines, the flight crew maintained reverse at 84% N1 until 35 knots.

Main gear tire cornering forces available to counteract a drift will be at a minimum when the anti-skid is operating at maximum braking effectiveness for the existing conditions.

The Air Canada CL-65 AOM identifies the appropriate pilot actions when landing on a slippery runway with a crosswind, and cautions:

When changing thrust from reverse to forward idle, pause at idle reverse to allow the engines to unspool before selecting forward idle. If the reversers are stowed while the engines are still spooled up, there will be a noticeable decrease in deceleration or a forward surge of the aircraft.

The AOM advises that reverse thrust levels be reduced symmetrically, if necessary, if control difficulties are experienced. The AOM, Normal Procedures Landings, also states in part, "If directional control difficulties are experienced, release the brakes."

During the investigation, landings were carried out in the flight simulator, with wind and runway conditions approximating those that existed at the time of the occurrence. The left veer off the runway could not be duplicated in the simulator. When the crosswind approached 20 knots, a left yaw and a slide to the right (downwind side), as identified in the flight crew training manual, were experienced. When the crosswind was increased to about 20 knots, the aircraft exited the runway off the right side.

Analysis

Since it was still snowing, runway contamination at touchdown would have been greater than reported in the RSC that was passed to the flight crew. The runway 15 RVR was 6,000 feet and would have allowed the flight crew to see the departure end runway lighting at touchdown.

Braking effectiveness was reduced because of the slippery runway surface condition. Also, the aircraft's proximity to the end of the runway during deceleration would have resulted in the crew continuing to use a high reverse thrust setting at a speed below that recommended by Canadair. The combination of the left crosswind, the slippery runway surface condition, and the high reverse thrust at low speed resulted in the aircraft weathercocking left into the wind. Since the engines had not spooled down to idle reverse before the reversers were stowed, the resultant forward thrust was sufficient to arrest the deceleration and
result in the runway excursion.

When reverse thrust was reselected, the idle reverse thrust on the left engine contributed to the increased rate of turn of the aircraft heading to the left. Also, with braking maintained after the veer, tire cornering forces were negligible. If the brakes had been released, the increased tire cornering forces could have helped to counteract the veer and maintain the aircraft on the runway. The rudder would have been ineffective at the low forward speed. After the aircraft yawed left during deceleration, the PF moved the thrust reverse levers to idle reverse; however, in his haste to accomplish this, he pushed the levers past idle reverse and unintentionally stowed the thrust reversers. Had the engines spooled down to idle before the reversers were stowed, the aircraft might have stopped on the runway.

The flight simulator landings did not result in the aircraft going left as the occurrence aircraft did. However, after the veer to the left, reverse thrust was reduced to idle reverse and transition to forward thrust was not simulated.

The following TSB Engineering Branch report was completed:

LP 41/96 - FDR Analysis.

The TSB Engineering Branch and the aircraft manufacturer, Canadair, have each produced a computer animation tape of the runway excursion, available on request from the TSB.

Findings

- On landing, the PF was unable to maintain directional control of the aircraft at low speed.

- The loss of directional control was initiated by the left crosswind and the slippery runway surface condition.

- The engines had not spooled down to idle before the reversers were stowed. As a result, the transition to forward thrust arrested the aircraft's deceleration.

- The runway surface condition and crosswind component did not exceed the landing limitations.

- The pilot maintained braking after the weathercock. This minimized the tire cornering forces available to counteract the veer.

- The rudder was ineffective in counteracting the veer due to the aircraft's low forward airspeed.

Causes and Contributing Factors
The flight crew was unable to maintain directional control of the aircraft on landing. Contributing to the loss of control was the crosswind, the slippery runway surface, and the forward thrust that resulted when the reversers were stowed before the engines reached idle power.

**Safety Action**

*Operator Action Taken*

Air Canada has indicated that they are producing an Information Supplement as part of the winter operation package; the supplement will augment the crosswind slippery landing information already in the CL-65 Operating 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 14 February 1997.*

1. Indications are that the selection of power on only the left engine was not intentional.

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Updated: 2002-10-06

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**Important Notices**
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 Loss of Separation Between Newfoundland Government Air Services Beechcraft King Air A-100 C-FGNL and Provincial Airlines Limited Fairchild SA227AC C-FIPW St. John's, Newfoundland 18 April 1996

Report Number A96A0057

Summary

C-FGNL, a medical evacuation (MEDEVAC) flight, was inbound on an instrument flight rules (IFR) flight plan to St. John's, Newfoundland, for a landing on runway 16. C-FIPW, also on an IFR flight plan and operating as Speedair (SPR) 904, was approximately 12 miles behind C-FGNL and also planning to land on runway 16. Approximately 33 miles from the St. John's airport, the pilot of C-FGNL requested and received radar vectors for an approach to runway 11.

A loss of separation occurred when Speedair 904 landed on runway 16 at the same time that C-FGNL was on short final for landing on runway 11. The distance between the two aircraft was 1.4 nautical miles (nm) when the required radar separation was 3 nm.

Ce rapport est également disponible en français.

Other Factual Information

The 2200 Newfoundland daylight saving time (NDT) surface actual weather for St. John's was as follows: indefinite obscured ceiling at 100 feet, visibility three-eighths of a mile in light drizzle and fog, temperature and dew point 3°C, wind 160° magnetic at 15 knots. The runway visual range (RVR) for runway 16 was 2,000 feet with the light setting on strength 5, and 2,200 feet on runway 11 with the light setting on strength 5.

Initially, both aircraft were being controlled by a Gander Centre
controller who had been licensed as a low domestic controller(1) for two years. In his planning, the controller anticipated that C-FGNL would land on runway 16 ahead of SPR 904. C-FGNL was cleared for an approach for runway 16 upon interception of the localizer; however, the pilot, after receiving the RVR for runways 16 and 11, requested a clearance for an approach on runway 11. The controller then cancelled C-FGNL's approach clearance for runway 16 and issued radar vectors to C-FGNL for an approach for runway 11.

![Figure 1 - Flight Paths](image)

At that time, the controller determined that the extra distance required for C-FGNL to reach the final approach for runway 11 would allow SPR 904 to land ahead of, but not delay, C-FGNL. SPR 904 was advised to keep the speed up. SPR 904 was then cleared for the instrument landing system (ILS) approach to runway 16 and instructed to contact St. John's tower.

The controller was then relieved by a second (relief) controller who had 25 years experience as a low domestic controller. The relief controller was briefed by the first controller about the possible traffic conflict developing between SPR 904 and C-FGNL.

The pilot of SPR 904 reduced airspeed upon interception of the localizer. The relief controller issued the following to C-FGNL: "GNL reduce to approach speed please. There's a speedair ..ah..8 miles final for runway 16". C-FGNL was about one mile from intercepting the localizer final for runway 11 when the relief controller issued the speed reduction and was six miles on final approach when cleared for the straight-in ILS approach on runway 11 and instructed to contact St. John's tower (YT-TWR).
<table>
<thead>
<tr>
<th>Time</th>
<th>Agency</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>19:54:42</td>
<td>C-FGNL</td>
<td>And ah..GNL confirm we are cleared to land.</td>
</tr>
<tr>
<td>19:54:44</td>
<td>YT-TWR</td>
<td>Golf November Lima, Tower. Negative. Merlin traffic about 2 miles back on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>approach for runway 16.</td>
</tr>
<tr>
<td>19:54:50</td>
<td>C-FGNL</td>
<td>GNL.</td>
</tr>
<tr>
<td>19:55:27</td>
<td>C-FGNL</td>
<td>GNL Medevac; understood.</td>
</tr>
<tr>
<td>19:55:30</td>
<td>YT-TWR</td>
<td>Speedair 904 advise when you are through the intersection runway 11.</td>
</tr>
<tr>
<td>19:55:56</td>
<td>C-FGNL</td>
<td>GNL is at minimums. What are we going to do. Over.</td>
</tr>
<tr>
<td>19:55:58</td>
<td>SPR 904</td>
<td>Through the intersection for 904.</td>
</tr>
<tr>
<td>19:56:00</td>
<td>C-FGNL</td>
<td>GNL's landing.</td>
</tr>
</tbody>
</table>

The *Aeronautical Information Publication* (A.I.P. Canada), RAC section 3.15.10 (b), addresses the use of the flight plan prefix "MEDEVAC." This section states that the term MEDEVAC is to be inserted in the flight plan when the operation is a medical evacuation flight responding to a medical emergency for the transport of patients, organ donors, organs, or other urgently needed life-saving medical material. Air Traffic Services will give priority to flights so designated. Note (1) states that discretion must be practised in the use of the term "MEDEVAC" as it is intended only for that portion of a flight requiring a priority as dictated by the medical requirement.

All flights undertaken by C-FGNL for the purpose of medical evacuation are classified by the operator as a MEDEVAC and the term "MEDEVAC" is used on all flight plans. However, it was determined during the investigation that some of these flights are responding to a non-critical patient transfer rather than medical emergencies.

The purpose of the occurrence flight was to pick up an infant, who was diagnosed with apnea episodes, in St. Anthony and transport her, a medical escort, and one other person to St. John's. The first leg of this flight, from St. John's to St. Anthony, was delayed leaving St. John's for about two hours because the aircraft was waiting for two non-priority passengers. However, the flight plan indicated that this portion of the flight was a "MEDEVAC".
The *Air Traffic Control Manual of Operations* (MANOPS), section 532.1 (B), states that three miles separation between aircraft is required provided:

- terminal control services are being provided;

- a maximum range of 60 miles is displayed on the radar display; and,

- (a) altitude readouts for both aircraft are displayed; or

  (b) both aircraft are at or below 15,000 feet asl.

All of the above requirements were being met in this instance.

Both of the controllers indicated that a high degree of priority is placed on an aircraft utilizing the MEDEVAC status. The option was available to the relief controller to issue an alternative clearance to either aircraft to maintain required separation; however, this was not done. He stated that he was willing to accept the loss of separation and the consequences it would bring rather than delay the MEDEVAC flight by having it conduct a missed approach. The controller was monitoring the flights on radar, and he was confident that there would be no risk of collision.

**Analysis**

The first controller was aware of the developing conflict between the two aircraft. He requested that SPR 904 keep his speed up, and he assumed that this increase in speed, along with the extra distance that C-FGNL had to fly to get to the approach for runway 11, would provide adequate, yet minimum, separation. He did not anticipate that SPR 904 would reduce his airspeed upon interception of the localizer, thereby reducing the separation between the two aircraft. The relief controller took over the position prior to SPR 904 reducing speed. He saw a loss of separation developing, but did not take action to prevent it.
The term MEDEVAC on a flight plan has a significant impact on the air traffic control system in that air traffic controllers give priority handling to these aircraft and do everything possible to avoid delays. In this occurrence, both controllers were aware that C-FGNL was a MEDEVAC, and they assumed that priority handling was required. Based on the assumption that the MEDEVAC was a priority, the relief controller was willing to accept the loss of separation that resulted, rather than issue an alternative clearance to either aircraft.

**Findings**

- C-FGNL's flight plan indicated that the flight was a MEDEVAC, even though priority handling was not required.

- The relief controller allowed the separation between the two aircraft to be reduced to 1.4 nm when 3 nm was required.

- The relief controller consciously allowed a loss of separation rather than issue an alternative clearance to either aircraft.

**Causes and Contributing Factors**

The developing conflict and subsequent loss of separation between the two aircraft was detected but not resolved by the relief controller. Contributing to the occurrence was the willingness of the controllers to accept the loss of separation in order to give priority handling to a MEDEVAC.

**Safety Action Taken**

Information regarding the use of the term “MEDEVAC” on flight plans when it is clear that the flight does not require high priority was sent in July 1996 to Transport Canada and others involved with this occurrence.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail and W.A. Tadros, authorized the release of this report on 13 November 1996.

1. ATC controller working aircraft in domestic airspace below 27,000 feet.
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
Power Loss/Hard Landing
Nova Scotia Department of Natural Resources
McDonnell Douglas 369E C-FGJK
Shubenacadie, Nova Scotia
16 June 1996

Report Number A96A0099

Summary

The helicopter departed the Nova Scotia Department of Natural Resources helicopter base with the pilot and three passengers on board. Approximately two minutes into the flight and at an altitude of 300 feet above the ground (agl), a loud bang was heard, followed immediately by an engine out horn and light. The pilot entered an autorotation and, as he was flying over a forest, extended the glide to reach a road. The main rotor rpm decayed during the extended glide, and the low rotor rpm light and horn were on when the helicopter touched down hard on the road. The helicopter bounced back into the air, moved to the left about six feet, touched down again, and came to rest in an upright attitude. The tail boom was severed by the main rotor blades during the landing. There were no injuries to any of the occupants.

Ce rapport est également disponible en français

Other Factual Information

A 300-hour inspection of the helicopter was started five days prior to the accident. On the second day of the inspection, the aircraft maintenance engineer (AME) responsible for completion of the inspection was dispatched with two other helicopters on forest fire fighting duties. Another AME was recalled from days off to finish the inspection. The inspection was completed two days prior to the accident, and this was the first flight following the inspection.

Access to the engine inlet area through the engine inlet by-pass door
is required to inspect some of the items on the 300-hour inspection sheet. To facilitate working in this area, the maintenance personnel use a make-shift inspection aid to prop open the engine by-pass door. This aid was a cardboard tube 9.5 inches long by 2.75 inches in diameter. There was no flagging attached to the tube that would attract attention to it. The tube was observed in position on the first day of the inspection, but after that no one could recall seeing it there.

When the replacement AME started work he noted that inspection of the mist eliminator screen, which is in the engine inlet area, and the hinge inspection on the by-pass door had not been carried out, as they were not signed off. The by-pass door has to be removed to complete the hinge inspection, so he removed it, carried out the remainder of the inspection items in the engine inlet area, and reinstalled the by-pass door. The AME then carried out a visual inspection for foreign objects, closed and latched the door, and signed off the applicable inspection items. There was no procedure in place to ensure that all tools were removed and accounted for following the completion of an inspection.

During examination of the aircraft after the accident the cardboard tube that was used to prop open the engine by-pass door was found lodged against the compressor inlet. The tube blocked off approximately fifty per cent of the compressor inlet causing the engine to flame out.

The accident flight was a non-revenue test flight. According to the operators Maintenance Control Manual there is no requirement for a test flight to be carried out after a 300-hour inspection. However, there is an informal procedure that gives pilots, who are on a self-dispatch system, the authority to carry out test flights after inspections or after the helicopter has been idle for some time to verify that all of its systems are serviceable in the event that it is required for operational duties, or for pilots who are scheduled to fly the helicopter and have not flown it recently. On 20 August 1993, the operator issued a memorandum to all its Air Service staff stating that personnel on test flights will be restricted to essential crew and personnel giving or receiving related training. Up to that time authorized passengers were permitted on maintenance test flights when non-critical components were being checked. The operator does not have any directives specifying a minimum safe altitude for these or any other flights.

Analysis

The engine power loss was caused by the make-shift inspection aid partially blocking off the compressor inlet. The analysis will concentrate on the chain of events that resulted in the inspection aid being left in the engine inlet area and the altitude at which the check flight was carried out.

The make-shift inspection aid was likely used to prop open the engine by-pass door by the AME who was dispatched on forest fire fighting duties. Prior to the second AME working in this area, the tube was likely dislodged, coming to rest aft of the door where it was hard to see; the AME did not detect the tube when he carried out the inspection for foreign objects. There was no flag attached to the tube, which would
have made detection easier, and there was no procedure in place to ensure that all tools were removed, such as a sign off section on the inspection sheets or a tool shadow board.

The flight was carried out at an altitude of 300 feet agl over a forest. There is no requirement to be at such a low altitude on a check flight. In general, the lower the altitude at which there is a loss of power, the less likely it is that a pilot will be able to reach a suitable landing area and successfully complete an autorotational landing.

Findings

- An un-flagged, make-shift aid was used to facilitate inspection and was left in the engine inlet area.

- There was a change of maintenance personnel part way through the inspection.

- The second AME did not see the make-shift aid when he carried out the inspection for foreign objects; consequently, it was not removed prior to the flight.

- There was no procedure in place to ensure that all tools were removed and accounted for on the completion of an inspection.

- The engine flamed out when the make-shift inspection aid partially blocked off the engine compressor.

- The pilot extended the glide to reach the woods road, and, as a consequence, the rotor rpm decayed resulting in a hard landing.

- The operator had not issued any directives specifying a minimum safe altitude for test check flights.

Causes and Contributing Factors

The engine flamed out when a make-shift inspection aid, inadvertently left in the engine inlet area, partially blocked off the compressor. Contributing to the occurrence was the use of an un-flagged inspection aid, the absence of a procedure to ensure that all tools were removed and accounted for on the completion of an inspection, and the low altitude at which the flight was conducted.

Safety Action Taken

Following the occurrence, the operator department initiated the following action:

- A special tool, with a 5-foot red flag attached, was manufactured for holding the engine inlet by-pass door open during maintenance activities.
- The Maintenance Control Manual was amended to include an inspection for foreign objects following every maintenance action requiring a maintenance release. These will be independent inspections carried out by two AMEs. The pilot and an AME shall complete the inspection when operating away from base.

- Work sheets were amended to include sign-off sections for the inspection for foreign objects.

- Completion of the tool shadow board has been made a high priority task, with the materials required to effect tool control procedures on order.

- All maintenance staff have been briefed on the consequences of inattentiveness.

- All pilots have been encouraged to conduct their own inspection for foreign objects, and engineers have been instructed to assist any pilot wishing to do so.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, Benoit Bouchard, and members Maurice Harquail and W.A. Tadros, authorized the release of this report on 15 October 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
Controlled Flight Into Terrain
Cargair Ltée
Cessna 172N C-GBZG
St. Pauls Inlet, Newfoundland
22 July 1996

Report Number A96A0134

Summary

C-GBZG was one of four aircraft that departed Natashquan, Quebec, at 1839 Coordinated Universal Time (UTC)\(^1\) on a visual flight rules (VFR) flight to Stephenville, Newfoundland. C-GBZG was last observed flying into clouds as it approached the Newfoundland shore at St. Pauls Inlet. Attempts to contact the pilot were unsuccessful. A search and rescue satellite picked up an emergency locator transmitter (ELT) signal in the vicinity of St. Pauls Inlet. Because of poor weather at the site, search and rescue was delayed and the aircraft wreckage was located the next morning. The aircraft struck rising terrain at about 1,100 feet above sea level (asl) at approximately 2010 UTC (1740 local time). The three people on board were fatally injured, and the aircraft was destroyed.

*Ce rapport est également disponible en français.*

Other Factual Information

C-GBZG was one of four airplanes rented by a group of foreign tourists for a Canadian flying vacation. Each pilot was appropriately licensed as per Transport Canada requirements, and all of the flying was to be carried out under visual meteorological conditions. The group members had not previously flown in the Canadian maritime region.

The group had spent the night in Sept-Îles, Quebec, and was en route to Stephenville, Newfoundland, with a refuelling stop at Natashquan, Quebec. Prior to departure, the group discussed the proposed route of flight and one of the pilots, the group organizer, telephoned the Sept-Îles Flight Service Station (FSS) about 1300 UTC and received a...
weather briefing. A transcript of the telephone conversation indicates that the group could expect some rain showers along the route of flight with ceilings between 800 and 3,000 feet above ground level (agl). The pilot was told of a low pressure system situated about 120 nautical miles southwest of Stephenville and moving northeasterly. Ceilings of 100 to 1,000 feet and visibilities of 1/4 to 3 miles in drizzle and fog could be expected where the low resulted in an onshore, southwesterly flow.

At the airport, the group organizer spoke in person with the FSS weather specialist, filed the group flight plan, and received a weather printout which was shown to the group. The FSS specialist suggested that, upon reaching Natashquan, the group organizer call for updated weather information before continuing en route. The group organizer stated that they did not request or receive updated weather information after their briefing in Sept-Îles.

The terminal forecast for Stephenville issued 22 July 1996 at 0909 UTC, valid for the 24-hour period 1000 to 1000 UTC was as follows:

Wind 070 degrees true at 10 knots, visibility greater than 6 statute miles, scattered cloud at 1,500 agl, and broken cloud at 3,000 feet agl. Temporary overcast ceiling at 1,500 feet agl between 1000 and 2200 UTC; wind becoming 030 degrees true at 10 knots between 1400 and 1500 UTC. After 2200 UTC: wind 310 degrees true at 10 knots; visibility greater than 6 statute miles; broken cloud at 3,000 feet agl.

The terminal forecast for Stephenville issued 22 July 1996 at 1524 UTC, valid for the 24-hour period 1600 to 1600 UTC was as follows:

Wind variable at 3 knots, visibility greater than 6 statute miles in rain showers, a few clouds at 800 feet agl, broken clouds at 1,500 feet agl and overcast cloud at 3,000 feet agl. Temporary, rain with broken cloud at 600 feet agl and overcast ceiling at 1,200 feet agl. between 1600 and 1900 UTC. After 2000 UTC: wind 330 degrees true at 15 knots, visibility greater than 6 statute miles; broken cloud at 800 feet and 6,000 feet agl.

The four aircraft departed Sept-Îles at 1600 UTC, arriving at Natashquan at 1741 UTC. The weather at Natashquan was sunny and warm with good visibility. At about 1839 UTC, after refuelling, the four aircraft departed Natashquan on a flight-planned route via the "whiskey" non-directional beacon at Cape Whittle, Quebec, direct Cow Head, Newfoundland. Each pilot had a VFR navigation chart on board and a personal global positioning system computer for navigating.

The group of four aircraft crossed the Gulf of St. Lawrence at altitudes between 1,000 and 3,000 feet asl, maintaining visual reference with one another; C-GBZG was the last aircraft in the group. As the group approached the Newfoundland coast, increased cloud formation made it increasingly difficult to maintain constant visual reference with the
ground and with each other. The pilots discussed the change in weather, but none of them made a radio call to an FSS for the latest weather information.

The aircraft in the group used the radio frequency 122.9 MHz as a common communication frequency. The last radio contact with the pilot of C-GBZG was about 30 miles west of St. Pauls Inlet, when he responded to a general remark made by another aircraft group member on their communication frequency. Ten miles from shore, the pilot of the lead aircraft announced his position and stated that he would be descending. The group organizer, who was piloting the aircraft in third position, reported that, as he descended below 1,000 feet asl over St. Pauls Inlet, he could see steeply rising terrain just beyond the inlet that became obscured by cloud cover. He turned his aircraft to the right, to a southerly heading following the first two aircraft. He then observed C-GBZG enter cloud, on what appeared to be the en route heading and at an altitude about 500 feet higher than his aircraft.

He called the pilot, instructing him to turn immediately; however, repeated attempts to contact the aircraft were unsuccessful. The three remaining aircraft continued to within 33 miles of Stephenville where the ceiling deteriorated to 500 feet agl. They executed a turn to the north, over the water, and returned to Natashquan.

![Figure 1 - Route of Flight](http://www.tsb.gc.ca/en/reports/air/1996/a96a0134/a96a0134.asp)

C-GBZG struck rising terrain at about 1,100 feet asl on the approximate en route heading. The landing flaps were fully retracted at impact. The engine and propeller separated from the aircraft, and there was major compression and buckling in the cabin area.

An examination of the engine and flight instruments by the TSB Engineering Branch in Ottawa revealed the following: the engine tachometer displayed 2,600 rpm; the vertical speed indicator showed a descent rate of 1,300 feet per minute; and electrical power was being supplied to the aircraft at the time of impact. A calculation of the aircraft's weight and balance indicated that the aircraft was within approved limits at impact. The aircraft had undergone a 100-hour inspection on 15 July 1996, at an airframe time of 6,549.4 hours, and had flown about 18 hours since the inspection. There were no recorded
aircraft deficiencies. Examination of the wreckage did not identify any pre-impact failure.

The pilot had about 1,341 hours total flight time, all on single-engine aircraft. He did not have an instrument rating, although he had received extensive instrument flight training during the previous year. On board C-GBZG with the pilot were his wife, who occupied the rear seat, and a non-flying pilot in the right front seat. The non-flying pilot was recently licensed, had about 74 hours total flight time, and had been pilot-in-command (PIC) during some of the Canadian flights.

Another member of the group had observed the occurrence pilot fly C-GBZG into cloud during a previous flight. The non-flying pilot had told a group member that the PIC intentionally entered cloud on occasion and demonstrated aircraft control with reference to the aircraft flight instruments. The non-flying pilot had enjoyed the experience and had expressed confidence in the PIC's piloting skills.

A review of the pilot’s medical records provided no evidence of prior medical conditions that would have adversely affected his performance. A post-accident pathological examination provided no evidence of pre-existing disease or conditions which could have led to pilot incapacitation prior to impact.

Toxicological tests revealed that the pilot had a blood-alcohol concentration (BAC) of 99 milligrams per 100 millilitres (0.099% w/v). The blood used for testing was taken from the body cavity, a location that can result in less accurate BAC results than blood sampled from a vein or artery. Post-mortem changes in the alcohol level of samples can occur as a result of putrefaction and contamination. The blood sample analyzed revealed that putrefaction may have taken place. As a result, the reported alcohol level may have increased or decreased from the alcohol concentration present at the time of death.

**Analysis**

The group was on vacation, and there were no time constraints that should have pressured them to complete the flight even if deteriorating weather conditions were expected. They were unaccustomed to flying in eastern Canada, where rapidly changing weather conditions could be expected. The good weather at Natashquan and the group's inexperience with local weather patterns probably led them to believe there was no need to request a weather update.

When the pilot of C-GBZG last communicated with the group, about 30 miles west of St. Pauls Inlet, there was no indication that he was having any aircraft difficulties. The aircraft's last observed flight characteristics and the accident site examination indicate that the aircraft was in controlled flight prior to and at the time of impact. Results of the pathological examination provided no evidence of pre-existing disease or conditions which could have led to pilot incapacitation prior to impact.

The weather at St. Pauls Inlet had not deteriorated to below VFR limits,
and the pilot should have had visual reference with the aircraft in front of him. He had a VFR navigation chart, and the visibility below cloud was sufficient to identify the coast and rising terrain beyond the inlet.

The group organizer was unsuccessful in contacting the pilot of C-GBZG after the aircraft was observed entering cloud. It is possible that C-GBZG hit the terrain before the pilot received the radio transmission "turn immediately" or that the transmission was received too late for him to take evasive action.

The pilot of C-GBZG, although not IFR rated, was an experienced pilot, had received a considerable amount of IFR flight training, and was known to have previously entered into instrument meteorological conditions during VFR flight. It is probable that the pilot intentionally entered cloud, unaware of his proximity to the rising terrain. Based on the vertical speed indication of 1,300 feet per minute down, it is probable that the pilot was descending the aircraft to regain visual reference with the ground when the aircraft hit the terrain.

Toxicological testing showed that there was alcohol in the blood sample taken from the pilot's body. However, because of the possibility that the percentage of alcohol in the blood was affected by putrefaction and contamination, the level of alcohol in the pilot's blood at the time of his death cannot be determined precisely.

The following Engineering Branch report was completed:

LP 99/96 - Instrument Examination.

Findings

- The aircraft was maintained in accordance with Transport Canada requirements, and the weight and balance was within approved limits at the time of impact.

- There was no evidence of any aircraft system failure prior to the accident.

- The aircraft was in controlled flight prior to and at the time of impact.

- The pilot was licensed in accordance with Transport Canada regulations.

- The pilot was not instrument rated; however, he had received extensive instrument flight training during the past year.

- The pilot had intentionally entered cloud on a previous flight.

- The group organizer indicated that they neither requested nor received updated weather information after their briefing in Sept-
The en route and destination weather deteriorated as the flight progressed.

- It is probable that the pilot intentionally entered cloud, unaware of his proximity to rising terrain.

- No firm conclusions could be made regarding the pilot's blood-alcohol concentration.

**Causes and Contributing Factors**

When the pilot encountered deteriorating weather, he did not alter course to avoid entering cloud, apparently being unaware of the high ground in his path; the aircraft struck terrain while in controlled 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 05 March 1997.*

1. For Quebec times, subtract four hours from UTC. For Newfoundland times, subtract two and one-half hours from UTC.
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
Risk of Collision Between
Martinair Holland Boeing 767 P-HMCL
and Air France Boeing 747 F-BPVS
Stephenville, Newfoundland 45 nm NW
27 July 1996

Report Number A96A0138

Summary

Martinair 806 (MPH806), a Boeing 767, was eastbound at flight level (FL) 330 from Newark to Amsterdam via EBONY and DOTTY. Air France 055 (AFR055), a Boeing 747, was eastbound at FL330 from Chicago to Paris via Killaloe VOR, Gander. The routing of the two aircraft placed them on converging tracks. (See Appendix A.)

The Gander area control centre (ACC) controller assumed responsibility of MPH806 and AFR055 after the radar hand-offs from Moncton ACC. Shortly after, he instructed AFR055 to proceed direct to St John's, Newfoundland, a heading change of about 20° toward the track of MPH806. The two aircraft continued converging at the same altitude until they were about three miles apart. At that time, the crews of both aircraft received and reacted to traffic collision avoidance system (TCAS) resolution advisories (RA), MPH806 climbing and AFR055 descending. The two aircraft crossed with about 1,200 feet vertical separation and 1/4 mile lateral separation when the required separation between the two aircraft was 2,000 feet vertically or five miles laterally.

Ce rapport est également disponible en français.

Other Factual Information

Following two days off, the Gander controller worked an overtime shift from 2045 to 0200 Newfoundland daylight time (NDT) (1) the night before the occurrence. The occurrence shift was scheduled from 1545 to 2400. At the time of the occurrence, the controller had been working for one hour and thirty-five minutes since his last break.

The most basic form of controlling air traffic consists of monitoring a flight data board displaying flight progress strips, a paper strip for each aircraft's data. The flight progress strip is received by the controller well before the aircraft enters the controller's sector.

The flight progress strip for AFR055, depicting its route of flight, was marked by the Gander controller to indicate that the aircraft would be crossing other aircraft tracks, thereby requiring controller action to maintain the required separation. AFR055 is a regular
scheduled flight from Chicago to Paris that often crosses other tracks.

On the evening of the occurrence, the Gander west radar was divided into three sectors to handle the peak period of eastbound traffic flow. The controller had taken over the northern sector about an hour and a half prior to the occurrence. With the traffic volume decreasing in his sector, the controller suggested to the shift supervisor that his sector could be combined with the next one south of his. The supervisor observed the traffic situation in the two sectors and, at about 2310, gave his permission to combine the sectors. The traffic volume was assessed as moderate with moderate complexity.

At 2312, the Gander controller received a hotline call from a Moncton ACC controller who asked him if AFR055, still in Moncton airspace, could be sent direct to the geographic fix of 50°00N 50°00W, because "he's real close there with Martinair 806". While the Moncton controller was giving this warning, the Gander controller cut him off with an acknowledgement that he would mark AFR055 at 50°N 50°W. The Gander controller later reported that he had not been aware of the Moncton controller's warning. Review of the Air Traffic Control (ATC) communications tape revealed several instances where the Gander controller had cut off the hotline conversation before the Moncton controller was finished.

At 2315:47, MPH806 and AFR055 were handed off to the Gander controller, who, at 2318:30, instructed AFR055 to proceed direct to St. John's. This re-routing of AFR055 produced about a 20° change in the aircraft's heading and established the final point of convergence with MPH806. The controller was later unable to explain why he was unaware of the conflict between the two aircraft. A controller can put a range bearing line (RBL) between two aircrafts that are converging to determine the exact distance between the aircraft and to serve as another reminder of a potential conflict. The controller did not have an RBL established between AFR055 and MPH806.

Section 401.1 of the ATC Manual Of Operations (MANOPS) states that the objective of the instrument flight rules (IFR) control service is to maintain a safe, orderly, and expeditious flow of air traffic under the control of an IFR unit. When the Gander controller re-routed AFR055 without detecting and resolving the conflict with MPH806, the safety of the aircraft under his control was compromised.

MANOPS section 502.1 instructs controllers to display and monitor a controller jurisdiction symbol (CJS) for each aircraft. The Gander controller did not have the CJSs selected on his radar display during this occurrence.

From 2323:16 to 2324:58, just prior to the controller being relieved, there were no transmissions on the controller's radio frequency. During his next transmission, the controller handed off two aircraft to the east radar sector, observed MPH806 and AFR055 converging at the same altitude, and instructed MPH806 to begin a descent. The pilot of MPH806 advised the controller that they were climbing in response to a TCAS/RA. The relieving controller arrived at the sector position about the time the conflict between the two aircraft was detected.

The controller had been involved in two other incidents during the previous 17 months. These two incidents were losses of separation which were investigated internally by the management staff at Gander ACC. The internal investigation reports were reviewed during the Board's investigations, and it was concluded that the deficiencies seen in this incident were not similar to those seen in the previous two incidents, and do not reflect a trend.

A performance review of the controller's proficiency was conducted by a Gander ACC supervisor after this incident. The review mentioned that the controller is regarded by his peers and supervisors to be a good controller. It also determined that his overall performance was at or above the Gander ACC unit standard and that he was ready to
continue his duties without the requirement of further training.

The original performance specifications for the ATC radar data processing system (RDPS) software, issued during the 1970s, included provisions for aircraft conflict alert detection. After RDPS detected a traffic conflict, the controller watching the radar display would see a blinking three-letter mnemonic and the aircraft present position symbols would become stars. During testing in the 1980s, the RDPS conflict alert function was found to have several faults and was not considered acceptable for operational use. This function is still not in operational use today.

There were 502 crew and passengers on board the two incident aircraft. The pilot of AFR055 had initiated an abrupt descent in response to the aircraft's TCAS/RA, and the company captured the data from the flight data recorder (FDR) after the aircraft's return to France. The FDR data indicated that a 6,000-feet-per-minute descent had been achieved with g-load decrease to 0.36. The company reported that most of the passengers had been asleep with their seat-belts fastened and there had been no injuries.

Analysis

The controller is considered to be a proficient and good controller, well regarded in the Gander ACC, even though this was his third incident in 17 months. Considering his abilities and the traffic situation, the controller should have detected and resolved the conflict between AFR055 and MPH806 well before the risk of collision occurred. Had the controller been aware of a possible conflict because of the converging tracks, he probably would have placed a range bearing line (RBL) between the two aircraft to determine the exact distance between them.

Despite the frequency of incidents involving this controller (3 in 17 months), the controller's reputation and demonstrated ability during performance reviews suggest that the incidents do not reflect a problem of ability. Rather, the incidents stem from human errors that can be corrected by a controller awareness program. The Gander ACC management put a disciplinary letter in the controller's file as a corrective action and to make the controller more aware of his job responsibilities in the future.

The controller had marked the AFR055 flight progress strip to indicate that it would be crossing other air traffic. If the controller had heard the Moncton controller's warning, he would have been alerted to the crossing traffic situation. In this case, important information in a hotline conversation was missed because the controller did not listen completely.

The controller was inattentive to the radar display and the traffic situation or he would have detected the conflict between MPH806 and AFR055 earlier and resolved it. When he rerouted AFR055 direct to St. John's, he should have looked at the radar display where he could have detected the conflict with MPH806 at that time. The minute and forty-two seconds of radio silence prior to his detection of the conflict suggests that the controller was not scanning the radar display during this time.

The controller was not aware of the conflict between MPH806 and AFR055. TCAS equipment on board the two aircraft and the quick response of the flight crews possibly prevented a mid-air collision. An operational conflict alert function as part of the RDPS software would also provide a safety alert for a degradation of radar service which could result in a loss of separation or risk of collision not otherwise detected by controllers.

Findings

- The Gander controller missed a warning from a Moncton controller that a conflict was developing between MPH806 and AFR055.
- When the controller re-routed AFR055 direct to St. John's, he did not confirm whether the turn would create a conflict with other traffic.

- The controller did not have CJSs displayed for the aircraft for which he was responsible.

- Although the controller was involved in two prior incidents during the previous 17 months, the deficiencies seen in this incident were not similar to those seen previously and do not reflect a trend.

- The controller's demonstrated ability during performance reviews suggests that the incidents involving the controller (3 in 17 months) were due to human error rather than limitations in ability.

- TCAS equipment on board the two aircraft prevented a more serious risk of collision.

- An operational conflict alert function as part of the RDPS software would help to detect risks of collision that otherwise go undetected.

**Causes and Contributing Factors**

A risk of collision between the two aircraft occurred because the controller was inattentive to the radar display and the traffic situation and did not detect and resolve the developing conflict.

*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 03 April 1997.*

**Appendix A - Flight Path Diagram**
1. All times are NDT (Coordinated Universal Time minus two-and-a-half hours) unless otherwise noted.

Updated: 2002-10-06 ▲ Important Notices
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
Smoke in the Cockpit
American Airlines Inc.
Boeing 767-223 N316AA
Sydney, Nova Scotia 44 nm NE
12 August 1996

Report Number A96A0146

Summary

The Boeing 767 aircraft was in cruise flight from La Guardia Airport, New York, to Zurich, Switzerland, at flight level 370 when the crew smelled electrical smoke in the cockpit. As they donned their oxygen masks and smoke goggles, thick acrid smoke suddenly poured from behind the glareshield on the first officer's side. The smoke was accompanied by a very hot heat centre that had the appearance of an "arc welder" and by a forward equipment overheat warning. The crew declared an emergency and asked Moncton Centre the location of the nearest airport. Moncton Centre advised the crew of the location of Sydney airport; the crew initiated an emergency descent and advised the in-charge flight attendant to prepare the cabin for landing. They later informed the in-charge that they did not anticipate an emergency evacuation since, after the initial big puff of smoke, there did not appear to be any more smoke entering the cockpit. The aircraft landed at the Sydney airport without incident, with emergency response services (ERS) in position, 23 minutes after the smell of smoke was first detected. The aircraft was brought to a stop on the runway and, after ERS determined that there was no fire, the aircraft was taxied to the ramp where the passengers safely deplaned through the main cabin door in an orderly manner.

Ce rapport est également disponible en français.

Other Factual Information

Shortly after the arcing fire and smoke started, an Engine Indication and Crew Alerting System (EICAS) message "Forward Equipment Overheat - FWD EQUIP OVHT" was annunciated. The crew then went
to Standby on the equipment cooling switch as per the emergency check list; at the same time, the arcing stopped and the EICAS message also disappeared off the screen. There was no EICAS message displayed during the flight concerning the window heat and therefore no required check list item to be carried out by the crew. The smoke began to clear up, and the crew, suspecting possible fire in the forward equipment bay located under the cockpit floor, continued to descend for landing at Sydney. Electrical power to the window heat was not shut down until after the aircraft landed and the crew went through their normal shutdown procedures.

Preliminary examination of the aircraft revealed no fire or smoke damage in the forward equipment bay. However, a terminal block located on the lower outboard corner of the right (first officer's side) front windshield was extensively heat damaged and the inner glass ply of the window was cracked. The circuit breaker protection for the windshield heat had not tripped. The damage to the windshield was not readily apparent until the aircraft was more closely examined on the ground after the occurrence. The damaged windshield, the right window heat control unit, and the cockpit voice recorder were forwarded to the TSB Engineering Branch for examination and evaluation.

Interviews and a review of the cockpit voice recording revealed that there was excellent crew coordination among the flight deck crew members and between the flight deck crew and the in-charge flight attendant. The flight attendants were in the middle of meal service when the incident occurred and the captain commented on the excellent job they did of keeping the passengers calm and preparing the cabin for landing in the short time available.

The window heat control unit controls three channels for the right forward windshield and the two left-side windows. This unit has a self-test feature which displays fault messages on the EICAS; however, the unit is not equipped with electronic memory which could store any fault once power has been removed. The unit was manufactured by Garrett Canada (now Allied Signal Aerospace Canada) on 11 October 1990. The unit was further identified by part number 624066-5, series 1, serial number 100C-1815. The control unit is subject to on-condition(1) maintenance and, according to Allied Signal, it had never been returned to their facility for repair/overhaul since new. The control unit was tested as per "ATP Test Data Sheet 85C6865 for Window Heat Control Unit P/N 624066-3 and P/N 624066-5." The unit passed all of the test procedures except for a minor problem noted in the ramp-up voltage for the "Window 1 Control Channel Functional Tests." During the ramp-up voltage test, the voltage after 10 seconds was measured as 35 VRMS, which was slightly below the low limit of 40 VRMS. The remainder of the test values were within the prescribed limits. The lower observed value would not cause a problem with the unit's operation and requires a minor adjustment of a potentiometer to correct. The unit was considered to have been serviceable at the time of the incident.

The right windshield, serial number 92154H2287, was manufactured by PPG Industries Aircraft and Specialty Products in Huntsville, Alabama. The windshield is also an on-condition component; it was installed in the subject aircraft in December 1992 and, according to the aircraft records, had accumulated 14,283 hours and 2,358 cycles since installation. There was no record of any maintenance having been carried out or required on the windshield or the wiring during this time.

After initial examination at the TSB Engineering Branch, the windshield was shipped to the PPG facility in Huntsville, Alabama, for further teardown and examination. Present at this teardown were representatives of PPG, American Airlines, Boeing, and the TSB. The window and connector were further analyzed at PPG's Pittsburgh, Pennsylvania, facility at a later date.

The following summarizes the findings of the examination carried out on the window:

- The inner glass ply exhibited melted glass and a crater-like depression directly under the location of the J5 terminal. The cracks noted in the inner ply were all directed outwards from this location. This particular glass has a melting point of 968°C (1,800°F).

- The power connector originally attached to the J5 terminal was manufactured by Wallace-Black. It consists of a cadmium-plated steel insert moulded in an epoxy block with the conductor crimped into the insert. The epoxy connector was cracked but did not exhibit gross heat damage. The top of the steel insert exhibited a small, somewhat shiny buildup of material on its upper surface. The shiny area was identified as resolidified cadmium, which has a melting point of 321°C (610°F). No evidence of any arcing or pitting was noted on this insert. The cap over the head of the screw, the screw, and the lock washer were not recovered for examination purposes. However, a photograph taken before the windshield was removed from the aircraft shows that the cap over the head of the J5 screw was blackened and the wiring insulation was charred where it entered the connector.

- The J5 terminal (PPG number 22-17-1385) consisted of a cast epoxy block with a threaded brass block embedded in it. The J5 terminal was extensively heat damaged and cracked. Two flat-braided copper conductors are soldered to the bottom of the brass block as installed on the window. These two braids are then routed under the glass ply and are attached to either end of a bus bar that is attached to the lower edge of the outer glass ply. There was no evidence of any copper braid remaining on the brass insert and only a small amount of solder residue was present. Microscopic examination of the brass showed it did not exhibit any pitting that may have resulted from arcing. The J5 terminal block has a cavity where the copper braids are attached to the brass block, and this cavity is filled with a polysulphide adhesive identified as PR1425. This adhesive contains carbon black as a UV stabilizer. The majority of this adhesive was either missing or had turned to ash.
The burned edge of the phenolic window sill was cut out, exposing the remains of approximately one-half-inch of flat, medium copper-braided conductor. Typically, there should be almost 2.5 inches of braid remaining from the edge of the inner glass ply to enable it to be soldered to the brass insert and then rotated for attachment to the edge of the window. Some of the ends of the braided copper were melted, typical of arcing damage. Copper melts at 1,080°C (1,980°F).

Boeing Aircraft Company reviewed its service history and found that three similar events had taken place within a year of each other from 1992 to 1993. In response to these events, Boeing sent out a "message to operators" in 1993 requiring an increase in the torque on the screws that hold the power conductors to the terminals on the windows. Maintenance personnel who removed the window from N316AA stated that the screw holding the power connector to the burned terminal was still tight.

Based upon Boeing's original concern that insufficient torque on the power lead screw might cause resistive heating, PPG conducted a test whereby a power terminal and a J5 terminal were set up in a circuit drawing 20 amperes. With the screw fully tight, a temperature increase of 10°F (5.6°C) above ambient (78°F, or 25.6°C) was recorded; when the screw was backed off until the two terminals were visibly loose, the temperature increased and stabilized at approximately 50°F (27.8°C) above ambient. This temperature increase is not considered significant and, based upon the maintenance personnel statement that the screw was still tight when removed from the J5 terminal, indicates that a loose screw did not initiate the overheating.

The length of copper braid brought out from the window edge is covered with heat shrink insulation. Before the braid is soldered to the terminal, this heat shrink is melted with a soldering gun and removed, exposing one-half to three-quarters of an inch of bare copper braid for soldering purposes. It is possible for the copper braid to be nicked during this operation, which would allow the strands to flex sufficiently to initiate separation. PPG had previously conducted tests using a heavy copper braid in a circuit carrying 32 amperes where they deliberately damaged the braid and measured the temperature rise. The braid was progressively cut after it had stabilized at approximately 150°F (65.6°C). As the braid went from 0% to 75% cut-through, the temperature increased approximately 20°F (11.1°C), and at 98% cut-through the temperature increased approximately 270°F (150°C) to 440°F (226.7°C). The braid used in this test was heavier than the braid used in the occurrence window, which is classified as a medium braid. It was noted that no arcing occurred during this test as the remaining copper strands carried the load, suggesting that the braids must separate for arcing to occur.

Analysis

The lack of any pitting damage on the surface of the brass block and in the remaining solder indicates that arcing did not occur at this interface. However, there was sufficient heat to melt the solder and allow the...
braid to completely detach from the block. The block also became sufficiently heated to melt the cadmium plate on the power terminal insert. The fact that some of the ends of the remaining copper braid in the window sill were melted is consistent with the electrical arcing observed by the pilot and strongly indicates that the arcing occurred at or near that location behind the glare shield. The high temperatures associated with arcing (thousands of degrees Centigrade) resulted in the cratering of the inner glass ply and generated sufficient thermal stresses to cause the glass windshield to crack. The temperatures associated with arcing could also vaporize copper, which may explain the loss of some of the braid.

The testing conducted by PPG indicates that the copper braid would have had to be completely separated before arcing occurred. The loss of the copper braid between the terminal and the remaining section of braid under the window edge precluded any definitive findings of what caused electrical arcing. However, it was speculated that nicking of the copper braid during construction of the window might allow the copper strands to flex sufficiently to initiate separation and allow electrical arcing to occur.

The circuit breaker for the windshield heat did not trip because there was no electrical short to ground, which would also explain the absence of an EICAS warning pertaining to the window heat system. It was not determined what caused the forward equipment overheat warning to appear on the EICAS shortly after the smoke began. However, according to Boeing and American Airlines, the EICAS message was not related to the window overheat problem.

The following Engineering Branch reports were completed:

- LP 111/96 - CVR Analysis; and
- LP 112/96 - Windshield Electrical Fault.

**Findings**

- An electrical failure under the J5 terminal block mounted on the right front window caused localized arcing.

- The circuit breakers for the window heat circuit did not trip nor was power removed from the system until after the aircraft landed.

- The arcing caused cratering and localized melting of the inner glass ply, which eventually led to the cracking of the inner ply and the combustion of the epoxy terminal block, creating smoke.

- Due to the extensive damage, the origin of the failure could not be isolated; however, it is suspected that the copper braid conductors must have severed to initiate the arcing.

**Causes and Contributing Factors**
An electrical failure under the J5 terminal block mounted on the right front window caused localized arcing and the combustion of the epoxy terminal block, creating smoke. Due to the extensive damage, the origin of the failure could not be isolated; however, it is suspected that the copper braid conductors must have severed to initiate the arcing.

Safety Action

Boeing informed the airline industry of this particular incident through an "In Service Action Report" which gave a brief description of the event and the findings from the teardown. Boeing also suggested that power to the window heat circuit be removed once any arcing or smoke is detected. This will prevent further heat and smoke generation, and may also allow for a more detailed analysis of the cause and origin of a failure.

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 09 May 1997.

1. "On condition" is defined in the Transport Canada Airworthiness Manual as a maintenance process having repetitive inspections or tests to determine the condition of the units, systems, or portions of structure.

Updated: 2002-10-06
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 Water
Castle Rock Exploration Corp.
De Havilland DHC-2 Beaver C-FFHF
Portage Lake, Labrador 3 km NE
30 September 1996

Report Number A96A0175

Summary

The pilot of C-FFHF, a float-equipped de Havilland DHC-2 Beaver, departed the company camp at Ugly Lake, Labrador, en route to Goose Bay. Prior to arriving at Goose Bay, the pilot contacted an overflying Air Labrador flight and advised them that he had landed on a pond and that he needed the SAR (search and rescue) time extended on his flight plan. The pilot also said that he would be departing the pond shortly, en route to Goose Bay. When C-FFHF did not arrive at the destination by the SAR time of 2030 Atlantic daylight saving time (ADT)\(^1\), a search was commenced.

Seven days later, an oil slick and a paddle with the company name on it were identified on a pond about 66 nautical miles (nm) north of Goose Bay. Divers located the aircraft wreckage in 120 feet of water. The aircraft was destroyed and the bodies of the pilot and passenger were located inside the wreckage.

Ce rapport est également disponible en français.

Other Factual Information

The pilot held a commercial pilot licence with an instrument rating endorsement and had about 894 hours total flight time. He had been based in Goose Bay since June and had flown C-FFHF about 234 hours during the 90 days prior to the accident.

The aircraft had recently been registered privately to Castle Rock Exploration Corporation and was used mainly for flights between the company base camp at Ugly Lake and Goose Bay. On 30 September,
the pilot departed Goose Bay to deliver helicopter parts to Ugly Lake and return with one passenger, a company junior geologist. The weather conditions at Goose Bay deteriorated after C-FFHF departed. The aircraft arrived at Ugly Lake after a refuelling stop and then departed for the return visual flight rules (VFR) flight to Goose Bay.

During the flight south to Goose Bay, the pilot of C-FFHF was in communication with several aircraft. A pilot who was flying a single-engine Otter south to Goose Bay asked the pilot of C-FFHF, who was further south, for the en route actual weather. The pilot of C-FFHF replied that an Air Labrador flight en route to Goose Bay had encountered snow showers.

The Otter pilot advised TSB investigators that the visibility had deteriorated during his flight south to Goose Bay. He remarked that he entered a band of snow showers north of Goose Bay (an area that included the accident site), extending west to east across his intended route. The pilot had maintained visual reference with the ground by flying as low as 100 feet above ground level (agl) and continued south by following shorelines where possible. Rough water conditions due to strong winds were observed on the lakes overflown en route. The pilot arrived at Goose Bay about 1735.

The pond where the accident took place was 1,000 feet above sea level (asl), about 3 kilometres (km) long and 1 km wide, with a small island near the centre. The terrain surrounding the shoreline rose gradually to 1,200 feet asl.

The aircraft wreckage, located by divers using a remotely operated video camera, was in 120 feet of water, and the bodies of the pilot and passenger were observed in the wreckage, in their seats with their seat-belts secured. The right wing was separated from the fuselage and the bow of each float was deflected up. There was substantial damage to the aircraft, although the empennage appeared intact and undamaged.

During the initial salvage operation, the aircraft's empennage separated from the fuselage. The pilot's body remained in the wreckage and was recovered. The passenger's body and passenger seat fell out of the wreckage during the salvage operation and were not found and recovered until 08 July 1997 during a search by the RCMP. It was determined that the seat attach points had failed during the impact. Autopsy results indicated that the pilot died from impact-force-related injuries; there was no evidence of drowning. The passenger also died as a result of impact injuries.

C-FFHF was not equipped with shoulder harnesses for the occupants. The lap belts installed on the aircraft met the minimum requirements of the Canadian Aviation Regulations. It has been proven that shoulder harnesses provide aircraft occupants with greater protection than lap belts alone.

Several weeks later, the aircraft wreckage was removed from the accident site and the aircraft journey log-book was recovered. It
indicated that C-FFHF had departed Ugly Lake at 1427 and landed on a pond 70 miles north of Goose Bay at 1620. For the last flight leg, from the pond to Goose Bay, the aircraft take-off weight was recorded as 4,719 pounds, which included 300 pounds of fuel. There was no evidence that a cargo net was installed in the aircraft at the time of the accident, although cargo including empty propane tanks was carried onboard the aircraft.

The Goose Bay terminal forecast for the accident date was as follows:

0100-1100: scattered cloud at 4,000 feet, ceiling 6,000 feet broken, visibility greater than 6 miles.

1300-1500: overcast ceiling at 2,000 feet, visibility 4 miles in light rain showers.

1500-1800: overcast ceiling at 600 feet, visibility one mile in light rain and mist.

Records indicate that the aircraft was maintained in accordance with Transport Canada requirements and had about 13,200 hours total time since new. A 100-hour maintenance inspection was completed on 09 September 1996. During this inspection, an engine cylinder assembly was replaced; the aircraft had flown 62.5 hours since the inspection. There were no aircraft deficiencies entered in the journey log-book.

The aircraft flight manual (AFM) indicates that the aircraft take-off speed is 55 to 65 miles per hour (mph). When landing, a final approach speed of 65 to 68 mph should be maintained to touchdown. The aircraft stall speed is 45 mph at a gross weight of 5,100 pounds with power off and landing flaps selected.

The airframe, aircraft instruments, engine, propeller, and exhaust stacks were analyzed by the TSB. Visual examination of the wings, engine, and float strut/cross-member attachment points assessed the failure mode as overload from impact forces. The wings separated forward in relation to the fuselage, and the right front float-strut attachment point sustained considerably more damage than the other three float-strut attachment points. The observed wreckage damage was consistent with heavy contact with the water in a nose-down, right-bank attitude. The wing flaps were at about 28 degrees extension (take-off flap is about 39 degrees).

The vertical speed indicator (VSI) was indicating 2,000 fpm down, which is its maximum down indication. Indicated airspeed (IAS) was between 100 and 110 mph at impact; the baroscale on the altimeter was set at 29.73 inches of mercury (in. Hg.) and the engine manifold pressure (MAP) gauge was indicating in the range of 28 to 31.5 in. Hg. The remaining instruments did not provide any reliable information.

The engine teardown analysis did not reveal any internal failure or mechanical malfunction. The propeller teardown analysis identified that the propeller was at the low pitch blade setting when the aircraft struck the water. Oil under pressure is supplied to the propeller by the
propeller governor, and maintains the blades at low pitch when selected by the pilot. If the engine was not operating prior to impact, loss of oil pressure to the propeller would have resulted in the propeller counterweights rotating the blades to a higher pitch. When the aircraft is in cruise configuration, the propeller is normally set to a higher pitch.

A section of engine crushed exhaust stack was analyzed to identify a temperature range of the metal when it was crushed. The exhaust stack crush analysis was considered inconclusive because the aircraft had struck the water, effectively quenching the exhaust stack metal.

Analysis

The weather at Ugly Lake was suitable for VFR flight and the pilot made the decision to depart for Goose Bay. En route weather that included rain and snow showers with reduced visibility was reported by other pilots who were airborne about the same time as C-FFHF, and these conditions were also predicted in the terminal forecast for Goose Bay. If the pilot of C-FFHF had a mechanical problem with the aircraft, it is likely that he would have communicated this information to the overflying aircraft. Since there is no evidence that there was a mechanical problem with the aeroplane, it is likely that the pilot flew C-FFHF into deteriorating weather conditions as he approached Goose Bay from the north, and that he landed on the pond to wait for improving weather conditions.

The last radio transmission from the aircraft was at about 1725, when the pilot relayed his intention of departing the pond momentarily. Any extended delay in departure from the pond would have required the pilot and passenger to spend the night there due to inadequate daylight time remaining to complete the trip to Goose Bay. It is probable that the pilot, aware of the strong winds, rough water conditions, and impending darkness, departed the pond hoping that the visibility to the south was sufficient to complete the flight, rather than spend the night on the pond.

The 2,000 fpm (minimum) descent rate and the airspeed indication between 100 and 110 mph suggests that the aircraft was in a phase of flight other than take-off at the time of the accident. The MAP gauge indication was consistent with an engine operating within the cruise power setting range. The same indication would also be present if the engine was not operating, because the MAP gauge would then indicate field barometric pressure. However, the engine teardown analysis indicated that the engine was capable of producing power. Since the aircraft flaps were set to 28 degrees, with MAP between 28 and 31.5 in. Hg, and the propeller blade angle at low pitch, it is likely that the aircraft was configured for slow flight, because of the poor visibility.

Although it is difficult to determine if shoulder harnesses would have provided increased protection for the occupants in this occurrence, they still provide more protection than lap belts alone.

It is probable that the pilot was unable to maintain visual reference with the surface sometime after take-off from the pond. The aircraft struck
the water either during the pilot's attempt to regain visual reference or because the pilot lost control of the aircraft in reduced visibility.

The following Engineering Branch reports were completed:

- LP 153/96 - Instruments Examination;
- LP 157/96 - Engine Disassembly Examination;
- LP 158/96 - Propeller Examination; and
- LP 170/96 - Exhaust Stack Temperature Analysis.

**Findings**

- The pilot held a commercial licence with 894 hours total flight time.
- There was no evidence to suggest that the pilot landed on a pond north of Goose Bay because of mechanical problems.
- The weather in the area at approximately the time of the occurrence was reported as reduced visibility in snow showers with high winds.
- Both the pilot and passenger were found in their seats with their seat-belts secured.
- The body of the passenger and the passenger seat fell out of the wreckage during the salvage operation and were finally recovered on 8 July 1997.
- Autopsy results determined that both the pilot and the passenger died from injuries sustained at impact.
- Records indicate that the aircraft was maintained in accordance with existing regulations.
- The aircraft struck the water in a nose-down, right-wing-low attitude with a rate of descent of at least 2,000 feet per minute, an airspeed of 100 to 110 knots, and a manifold pressure of 28 to 31.5 in. Hg.
- The engine was capable of producing power, and there was no evidence of a mechanical malfunction.
- The propeller was at the low-pitch blade setting when the aircraft struck the water.

**Causes and Contributing Factors**

It is probable that the pilot was unable to maintain visual reference with the surface sometime after take-off from the pond. The aircraft struck
the water either during the pilot's attempt to regain visual reference or because the pilot lost control of the aircraft in reduced visibility.

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 July, 1997.

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

Updated: 2002-10-06

Important Notices
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 Level Terrain
Chrysler Aviation Inc.
Learjet Corporation L36A N14TX
Stephenville, Newfoundland
06 December 1996

Report Number A96A0207

Summary

Learjet L36A (serial number 033), N14TX, was on an instrument flight rules (IFR) flight from Grand Rapids, Michigan, to Stephenville, Newfoundland. At 0216 Newfoundland standard time (NST)\(^{(1)}\), N14TX was cleared by Gander Area Control Centre (ACC) for an approach to the Stephenville airport. The co-pilot contacted the St. John’s Flight Service Station (FSS) and advised that they would be conducting an approach to runway 28. The FSS specialist relayed the latest Stephenville weather observation and runway surface condition report to the aircraft and requested that the crew advise St. John’s FSS when they had landed.

When the crew of N14TX did not report after landing at Stephenville, the St. John’s FSS specialist advised Gander ACC that the aircraft was missing, and a search was begun. Initial information received by the agencies searching for the missing aircraft did not include the aircraft's last recorded radar position. The wreckage was located approximately three hours and ten minutes after the aircraft was reported missing, within the airport perimeter, close to the last observed aircraft radar position. The aircraft struck a service road embankment in an inverted, wings-level attitude. The two crew members were fatally injured. The accident occurred during the hours of darkness at approximately 0238 NST.

Ce rapport est également disponible en français.

Other Factual Information

Both the pilot and co-pilot were highly regarded by company
management personnel. A review of the flight crew's pilot records indicated that they were certified and qualified for the flight in accordance with existing regulations. The pilot had worked for the company for several years and had about 5,700 hours total flight time, with 3,000 hours on Learjets. He was also a multi-engine aircraft instructor and a licensed airframe and power plant mechanic (A&P). The co-pilot had about 2,800 hours total flight time, with 400 hours on Learjets, and was also a multi-engine aircraft instructor. Both crew members had landed at the Stephenville airport on prior occasions.

The 0230 NST Stephenville weather, passed to the crew of N14TX by the St. John's FSS specialist, was as follows: wind 040 degrees magnetic at 17 knots; visibility 12 miles in light snow and drifting snow; ceiling 4,000 feet overcast; temperature 1°C, dew point -3°C; and altimeter setting 29.75. The wind information was taken from the latest Stephenville weather observation (0230 NST), as the St. John's FSS specialist does not have the actual Stephenville wind direction and speed. The winds reported to the crew would yield a tailwind component of 10 knots; the aircraft's operational maximum tailwind component limit for landing is 10 knots. After the accident, the Stephenville wind velocity was determined from the surface wind recording (chart). When N14TX approached the threshold to runway 28, the recorded wind direction and speed was 040 degrees magnetic at 20 knots with gusts to 22 knots, giving a tailwind component of about 12 knots. During certification tests, adequate control of the aircraft was demonstrated during landing and take-off in crosswinds up to 24.7 knots. The runway surface condition at 2212 NST was as follows: a 180-foot centre line was 60 per cent bare/dry. 20 per cent compacted snow, 20 per cent light snow 1/8-inch deep, with a windrow on the north side, 10 feet inside the edge lights and 2 ½ to 3 feet in depth. The James Brake Index (JBI), with a temperature of -1°C, was reported to be 0.42.

The aircraft was equipped with a cockpit voice recorder (CVR), although it was not required by Federal Aviation Regulations (FAR) for this flight. The recorder was recovered and sent to the TSB Engineering Branch for analysis. For undetermined reasons, the CVR cockpit area microphone channel was not being recorded; therefore, no flight crew conversations were available to investigators. The CVR recording did provide other information relative to the flight, such as landing gear warnings, autopilot disconnect, keying of the microphone(s), radio transmissions, and ignition on selection. The aircraft was not equipped with a flight data recorder (FDR) nor was one required by regulation.

Runway 28 at the Stephenville airport is 10,000 feet long by 200 feet wide. The approach to the ILS runway 28 has a non-standard 4.5° glide path angle and the runway has a 0.69% downslope. An aircraft radio control aerodrome lighting (ARCAL) system controls the centre row approach lights, threshold lights, and runway edge lights. The pilot's setting of the lights was determined by counting the microphone clicks on the CVR recording. The ARCAL system was activated to medium setting when the aircraft was established on the approach 8.4
nm from the threshold and about 3,200 feet above sea level (asl). The pilot selected the low setting at 7.3 nm and then reselected the medium setting when the aircraft was 6.6 nm from the threshold.

An analysis of the recorded Gander ACC radar data showed that the aircraft flew the complete approach for the instrument landing system (ILS) approach on runway 28, tracked the localizer correcting for the crosswind, and then deviated to the left of the runway after crossing the runway threshold. It was determined from the CVR tape that the autopilot was selected OFF while the aircraft was on the procedure turn.

Field examination of the aircraft wreckage identified that the aircraft flaps were extended to 20° at impact. The horizontal stabilizer was trimmed to an aircraft nose-up position that was consistent with a normal trim position for landing. The aileron and elevator trim tabs were in the neutral positions, spoilers were stowed, and the landing gear was retracted. The engine thrust reversers were also in the stowed position. All major aircraft components were identified at the wreckage site, and no mechanical malfunction was identified.

Nothing was found to indicate that the aircraft touched down on the runway. Runway sweeping operations re-commenced at 03:20 NST in preparation for the next scheduled arrivals, therefore, any touchdown marks that may have been present on the runway were removed. The first landing indication was a ground scar made by the left main wheel beginning in the snow at the left edge of runway 28, about 1,750 feet beyond the runway threshold, and extending for 400 feet on a heading of about 261° magnetic. This was a light impression leaving a shallow ground scar; there was no impression made by the right main wheel. Analysis of the mark and aircraft configuration showed that the aircraft was banked left about 10° when the impression was made. A second mark, about 200 feet long, started 3,650 feet beyond the threshold and 330 feet from the left edge of the runway. Examination of this scar and the aircraft's left tip-tank fin revealed that the scar had been produced by the fin when the aircraft was in a left-banked attitude of between 40° and 45° and pitched up about 12° to 14°. The left tip-tank struck the ground a second time about 4,200 feet from the threshold, with the aircraft banked about 10° to the left. Because of the absence of any wheel marks, it was concluded that the landing gear was retracted. When the tip-tank struck the ground, the left aileron was deflected nearly full down, and it was trapped in this position when the wing buckled from the impact. The aircraft rolled to the right after striking the ground, then went through a small stand of alders at 4,400 feet; the tree breaks and witness marks on the aircraft indicated that the aircraft was in a shallow right bank with the landing gear up. The aircraft continued to roll to the right and crashed in an inverted, wings-level attitude 5,080 feet from the runway threshold near the centre of the airport, just east of the intersection of runways 28 and 20. The average direction of flight of the aircraft as evidenced by the ground marks was about 261°.

Engine instruments, flight instruments, indicator lights, and other aircraft cockpit components were removed from the site and sent to the TSB
Engineering Branch for further examination. Instrument analysis revealed some instrument indications, marks, or settings as follows: (left/right) fan 86.5/75%; turbine 92.6/91%; inter-stage turbine temperature (ITT) 731/866°C; indicated airspeed 120/122 knots; compass rose 260°; digital course display 275°; heading index bug 285°; course arrow 275°; airspeed bug 133 (VREF); and set altitude 3,100 feet. The flight director NAV ENG (green) light was on, the GS ENG (green) light was possibly on, and the go-around indicator light was not illuminated.

Teardown and analysis of the engines was carried out at the Allied Signal engine manufacturer's facility in Phoenix, Arizona, and was witnessed by a USA Federal Aviation Administration aviation safety inspector on behalf of the TSB. Foreign object damage (FOD) to the fans and compressor blades on both engines was consistent with fan rotation during impact. The extent of debris distributed throughout the gas path of both engines and the presence of metal spray deposits in the power turbine section confirmed that both engines were operating at impact.

Climb performance for the Learjet L36A was examined in consultation with the operator, the manufacturer, and other Learjet L36A pilots. In addition, investigators conducted trials in a Learjet L36A simulator under conditions similar to those that existed in Stephenville at the time of the accident. It was found that the Learjet L36A has more than adequate power to successfully perform a missed approach procedure under all possible combinations of aircraft configuration, provided the proper climb attitude is established and maintained. The Flight Safety International (flight training organization) procedure for a go-around/balked landing is for the pilot flying (PF) to call "going around flaps 20", simultaneously disengage the autopilot by selecting flight director go-around mode, establish a 9° nose-up attitude on the flight director V-bars, set power as required, and check that the spoilers are retracted. The pilot not flying (PNF) sets or confirms that the flaps are at 20, and calls out the direction of turn, if required, and the missed approach heading and altitude.

Based on known weights of the aircraft, crew, and cargo, and estimating the amount of fuel on board, it was calculated that the aircraft weighed about 15,300 pounds at the time of landing, which is the aircraft's maximum allowable landing weight. Take-off power is used in the go-around procedure. For the conditions at the time of the accident, take-off power would have been about 93% fan rpm. The indicated fan rpm at impact was somewhat lower; however, it is not possible to determine what power was set for the go-around. The stall speed at 15,000 pounds, with flaps 20°, in level flight, would have been about 107 knots indicated airspeed (KIAS). From the weight of the aircraft, VREF for the approach was calculated to be 127 KIAS. The VREF set by the flight crew was 133 KIAS, which was appropriate considering the gusty wind conditions.

It was concluded that icing, either airframe or engine, did not play a part in this occurrence. There was no freezing precipitation at the
surface, there was no icing in cloud (as reported by another pilot flying in the area at the time), and there was no indication, either verbally or from analysis of the radar tapes, that the pilot was experiencing control difficulties.

It is not known with certainty why the pilot elected to land on runway 28 with a tailwind rather than land straight-in on runway 10 with a headwind. The pilot apparently discussed the landing runway prior to departing Grand Rapids and decided at that time to land on runway 28. The approach to runway 10 is over water; therefore, there are no lights under the approach path, and there is no precision approach to runway 10, whereas runway 28 is served by an ILS.

The Gander ACC was equipped with RADEX (radar data examination), a computer program that can be used to display recorded radar data. In addition to examining files of pre-recorded radar data, RADEX can also display live radar data. A computer at the Technical Duty Manager's station in the Gander ACC operations room displays and records the live radar data. The RADEX program on this computer can be used to obtain, within minutes, a missing aircraft's last recorded radar position. RADEX was developed as a test tool for the Technical Services Branch, and its full capabilities were not known to the operational management staff who had not received training or user manuals for RADEX.

The aircraft's was equipped with an emergency locator transmitter (ELT); however, it did not activate at impact. Analysis of the ELT identified that the batteries were overdue for replacement and that they were the incorrect type for operations in an environment where the temperature goes below 20° Fahrenheit. Although according to FAR 91.207 an ELT is not required equipment on a US-registered, turbojet-powered aircraft, the installation and serviceability of an ELT can provide greater safety potential by reducing the response time to locate a downed aircraft.

**Analysis**

There was nothing found during the investigation to indicate that the aircraft suffered any mechanical malfunction prior to the crash. Based on the instrument analysis, the engine teardown results, the aircraft's speed during the approach and excursion over the ground, and the distance the aircraft travelled after the first impact, it was concluded that the engines were operating normally and were producing high power at the time of impact.

The weather was good at the time of the approach, in that the ceiling was 4,000 feet above ground level (agl) and the visibility was 12 miles, and the crew flew a normal, uncomplicated ILS approach. In such conditions, the crew should have been able to successfully land the aircraft. The only apparent conditions that may have affected the final stages of the flight were the darkness and the drifting snow from the right tailwind. Radar and instrument indications show that the aircraft was set up for the ILS, and that the flight director system was engaged in the approach mode, although there is uncertainty as to whether the
glide slope was engaged. The crew did not advise ATC of any problems with the aircraft; had they not been satisfied that they could make a safe landing, the crew would have commenced a missed approach procedure as the aircraft approached the runway. The pilot's adjustments of the ARCAL light system on final approach indicate that at least one of the pilots could see the runway lights, from about 3,000 feet agl and 6.6 miles from the threshold, and was adjusting their intensity.

Analysis of the recorded radar data indicates that the aircraft, while on the approach, remained established on the localizer, correcting for the right quartering tailwind. The heading bug selection, 10° to the right of the inbound course, also indicates a correction for the wind. When the aircraft approached the runway threshold, its landing lights would have illuminated the drifting snow and the snow covering much of the runway surface, probably making it difficult to distinguish the runway's white centre line and, perhaps, the runway edge lights. The illuminated snow drifting across the runway at a 45° angle from behind the aircraft would give a pilot the illusion of lateral aircraft motion. Considering that there was no mechanical or aerodynamic explanation for a directional control problem, it is most likely that a flight control input, or lack of input, allowed the aircraft to drift to the left. This could have been the result of the pilot wanting to remain clear of the window on the right side of the runway, or his removal of the 10° crosswind correction in preparation for landing. The pilot's reference to the runway edge lights may have been degraded by the drifting snow, and when the aircraft began to drift to the left, in the same direction as the drifting snow, it could have been difficult for the pilot to detect and correct the aircraft's movement.

Touching down in the snow off the left side of the runway would have surprised the pilot and would have affected his subsequent performance in the missed approach. Heading left off the runway, in the dark and with a lack of ground lights in that direction, the pilot had a limited horizon comprised of the snow surface illuminated by the aircraft's landing lights, which would have made recognition of the aircraft's attitude extremely difficult. The pilot's attention during the landing flare would have been concentrated on the visual environment outside of the aircraft, and it is likely that the pilot attempted to establish the missed approach attitude using outside references. That the aircraft was at various bank angles of wings level, 10° left, 45° left, and 10° left, until the ailerons jammed, indicates that the pilot had lost control of the aircraft during the missed approach attempt. Once the aileron jammed, the pilot could no longer control the bank of the aircraft. To maintain a nearly straight ground track of 261°, the aircraft would have had to be banking back and forth along the entire track. The pilot also did not maintain the required nose-up pitch attitude; simulator trials and examination of the aircraft's climb performance demonstrated that the aircraft would have flown away from the ground had such an attitude been maintained.

A pilot commencing a missed approach with reference to the cockpit instruments would normally select the go-around mode on the flight director so the V-bars could command the proper aircraft attitude on
the attitude director indicator.

Had the Gander ACC operational staff been aware of the RADEX capability to quickly identify an aircraft's last recorded radar position and had that information been provided to the agencies conducting the search, the aircraft crash site would have been located much sooner.

Findings

- The flight crew was certified and qualified for the flight in accordance with existing regulations.

- The St. John's FSS operator did not have the actual Stephenville wind direction and speed. The wind velocity he passed to the crew was from the latest Stephenville observation and was 040° at 17 knots, within the tailwind landing limitations of the aircraft.

- The actual Stephenville wind of 040° magnetic at 20 knots with gusts to 22 knots exceeded the aircraft’s maximum allowable tailwind component for landing.

- The pilot attempted a missed approach after the aircraft had touched down in the snow, just off the runway surface.

- The pilot did not maintain the correct aircraft attitude for a missed approach.

- The pilot did not select the go-around mode on the flight director during the missed approach.

- The CVR cockpit area microphone channel was not recorded for undetermined reasons.

- The capabilities of RADEX to quickly locate a missing aircraft were not known to the Gander ACC operational management staff.

- All major aircraft components were identified at the wreckage site, and no mechanical malfunction was identified.

- Engine and instrument analysis identified that both engines were operating at high power during the impact.

- There was an ELT installed in the aircraft, although, according to FARs, the aircraft was not required to be so equipped. The ELT did not activate at impact; the batteries were not the correct type and were overdue for replacement.

Causes and Contributing Factors
Shortly after crossing the runway threshold, the aircraft began moving to the left of the runway. The motion probably was undetected by the pilot until the aircraft touched down off the left side of the runway surface. The pilot did not maintain the proper aircraft attitude during an attempted missed approach, and the aircraft struck the terrain.

**Safety Action Taken**

The capability of RADEX to quickly locate the last radar position of missing or overdue aircraft was recognized by NAV CANADA authorities and action was taken to make the equipment and the program available to operations personnel in all ACCs for use in similar occurrences. NAV CANADA conducted training sessions for Data Systems Controllers in all ACCs specifically aimed at the use of RADEX as a search tool.

As a result of this accident and in an effort to enhance the safety of operations at Stephenville airport, the Airport Authority initiated discussions with NAV CANADA and Transport Canada to establish an Authorized Approach Unicom (AAU) service to provide operational information to pilots for the purpose of conducting instrument approaches published in the Canada Air Pilot (CAP). An AAU is authorized to provide airport advisory services including surface wind speed and direction, current altimeter setting and runway condition (surface condition, vehicles, etc.) to 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 17 September 1997.*

1. All times are NST (Coordinated Universal Time [UTC] minus 3 ½ hours) unless otherwise noted.

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Updated: 2002-10-06
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.

Controlled flight into terrain
CESSNA T210M Centurion C-GPID
FLIN FLON airport, Manitoba 1.5 mi S
10 January 1996

Report Number A96C0002

Synopsis

On 10 January 1996 at 2108 central standard time (CST), the pilot of a Cessna 210 aircraft radioed The Pas Flight Service Station (FSS) to advise them that he was ready to taxi for take-off on a visual flight rules (VFR) flight from Flin Flon to Lynn Lake, Manitoba. The Pas FSS acknowledged his transmission and gave him Flin Flon's current wind information and The Pas's altimeter setting. At 2110 CST, the pilot indicated that he would call airborne after take-off from runway 18. There was no further communication with the pilot. At 2123 CST, The Pas FSS contacted the Flin Flon RCMP detachment and told them that they had lost radio contact with the aircraft. The RCMP conducted a preliminary ground search of the airport and surrounding area, but could not locate the aircraft. At 2224 CST, the Search and Rescue Satellite (SARSAT) picked up an ELT signal in the vicinity of the Flin Flon airport, and the Canadian Armed Forces Rescue Control Centre (RCC) tasked Search and Rescue (SAR) Winnipeg with the search mission. The Flin Flon RCMP organized a ground search party and began a search of the surrounding area with the use of snowmobiles. The aircraft was located at 0200 CST, approximately 1 1/2 mile from the end of runway 18; the pilot was transported to hospital where he was pronounced dead.

Other Factual Information

The aircraft had arrived in Flin Flon from Saskatoon, Saskatchewan, earlier in the day. After arrival, the pilot filed a VFR flight plan with The Pas FSS for a 2050 CST departure to his home base in Lynn Lake. The pilot estimated that the trip would take one hour and indicated that he had four hours of fuel available on board the aircraft. Witnesses in a cottage south of the airport saw the lights of an aircraft departing the airport at approximately 2110 CST. The aircraft was approximately 1/8 mile off the end of runway 18 and about 400 to 500 feet above ground
level. The aircraft reportedly looked and sounded normal as it flew past the cottage.

The Flin Flon/Lynn Lake area was under the influence of an upper trough which was oriented on a line southward from Lynn Lake toward Grand Rapids. Ceilings along the proposed route of flight were forecast to be 1,000 feet above ground level (agl) with visibilities between four and six miles in light snow. The top of the low overcast cloud layer was at 6,000 feet above sea level (asl); a second layer of scattered clouds was located above, between 10,000 and 12,000 feet asl. Light to moderate rime icing was expected in cloud. At the time the aircraft took off, the surface wind at Flin Flon was from 200 degrees true at six knots; the temperature was measured to be -10 degrees Celsius. There was no report of freezing precipitation in the Flin Flon area on the night of the accident.

The Flin Flon aerodrome is located in a relatively remote northern community. There are very few ground lights southwest of the aerodrome, and at the time of the accident, there was little or no illumination from either the lights of the community or from the night sky.

The aerodrome is situated in controlled airspace; flights through controlled airspace may be conducted either under visual flight rules or instrument flight rules (IFR). Visual flight, at night or otherwise, is governed by the Air Regulations, which state that "when operating in accordance with Visual Flight Rules, aircraft shall be flown with visual reference to the ground or water...." Weather minima for flight in controlled airspace are outlined in the Air Navigation Orders; a ceiling of 1,000 feet agl and a flight visibility of three statute miles are required. The Flin Flon airport has a designated control zone extending outwards to five miles from the airport. Any VFR aircraft that is operating within this zone must remain at least 500 feet below cloud, and must operate at a minimum height of 500 feet agl.

The crash site was located on the frozen surface of Athapapuskow Lake, approximately 1 1/2 miles off the end of runway 18. The aircraft struck the ice in a slight right-wing-low, shallow pitch attitude, and at high speed, on a heading of 240 degrees magnetic. The aircraft broke apart as it travelled approximately 800 feet across the frozen lake surface before coming to rest. Due to the extreme aircraft destruction, the accident was non-survivable.

Examination of the wreckage revealed no evidence of a powerplant, flight control, or aircraft system failure that would have contributed to the occurrence. Damage to the propeller blades was consistent with a high engine power setting at impact. The landing gear was retracted; however, the main gear doors were open. It could not be determined if the gear doors opened as a result of the impact, or because the landing gear was in an intermediate stage of operation. The flaps were retracted. Light bulb analysis confirmed that the instrument and electrical systems were being powered at the time of impact. An examination of the flight instruments confirmed that they were operating at impact. Marks on the attitude gyro indicated an approximate 15-
degree nose down, near wings-level attitude at impact. The horizontal situation indicator (HSI) card indicated a heading of 240 degrees, consistent with the wreckage trail heading.

The pilot held a valid private pilot licence and a night rating; he had approximately 1,600 hours of flying experience. In 1991, he attempted to obtain an instrument rating for his licence but was unsuccessful on four separate attempts before finally achieving his rating in May of 1992. Two years later, he failed a routine instrument re-test conducted by a Transport Canada inspector, and his instrument rating was revoked. Weak departure procedures and altitude control were identified as being below the standard required for the instrument rating.

Toxicological and pathological examinations completed following the accident provided normal results, and gave no indication of pilot incapacitation prior to impact. The severe trauma, induced during the accident, would have caused immediate unconsciousness and death within minutes of the accident. A review of the pilot's personal records provided no evidence of medical issues that would have adversely affected the pilot's performance.

The aircraft was a 1978 Cessna T210M Centurion with a turbocharged engine and retractable landing gear. The aircraft was privately registered and was being maintained on a 100-hour annual inspection schedule. The last inspection was completed on 13 April 1995 at an airframe time of 2,309.9 hours. At the time of the occurrence, the aircraft had accrued approximately 30 hours since the last inspection. The aircraft's last recorded unserviceability occurred during a trip to Saskatoon approximately four days prior to the accident. The aircraft experienced an electrical problem attributed to a broken alternator belt. The alternator belt was replaced and the battery was serviced. There was no known problem with the aircraft on the return flight from Saskatoon to Flin Flon.

Sensory illusions can cause spatial disorientation which can have a strong influence on pilot behaviour and performance. Disorientation is defined as the false perception and/or interpretation of aircraft attitude with regard to horizontal and gravitational references. Pilots with limited instrument flight time are particularly susceptible to spatial disorientation when they are confronted with no external visual attitude references.

The Cessna T210 Centurion has a relatively fast acceleration profile. High acceleration during take-off and initial climb can cause an illusion of increasing pitch. Somatogravic illusion is an erroneous sensation of pitch (rotation in the vertical plane) caused by linear acceleration. Under normal conditions this sensation can be recognized and corrected by visual means; however, when a take-off is being made on a very dark night, and toward an area that provides few visual references, this illusion will remain a powerful influence. A pilot's normal response to this pitch-up illusion is to apply forward pressure to the control column, and to reduce the aircraft's angle of climb.
Certain flight conditions can also create a lack of situational awareness. The achievement and maintenance of situational awareness can become degraded whenever the pilot needs to simultaneously diagnose faults or situations that were not predicted and cope with the consequences.

**Analysis**

Because of the low ceiling and normal VFR control zone procedures, the pilot would have been required to climb to approximately 500 feet agl after take-off before commencing his turn towards the north to pass abeam the airport. Witness accounts of the aircraft's profile after take-off indicate that the pilot was likely following normal VFR control zone departure procedures.

The aircraft struck the frozen surface of Athapakuskow Lake approximately 1 1/2 miles from the departure end of runway 18, indicating that the aircraft descended after take-off. The wreckage trail was oriented on a heading of 240 degrees magnetic, indicating that, just prior to the crash, the pilot was likely initiating a shallow turn to the right, on course towards the north.

An examination of the wreckage after the occurrence could find no evidence of a powerplant, flight control, or aircraft system failure that would have contributed to the occurrence. However, given the extent of the damage, the possibility cannot be ruled out that some unidentified fault or unexpected situation diverted the pilot's attention from the task at hand. Toxicological and pathological examinations completed following the accident provided normal results, and gave no indication of pilot incapacitation prior to impact.

A night departure from a remote northern aerodrome can be a challenging task. Even in VFR weather conditions, this type of departure requires the pilot to place increased reliance on available visual references and on basic instrument flying skills. This pilot had shown consistently poor IFR flight test results relating to altitude control and procedural errors and had failed his last instrument flight re-test.

In the area of the accident, there was little or no illumination from either the lights of the community or from the night sky. At night, particularly with overcast ceiling conditions, a lack of external visual references caused by inadequate ground and sky illumination, coupled with the requirement to use cockpit lighting to illuminate the instrument panel, could have adversely affected the pilot's ability to maintain required visual reference with the ground during the initial climb, and may have required the pilot to rely on instrument flying skills. Any distraction during flight under these conditions would have further compounded the pilot's workload, making the maintenance of situational awareness very difficult.

The forward acceleration of the Cessna 210 aircraft is sufficient to produce a powerful illusion of increasing pitch attitude. Under the prevailing dark night conditions and with restricted outside visual references, a somatogravic illusion could have caused the pilot to
erroneously perceive an increase in the aircraft pitch attitude. This illusion would be intensified by a quicker than normal aircraft acceleration associated with a shallow departure climb. If the illusion went unrecognized, the pilot may have responded inappropriately by pushing the control column forward, causing the aircraft to descend after take-off and contact the ice surface.

The following Engineering Branch report was completed:

LP 10/96 - Instrument and Light Bulb Examination.

**Findings**

1. Weather at the time of the departure from Flin Flon was VFR, with an overcast cloud ceiling at about 1,000 feet agl.

2. There are very few ground lights southwest of the Flin Flon aerodrome and, in the area of the accident, there was little or no illumination from either the lights of the community or from the night sky.

3. Poor ground and sky illumination may have prevented the pilot from maintaining adequate visual reference with the ground and likely required the pilot to rely on instrument flying skills, especially during the initial climb portion of the flight.

4. The pilot had shown consistently poor IFR flight test results relating to altitude control and procedural errors and had failed his last instrument flight re-test.

5. Examination of the wreckage revealed no evidence of a powerplant, flight control, or aircraft system failure that would have contributed to the occurrence.

6. Given the extent of the damage, the possibility cannot be ruled out that some unidentified fault or unexpected situation diverted the pilot's attention from the task at hand.

7. Toxicological and pathological examinations completed following the accident provided normal results, and gave no indication of pilot incapacitation prior to impact.

8. The accident was non-survivable because of the severe aircraft destruction.

9. Somatogravic illusion may have adversely affected the pilot's performance during the acceleration stages of the take-off and initial climb.

**Causes and Contributing Factors**

The pilot likely lost situational awareness and inadvertently flew the aircraft into the ice surface while in controlled flight because of the combined effects of the lack of external visual references and his weak instrument flying skills. The effects of somatogravic illusion may have
contributed to the pilot's disorientation.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, Benoît Bouchard, and members Maurice Harquail and W.A. Tadros, authorized the release of this report on 14 August 1996.
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
Risk of Collision
Between Wildcountry Airways Ltd
Piper PA-31-350 Chieftain C-FPIO
and Fast Air Ltd
Piper PA-31-325 Navajo C-GMDL
Dryden, Ontario 18 nm NW
15 February 1996

Report Number A96C0018

Summary

The Wildcountry Airways Ltd Chieftain was on an instrument flight rules (IFR) flight from Red Lake, Ontario, to Atikokan via airway Amber 4 at an assigned altitude of 7,000 feet above sea level (asl). The Chieftain was radar identified by the Kenora Sector controller and the altitude was verified. Approximately 20 nautical miles (nm) northwest of Dryden, the pilot observed, at his two o'clock position, another aircraft which appeared to be at the same altitude and flying on a collision course. The pilot of the Chieftain transmitted a position report on 126.7 MHz in order to alert the other aircraft of his presence. However, radio contact was not established, and he took evasive action to avoid a collision. The conflicting aircraft was a Fast Air Piper Navajo which was on a visual flight rules (VFR) flight from Winnipeg, Manitoba, to Sioux Lookout, Ontario, at a planned altitude of 7,500 feet asl. The pilot of the Navajo did not see the conflicting traffic until the Chieftain had taken evasive action.

Analysis of the radar data revealed that the aircraft were about one quarter of a mile apart laterally and 200 feet vertically when the two tracks crossed. The pilot of the Chieftain reported that he flew through the wake of the Navajo during his avoidance manoeuvre.

Ce rapport est également disponible en français.

Other Factual Information

The weather was clear in the area of the occurrence.
This occurrence took place in Class E airspace within the altimeter setting region. Class E airspace is controlled airspace where air traffic control (ATC) separation is provided only to aircraft operating under IFR. The Aeronautical Information Publication (AIP) defines the altimeter setting region as an airspace of defined dimensions below 18,000 feet asl within which the altimeter of an aircraft en route shall be set to the current altimeter setting of the nearest station along the route of flight, or where such stations are separated by more than 150 nm, the nearest station to the route of flight. For both occurrence aircraft, the nearest station was Dryden.

The altimeter setting is the pressure that when set on the altimeter will cause the altimeter to read aerodrome elevation when the aircraft is on the ground at the aerodrome. The altitude obtained using the altimeter setting is called the indicated altitude. If the altimeter setting is not set as required, an erroneous indicated altitude is displayed on the instrument. An altimeter setting which is too high results in an altimeter reading that is too high; that is, the aircraft would actually be at a lower altitude than the altimeter indicates.

Both aircraft were operating in the altimeter setting region and were required by their respective routings to have their altimeters set to the Dryden altimeter setting. The pilot of the Chieftain re-set his altimeter as required at the mid-point of his route between Red Lake and Dryden to the Dryden altimeter setting of 30.08 inches of mercury. The pilot of the Navajo had not reset the altimeter after departing Winnipeg and still had the Winnipeg setting of 30.38 set on the altimeter. Each .10 inches of mercury changes the altimeter by approximately 100 feet.

ATS Sector control positions may be operated by either one or two controllers, depending on workload. When two controllers are working, controlling tasks are divided between two positions: the radar controller performs radar control responsibilities, and the data controller performs administrative control activities such as coordinating flight plans between sectors and updating the flight progress strips. At the time of the occurrence, the Kenora Sector was being operated by one controller, who was performing the duties of both positions. His workload was assessed by his supervisor as moderate.

The Chieftain was under the control of the Kenora Sector and was transponding a discrete code that was providing altitude information. Thus, the digital target symbol of the Chieftain that was displayed on the controller's monitor was a "correlated target" symbol that had an associated full data block, which included the altitude of the aircraft. The Navajo was a VFR flight and was not controlled by ATS. The Navajo was transponding the VFR code 1200, a non-discrete code, that was providing altitude information. Thus, the digital target symbol of the Navajo that was displayed on the controller's monitor was an "uncorrelated target" symbol, and had an associated limited data block but included the altitude of the aircraft.

At the time of the occurrence, the controller was engaged in data controller tasks and had reduced his radar controller tasks correspondingly by not monitoring uncorrelated target symbols. The
controller did not observe the uncorrelated target symbol of the Navajo merge with the target of the Chieftain until the pilot of the Chieftain reported his avoidance action.

The *Air Traffic Control Manual of Operations* (MANOPS), TP703E, specifies the rules, procedures, and separation minima in the control of air traffic. Section 165.3 of MANOPS states that the controller must provide traffic information to radar-identified IFR aircraft if the targets appear likely to merge with another radar-observed target. The controller does not have to apply this procedure if the aircraft are known to be separated by more than the appropriate vertical separation minimum or if precluded by higher priority duties. Sections 131.1 and 131.2 of MANOPS state that the controller must give priority to the provision of control service over other services, and make every effort to provide the other services to the fullest possible extent.

The AIP summarizes information concerning rules of the air and procedures for aircraft operation in Canadian airspace. In the "Rules of the Air and Air Traffic Services" (RAC) section, paragraph 5.7, the AIP states that when operating in areas where radar coverage exists, aircraft operating in accordance with VFR and equipped with a transponder may request traffic information if traffic and ATC workload permit. The Navajo was transponder equipped and transponding the VFR transponder code 1200, but the pilot had not requested en route radar surveillance. RAC, paragraph 6.2, states that an IFR clearance provides separation between IFR aircraft only and that pilots operating IFR must be aware of the need to provide their own separation visually from VFR aircraft when operating in VFR conditions.

Air Navigation Order (ANO) Series V, No. 2, specifies aircraft cruising altitudes appropriate to aircraft track. Cruising altitudes for the tracks of the occurrence aircraft are specified as odd thousands of feet for IFR aircraft and odd thousands of feet plus 500 feet for VFR aircraft. Both aircraft were flown at indicated altitudes appropriate to direction of track.

The AIP, in RAC, Section 4.5.6, NOTE, states the following: "Pilots operating VFR en route in uncontrolled airspace or VFR on an airway should continuously monitor 126.7 MHz when not communicating on the MF [mandatory frequency] or the ATF [aerodrome traffic frequency]." This guidance is contained in a section entitled "Airport Operations" and is not found in the "VFR Enroute Procedures" section. Enroute Low Altitude charts contain the note that, "Whenever practicable 126.7 should be continuously monitored when VFR in controlled airspace unless another frequency is more appropriate." Enroute Low Altitude charts are designed for IFR use and are not commonly used by VFR pilots. The pilot of the Navajo was monitoring 122.8 MHz, which many pilots operating VFR in northwestern Ontario use for en route communication.

**Analysis**

This analysis will discuss the altimeter settings of the two aircraft, and assess the air traffic control procedures and pilot actions.
When the Navajo arrived in the vicinity of Dryden, the pilot did not reset the altimeter from 30.38 to the appropriate setting of 30.08. Consequently, although the pilot of the Navajo flew at a VFR cruising altitude of 7,500 feet with reference to the altimeter, the aircraft was actually flying at about 7,200 feet asl. The vertical distance between the two aircraft was about 300 feet less than the required vertical distance of 500 feet.

Because the controller was performing the duties of both radar and data controller, he prioritized his tasks, giving higher priority to the data controller tasks and lower priority to the provision of traffic information. Thus, he spent little time monitoring the uncorrelated digital target symbols. This prioritization is permitted by the ATC procedures specified in MANOPS. As a consequence, he did not provide traffic information to the Chieftain. The pilot of the Chieftain, while on an IFR flight plan, correctly maintained a visual lookout, saw the conflicting traffic, and took evasive action. The pilot of the Navajo chose not to ask for en route ATS radar surveillance. This decision precluded the verification of the altitude of the Navajo by the Kenora Sector controller, which probably would have prevented the altitude conflict. The lack of guidance on the use of the recommended en route frequency of 126.7 MHz reduced the possibility of immediate communication between the pilots when the altitude conflict occurred.

Findings

- The pilot of the Navajo did not reset the aircraft’s altimeter to the nearest station, as required, as the aircraft progressed along its route.

- Because of the incorrect altimeter setting, the Navajo was flying about 300 feet lower than the indicated altitude.

- When the aircraft passed, the vertical distance between them was about 300 feet less than the required vertical distance of 500 feet.

- The Kenora Sector controller was performing the combined duties of the radar controller and the data position.

- The Kenora Sector controller prioritized his control responsibilities and did not monitor uncorrelated digital target symbols.

- The Kenora Sector controller did not provide traffic information to the Chieftain nor did MANOPS obligate him to do so.

- The pilot of the Navajo did not request en route radar surveillance and, therefore, did not get confirmation of altitude or receive traffic information.
The pilot of the Navajo did not see the other aircraft prior to the occurrence.

The pilot of the Navajo did not monitor the recommended en route frequency of 126.7 MHz in controlled airspace.

Guidance on the use of the en route frequency in controlled airspace is not readily available to VFR pilots.

**Causes and Contributing Factors**

The Navajo came within 200 vertical feet of another aircraft as a result of the pilot not resetting his altimeter to the pressure setting of the nearest station along his route of flight, as set out in the AIP. Contributing to this occurrence were ATS procedures that gave controllers the discretion to assign data services a higher priority than that assigned to the provision of traffic services. Also contributing to this occurrence were the fact that directions to VFR pilots on the use of radio frequencies are not well publicized and the Navajo pilot did not request en route radar surveillance.

*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 20 December 1996.*
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 Loss of Separation
Between Northwest Territorial Airways
Boeing 737-210C C-GNWI
and Northwest Airlines
Boeing 747-451 N666US
Winnipeg, Manitoba 160 nm NE
01 June 1996

Report Number A96C0081

Summary

Northwest Territorial 962 (NWT962), a Boeing 737-210, was en route from Rankin Inlet, Northwest Territories, on an instrument flight rules (IFR) flight at flight level (FL) 310 via Churchill, Manitoba, direct to Winnipeg. Northwest 69 (NW69), a Boeing 747-451, was en route from Detroit, USA, also on an IFR flight at FL310, via Red Lake, Ontario, and airway NCA20 to Kansai, Japan. (See Appendix A.) As NWT962 approached the southern boundary of the Winnipeg North High (North) sector, the radar controller observed an unidentified target converging with NWT962's track. The controller identified the target as NW69, and at 1455:19 central daylight saving time (CDT), re-cleared NWT962 to FL290. NWT962 commenced descent from FL310 at 1455:58 CDT with 9.5 nautical miles (nm) horizontal separation from NW69, and levelled at FL290 at 1456:32 CDT with about 3 nm horizontal separation. The minimum required separation in the Class A airspace where the incident occurred is 5 nm horizontal or 2,000 feet vertical separation.

Ce rapport est également disponible en français.

Other Factual Information

Air traffic control (ATC) in the area of the occurrence is provided by the Winnipeg Area Control Centre (ACC). The two flight paths crossed about 160 nm northeast of Winnipeg at 1456:48 CDT, about 6 nm north of the boundary between the North sector and the Winnipeg East (East) sector. At that point, the two aircraft had about 500 feet horizontal and 2,000 feet vertical separation. NW69 crossed from the East sector into the North sector, but the East controller had not yet handed off the flight to the North radar controller.

The East sector controllers have two methods of determining an aircraft's position: the flight progress strips, and the radar display. There was no posted time estimate for a co-located position for the two flights. To recognize the conflict between NWT962 and NW69, it would have been necessary to use NWT962's Gimli estimate to calculate the time of its crossing of NCA 20, NW69's route of flight. Neither the East data controller nor the radar controller recognized the conflict between NWT962 and NW69 from an examination of the flight
progress strips. Both were aware of the procedure for calculating the separation between the flights. The East sector was operated by a radar controller and a data controller until 1449 CDT, when the data controller left for a rest break and the radar controller assumed both positions. Traffic in the sector was judged to be light at that time. The East controller was taking a position estimate by telephone when the North controller indicated that he was descending NWT962 and that NW69 should be left at FL310.

The East controller had planned to hand off NW69 to the North controller at or immediately before the aircraft reached the sector boundary. However, the East controller usually did not hand off most aircraft on NCA20 to the North sector before the sector boundary because of potential communications difficulties, as the next remote communications outlet (RCO) near that route is located at The Pas. Flights attempting to use the RCO at The Pas from a position in the East sector often find The Pas RCO to be out of range. Such flights could be assigned to the other available RCO frequency at Island Lake, but they would be out of range of Island Lake several minutes later, and the North controller would then be required to switch the flights to the RCO at The Pas. The East controller considered it desirable to reduce unnecessary workload on aircraft crews and controllers in other sectors by delaying the hand-off of aircraft entering the North sector until the aircraft were within communications range of The Pas.

The North radar controller's instruction to NWT962 at 1455:22 CDT was: "Territorial nine six two maintain flight level two nine zero. Start descent now." NWT962 replayed: "Territorial 962 we're leaving three one zero." At 1455:52 CDT, NWT962 asked: "Centre it's nine sixty two. Do you want us to start our descent now?" The North radar controller replied: "Territorial nine six two affirmative. Two nine zero right now please." At the time they received the first message from the controller, the NWT962 crew was not expecting a new clearance from the controller, and discussed the situation in the ensuing 30 seconds. During that time, the two aircraft closed from a horizontal separation of 19 nm to 12 nm. Neither crew member recalled hearing the clearance limit of FL290 or the urgency of the instruction to descend.

Pilots and controllers form "mental pictures" of the relative positions of aircraft and reporting points to assist them in understanding the overall traffic situation. Pilots and controllers who are involved in a communication exchange usually process the received information using mental expectations that seem most appropriate for the activity that they are performing at the time of the communication. If the message is unexpected or unusual, then the mental expectation held by the information receiver may hinder the understanding of the message, and could delay the response to the new information. At the time that the radio transmissions were made, the crew of NWT962 was in cruise flight conditions approximately 160 nm from their destination. They were not aware of any impending traffic conflict, had not requested a descent, and were not anticipating a descent clearance from that point.

The Air Traffic Control Manual of Operations (ATC MANOPS), section 507.1 instructs controllers to, "Issue a safety alert to traffic if you are aware that the aircraft is at an altitude which...places it in unsafe proximity to...another aircraft." The phraseology to be used in such a situation is, "Traffic alert (position of traffic if time permits)...climb/descend (specific altitude if appropriate) immediately." The procedure set out in this section is reportedly used mostly in connection with mixed IFR/visual flight rules (VFR) traffic.

The North radar controller set his indicator module (IM) to show only the data blocks of the aircraft under his control. On this setting, his IM showed only an octagonal "present position symbol," but no data tag, for aircraft controlled by the North Low sector or by an adjacent sector such as East. At the time of the occurrence, the North IM was set on 256 nm scale, the maximum available setting. The North sector is geographically larger than most other sectors controlled by the Winnipeg ACC, and even at the 256 nm setting, the sector depiction occupies most of the space available on an IM. However, if the North sector is
centred on the IM display, part of the East sector airspace will be displayed in the lower left corner of the IM.

NWT962's track was about 190 degrees magnetic (°) at the time of the occurrence. The flight crew had been in radar contact with Winnipeg ACC controllers since entering the North sector near Churchill. NW69's track was about 310°, and the flight had been in radar contact with Winnipeg ACC controllers in the Marathon and Dryden sectors before entering the East sector about 40 nm northwest of Red Lake. Above FL290, aircraft on tracks from 180° to 359° are assigned cruising altitudes at 4,000 foot intervals, beginning at FL310.

At the time of the occurrence, the Winnipeg North specialty, comprising the data and radar controller positions in the Winnipeg High, Winnipeg Low, and Trout Lake sectors, was staffed with three controllers and two supervisors. No controllers from the other specialties were qualified in the Winnipeg North specialty. One of the two supervisors was working the Trout Lake sector, and the other was on a break.

At 1422 CDT, the two controllers working the North Low sector observed that the single controller working the North sector was experiencing a period of heavy workload. One of the North Low controllers then moved to the North radar position to assist that controller, who then assumed the North data position. The incoming controller received no status briefing on assuming the North radar position; the incumbent North controller was reportedly too busy to provide one. A status briefing is to apprise an incoming controller of the existing and expected traffic in a sector and of any anticipated conflicts. On the morning of the occurrence, staffing in the North sector was judged by the ACC shift manager to be sufficient for the day's traffic requirements.

The controllers in the Winnipeg North specialty have three methods of determining an aircraft's position: the flight progress strips, the radar display, and the Northern Airspace Display System (NADS). The NADS is a computer-driven, representational display system which plots position estimates and crossing points for aircraft beyond the range of radar coverage. NADS helps controllers to recognize and avoid traffic conflicts at crossing points. The system depends on timely and accurate input of aircraft positions. The first estimate for NWT962's position abeam Gimli was 1519 CDT, based on that flight's departure time and estimated time en route. NADS issued a track crossing warning for NWT962 and NW69 based on this original estimate, and indicated that the two aircraft would cross with six minutes separation. ATC MANOPS directs controllers to post red "W" warning indications on flight progress strips to identify conflicts with other aircraft. Neither North controller marked a warning indication on either aircraft's flight progress strip. Both North controllers believed that a crossing with six minutes separation could be monitored on radar, without the need to change the clearances of the aircraft. After NWT962 came into radar contact and its position and speed could be determined more accurately, the North radar controller calculated that the flight would be abeam Gimli at 1513 CDT. He marked the revised estimate on the North sector's flight progress strip and passed it to the East data controller, who marked it on the East sector's NWT962 flight progress strip. The North data controller then continued updating NADS but did not enter the revised time estimate into NADS before the occurrence. There was no posted time estimate for a co-located position for the two flights. As in the East sector, to recognize the conflict between NWT962 and NW69, the North sector controllers would be required to use NWT962's Gimli estimate to calculate the time of its crossing of airway NCA 20, NW69's route of flight. Neither North controller could recall performing this calculation.

Both aircraft were equipped with traffic and collision avoidance systems (TCAS), although TCAS systems are not required by Canadian regulation. The TCAS system in NWT962 reportedly activated when that aircraft was descending through 29,200 feet, at a range of 5 nm from NW69, with a time to closest point of approach (CPA) of about 35 seconds. The
system issued an aural traffic alert, along with position and altitude information on NW69. The TCAS system inNW69 reportedly issued an aural traffic alert about 40 seconds before the CPA between the two aircraft, and when the crew selected the TCAS screen on their navigation display, it indicated the position and altitude of NWT962. In both cases the TCAS indications preceded and corresponded with the visual sighting of the aircraft traffic by the crews.

The radar modernization project (RAMP) radar system in use at the Winnipeg ACC is not capable of conflict advisory or resolution. A conflict advisory system was developed after the commissioning of the RAMP radar system. The system compared aircraft tracks and altitudes and issued conflict advisories to controllers when it determined that separation standards were likely to be compromised. When the system was tested, deficiencies were identified that required corrective action. Developmental work on a replacement system is reportedly in progress.

**Analysis**

Both aircraft were at the appropriate altitude for their direction of flight. They were converging at a relative angle of 120° when a loss of separation occurred between NW69 at FL310 and NWT962, which was descending from FL310 to FL290.

Although both the East radar and East data controllers had NWT962's revised estimate for a position abeam Gimli available to them, neither controller recognized that flight's conflict with NW69. Estimates for NW69 and NWT 962 were not posted for a co-located point and the required mental calculation necessary to correlate the estimates made it harder for the East controllers to recognize a conflict between the flights.

Because of the difficulty in communications that might have resulted if the aircraft were handed off early, the East radar controller delayed transferring control of NW69 for as long as possible; the controller then became preoccupied with data work rather than radar monitoring as NW69 left the sector.

Because the workload in the North sector was high, the incoming North radar controller was not given a status briefing when he assumed that position. The data controller was updating the information in the NADS system, but, because he had not yet completed the update, the NADS system was operating on outdated information. Although the NADS conflict warning indicated a six minute crossing time separation between NWT962 and NW69, NWT962 was six minutes early; therefore, the time separation decreased to nil. Although both North controllers were aware of the new estimate, they did not compare NWT962's revised strip with that of NW69 to update their mental picture of the separation between the aircraft. Formulation of an accurate mental picture was made more difficult by the lack of a co-located time estimate for the two flights. By concentrating on the NADS system, the North controllers relied more on the NADS separation calculation to detect conflicts than on their analyses of the flight progress strips.

The North radar controller's IM setting helped him avoid screen clutter by deleting the data tags of targets not under his control. However, the deletion of the data tags of the targets controlled by the sectors geographically adjoining the North sector decreased his ability to detect information about the incoming NW69, for which he had not yet accepted control.

Although one of the crew members of NWT962 responded that they were leaving FL310 when the North radar controller first issued an instruction to NWT962 to descend, a period of about 40 seconds passed before the crew commenced the descent from FL310. Because the crew members were not expecting a descent clearance, they did not fully understand the message or the reason for it, and initially took no action. During this time, the separation between the two aircraft decreased by 7 nm, and the situation was only resolved when the
crew asked for clarification. This confusion might have been averted if the controller had used phraseology such as that in MANOPS 507.1, which incorporates the reason for the controller's instruction. Although section 507.1 is mainly used in mixed IFR/VFR traffic, its use in IFR/IFR traffic could improve pilots' understanding of the meaning and urgency of ATC messages.

The TCAS system in NWT962 issued a traffic advisory after the conflict with NW69 was already recognized by ATC and NWT962 was descending. The TCAS system in NW69 activated in the absence of an ATC traffic advisory and helped that crew monitor the position and altitude of NWT962. Although the TCAS systems were not needed to resolve the conflict between the two flights, they helped the crews visually acquire and monitor their aircraft traffic.

There was no radar system conflict advisory system available to alert the controllers to the impending loss of separation.

Findings

- A loss of separation occurred about 160 nm NE of Winnipeg between NW69 at FL310 and NWT 962, which was descending from FL310 to FL290.

- Neither the East nor the North sector flight progress strips displayed co-located position estimates for NW69 and NWT962.

- The required mental calculation necessary to correlate the position estimates of the two flights made it more difficult for the North and East controllers to recognize the conflict between the flights.

- The East controller delayed NW69's hand-off to the North sector in an attempt to avoid potential communications problems in the North sector.

- The East controller became preoccupied with data functions and did not hand off NW69 before it left the East sector.

- The North data controller's workload prevented him from providing the incoming North radar controller with a status briefing.

- The NADS system listed an incorrect separation warning at the time of the occurrence, based on an outdated time estimate for NWT962.

- The North controllers relied more on the NADS separation calculation to detect conflicts than on their analyses of the flight progress strips.

- The North radar controller's IM setting prevented him from receiving information about aircraft not under his control.

- The North radar controller's descent instruction to the NWT962 crew did not use MANOPS 507.1 phraseology, and did not convey the desired sense of urgency to that crew.
- Both aircraft TCAS systems helped the respective crews visually acquire the other aircraft and monitor the situation.

- No radar system conflict advisory system was available to alert the controllers to the impending loss of separation.

**Causes and Contributing Factors**

A loss of separation occurred because the North and East controllers did not recognize the potential conflict after NWT962's estimate was updated. Contributing to the occurrence were the high workload in the North sector, the North controllers' reliance on outdated NADS information, and the East controller's delayed hand-off of NW69.

*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 05 March 1997.*

**Appendix A**
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
In-flight Fire
Wildcountry Airways Ltd.
De Havilland DHC-3 Otter C-FMEL
Cochenour, Ontario 5 nm E
16 June 1996

Report Number A96C0091

Summary

The float-equipped DHC-3 (Otter), carrying the pilot and six passengers, departed the company's water base at Cochenour, Ontario, on a charter flight to Sandy Beach Lodge, located on Trout Lake approximately 25 miles to the east. The pilot levelled the aircraft and configured it for cruise flight at approximately 2,500 feet above sea level (asl). Shortly after level-off, the pilot heard a popping sound and noted a slight loss of engine power, and wisps of whitish-grey smoke entered the cabin. The aircraft instruments indicated normal engine operation, and the fire warning system did not activate.

The pilot suspected that the engine had suffered a cylinder failure and turned to return to Cochenour. A passenger seated in the right front crew seat reported flames near the floor at the front, right corner of the cockpit. The pilot radioed the Thunder Bay Flight Service Station to advise of the emergency, had the passenger vacate the crew seat, and attempted to suppress the fire with a hand-held extinguisher. Thick, black smoke billowed into the cabin, restricting visibility and causing respiratory distress for all of the occupants. The pilot opened the left crew door in order to see ahead and landed the aircraft, still on fire, on McNeely Bay, the first available landing site. The aircraft landed hard but remained upright on the floats. The occupants left by the main door, with their life jackets, and were picked up almost immediately by nearby boats. The aircraft was consumed by fire within minutes after landing. The pilot suffered second degree burns to his face and right forearm, and the passenger in the right crew seat suffered burns to his right leg. The remaining five passengers escaped serious injury.

Ce rapport est également disponible en français.
Other Factual Information

The weather conditions were good and were not a factor in the occurrence.

The aircraft manufacturer considers an engine to have "failed" if it is not capable of producing power demanded by the pilot. Engine-related emergency procedures are provided in the aircraft flight manual under the heading of "ENGINE FAILURE...". These procedures list the steps for a "dead engine landing" that occurs above 800 feet after take-off, and also lists a "re-start" procedure if an engine failure occurs during flight. The aircraft manufacturer does not provide procedures to be followed in the event of a partial loss of engine performance, and there are no warnings relating to continued operation of a rough-running engine.

The pilot was certified and qualified for the flight. He had 20,000 hours total flight time with over 8,000 hours on this aircraft type. He was familiar with the local area and with the charter operation. The pilot had experienced a number of engine malfunctions related to cylinder failures during his Otter flying. These malfunctions had been minor in nature, and the pilot had always been able to recover the aircraft safely at a suitable landing site. In this instance, after experiencing a possible cylinder failure and encountering a reduction of engine performance, the pilot monitored his instruments as he continued to operate the engine and turned the aircraft back toward the departure water base.

The DHC-3 (Otter) aeroplane is an all-metal, high-wing monoplane powered by a single Pratt & Whitney R-1340 radial engine. This geared, nine-cylinder engine is supercharged and rated at 600 brake horsepower. Engine exhaust is routed to four exhaust augmentor tubes, two of which are installed on either side of the fuselage, just below the cockpit doors. The flow of the exhaust gases through the augmentor tubes produces suction that is designed to pull cooling air around the engine and engine accessories compartment, while simultaneously producing increased thrust in cruise flight.

The engine compartment is equipped with a fire warning sensor and extinguisher system that is controlled from a panel below the flight instruments. The system provides fire warning and fire protection in the area of the carburettor and engine accessories section of the engine; other areas of the engine and the remainder of the aircraft are not equipped with fire sensors or extinguisher systems. In the event of an engine compartment fire, a red warning light on the extinguisher panel illuminates, and the extinguisher system can be activated after the engine has been shut down. A hand-operated fire extinguisher is stowed in the cockpit within reach of the pilot.

A Janitrol heater, for cabin heat, is normally mounted on the upper right forward face of the engine firewall. When in use, the heater feeds heated air through the firewall to a fibreglass duct that routes the air down the cabin side of the engine firewall, through the cockpit floor, and back to heater discharge tubes in the cabin area. The heat duct turns rearwards beneath the cockpit floor, near the right side of the
firewall and close to and above fuselage skin that is shaped to enable installation of the upper right exhaust augmentor on the outside of the aircraft. The Janitrol heater in this aircraft had been removed prior to this occurrence, and a temporary aluminium blanking plate had been installed in the porting chamber for the heat ducting. The blanking plate was smoke stained on the cabin side and relatively clean on the side facing the engine compartment.

Following the landing, the engine compartment, aircraft tail section, and both wings broke free from their support structures because of the fire damage to the upper fuselage. Fire damage to the right-side firewall and sub-floor area of the aircraft was extensive. Aluminum had melted in this region, and the fibreglass ducting to the heater system had burned to ash. On the left side of the cockpit, the corresponding floor structure and fuselage skin did not display burn patterns, and the floor structure was torn rather than burned away from the firewall.

All interior components of the aircraft had been destroyed by the fire. The aircraft upholstery was not original de Havilland fabric; some 15 years earlier, the interior walls of the cockpit and cabin had been recovered with a Naugahyde-like material. The same material was applied to the upper portion of the main doors, but the lower portions of the doors were covered with metal plating to limit damage during aircraft loading and unloading. The majority of the upholstery fabric had been reduced to ash. The forward left door panel and associated upholstery had broken free of the fuselage and submerged in the lake, along with the engine section, and remained relatively undamaged. The upholstery on the left rear door panel showed a progression of heat stress ranging from minor shrivelling to total charring. All undamaged interior upholstery was forwarded to the TSB Engineering Branch for testing and evaluation respecting its fire retardant properties. Tests of the fabric material determined that the material met the fire retardant standards identified in the type certificate, and it is probable that the fire in the cabin was fuelled by some other source.

Fuel tanks, located below the cabin flooring, remained intact throughout the landing and post-crash fire. About 300 litres of fuel were removed after the occurrence, and it was evident that the fire had not been fed by fuel from the tanks, with the possible exception of fumes from the tank vents.

The propeller, engine, engine cowlings, and forward face of the engine firewall were relatively clean and undamaged. The No. 2 cylinder head had been split in two and separated from the cylinder barrel, the cylinder induction pipe had been pulled from the engine case, and the oil transfer tube had separated between the intake and exhaust rocker bosses. A section of the upper cowl was scorched and a corresponding section of the inner aft cowl evidenced a narrow path of scorching and panel burn-through. The path was from the No. 2 cylinder, along the outside of the upper right engine mount, across and down toward the upper augmentor tube at the right side of the firewall.

The insides of three of the four exhaust augmentor tubes were covered with considerable carbon and oil by-products, consistent with operation
under normal exhaust temperature ranges. However, the interior of the
top right exhaust augmentor tube was notably different in that the
exhaust by-products had been burned away, leaving the tube clean.
This upper right augmentor tube receives exhaust gases from an
exhaust stack shared by No. 2 and No. 3 cylinders.

Aero Recip Canada Ltd. completed an overhaul of this engine (Pratt &
Whitney model R1340-61 S1H1G, serial number ZP102072) on 05
April 1993. Within one year and five months of the overhaul, six
cylinders had been changed. A cam-follower problem was then
identified in the nose case, and the engine was removed, repaired, and
re-installed. The aircraft operated uneventfully for an additional one
year and seven months until two cylinders were changed because of
anomalies noted during a routine inspection. A 500-hour inspection of
the aircraft was completed 12 days after the double cylinder change.
The failure of the No. 2 cylinder and subsequent fire on this occurrence
was four days and 24.9 flight hours after completion of the 500-hour
inspection. The pilot indicated that the engine had been running
smoothly and was dependable prior to this cylinder failure.

The No. 2 cylinder (Part number CE91ER-W, Serial number AR16418)
had been installed at the time of the engine overhaul and, along with
the engine, had accumulated 887.9 flight hours. Cylinders do not have
a time-life nor are they tracked, and records for the total number of
hours of operation for the cylinders and their components are not
maintained.

The No. 2 cylinder was forwarded to the TSB Engineering Branch for
analysis. A heli-coil insert in the exhaust stud hole indicated that there
had been a previous exhaust stud/attachment problem on this cylinder.
Fretting and heat discoloration at the exhaust valve port and evidence
of exhaust by-products in cracks between cooling fins in the cylinder
head indicated that an overheating of the exhaust ear had been
occurring for some time prior to the failure of the cylinder. High
operating temperatures in the exhaust ear resulted in an interdendritic
cracking of the exhaust valve guide and a subsequent failure of the
exhaust valve. Continued operation of the engine with failed valve
components inside the cylinder resulted in progressive breaching, and
eventual overload failure, of the cylinder head.

The TSB Engineering Branch burn-tested a sample piece of fibreglass
heat ducting following the occurrence. The test showed that at 300
degrees Celsius, a grey smoke was emitted; at 350 degrees, the edges
of the fibreglass began to glow red; at 600 degrees, the samples
ignited within 10 seconds; and at 650 degrees, the samples ignited
within 5 seconds. A second test was conducted igniting the ducting with
a match flame (750-800 degrees Celsius); the duct burned until the
resins were consumed, leaving the fibreglass tape. It was further noted
that, once the duct erupted into flames, it gave off thick, black smoke.

The passengers had difficulty breathing due to the thick smoke. They
opened both rear doors of the aircraft and moved from their seats to
the floor of the aircraft where there was less smoke, and where they
would be in a better position to evacuate the aircraft at the earliest
opportunity.

Analysis

The precipitating event to this accident was a fatigue failure of the exhaust valve in the engine's No. 2 cylinder. This failure allowed combustible fuel-air mixture and exhaust by-products to pass through a damaged and continuously open exhaust port into an exhaust manifold that is shared with the No. 3 cylinder. Flaming gases from the two cylinders combined in the manifold and were ported into the upper right exhaust augmentor tube. The abnormally high temperatures that developed inside the augmentor tube were sufficient to cause carbon and oil deposits, normally found in the tube, to be burned away.

The fretting and heat discolouration at the exhaust valve port and evidence of exhaust by-products found within the cracks between cooling fins in the cylinder head indicate that an overheating condition of the exhaust ear had been occurring for some time prior to the failure of the cylinder. These conditions may have existed and gone undetected at the time of the 500-hour inspection, completed approximately four days and 25 flight hours prior to the occurrence.

Engine cylinders do not have a time-life nor is their usage tracked. Records for total hours of operation are not maintained for cylinders or their components, nor are such records required by regulation.

When the cylinder head failed, the resultant flame/gas path was above and away from the area of the engine that is sensed by the fire warning system; consequently, the fire warning light did not activate. The flame path proceeded to the right side of the firewall and down towards the right augmentor. The in-flight buildup of light grey smoke, flames, then dense black smoke was consistent with the burning characteristics noted during fire testing of duct samples. The flames and smoke observed coming through the floor were at the location of the fibreglass heat duct. It is concluded that the fire was related to the failure of the cylinder; however, fire damage precluded a determination of how the fire travelled from the engine compartment to ignite the fibreglass duct work.

The pilot's response to the fire emergency was consistent with procedures that are published in the aircraft flight manual. However, the hand-held extinguisher was ineffective against the fire.

Once the aircraft was on the water, the fire spread rapidly. Within minutes, the engine and instrument panel of the cockpit, both wings, and the tail of the aircraft had burned away from the fuselage and dropped into the water. The aircraft fuel tanks remained intact throughout the hard landing and post-crash fire. Based on the amount of fuel removed after the occurrence, it is apparent that the fire was not directly fed by the fuel, although it is possible that fumes escaping from the fuel tanks may have fed the post-crash fire.

The following Engineering Branch reports have been completed:
Findings

- The pilot was certified and qualified for the flight.
- Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.
- Engine cylinders do not have a time-life nor are they tracked. Records are not maintained for the total number of hours of operation of cylinders and their components, nor are such records required by regulation.
- Cracks developing between cooling fins in the cylinder head and evidence of exhaust leakage may have gone undetected during the 500-hour inspection completed approximately four days and 25 flight hours prior to the occurrence.
- Failure of the No. 2 exhaust valve guide and subsequent failure of the exhaust valve likely occurred as a result of the effects of exhaust gases leaking at the exhaust port and heating the exhaust ear of the cylinder.
- There are no procedures to be followed in the event of a partial loss of engine performance, nor are there warnings relating to continued operation of a rough-running engine.
- Following the loss of engine performance, the pilot continued to operate the engine as he initiated a recovery to the departure water base.
- As the engine continued to operate, flaming fuel-air mixture escaped from the cylinder through the continuously open exhaust port and joined with the exhaust from the No. 3 cylinder. These combined exhaust gases produced a high heat that burned away carbon and oil residues normally found in the upper right exhaust augmentor tube.
- Failure of the valve in the No. 2 cylinder resulted in failure of the cylinder head and development of a gas/fire path across the top of the engine to the firewall and down towards the upper right augmentor.
- The fire started following the failure of the cylinder; however, fire damage precluded a determination of how the fire travelled from the engine compartment to ignite the fibreglass duct work.
The pilot was unable to extinguish the fire using the on-board hand-held fire extinguisher. The aircraft was destroyed by fire within minutes after landing.

Causes and Contributing Factors

Continued operation of the engine following an exhaust valve failure on the No. 2 cylinder resulted in a flaming gas path near the right side of the firewall, an exhaust system overheat, and a subsequent cabin fire.

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 29 July 1997.

Updated: 2002-10-06

Important Notices
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
Flight into Terrain
Piper Comanche PA24-250 N6541P (USA)
Pelican Narrows, Saskatchewan
15 June 1996

Report Number A96C0092

Summary

After spending a week's vacation in the vicinity, the private pilot and three passengers were departing from a private airstrip located at the U-Fly-In Camp three miles east of Pelican Narrows, Saskatchewan. The pilot intended to fly to Flin Flon, Manitoba, to top up the aircraft fuel tanks before heading home to Colorado, USA. Shortly after the take-off, the PA24-250 aircraft, serial No. 24-1663, failed to clear a stand of trees, crashed, and came to rest approximately 800 feet off the end of the airstrip. The aircraft was destroyed by the impact and post-crash fire. Two passengers were fatally injured; the pilot was seriously injured, and the third passenger received minor injuries.

Ce rapport est également disponible en français.

Other Factual Information

The grass-surfaced airstrip was approximately 3,000 feet long and 100 feet wide, and was surrounded by poplar and spruce trees 50 to 60 feet high. The runway was oriented 010/190 degrees and had an elevation of approximately 1,000 feet. The surface was slightly bumpy and had a pronounced hump at the 1,000-foot point on runway 01, the take-off runway. The grass was approximately 2.5 inches long near the centre line, and the airstrip was in a slightly soft condition because of recent rainfall. The aircraft tires left 1/8 to 1/4-inch-deep tire indentation marks at the location where the aircraft turned around prior to the take-off.

The local weather was reported by an observer as follows: temperature 13 degrees Celsius (°C), and wind from 325 degrees at 10 to 15 miles per hour (mph). The weather at Flin Flon, approximately 50 miles southeast of the departure airstrip, was as follows: scattered cloud at
1,100 feet above ground level with an overcast layer at 1,800 feet, temperature 13°C, dew point 10°C, and winds 300° True at 10 knots.

The licensed private pilot was rated for single-engine land visual flight rules (VFR) flight, and had approximately 1,800 hours total flying time, with 583 hours of complex/retractible flying time and 540 hours on type. In the last 30 days, the pilot had flown approximately 15 hours including the recent trip from Colorado. The pilot was relatively inexperienced with soft-field, grass-runway take-offs.

The pilot estimated the gross weight of the aircraft to be 2,975 pounds, with the centre of gravity (C of G) within limits. The maximum gross weight for the aircraft was 3,000 pounds, as equipped with tip tanks which were installed under a Supplementary Type Certificate (STC).

Take-off performance calculations for the conditions indicate that a ground run of about 1,400 feet would have been required before the airplane became airborne, and that a total distance of about 2,000 feet would have been required to reach an altitude of 50 feet. The stopping distance required would have been significantly more than the 650 feet indicated in the approved flight manual for landing with flaps down on a hard-surfaced runway; this, in turn, indicates that the safe abort point would have been at about 1,000 feet from the end of the runway.

The pilot reported that the pre-take-off run-up was uneventful. He utilized a soft-field take-off technique and attempted to hold the nose off the runway immediately at the start of the take-off roll. The aircraft was observed to lift off with an abrupt and pronounced rotation after a ground run of about 1,100 feet. The aircraft was then seen to fly 5 to 10 feet above the ground in a nose-high attitude. The aircraft was observed to touch down about 900 feet further down the airstrip. The aircraft lifted off again and flew with a nose-high attitude and shallow climb angle at approximately 60 miles per hour (mph). The pilot decided to continue the take-off, but found that the aircraft would not climb without sacrificing airspeed. The pilot then levelled the aircraft and retracted the gear in order to reduce drag and build up airspeed. An observer reported that the aircraft's engine sound was not as loud or sharp as that of other aircraft of the same make and model. The observer reported that the aircraft cleared lower trees at the end of the airstrip, but that its trajectory was such that it did not appear able to clear higher trees on the rising ground beyond the runway. At the end of the airstrip, the pilot pulled back on the control column in an attempt to clear the approaching trees and turned to the right towards the lake. The aircraft lost airspeed, stalled, and dropped into the forest.

The aircraft was found in a stand of trees 50 to 60 feet high, about 800 feet beyond and slightly to the right of the runway. The damage signatures on the aircraft and the ground scars showed that the aircraft entered the trees in a right-wing-low attitude. The aircraft's right wing struck the ground first, severing the outboard section. The aircraft then rotated to the right and came to rest on a heading of 220° magnetic. The damage to the surrounding trees indicated that the propeller was producing power until the engine struck the ground. The aircraft was severely damaged by the impact and the subsequent intense fuel-fed
fire which consumed the entire cabin area, most of the remainder of the right wing, the inboard section of the left wing, and portions of the tail.

The flaps were found in the up position. The ailerons, rudder, and elevators sustained damage from the impact forces and from the fire; however, all failures and damage in the structure and attachments were assessed to be overload or fire related. The elevator trim was in a neutral to slightly nose-down position. Flight control continuity was established to the extent possible, given the fire damage.

The engine compartment was severely damaged by fire; the carburettor and induction system, accessory section, and both magnetos were entirely consumed. No useful information was obtained from the cockpit instruments because of the fire damage.

Aircraft records indicate that the aircraft's tachometer had been changed to an electronic type in January of 1996. At the time of the installation of the new tachometer, the engine was found to be over-speeding by approximately 300 revolutions per minute (rpm). The maintenance engineer involved in the installation believed that the old tachometer had been indicating approximately 300 rpm low and adjusted the propeller governor maximum speed setting downward accordingly. Subsequent testing of the old tachometer confirmed that at 2,500 rpm it was indicating 300 rpm too low. This indicates that the pilot had been operating the engine in an over-speeding condition for an unknown period of time, during which time the engine had been producing more power than was being indicated by the tachometer.

The propeller governor was tested at two independent propeller overhaul shops and was found to be operating within normal expected parameters. The propeller was dismantled and examination revealed that, at the time of ground impact, the blade pitch mechanism was slightly off the low pitch stop. This is the expected position for a propeller which is operating in flight in the "fine pitch" or take-off position.

Although the temperature and dew point were conducive to carburettor icing, the pilot reported that there were no indications of icing and that engine performance prior to take-off was normal.

The low-wing PA24-250 is equipped with a laminar flow wing. Laminar flow wings have sharper leading edges and are thickest at about 50 per cent of the chord position, whereas conventional airfoils are thickest at about the 30 per cent chord position. The laminar flow airfoil tends to be more efficient in terms of reduced drag, but only over a narrow range of angles of attack, commonly called the "drag bucket." As long as this airfoil operates within this narrow range of angles of attack, the air flow remains laminar for a much farther distance back from the leading edge than on a conventional airfoil, resulting in reduced and constant drag loads. As the angle of attack is increased, however, a point is reached where the drag increases rapidly and the advantage of the laminar flow airfoil disappears. Once the airfoil is operating outside of the "drag bucket," small increases in angle of attack result in significant increases in drag.
Analysis

On the basis of the propeller governor and tachometer test results, the propeller examination and damage signatures, and the lack of any conflicting evidence, it is likely that the engine was producing substantial power at impact. Although a reduction in available take-off power as a result of carburettor icing or other system malfunction cannot be ruled out, the investigation of the evidence available did not reveal any such pre-impact condition.

The cause of this accident likely involves a combination of several factors. The pilot was relatively inexperienced with soft-field grass-runway take-offs. The aircraft was near its maximum gross weight. The pilot may have had an expectation of greater aircraft performance based on the aircraft's past performance when the engine propeller governor was set 300 rpm higher and, therefore, producing more take-off power.

The pilot used a soft-field take-off technique which, in combination with the terrain rise at about the 1,000-foot mark of the airstrip, caused the aircraft to become airborne prematurely at a low airspeed with a nose-high attitude. During a soft-field take-off using such a technique, the aircraft would be operating at a relatively high angle of attack and in a region of the flight envelope where small increases in angle of attack result in significant increases in drag. Because of the characteristics of the laminar flow air foil, the aircraft nose must be lowered substantially before drag is reduced to allow the aircraft to accelerate.

The aircraft touched down again about 900 feet further down the airstrip, at about the safe abort point. Once the pilot continued the take-off beyond the safe abort point, the high drag loads did not allow the aircraft to accelerate sufficiently to climb and clear the obstructions beyond the end of the airstrip. The aircraft stalled when the pilot manoeuved to avoid impact.

The following Engineering Branch report was completed:

LP 133/96 - Take-Off Performance Analysis.

Findings

- Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and procedures.

- The pilot estimated that the aircraft's weight was slightly below the maximum limit and that the C of G was within the prescribed limits.

- The pilot was certified and qualified for the flight in accordance with existing regulations.
Because of the almost complete destruction of the aircraft by the crash and fire, it could not be determined whether any pre-impact failure or system malfunction contributed to the accident; however, none was identified.

There was no evidence of carburettor icing.

The tachometer which was removed in January of 1996 was found to be indicating approximately 300 rpm low. The propeller governor maximum speed setting was decreased by approximately 300 rpm when the new electronic tachometer was installed.

Having previously operated the aircraft at an engine speed that was 300 rpm higher, the pilot may have had an expectation of greater aircraft performance that could not be achieved on the day of the accident.

On take-off, the aircraft became airborne prematurely and maintained a nose-high attitude which prevented the aircraft from accelerating and climbing sufficiently to clear the obstacles.

The pilot continued the take-off beyond the safe abort point.

The aircraft stalled at an altitude from which recovery was not possible.

Causes and Contributing Factors

The technique used during the take-off from the soft field caused the aircraft to become airborne prematurely and prevented sufficient acceleration to climb and clear the obstacles in the take-off flight path. The aircraft stalled at an altitude from which recovery was not possible when the pilot manoeuvred to avoid impact with trees.

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 April 1997.

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
VFR Flight Into Adverse Weather
Rusty Myers Flying Service
Beech D18S C-FBGO
Sioux Lookout, Ontario 35 nm SE
06 July 1996

Report Number A96C0126

Summary

A Rusty Myers Flying Service float-equipped Beech D18S, C-FBGO, serial No. CA-215, departed Fort Frances, Ontario, with the pilot and four passengers on a visual flight rules (VFR) flight to Granite Lake. The weather was overcast with good visibility on departure. However, about one-half of the way to Granite Lake, just north of Ignace, the pilot encountered an area of increasing rain and decreasing visibility. The pilot made several course deviations to find a route through the poor weather, but eventually could find neither a way out of the poor weather nor a lake with suitable conditions for landing. While manoeuvring at low level and with heavy rain obscuring the horizon, the pilot reported that the engines lost partial power because of carburettor icing. The pilot applied carburettor heat but was unable to restore engine power or sustain aircraft altitude. The pilot attempted to keep the aircraft level, and in a matter of seconds, the aircraft descended into the trees. The aircraft travelled approximately 500 feet through the trees; the left wing was torn off and a fuel-fed fire broke out almost immediately. All occupants survived the crash with minor injuries and exited the aircraft. The passenger occupying the co-pilot seat received burns to his upper body. The crash site was overflown about 15 minutes later by a second company pilot who transmitted a Mayday. The occupants were picked up by helicopter about one hour later.

Ce rapport est également disponible en français.

Other Factual Information

The company operates float-equipped aircraft from its main water base in Fort Frances and provides transportation services to many outpost
camps in northwestern Ontario. The terrain is typical of the Canadian Shield, rugged with many lakes. The operation is conducted under VFR, which permits the pilots to operate with a minimum of one mile flight visibility and clear of cloud. There is no minimum en route altitude. Pre-flight and en route weather is predominantly acquired from other pilots and camp operators. The pilots tend to fly over-water routes to the camps so that they can land in case of an in-flight emergency or to wait out marginal weather.

At about the time C-FBGO took off, a second Rusty Myers' Beech D18S departed the Fort Frances area on approximately the same over-water route to another fishing camp located about 10 miles from Granite Lake. The second aircraft was a few minutes ahead of C-FBGO. The two pilots were in radio communication with each other, and the pilot of C-FBGO expected that the other pilot would be further along the over-water route for the entire flight and would provide weather information. The two pilots did pass weather and position reports to each other; however, the second aircraft deviated around the marginal weather area that C-FBGO subsequently entered and was, in effect, behind C-FBGO for a period of time. The subsequent manoeuvring of both aircraft then resulted in the second aircraft being again ahead of C-FBGO on an alternate over-water route to the destination. Just prior to the occurrence, the pilot of C-FBGO was in communication with the pilot of the second aircraft and knew that the other aircraft was ahead and in better weather. However, the pilot of C-FBGO was not fully aware of how the relative positions of the aircraft had changed during the weather deviations. Some 30 seconds after the last communication between the two pilots, C-FBGO descended into the trees. The second pilot was unaware that C-FBGO had crashed, but in subsequent manoeuvring around marginal weather saw the smoke from the crash site and after overflying the site called the Mayday.

At the time of the accident, the reported weather at Sioux Lookout, about 35 miles north and the closest weather reporting station, was 300 feet overcast, visibility two miles in drizzle and fog, and temperature and dew point 12.6 degrees Celsius. Just prior to the occurrence, the pilot had flown into an area of heavy rain that obscured the horizon. The heavy rain and lack of horizon were confirmed by the passenger occupying the co-pilot's seat.

The aircraft was being operated on a mixture of 25% 100 low lead aviation gasoline and 75% automotive fuel (MOGAS). The Aeronautical Information Publication (AIP), paragraph AIR 2.3, contains a carburettor icing chart which indicates that at a temperature and dew point of 12.6 degrees Celsius, serious carburettor icing can occur at any power setting. A note to the chart states the following:

This chart is not valid when operating on MOGAS [automotive fuel]. Due to its higher volatility, MOGAS is more susceptible to the formation of carburettor icing. In severe cases, ice may form at OATs [outside air temperatures] up to 20°C higher than with AVGAS.
The carburettor heat technique recommended by the company chief pilot was to apply full carburettor heat before entering precipitation and leave it on. His technique was motivated by a desire to reduce the number of actions required in poor weather and thus enable the pilot to concentrate on navigation. Other company pilots also used this technique. The occurrence pilot was aware of the chief pilot's recommended procedure; however, she preferred to use a different technique learned on other aircraft and applied the carburettor heat only when areas of precipitation were entered or carburettor ice occurred.

The Airplane Flight Manual applicable to the Beechcraft D18S aircraft states the following with regard to carburettor icing: "There is a minimum of 120°F heat rise available at 30°F OAT when using 75% METO [maximum except take-off power]. It is not recommended that heat be used unless the engine starts to get rough or there is a drop in manifold pressure."

The aircraft was previously owned by the Royal Canadian Air Force (RCAF) and was designated as an Expeditor. The flight manual used by the company, and accepted by Transport Canada inspectors for company use, is EO 05-45B-1, *Pilot's Operating Instructions - Expeditor*, issued 1 July 1957 by the RCAF. Under the heading AFTER TAKE-OFF, CLIMB AND DURING FLIGHT is the following paragraph: "72. When icing conditions prevail, use manifold heat as necessary to maintain the carburettor air temperature outside the icing range. (Recommended range +5°C to +10°C). Manifold heat is effective as an ice preventative, hence should be used continuously to prevent ice rather than periodically to remove it. In severe icing conditions frequently move the throttle levers so that they will not become frozen in any one position."

The AIP in paragraph AIR 2-4 provides information with respect to flight in rain. The AIP states that a refraction error can occur because of rain on the windshield, which causes the terrain ahead of the aircraft to appear to be lower than it is. The AIP gives an example indicating that terrain about one-half mile ahead of the aircraft could appear to be approximately 260 feet lower than it actually is. The AIP states further that, "Pilots should remember this additional hazard when flying in conditions of low visibility in rain and should maintain sufficient altitude and take other precautions, as necessary, to allow for the presence of this error.

There was no evidence found that indicated company management personnel pressured pilots to accomplish revenue flights in poor weather. The pilot indicated that she had experienced such pressure from time to time from customers. The company did, however, approve of pilots flying low, based on their own judgement, to see if a clear horizon existed below the cloud base if deteriorating weather conditions were encountered en route.

After the crash, the pilot and passengers abandoned the aircraft, and the pilot attempted to grab the first aid kit. However, it was mounted in such a way that the pilot could not remove it quickly under the pressure
of the post-crash fire. The survival kit was stowed as required, but access to it was blocked by baggage. Because of the intensity of the fire, neither the pilot nor passengers could return to the aircraft to retrieve the survival kit.

**Analysis**

Investigators did not visit the accident site because witnesses provided enough information to be able to determine the nature of the accident. Weather information from Sioux Lookout helped to confirm the kind of weather that the pilot encountered. The remoteness of the site made ground access difficult; however, the site was overflown by investigators and examined from the air. Photographs taken by Ministry of Natural Resources employees were reviewed to complement witness reports. Consequently, this analysis will not include the discussion of technical issues other than carburettor icing.

When deteriorating weather conditions were encountered in the vicinity of Ignace, the pilot attempted to look for better weather by staying at low altitude and looking for a clear horizon beneath the cloud base. Because the pilot did not fully understand how the other aircraft had diverted around the marginal weather area, the pilot was expecting to find better weather ahead. Influenced by the perception that another pilot was in better weather on a different over-water route, the occurrence pilot flew across a land area towards the over-water route. However, the weather conditions rapidly deteriorated and the horizon disappeared in heavy rain. There was then no option of landing on a suitable lake and waiting out the weather.

The chart in the AIP indicates that in heavy rain at the ambient temperature/dew point existing at the time of the accident, a risk of serious carburettor icing is present at any power setting. The fuel mixture of 100 low-lead aviation gasoline and MOGAS significantly increased this risk. Consequently, the engines' near simultaneous partial power loss was probably caused by carburettor ice, as reported by the pilot.

The pilot's technique for the application of carburettor heat differed from the recommended company procedure; the pilot did not apply carburettor heat as a precautionary measure prior to entering the area of marginal weather. When the heavy rain was encountered, the pilot then had to contend with the increased workload of restoring engine power and flying in the rain at low level with no horizon, until power could be restored. When the pilot did apply carburettor heat, there was not sufficient time to clear the carburettor ice and restore engine power before contact with the trees. It is possible that the refraction effect of the rain on the windscreen led the pilot to believe that the aircraft was higher than it actually was and consequently, the pilot flew at an altitude that left no margin for dealing with emergency situations.

The mounting of the first aid kit prevented the pilot from removing it quickly from the aircraft when the survivors abandoned the aircraft. The location of the survival kit behind the baggage prevented the survivors
from removing the kit when exiting the aircraft and the kit was destroyed in the post crash fire.

Findings

- Records indicate that the pilot was certified and qualified for the flight.

- While on a VFR flight, the pilot continued flight into adverse weather and lost all reference to the horizon.

- The pilot had been exchanging weather and position information with another company pilot and believed that the weather conditions would improve.

- The pilot deviated from the company practice of either staying on an over-water route or landing and waiting out the weather.

- The pilot may have been at a lower level than anticipated because of the refraction effect of rain on the windshield.

- The temperature and dew point at the time of the accident were conducive to serious carburettor icing at any power setting.

- The aircraft fuel mixture consisted of aviation gasoline and MOGAS and hence was more susceptible to carburettor icing than aviation fuel alone.

- The pilot's technique in attempting to eliminate carburettor ice was not as recommended by the company.

- The engines lost partial power, likely because of carburettor ice.

- There was insufficient time to recover from the partial power loss effects of carburettor icing.

- The location of the first aid and survival equipment prevented their quick removal during the rapid egress from the aircraft.

Causes and Contributing Factors

The pilot continued the flight into adverse weather at low level and force-landed the aircraft into trees when the engines experienced a partial power loss that was probably caused by carburettor icing.

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 09
May 1997.

Updated: 2002-10-06

Important Notices
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
In-flight Fire
Perimeter Aviation Ltd
Beech Aircraft Corporation 95-B55 Baron C-GCIK
Thunder Bay, Ontario 28.5 nm W
22 October 1996

Report Number A96C0223

Summary

The Perimeter Aviation Ltd Beech 55 Baron, serial No. TC 1905, departed Atikokan, Ontario, at 0816 central daylight saving time (CDT)\(^1\) for Thunder Bay on a continuation of a single-pilot courier flight that began in Winnipeg, Manitoba, earlier in the day. At 0834, the pilot contacted the Winnipeg Area Control Centre (ACC) Marathon sector controller and advised that he was experiencing an electrical problem with smoke coming into the cockpit. The pilot requested an immediate descent and vectors for an instrument landing system (ILS) approach to runway 07 at the Thunder Bay airport. The aircraft was given a 15-degree turn to the right and was cleared down to 5,000 feet above sea level (asl). Shortly thereafter, radio communication was lost and the aircraft disappeared from radar coverage. Overflying aircraft initiated a communications search, but there was no further radio contact with the aircraft and no emergency locator transmitter (ELT) signal was received. The Department of National Defence Search and Rescue conducted an intensive air and ground search, but the search was hampered by poor ground visibility. The aircraft was located the following day about one mile south of Shebandowan Lake. The pilot did not survive the severe impact.

Ce rapport est également disponible en français.

Other Factual Information

The aircraft departed Winnipeg with a load of about 550 pounds of bankers’ dispatch notes from Winnipeg destined for Fort Frances, Atikokan, and Thunder Bay. The bags were stored in the nose
baggage compartment and in the back of the aircraft, behind a cargo net mounted directly behind the pilot's seat. The aircraft left Winnipeg with 700 pounds of fuel, and was not refuelled en route. The aircraft was operating within its design weight and centre of gravity limits.

The pilot's normal practice at the station stops was to shut down the aircraft's right engine to allow the courier driver to approach the aircraft, open the rear baggage door, remove the baggage for that station stop, and load the baggage for the aircraft's destination. At the pilot's first station stop in Fort Frances, the pilot shut down both engines and advised the courier driver that he was having problems with his dash and that his radios were cutting in and out. He stated that there might be a fault with the wiring and that the situation warranted a call to the operator in Winnipeg. The pilot was seen to use the telephone in the airport terminal building for at least five minutes, and then he departed Fort Frances. In subsequent interviews, no company personnel reported receiving a call that morning from the pilot. The company phone lines were reported to be very busy that morning because of general inquiries into flight scheduling due to poor weather, and it is possible that the pilot's call could not get through. A telephone record check disclosed no completed calls made to the operator from the phone the pilot was seen to use.

The station stop at Atikokan was reportedly routine. The courier agent removed baggage from the rear cargo compartment and reported nothing unusual. The pilot obtained an instrument flight rules (IFR) clearance to Thunder Bay through the Thunder Bay flight service station (FSS) remote communications outlet (RCO) at Atikokan. The aircraft departed runway 22 and made a left turnout. Once airborne, the pilot was cleared to 7,000 feet asl by the Winnipeg Centre air traffic controller. The pilot radioed a pilot weather report to the effect that the ceiling at Atikokan was about 10,000 feet asl with good visibility beneath the cloud. The flight continued as scheduled and at 0834:10, the pilot asked for an initial descent clearance for Thunder Bay. Fifteen seconds later, the pilot indicated that he had smoke coming into the cockpit and asked for an immediate descent. The aircraft was cleared to 5,000 feet asl and given vectors to the airport. At 0837:28, the pilot reported that there was a lot of smoke coming in the cockpit and that he was going to have to "do something." The controller cleared the flight to proceed directly to the airport. There was no further response from the pilot.

The distance from Atikokan to Thunder Bay is about 92 nautical miles (nm). The Thunder Bay Radar Modernization Project (RAMP) radar established radar contact with the aircraft as it was climbing through 5,900 feet asl, about 81 nm west of Thunder Bay. The radar received both primary and secondary target information from the aircraft. The aircraft's transponder was providing Mode A (positional) and Mode C (altitude) data, except for the last 30 seconds of the flight, when only Mode A was transmitted. Radar data indicate that, after departing Atikokan, the aircraft climbed to 7,000 feet asl and commenced a descent from that altitude 39.5 nm west of Thunder Bay at 0834:25. Mode C coverage was lost as the aircraft was descending through
3,700 feet asl. The aircraft's average rate of descent from 5,000 feet asl to 3,700 feet asl was 2,900 feet per minute. Radar contact with the aircraft was lost at 0837:51, at a distance of 29.12 nm from Thunder Bay. The wreckage was found 0.7 nm northeast of the aircraft's last radar position.

The Environment Canada weather observation for 0900 CDT at the Thunder Bay airport (elevation 653 feet asl) was as follows: winds calm, visibility 1.5 statute miles in mist, scattered cloud at 400 feet above ground level (agl), broken cloud at 800 feet agl, overcast cloud at 4,400 feet agl, temperature and dewpoint eight degrees Celsius, and altimeter setting 29.88 inches. The remarks associated with the observation noted that the ceiling was composed of 2/8 fog, 4/8 stratus-fractus cloud, and 2/8 stratus-cumulus cloud.

Residents on the ground in the area of the accident reported that, at the time of the accident, the winds were light, the cloud base was at ground level, and visibility was reduced to several hundred feet by fog and mist. The crew of another aircraft flying in the area of the accident at 7,000 feet asl reported that they did not have visual contact with the ground and were between cloud layers with the cloud tops about 10,000 feet asl.

The 28-year-old pilot was hired by the operator in May 1995 and had completed a multi-engine instrument rating. The pilot was then employed as a first officer on the Swearingen SW-3 aircraft type and flew about 1,000 hours on that type. In August of 1996, the pilot underwent flight training on the Beech 95-B55 and passed a pilot proficiency check on that type. The pilot then flew the scheduled courier route to Thunder Bay with that aircraft type in September and October 1996. At the time of the accident, the pilot had accumulated a total of about 1,660 hours of flight time, with about 160 hours on the accident aircraft type. The pilot was described as eager to do his job well and complete the tasks which were assigned to him. However, no information was found to indicate that he was under external pressure to fly an unserviceable aircraft. The operator was reportedly able to arrange alternate means of transportation for the cargo in the event that an aircraft became unserviceable during a courier route.

Part of the pilot's initial flight training on the Beech 95-B55 included training on aircraft emergency procedures. Company personnel indicated that, during this training, they instructed the pilot on the procedures to use in case of electrical smoke or fire. The training outlined the need to isolate the fault and stop any smoke from coming into the cabin, because the smoke could be very incapacitating. The pilots were instructed to shut off all electrical power to isolate the fault, and then attempt to ventilate the cabin. Vacuum-driven flight instruments continue to provide instrument flight reference information. If the smoke subsides, essential systems may then be re-energized, barring any further recurrence of the problem.

The aircraft manufacturer's published procedure for electrical smoke or fire is as follows:
Action to be taken must consider existing conditions and equipment installed:

- Battery and Generator/Alternator Switches - OFF

  **Warning** - Electrically driven flight instruments will become inoperative.

- Oxygen - AS REQUIRED

- All Electrical Switches - OFF

- Battery and Generator/Alternator Switches - ON

- Essential Electrical Equipment - ON (isolate defective equipment)

  **Note** Ensure fire is out and will not be aggravated by draft. Turn off CABIN HEAT switch and push in the CABIN AIR control. Open pilot's storm window, if required.

The aircraft was manufactured in 1975 and had been maintained and operated by the company since 1977. The aircraft had accrued approximately 15,112 hours time in service since new. The aircraft last underwent a 50-hour inspection on 09 September 1996 and was due for a 100-hour inspection at 15,120.9 hours. The aircraft was equipped with a vacuum-driven directional gyro and a vacuum-driven artificial horizon, both mounted on the pilot's instrument panel and independent from the aircraft's electrical system. There were no recorded unserviceabilities with these instruments. The aircraft was not equipped with smoke goggles or an oxygen system, nor were these items required by regulation.

The aircraft was equipped with a Halon 1211 fire extinguisher mounted on the floor between the pilot's legs. The fire extinguisher was weighed after the accident and was found to be discharged. The extinguisher was severely damaged, making it impossible to determine whether the extinguisher was discharged by the pilot or as a result of impact damage.

The aircraft struck the ground at an elevation of 1,800 feet asl, and in an estimated 60 degrees nose-down, 90 degrees left-bank attitude on a heading of approximately 050 degrees magnetic. The left wing tip contacted the ground first, leaving an elongated outline of the leading edge of the wing, followed by three craters made by the left engine, nose, and right engine. The aircraft then cartwheeled and broke apart, spreading wreckage over a distance of approximately 620 feet. An initial fire-ball erupted on impact, followed by small, sporadic ground fires which were primarily associated with the remaining fuel in both ruptured wing tanks.
Numerous pieces of the front windscreen were recovered, and the interior surfaces were covered with a thick, black, soot deposit. Soot trails were evident coming from the upper cabin roof-vent and from around the upper cabin door-seal. The cabin door handle was found in the latched position. During the crash, the radios and navigation equipment were torn from the avionics rack and were scattered throughout the wreckage. The radios, which exhibited considerable heat and fire damage, were not located in the areas of the post-impact ground fire. Severe fire damage was noted in the area of the co-pilot's rudder pedals, the co-pilot's side-fuselage foot panel, and the co-pilots instrument panel. A 1/4-inch outside-diameter aluminum fuel line, feeding the right engine fuel-flow gauge and mounted behind the co-pilot's side-fuselage foot panel, was found breached with a large hole in it. The fuel in this line is under pressure during engine operation.

A soot streak was noted flowing out the nose baggage compartment vent, which is located just aft of the nose baggage door on the right side of the aircraft. The vent suffered localized heat damage indicated by burnt paint and metal. The interior of the nose baggage compartment, in the area of the vent, was found to house several relays. Wiring bundles associated with these relays showed signs of severe electrical arcing and fusing. The insulation covering most of the wiring had been burned away. The radio-rack plastic air-cooling line, running from the nose cone area and feeding fresh air to the radios, was found melted and bubbled in the area of the relays. The air-cooling line passes through the forward cabin bulkhead in the area of the co-pilot's rudder pedals.

Following the accident, the aircraft was partially re-constructed and the initial source of heat was determined to have come from the nose baggage compartment in the area of the nose baggage compartment vent. The electrical relays in this area were examined, and no signs of failure were found. The avionics relay, which had been mounted on the aft side of the nose baggage door frame, in line with and just forward of the vent, could not be located. The frame in this area showed signs of heat distress with pieces of the frame broken away. The accident site was revisited, but the relay was not found.

A check with the manufacturer showed that the avionics relay was not a factory installed item. Transport Canada files and the aircraft's technical records (dating back to 1985) were examined, but no documentation or wiring diagram could be found concerning the installation of the avionics relay. Discussions with company maintenance personnel indicate that the relay was most likely installed in the late 1970's or early 1980's. During that period of time, the regulatory guidance for avionic installations came from the Engineering and Inspection (E&I) Manual Part 2, Chapter 1, Section 1.9. Installations that were considered major in nature required that documentation concerning the installation be sent to Transport Canada. However, the definition of what constituted a major installation was often open to interpretation, and the installation of the avionics relay may not have been considered a major modification. In any case, the appropriate log-book entries, along with changes to the aircraft's
electrical schematic and electrical load analysis sheet, would still have to be made. The only document found to support the installation of the relay was an amendment to the aircraft's electrical load analysis sheet. With the adoption of the Airworthiness Manual in 1990 and the new Civil Aviation Regulations (CARS) in 1996, such an installation would clearly be considered a major modification requiring the appropriate documentation.

Technical records indicate that the avionics relay was last replaced on 06 January 1986 at an airframe time of 6,528.7 hours. In February 1993, the aircraft underwent a major avionics and wiring upgrade. New No. 8 bus wires were installed on the battery master and the avionics master relay. On 10 May 1994, the avionics master switch was reported as not being able to shut off the avionics. The problem was traced to a faulty diode on the avionics relay; the diode was replaced. On 07 October 1996, approximately two weeks prior to the accident, the avionics master switch was reported as intermittent and unable to shut off the avionics. The avionics relay was checked with a test bulb to confirm electrical power at the relay terminals. The avionics master switch was cycled several times, and the relay operated normally. The relay terminals were sprayed with a contact cleaner, and the aircraft was returned to service.

The avionics relay manufacturer and part number could not be confirmed through technical records. The operator indicated that the relay's part number was MS24187-D1, manufactured by Cutler-Hammer (Eaton Corporation). The Transport Canada service difficulty report (SDR) data base was checked for reported difficulties with this relay. Four SDR records in varying installations were found. Three SDR records reported the relay as either intermittent or not operating. One SDR record reported white smoke coming from the area of the relay; the relay and a burnt ground wire were replaced. The relay manufacturer was contacted and a search of the manufacturer's data base showed that two relays had been returned to the company in the past year for reasons unknown. The manufacturer indicated that the relay is not field repairable, and that it is rated for a continuous duty of 50 amperes at 28 VDC for 50,000 electrical cycles. The relay is regarded as an "on condition" maintenance item which does not have to be replaced as long as it is giving satisfactory service.

Analysis

From the wreckage examination and reconstruction, it was determined that the smoke and fire originated in the nose baggage compartment in the area of the nose baggage compartment vent. The progression of the fire damage suggests that a heat source likely ignited a bag of bankers' dispatch notes, causing a localized fire in the nose baggage compartment. The fire quickly melted through the radio-rack plastic air-cooling line and directed hot air and smoke into the cabin. The unlimited source of fresh air from the cooling line likely began a blowtorch effect into the cabin, which breached a fuel line feeding the right engine fuel flow gauge. Given a constant supply of fuel and air, the fire progressed rapidly, causing heavy, black smoke as it burned through the avionics rack and plastic mouldings. This rapid progression
of events, from the time of the pilot's first distress call until the time of the crash, took less than four minutes.

The only sources of heat in the area in which the fire originated would have been a short circuit in the aircraft's wiring or a high resistance hot spot, such as a loose terminal on an electrical relay. The relays in this area were examined and there were no apparent signs of failure or loose terminals. The wiring associated with these relays, however, showed signs of severe electrical arcing. The wiring had recently been replaced; therefore, it is unlikely that abraded wiring would have caused an electrical short circuit. It is more probable that the severe arcing was the result of the fire burning off the protective shielding to expose bare wires. The relay in the immediate vicinity of the initiating hot spot was the avionics relay. There had been an intermittent problem with the relay two weeks prior to the accident, which probably reappeared prior to, or at, the station stop in Fort Frances. A loose terminal or a fault within the relay could account for these problems; since the avionics relay could not be located at the crash site, however, its status cannot be confirmed.

Technical records indicate that the relay had been in service for approximately 11 years and 8,555.3 airframe hours prior to the accident. The total electrical cycles on the relay could not be established. A check with the manufacturer and the Transport Canada SDR data base indicates that there were only a few reports of problems associated with this relay. There was one reported case of white smoke coming from the area of the relay; however, the circumstances surrounding that incident could not be confirmed.

When the pilot reported that he had smoke coming into the cockpit, the aircraft was approximately 40 nm from Thunder Bay and between cloud levels at 7,000 feet asl. The aircraft was approximately 18 minutes out of Atikokan and about 16 to 17 minutes out of Thunder Bay, with direct routing. The pilot had just requested clearance to begin his initial descent into Thunder Bay when the problem was reported, and he may have been predisposed to the idea of landing there.

The pilot's initial emergency training on how to respond to electrical smoke or fire reportedly included shutting off all electrical power and isolating the problem. The pilot may have initially assessed the smoke as a recurrence of the intermittent problem he had experienced in Fort Frances, a problem that had evidently disappeared without warranting shutting down the electrical system. Because of the weather conditions, the pilot knew that he would need the electrically driven navigation and communication equipment to complete the approach into Thunder Bay. As the aircraft descended from 7,000 feet asl, it would have entered the cloud, increasing the pilot's reliance on electrical power for directional guidance. The pilot's radio transmissions and continued secondary radar coverage (transponder operation) indicate that the pilot did not shut off the aircraft's electrical supply to isolate the fault. When the pilot radioed that the smoke was becoming very thick and that he was going to have to do something, the fire was probably out of control.

Immediate isolation of the electrical fault likely would have reduced the speed with which the smoke or fire progressed. The aircraft's high rate
of descent shortly after the last radio transmission and the aircraft's steep impact angle indicate that the pilot likely became incapacitated because of the smoke and fire.

The following Engineering Branch report was completed:

LP 173/96 - In-flight Fire Investigation.

Findings

- The aircraft was within its design weight and centre of gravity limits at the time of the occurrence.

- The pilot was certified and qualified for the flight.

- Approximately 40 nm west of Thunder Bay, the pilot reported an electrical problem with smoke coming into the cockpit.

- The pilot reported an intermittent electrical problem at the first station stop in Fort Frances, warranting a telephone call to the operator; however, no record of a completed call was found.

- The smoke and fire started in the nose baggage compartment in the area of electrical relays and wiring.

- The avionics relay was mounted in the immediate vicinity of the initiating hot spot; however, the avionics relay could not be located at the crash site.

- The avionics relay was not a factory-installed item in the aircraft, and proper documentation concerning the installation of the relay could not be found.

- The pilot was reportedly trained to shut off all electrical power to isolate the fault when confronted with electrical smoke or fire.

- The pilot's radio transmissions and continued secondary radar coverage indicate that the pilot operated the aircraft's electrical system for at least three minutes after experiencing smoke in the cockpit.

- Immediate isolation of the electrical fault likely would have reduced the speed with which the smoke or fire progressed.

- The aircraft was not equipped with smoke goggles or an oxygen system, nor were they required by regulation.

Causes and Contributing Factors

The aircraft went out of control following incapacitation of the pilot by
heavy smoke in the cockpit. The smoke and subsequent fire were likely caused by heat generated by a mechanical fault associated with the avionics relay. A contributing factor that likely aided in the progression of the fire was the continued operation of the aircraft's electrical system after the smoke was reported.

**Safety Action**

**Action Taken**

- The operator has amended the company recurrent pilot training curriculum to incorporate additional issues relating to equipment serviceability and reporting, electrical failure, and smoke and fire.

- Transport Canada indicated that they would undertake the following action:

  a) The operator will be made aware of its responsibility to ensure that any maintenance carried out on its aircraft must be performed in accordance with national regulatory standards. A review of its quality assurance policies regarding repairs and modifications will also be performed.

  b) Other aircraft operating in Perimeter Aviation's fleet will be reviewed to determine if there have been any other unapproved or undocumented modifications performed on those 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 14 August, 1997.*

1. All times are CDT (Coordinated Universal Time minus five hours) unless otherwise noted.

*Updated: 2002-10-06*
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
Uncommanded Gear Retraction
Perimeter Airlines (Inland) Ltd
Swearingen SA226-TC Metro C-GYRD
Winnipeg, Manitoba
06 November 1996

Report Number A96C0232

Summary

Perimeter Airlines Flight 625, a Fairchild SA226-TC Metro II, serial number TC 278, was returning to Winnipeg, Manitoba, after a freight charter flight to Regina, Saskatchewan. The aircraft was operated by a crew of two pilots, and there were no passengers on board. The crew completed a vectored instrument landing system (ILS) approach to runway 36, with the first officer at the controls. The aircraft touched down about 1,200 feet from the threshold and had rolled about 2,000 feet down the runway when the landing gear retracted. The aircraft came to rest on its fuselage on the runway, near the intersection with runway 07/25, about 3,300 feet from the point at which the aircraft touched down. The crew shut down the engines and evacuated the aircraft. No injuries occurred.

Ce rapport est également disponible en français.

Other Factual Information

The captain had a total flying time of about 4,500 hours, of which 70 hours were flown during the previous 30 days. The first officer had about 750 hours of flight time, 70 hours during the previous 30 days. Both the captain and the first officer were certified and qualified for the flight. Both reported that the landing gear was selected down during the approach, that the landing gear selector was left in the down position, and that the indicated hydraulic system pressure was 2,000 pounds per square inch (psi) after the landing gear was extended. The standard company procedure is to extend the landing gear as the aircraft intercepts the glide slope during the approach. Normal hydraulic system pressure is 1,750 to 2,000 psi. The landing gear indicator
reportedly showed that all three gear legs were down.

The aircraft was observed to break out of the cloud at about 200 feet above ground level (agl), somewhat to the right of the runway centre line, then manoeuvre into position while descending to the runway. The landing was described by several witnesses as normal. After touching down, the aircraft rolled about 2,000 feet and slowed to an estimated 40 nautical miles per hour before disappearing from the view of the witnesses. The landing gear was reported to be extended during the landing and initial landing roll. Shortly thereafter, all three landing gear legs began to retract, and the aircraft sank to the runway. When the aircraft's propellers struck the runway, they curled back and broke, and several pieces penetrated the aircraft's fuselage, severing a large electrical wiring bundle and some hydraulic lines.

The time of the occurrence was 1251 central standard time (CST). The weather at Winnipeg at 1300 CST was as follows: wind 360° true at 14 knots, visibility one-half statute mile in snow with a vertical visibility of 200 feet, and temperature and dew point both zero degrees Celsius. A surface condition report for 1200 CST indicated that the centre 100 feet of runway 36 was covered with snow and slush to a depth of one-eighth inch, the remainder was covered with two inches snow and slush, and de-icing chemical had been applied. The crew reported that there was slush on the runway at Regina on departure.

The maximum allowable gross weight of the aircraft is 12,500 pounds. The gross weight of the aircraft at take-off from Regina was 11,145 pounds, and its landing weight at Winnipeg was 10,295 pounds. The allowable centre of gravity limits at 10,295 pounds are 256.3 inches to 277 inches aft of datum. The aircraft's centre of gravity at landing was 257.5 inches aft of datum.

The landing gear is actuated by hydraulic pressure. The hydraulic system includes two engine-driven pumps which supply pressurized fluid to a hydraulic power pack. In the power pack, electrically operated valves direct the fluid to the "up" or "down" landing gear lines. The landing gear selector was found in the down position after the occurrence. The aircraft was lifted by cranes, and the left main gear was found in the up-and-locked position, and the right main gear and the nose gear were partially extended. When the landing gear doors and uplocks were released, the landing gear extended easily to the down and geometric over-centre position. The extent of the fuselage hydraulic and electrical damage precluded the application of power to the electrical or hydraulic systems; however, the aircraft was inspected and tested to the extent possible.

The landing gear selector switch and the flap selector switch route 28-volt electricity from the cockpit, along their respective "up" or "down" circuits, to the hydraulic power pack. The electrical circuitry from these switches in the cockpit to the terminal strip in the left engine nacelle was tested, and no discrepancies were found. However, this circuitry incorporates several connectors between the cockpit and the terminal strip, and an intermittent fault cannot be ruled out. The electrical system incorporates "weight-on" (squat) switches at each gear leg. The
weight-on switches are designed to prevent an "up" signal at the cockpit landing gear selector from reaching the hydraulic power pack when the aircraft's weight is compressing the landing gear oleos on the ground. The weight-on and gear selector switches were tested and found to be functional. The landing gear oleo extension was found to be greater than that recommended by the aircraft manufacturer, but still in the range that allowed for proper operation of the weight-on switches.

Examination of the electrical circuitry revealed that the flap and gear wiring harnesses in the left engine nacelle, between the hydraulic power pack cannon connectors and the nacelle terminal strip, had been replaced after the aircraft entered service with this operator. This wiring displayed numerous small areas of bare wiring, where the nylon insulation on the wiring harnesses appeared to have been removed by abrasion. The flap harness was partly enclosed by soft insulating tubing (spaghetti), and the gear harness was wrapped with spiral wrap. Neither harness was attached to the aircraft structure in the portion between the terminal strip and the hydraulic power pack. Some oil contamination was found on the wiring harnesses in the power pack area.

The operator's records indicated that the aircraft was maintained in accordance with existing airworthiness regulations. There was no entry in the records specifically mentioning repair of the wiring harnesses from the terminal strip to the hydraulic power pack. However, an entry dated August 09, 1994, noted that "landing gear control circuit breaker keeps popping; repaired wiring for landing gear hydraulic control valve as per S/B 226 29 008, installed terminal block and relocated diodes for flap and landing gear wiring at power pack."

Bare wiring is subject to short circuits by contact with other uninsulated wiring or conducting material, or from contact with contaminants such as water, oil, slush, or de-icing fluids. Airworthiness regulations do not specify any one particular method of protecting wiring from chafing. However, acceptable engineering practices require that wiring be protected from short circuits resulting from abrasion or contamination. Acceptable practices include tying or clamping wiring to the aircraft structure, or enclosing it in tubing or conduits in areas where abrasion is likely.

The hydraulic power pack was removed and examined at the TSB Engineering Branch in Ottawa (see LP 166/96). No damage to the power pack was noted, and no anomalies were found in its operation. There is no time-before-overhaul limit on the power pack or related wiring in either the operator's approved maintenance procedures or in the aircraft manufacturer's requirements. These items are "on condition" systems and do not have to be replaced as long as they are giving satisfactory service. The power pack was manufactured in 1983; however, no record was found of when it was installed on the aircraft or the total time accumulated on the component.

In order for the hydraulic power pack to retract the landing gear after landing, the electrical "down" signal would need to be removed, and an
"up" signal applied. The bare wiring in the left engine nacelle is electrically downstream from the landing gear selector. It is also downstream from the weight-on switches in the landing gear. These switches are designed to prevent an "up" signal going to the power pack by an inadvertent selection of the landing gear selector in the cockpit while the aircraft is on the ground.

The accident aircraft is on the Fairchild Phase Inspection Program. The inspection program involves dividing the aircraft inspection into 10 segments referred to as "zones". During the course of an 800-hour cycle, each zone is scheduled for inspection at least once in a "heavy" and once in a "light" inspection. A light inspection is only a visual inspection, with no panel removal; a heavy inspection is more detailed, requiring panel and access door removal. According to the operator’s Transport Canada approved Maintenance Control Manual (MCM), the phase inspections are to be done at 150-hour intervals over a total cycle of 1,200 hours. An objective stated in Section 1 of the Phase Inspection Program is the inspection of the power pack and associated electrical harnesses.

Both the aircraft manufacturer and the MCM require the inspection of each zone to be done in accordance with check sheets. In the case of heavy inspections, panel diagrams are incorporated. According to the panel diagram, zone 5 comprises the landing gear and wheel wells, while zone 9 comprises the engines. However, the zone 9 panel diagram includes not only the engines but the entire nacelle, which is outside of the wheel well. The check sheets indicate that a heavy inspection of zone 5 requires the removal of 11 access panels but does not require that the hydraulic power pack transmitter access panel be removed; in fact, the transmitter access panel is not identified. The check sheets state that the power pack area is to be inspected through panel 551 in the forward wheel well area. However, there is no specific mention of a requirement to check the power pack's associated electrical harnesses or the terminal strip and diodes. It is difficult to inspect the condition of the power pack through the wheel well panel; a complete inspection, including inspection of the electrical components, requires the removal of the transmitter access panel.

For a heavy inspection of zone 9, the check sheets require the removal of panels 958 and 959, but these panels are not illustrated. The zone 9 inspection sheets require the inspection of certain items which are accessible only through the transmitter access panel located below the power pack area.

The following Engineering Branch report was completed:

LP 166/96 - Hydraulic Power Pack and wiring.

Analysis

The aircraft's weight and centre of gravity were within approved limits during the accident flight. The aircraft's electrical and hydraulic systems apparently functioned normally during the flight, until the aircraft landed at Winnipeg.
Although the crew shut down the aircraft's engines as soon as the aircraft sank to the runway, pieces of the propellers broke off and penetrated the fuselage, disrupting electrical cables and hydraulic lines.

The crew and witness reports indicate that the crew selected the landing gear down during the approach, and that the gear extended to the down position well before the aircraft landed. The distance travelled by the aircraft on its landing gear and its reduction in speed during that time make it likely that the aircraft's weight was substantially on the landing gear before the gear retracted after landing. The serviceability of the landing gear weight-on switches and oleo extension make it unlikely that the hydraulic power pack received an "up" signal from the landing gear selector in the cockpit after the aircraft touched down.

Part of the flap wiring harness at the terminal strip was enclosed by soft plastic tubing, and the gear harness in that area was wrapped with spiral wrap; however, these measures did not adequately protect the wiring, and the wiring sustained abrasion damage as a result. Although these measures did not contravene existing regulations, they did not meet the standards of acceptable engineering practices.

The most likely accident scenario is that the hydraulic power pack received an electrical "up" signal and lost its normal electrical "down" signal, which resulted in the retraction of the landing gear. The serviceability of the landing gear and the electrical circuitry leading to the terminal strip indicate that the most likely source of the electrical "up" signal was the area between the terminal strip and the hydraulic power pack containing bare electrical wiring for the landing gear and flap systems. The oily condition of this wiring, together with the wet, slushy runway conditions at Winnipeg and Regina and the use of chemical de-icing fluids, increased the likelihood of electrical short circuits in the area of the terminal strip and the power pack connectors.

Although the Fairchild inspection sheets require the removal of 11 panels to complete the zone 5 heavy inspection, they do not identify or refer to the hydraulic power pack transmitter access panel. The extensive detail contained in the sheets and panel diagrams suggests that the procedures contained therein are sufficient to accomplish the inspection, and that further inspection and panel removal is not required. However, the procedures contained in the zone 5 check cannot adequately accomplish the objective, stated in Section 1 of the Phase Inspection Program, of inspecting the condition of the power pack and associated electrical harnesses without the removal of the transmitter access panel. Because the components involved are "on condition" with no mandatory replacement interval, inspection of the area is unlikely to occur under the existing inspection program until a component fails.

The inspection procedures outlined in the manufacturer's Phase Inspection Program and the MCM, in referring to panels which are not illustrated and in requiring the inspection of items which are not accessible by following the listed procedures, are ambiguous and reduce the effectiveness of the inspections.
Findings

- The crew was certified and qualified for the flight.
- The aircraft's weight and centre of gravity were within approved limits throughout the accident flight.
- The crew selected the landing gear down during the approach, and the gear was extended before the aircraft landed.
- The aircraft rolled on the landing gear wheels for about 2,000 feet on runway 36 before the gear began an uncommanded retraction.
- The aircraft records indicate that the aircraft was certified and maintained in accordance with existing regulations.
- It is unlikely that the hydraulic power pack received an "up" signal from the landing gear selector in the cockpit after the aircraft touched down.
- The electrical wiring harnesses of the landing gear and flap systems between the left nacelle terminal strip and the hydraulic power pack had numerous small areas of chafed insulation, exposing bare wiring.
- The repairs that had been made to the wiring harnesses after the aircraft entered service with the operator did not adequately protect the harnesses from chafing and were not in accordance with acceptable engineering practices.
- The wet, slushy conditions at the departure and landing runways and the oily condition of the wiring harnesses were conducive to electrical faults in unprotected wiring.
- The manufacturer's Phase Inspection Program and the operator's approved maintenance program are ambiguous and do not clearly require the inspection of the hydraulic power pack or its wiring harness area.
- Parts of the propeller blades penetrated the fuselage and disrupted the electrical and hydraulic systems.

Causes and Contributing Factors

The landing gear began an uncommanded retraction after landing, most likely as a result of one or more electrical short circuits in the landing gear and flap wiring harnesses in the area of the hydraulic power pack. Contributing to the electrical faults were the ambient environmental and runway conditions, the inadequate wiring protection
provided by a repair of the wiring harnesses, and the ambiguous procedures in the manufacturer’s and operator's inspection programs.

**Safety Action Taken**

In January 1997, the operator revised the Zone 5 Heavy Inspection sheets. The revision includes the following additions: "Heavy Zone 5L, item No.3: Remove panel below power pack. Inspect wiring for condition. Note: If area below power pack is dirty, Varsol wash prior to inspection."

Newer Fairchild Metro aircraft are equipped with composite shields on the fuselage next to the propellers for ice protection, and Kevlar blankets inside the fuselage for shrapnel protection. The incorporation of these shields and blankets reportedly reduces the likelihood that detached propeller blade sections will penetrate the aircraft fuselage.

In an effort to clarify the Phase Inspection Manual P/N 27-10054-031 with respect to inspection procedures, Transport Canada (TC) advises that it will request Fairchild to amend Form 2.609 of the Zone 9 inspection requirements to identify the locations of panels 958 and 959. Additionally, TC will ask Fairchild to determine if the power pack's electrical harness, terminal strip and diodes should be identified as items to be inspected through panel 959.

*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.*

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Updated: 2002-10-06
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
Power Loss/Collision with Terrain
Beaver Air Services Ltd.
Piper PA31-310 Navajo C-GERV
Pukatawagan, Manitoba
19 December 1996

Report Number A96C0267

Summary

The Beaver Air Services Ltd. Piper Navajo PA31-310, serial No. 31-7612107, was departing Pukatawagan at night, on a visual flight rules (VFR) company flight notification to The Pas, Manitoba. The pilot boarded the six passengers and a small amount of hand luggage. Shortly after engine start, the pilot configured the aircraft with 15 degrees of flap, which is normally used for a short field take-off, and backtracked to the threshold of runway 15. The aircraft accelerated normally and the pilot rotated at 85 mph. Immediately after the aircraft became airborne, the left wing dropped sharply. The pilot levelled the wings; however, the aircraft was now off to the side of the runway, and the pilot lost sight of the runway lights. He noticed the left engine surging and decided to carry out an engine failure procedure. He moved the landing gear lever to the UP position and, concerned about rising terrain to the left of the runway, pulled back on the control column while maintaining a wings-level attitude. The aircraft descended rapidly into the terrain to the left of the runway, struck the ground in a nose-high attitude, and slid about 150 metres through deep snow. The aircraft came to rest about 100 metres to the left of the departure end of the runway. One passenger sustained a back injury.

Ce rapport est également disponible en français.

Other Factual Information

The runway at Pukatawagan is 2,850 feet long. There is a downslope towards the departure end of runway 15. At the departure end of runway 15 there is a deep gully, after which the terrain immediately rises about 100-125 feet. This rise in elevation occurs directly in line
with the runway, about 600 feet past the end of it. To the left of the runway, across the gully, the terrain also rises quickly about 100 feet. The terrain causes turbulence off the end of runway 15, particularly in the warmer months or when there is strong wind. Because of the rising terrain off the end of runway 15, the accepted practice for company pilots was to use a short field take-off procedure for the Navajo on this runway. The short field take-off procedure is authorized in the PA31-310 Approved Flight Manual (AFM).

The pilot reported that there was a high overcast ceiling with about six miles visibility in light snow at Pukatawagan. The wind was about five knots from the south, and favoured take-off on runway 15. These conditions were consistent with reports from other aerodromes in the area and from another company pilot awaiting take-off on the taxiway about halfway along the runway. The take-off was conducted in darkness, and there were no lights on the ground beyond the end of the runway. The company pilot waiting on the taxiway observed that the occurrence aircraft crossed the mid-point of the runway at a higher-than-normal altitude. After the aircraft passed his position, he observed it to descend rapidly and crash. Several occupants on the occurrence aircraft reported hearing a warning horn after take-off.

The pilot completed his initial flight training in 1992 and subsequently gained experience with several small aviation companies. He obtained a commercial pilot licence with a multi-engine land and sea aeroplane endorsement, and an instrument rating in 1994. Prior to joining Beaver Air Services, the pilot had accumulated approximately 1,400 hours total flight time, with approximately 900 hours on multi-engine aircraft, primarily the Britten Norman Islander. The pilot completed his Navajo training with Beaver Air Services and flew a successful pilot proficiency check (PPC) with a Transport Canada inspector on 21 November 1996. The training and the PPC were completed in a Piper PA31-350, Chieftain. For the purposes of pilot proficiency, the PA31-310 and PA31-350 are grouped together and the PPC is valid in either model. At the time of the occurrence, the pilot's experience on the PA31, both the 310 and 350 combined, was about 70 hours and he was qualified to fly the aircraft single-pilot IFR. He had completed his aviation medical in July 1996.

The pilot indicated that his decision to continue with the take-off, following his detection of an engine anomaly, was primarily based on the inadequate runway length on which to land and the rugged terrain under the flight path. The pilot indicated that he did not have to use a significant amount of rudder to stop the aircraft from yawing. He reacted to the engine emergency immediately by cycling the landing gear up to reduce drag. The pilot was concerned about the aircraft's proximity to rising terrain and pulled back on the control yoke. He did not try to establish an airspeed or aircraft attitude and had no recollection of aircraft attitude or airspeeds during the emergency other than the rotation speed of 85 mph. He maintained full back pressure on the yoke until he heard the stall warning horn. He relaxed some back pressure, but the aircraft struck the ground before he could take any other action.

The aircraft was examined after the occurrence, and no faults with the
airframe or fuel delivery system could be found. The fuel was clean,
bright, and free from contamination or suspended ice particles. The left
engine was removed and examined in the TSB regional facility. The
examination revealed no discrepancies except for two loose clamps on
the turbocharger compressor discharge housing duct. Technical
records indicated that the exhaust transition assembly on both engines
had been replaced about three weeks prior to the accident,
necessitating the loosening of the two clamps.

The left engine was mounted in a test cell and fitted with a fixed pitch
test club propeller. The engine turbocharger and fuel systems were left
intact and run "as is." The clamps on the turbocharger compressor
discharge housing duct were left loose. The engine was primed and
started on the second attempt. The engine was run at a low power
setting and was brought up to normal operating temperatures. A
magneto check was done and normal rpm drops were experienced.
The engine was then run to 2,000 rpm and a fuel flow check confirmed
normal pressure and flow. The engine was brought up to 2,575 rpm to
simulate take-off power. As the engine reached 2,575 rpm, there was a
sudden drop of 500 rpm in engine speed and a drop of five inches of
manifold pressure. The engine surged momentarily and then regained
rpm. Several further attempts were made to reproduce the sudden
engine surge; however, none were successful. Subsequently, the
engine ran normally at 2,575 rpm with a normal turbocharger boost
pressure of 39 inches manifold pressure with the turbocharger
compressor discharge housing duct clamps left loose. Because of
safety requirements, it was not feasible to simulate an instantaneous air
leakage at the duct clamps during the test run.

The aircraft engines are equipped with compressor bypass doors on
the induction housings. The AFM indicates that in the event of a
turbocharger compressor failure, the engine will automatically revert to
normally aspirated operation, or approximately 75% of normal rated
power.

Analysis

The analysis will concentrate on the issue of the surging left engine,
and the procedure followed by the pilot in reaction to the engine
problem.

The magnitude of the engine surge that was observed during the initial
ingine run in the test cell likely duplicated the reported engine surge
experienced during the occurrence. Consequently, it is likely that the
engine was producing partial power during the take-off. It should be
noted that the drop of 500 rpm experienced during the initial engine
test run would not likely occur when the engine and its governing
propeller system are mounted in the aircraft; however, a similar drop in
manifold pressure and engine power would be expected. A scenario of
partial power is consistent with the pilot's observation of not having to
use a significant amount of rudder to counteract yaw. Because no other
fault could be found in the engine to explain the surge, it is possible
that the loose clamps allowed an unsealing of the duct, thereby
producing an instantaneous change in the turbocharger discharge
pressure which then resulted in the engine surge. Because it was not feasible during the test cell run to reproduce an instantaneous change in the turbocharger discharge pressure, it was not possible to directly link the loose ducting to the engine surge. However, if such a leak had occurred, the engine could have momentarily reverted to the normally aspirated mode, and the engine power would have been reduced by as much as 25%, producing a surge in the engine. It is likely that the loss of thrust when the engine surged caused the left wing to drop.

Under the circumstances, with the aircraft's left engine likely producing partial power, the right engine producing full power, and a deep gully lying along the flight path, the pilot's decision to continue with the take-off was likely the best decision. However, the pilot's unawareness of his actual airspeed and aircraft attitude during the event and his maintenance of full aft pressure on the control yoke probably placed the aircraft in an abnormally high pitch attitude. The higher-than-normal pitch attitude, coupled with the available engine power, likely caused the higher-than-normal departure path of the aircraft as observed by the company pilot waiting on the taxiway. Although the engines were likely producing sufficient power to continue the take-off, the higher-than-normal pitch attitude, the slow speed regime, and the high drag configuration of the aircraft probably combined to further reduce the airspeed of the aircraft until it approached the aerodynamic stall speed. The stall warning horn heard by the pilot and by several passengers also corroborates the scenario that the aircraft was approaching an aerodynamic stall. As the aircraft approached the stall, it descended rapidly into the terrain.

**Findings**

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

- The left engine surged immediately after the aircraft became airborne.

- During a test cell run, the engine surged momentarily; however, the surge could not be subsequently reproduced or isolated.

- The two clamps securing the duct between the compressor discharge housing and the engine fuel controller inlet housing were loose. A sudden leak at this location could cause the engine to surge.

- The clamps may not have been adequately tightened during maintenance conducted three weeks prior to the occurrence.

- After the engine surge, the pilot pulled back fully on the control column in an attempt to clear rising terrain.

- The aircraft was likely approaching an aerodynamic stall prior to
ground impact.

Causes and Contributing Factors

The left engine surged immediately after take-off for reasons which could not be determined. While attempting to continue the take-off, the pilot allowed the airspeed to decrease close to the aerodynamic stall speed. A high rate of descent developed, and the aircraft descended into the terrain on the airfield.

Safety Action Taken

Following the occurrence, all of the company's Navajo pilots flew a review program simulating single engine procedures.

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 17 September 1997.

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.

Collision with Terrain
Telford Aviation Inc.
Piper PA-31-350 Chieftain N744W
Eel River Crossing, New Brunswick
20 October 1996

Report Number A96H0005

Synopsis
The aircraft, a Piper PA-31-350 Navajo Chieftain (hereafter referred to as a Chieftain), took off at 1113 Atlantic daylight saving time on a charter flight from Port Menier, Quebec, to Bangor, Maine, with one pilot and seven passengers on board. As the aircraft was approaching Charlo, New Brunswick, the pilot reported to Moncton Air Traffic Control Centre that his aircraft had a rough-running engine, and that he would be making an emergency landing at Charlo airport. While the pilot was apparently manoeuvring to land the aircraft, it crashed three miles west of the runway, in the community of Eel River Crossing. All eight occupants of the aircraft received fatal injuries.

The Board determined that there was a loss of power from the right engine, and the pilot did not conserve altitude or configure the aircraft for maximum performance following the loss of power. Control of the aircraft was lost, probably as the pilot was attempting to intercept the ILS for runway 13 during a low-level turn. Contributing factors were the overweight condition of the aircraft and the lack of in-flight emergency procedures training received by the pilot.

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2.2.1 Introduction
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1.0 Factual Information

1.1 History of the Flight

The Chieftain, N744W, serial number 31-7952246, was one of two aircraft assigned to pick up a hunting party of seven and fly them from Port Menier, Quebec, to Bangor, Maine. The other aircraft was a Cessna 208 Caravan that was to carry the baggage and cargo. Both aircraft were flown to Port Menier on Saturday, 19 October 1996, with a stop in Gaspé to clear Canadian customs. During the stop in Gaspé, the Chieftain was refuelled to full tanks.

On Sunday, 20 October 1996, the Chieftain departed Port Menier at 1113(1), with one pilot and seven passengers on board on an instrument flight rules (IFR)(2) flight plan to Bangor, Maine. The flight-planned route was direct Charlo, New Brunswick, direct Houlton, Maine, and direct Bangor at 6,000 feet. The Caravan, carrying all the baggage and cargo, had departed about ten minutes earlier on the same flight-planned route at 8,000 feet.

At 1153, the Chieftain pilot informed the Moncton Area Control Centre (ACC) that he was 30
nautical miles (nm) northeast of Charlo at 6,000 feet. He requested clearance direct to Bangor, which he received at 1154. From the pilot’s position, a track direct to Bangor would take the aircraft overhead the Charlo airport. At 1201, when the Chieftain was about 5 nm east of Charlo airport, the pilot informed Moncton ACC that his aircraft had a rough-running engine, and that he would be diverting to Charlo. In the minutes prior to making this call to Moncton ACC, the Chieftain pilot had told the Caravan pilot, on a non-recorded air-to-air frequency, that he had an indication of a high cylinder head temperature, but that the engine was running fine. Then, in a second call some minutes later, he indicated that an engine was starting to run rough. After receiving the call at 1201, the Moncton ACC controller instructed the Chieftain pilot to contact the Charlo Flight Service Station (FSS). The pilot then requested that Moncton ACC provide him with radar vectors to Charlo, but he was informed that the ACC did not have radar contact with his aircraft.

At 1203, the Chieftain pilot contacted Charlo FSS and requested the latest weather for Charlo. He was provided with the 1200 weather which was as follows: wind calm, visibility ¾ statute miles (sm) in fog, ceiling 200 feet overcast, temperature 2°C, dew point 2°C, with a runway visual range (RVR) of 3,000 feet. The pilot then asked for the nearest visual flight rules (VFR) airport. The FSS operator reported that St. Leonard, west of Charlo, and Chatham, south of Charlo, were both VFR, with the closer being Chatham at 68 nm. The pilot stated that he was going to have to make an emergency landing in Charlo and asked the FSS operator for, and was provided with, information on the frequencies and inbound heading for an instrument landing system (ILS) approach to runway 13. He also asked the pilot of the Caravan for information about navigation facilities for Charlo airport. At one point, the Chieftain pilot reported to the Caravan pilot that his aircraft was at 1,100 feet and could not maintain altitude.

At 1209, the FSS operator received a telephone call from a citizen who lived about 4 nm southeast of the airport, near the Lima non-directional beacon (NDB), who reported hearing an aircraft pass overhead with what sounded like a malfunctioning engine. The FSS operator called the municipal emergency services and asked them to respond to the airport in anticipation of an aircraft landing with an engine problem. At 1211, the FSS operator called the Chieftain pilot to request his position. The Chieftain pilot responded that he was "coming around the beacon here for the ILS." The FSS operator advised that the RVR was now showing 6,000 feet. At 1212, the Chieftain pilot called Charlo FSS. The FSS operator responded to the call, but the Chieftain pilot did not respond to this or any subsequent radio calls.

The aircraft crashed in the community of Eel River Crossing, about 3 nm to the west of Charlo airport. Immediately prior to ground impact, the aircraft was seen, and heard, to be flying in a westerly direction, away from the airport, in thick fog, at an altitude of less than 200 feet. Witnesses described hearing what sounded like a malfunctioning engine. The aircraft was seen to enter a roll to the right to an inverted attitude, then pitch straight nose-down and strike the ground in a near vertical attitude. The aircraft caught fire immediately, and was consumed by a post-impact fire. The pilot and all seven passengers were fatally injured on impact.

The accident occurred at 1213 at latitude 47°59'N, longitude 66°25'W during the hours of daylight. The elevation of the occurrence site is 60 feet above sea level (asl).

### 1.2 Injuries to Persons

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<th></th>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
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<td>Fatal</td>
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<td>7</td>
<td>-</td>
<td>8</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>
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<tr>
<td>Total</td>
<td>1</td>
<td>7</td>
<td>-</td>
<td>8</td>
</tr>
</tbody>
</table>

1.3 Damage to Aircraft

The aircraft was destroyed by impact forces and a post-impact fire.

1.4 Other Damage

Nil.

1.5 Personnel Information

<table>
<thead>
<tr>
<th>Pilot-In-Command</th>
<th>39</th>
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</thead>
<tbody>
<tr>
<td>Age</td>
<td>39</td>
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<tr>
<td>Pilot Licence</td>
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<td>Medical Expiry Date</td>
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</tr>
<tr>
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</tr>
<tr>
<td>Hours Off Duty Prior to Work Period</td>
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</table>

The pilot obtained a United States Federal Aviation Administration (FAA) private pilot certificate in November 1986, an instrument rating in July 1987, an FAA commercial pilot certificate in September 1990, and a multi-engine rating, using a Piper PA-31 Navajo, in April 1992. At the time of the occurrence, both his pilot certificate and pilot medical were valid and appropriate for the type of operation. He had no record of any violations or enforcement actions, or of previous accidents or incidents.

The pilot had been employed with Telford Aviation Inc. as a pilot since July 1991. He was current as pilot-in-command on three types of aircraft: the Cessna C-208 Caravan (since March 1993), the Piper PA-31-350 Chieftain (since March 1994), and the Beechcraft BE-99 (since February 1996). He had completed his required recurrent ground training on the Chieftain on 20 May 1996 and his recurrent competency/proficiency flight check on 27 June 1996. All items covered were assessed as satisfactory.

1.6 Aircraft Information

<table>
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<th>Manufacturer</th>
<th>Piper Aircraft Corporation</th>
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<td>Type and Model</td>
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<tr>
<td>Year of Manufacture</td>
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</tr>
<tr>
<td>Serial Number</td>
<td>31-7952246</td>
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<tr>
<td>Certificate of Airworthiness</td>
<td>Issued 12 December 1986</td>
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<td>Total Airframe Time</td>
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<td>Engine Type (number of)</td>
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<tr>
<td></td>
<td>(R) Lycoming LTIO-540-J2BD (1)</td>
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<tr>
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</tr>
<tr>
<td></td>
<td>(R) Hartzell HC-E3YR-2ALFT/FJC8468-6R (1)</td>
</tr>
<tr>
<td>Maximum Allowable Take-off Weight</td>
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<tr>
<td>Recommended Fuel Type(s)</td>
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<td>Fuel Type Used</td>
<td>Aviation Fuel 100LL</td>
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</tbody>
</table>
At the time of the occurrence, the registered owner of the aircraft was JPS Corp. of Boston, Massachusetts. Telford Aviation Inc. leased the aircraft from JPS Corp. and used it in their Federal Aviation Regulations (FAR) Part 135 operation. Maintenance was carried out by Telford Aviation Inc. and billed back to JPS Corp. A review of the airframe log-books and maintenance work orders indicates that all scheduled maintenance was being carried out. An examination by TSB investigators on several other aircraft in the operator's fleet showed that all had the appearance of being maintained to a high standard. The FAA Primary Maintenance Inspector (PMI) for Telford Aviation Inc. was of the opinion that the company was reputable and was making every effort to see that all of their aircraft were maintained to a standard higher than the minimum required by regulations. Documentation indicates that the occurrence aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. There were no known deficiencies at the commencement of the occurrence flight.

Most of the documentation carried aboard the aircraft was destroyed in the post-impact fire. It could not be determined if the pilot completed a weight and balance calculation for the flight, and it was not possible to determine the exact weight of the aircraft at take-off in Port Menier. Calculations for the flight from Gaspé to Port Menier were completed (see Appendix B) using a fuel burn of 43 gallons per hour (gph), which is near the maximum fuel flow for cruise flight. Passenger weights were obtained from hunting licences, medical records, and employment records, and estimates were made of the weights of a cooler and the pilot's flight bag. Using these estimates, the calculations indicate that at take-off in Port Menier, the aircraft exceeded its maximum allowable weight of 7,000 pounds by 428 pounds. If the actual fuel burn was less than 43 gph, the take-off weight in Port Menier would have been higher. Calculations for the occurrence flight, again using a fuel burn of 43 gph, indicate that at impact the aircraft exceeded the maximum allowable gross weight by about 68 pounds.

1.7 Meteorological Information

At 1036, about 40 minutes prior to take-off, the pilot of the Cessna Caravan telephoned the Sept-Îles FSS to obtain weather information for both himself and for the pilot of the Chieftain, and to file flight plans for both aircraft. His call was automatically relayed to the Quebec FSS. The weather briefing that he obtained concentrated on weather at the destination end of the flight, as a major weather system was approaching the Bangor area from the south. He was advised that weather for the first portion of his flight would be good VFR, with actual observations at Gaspé and Mont-Joli showing the lowest cloud at 23,000 feet. He did not ask for, nor was he provided with, weather information for Charlo.

The area forecast covering the New Brunswick area, valid at 0900 and in effect at the time of the occurrence, was as follows: local ceilings 100 to 800 feet, visibility ¼ to 2 sm in fog and mist forming over land, dissipating early in the period. The actual weather was consistent with the area forecast. The sky was clear over most of the province except in the immediate vicinity of Charlo. Other pilots flying in the area described the sky as clear over the land areas, with the exception of the area around the Charlo airport. Satellite pictures show fog extending inland from Chaleur Bay and covering the Charlo airport and the surrounding area to about 10 nm inland from the airport, which is near the coastline.

The Charlo aerodrome forecast, issued at 0725 and valid from 0800 to 2000, was as follows: wind variable at 3 knots or less, visibility 1 sm in mist, cloud at 25,000 feet scattered; temporarily from 1100 to 1300, visibility ¼ sm in fog, vertical visibility 100 feet; from 1000, wind from 080 degrees magnetic at 5 knots, visibility greater than 6 sm, cloud at 25,000 feet scattered; temporarily from 1000 to 1100, visibility 2 sm in mist, cloud at 25,000 feet scattered.

The surface weather record for Charlo shows the following observations:

1100: Sky obscured, measured 200 feet overcast; visibility ½ sm in fog; temperature 0.3°C; dew point 0.3°C; wind calm; altimeter setting 30.41; RVR of 4,000 feet for runway 13.
1140: Sky obscured, measured 200 feet overcast; visibility ¾ sm in fog; wind calm; RVR of 5,000 feet for runway 13.

1200: Sky obscured, measured 200 feet overcast; visibility ¾ sm in fog; temperature 2.2°C; dewpoint 2.0°C; wind calm; alimeter setting 30.40; RVR of 3,500 feet for runway 13.

1227: Sky obscured, measured 200 feet overcast; visibility 1½ sm in fog; wind calm; alimeter setting 30.40.

The pilot of the Caravan reported that the sky was clear for the departure from Port Menier, and that he was clear of cloud at all times as he flew past Charlo at 8,000 feet. The crew of a flight that departed Charlo at 1137 reported that the visibility was about ¾ sm, the ceiling was about 200 feet, and the top of the fog layer was at about 1,500 to 2,000 feet. They also reported that the sky was clear above the fog, there was little or no turbulence, and there was no icing in the cloud.

Residents near the occurrence site reported that, at the time of the occurrence, the area was shrouded in thick fog.

1.8 Aids to Navigation

The Charlo airport is served by the following instrument approaches: an ILS approach to runway 13, an NDB/DME (distance measuring equipment) approach to runway 13, a localizer approach to runway 13, an NDB A approach to runway 13, a localizer back course (BC) approach to runway 31, and an NDB approach to runway 31. The ILS approach chart for runway 13 is attached as Appendix C.

The Charlo (CL) NDB, located 3.9 nm from the threshold of runway 13 and on the extended runway centre line, serves as the final approach fix (FAF) for runway 13. The Lima (L) NDB, located 3.9 nm from the threshold of runway 31 and on the extended runway centre line, serves as the FAF for runway 31. The DME is located on the field, near the threshold of runway 13. Charlo airport does not have radar coverage. All navigation equipment at Charlo airport was reported as serviceable at the time of the occurrence.

For navigation, the aircraft was equipped with two King KNS 80 VOR/ILS receivers, a King KR87 automatic direction finder (ADF), and an Ilmorrow 360A global positioning system (GPS) placarded as limited to VFR use only. The destruction of the navigation equipment in the post-crash fire precluded obtaining any information about navigation frequencies selected. A spiral-bound book containing current instrument approach procedures was found in the wreckage, open to the pages depicting runways 13 and 31 at Charlo. There were no known defects in any of the onboard navigation radios at the commencement of the occurrence flight.

1.9 Communications

Aircraft arriving at Charlo airport communicate with the Charlo FSS. The communication equipment at the Charlo FSS was serviceable throughout the time that the occurrence aircraft was approaching the airport. All recorded transmissions from Charlo FSS were of good technical quality.

For communications, the Chieftain was equipped with two King KX 196 transceivers. There were no unserviceabilities reported with the communication equipment in the aircraft. All recorded transmissions from the aircraft were of good technical quality.

1.10 Aerodrome Information

Charlo airport has a single asphalt-covered runway that is 6,000 x 150 feet, and oriented 13 (126°)/31 (306°). The airport reference altitude is 132 feet asl.
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 Site Observations

The terrain in the area of the occurrence site is generally flat. Just prior to impact, the aircraft was travelling at a low altitude in a westerly direction and passed over houses located on either side of a road running through the community of Eel River Crossing. Immediately after crossing over the houses, the aircraft rolled inverted, and then dove to the ground in a near vertical, nose-down attitude. Witnesses described seeing a fireball associated with the impact. After coming to rest, the fuselage, back to the tail section, and the wings, inboard of the fuel tanks, were destroyed by a post-impact fire.

When it struck the ground, the aircraft left three main impact marks (one from each engine and one from the nose) in a straight line running north/south. The aircraft's momentum in the direction of flight carried it to the west of this line; it came to rest approximately 15 feet from the initial impact marks, upright and on a heading of 110 degrees magnetic.

The nose and cockpit areas of the aircraft were severely damaged by the impact, and the leading edges of both wings were crushed rearward back to the spar. The fuselage, wings, and tail remained intact and attached to each other. The tail did not break off or bend; such damage would have been typical of a high-speed vertical impact. At impact, the landing gear, flaps, and cowl flaps were all in their retracted positions. Both the rudder and the rudder trim were found deflected to the left. The rudder trim jackscrew actuator was found in a position corresponding to three-quarters right trim. One of the rudder trim cables had severed during the impact. Since release of tension from one cable can cause the rudder trim to reposition, the position of the rudder trim as found was considered to be an unreliable indication of the rudder trim prior to impact.

1.12.2 Examination of the Propellers

Detailed information on the examination of the propellers is included in TSB LP 155/96.

The right propeller, which separated from its engine at the propeller mounting flange at impact, was found imbedded in the ground at the initial impact point. All three blades were intact. The left propeller remained attached to its engine. The left propeller pitch change dome separated from the propeller at impact, and was found in the ground scar created by the left propeller.

The propellers were disassembled and examined. There were no discrepancies found that would have precluded normal propeller operation. Neither propeller was feathered at impact, and both showed indications that their respective engines were producing power at impact. On both propellers, blade angles at impact were within the normal range of operation. The left propeller was in the 19 to 21 degree range, and the right propeller was at approximately 18 degrees.

The following chart, provided by the propeller manufacturer, can be used to relate propeller blade angle, propeller rpm, airspeed (KIAS), and engine power. As the chart shows, at a given airspeed and propeller rpm, lower propeller blade angles are associated with less power. Similarly, at a given power value and propeller rpm, lower propeller blade angles are associated with lower airspeed. The manufacturer cautions that the values shown are estimates only, and are based on the best available data. In the chart for 2,400 rpm, the 100% power value is omitted since full rated power is not available at less than full rated rpm (2,575 rpm).
PROPELLER BLADE ANGLE (DEGREES) @ 2,575 RPM

Airspeed (KIAS)

Power (%) 90 100 110 120
100 17.83 18.46 19.14 19.86
90 17.04 17.70 18.41 19.17
80 16.20 16.91 17.66 18.46

PROPELLER BLADE ANGLE (DEGREES) @ 2,400 RPM

Airspeed (KIAS)

Power (%) 90 100 110 120
90 19.31 19.98 20.69 21.45
80 18.37 19.08 19.84 20.64

A spectral analysis of the Charlo FSS tape was completed to look for engine and propeller noise transmitted by the accident aircraft during radio calls (see TSB LP 148/96). The last three radio transmissions from the Chieftain contained background noise with a discernable propeller speed which was most evident in the last two transmissions. The spectrograph shows a propeller speed of approximately 2,480 rpm. Earlier transmissions did not contain any discernable information.

The amount of impact damage sustained by a propeller can indicate, in relative terms, the amount of engine power being produced. In this case, the blades and components from the left propeller sustained more physical damage than those from the right propeller. There was significantly more leading-edge damage on the left propeller blades.

1.12.3 Examination of the Engines

1.12.3.1 General

At impact, the right engine folded back over the top of the right wing, and the right turbocharger separated from the engine. The left engine remained partially attached to the wing. Both engines were subjected to high heat from the post-impact fire. The fire destroyed virtually all of the accessory engine components, with the exception of both turbochargers and the left fuel injector servo. Examination of the engines at the site did not reveal any external signs of pre-impact mechanical failures. Both engines were recovered for further examination. During the initial teardown of each engine, no mechanical failures or abnormalities were found that would have precluded normal operation.

A difference in the amount and colour of carbon deposits on the two engines was noted. The left engine spark plugs exhibited a light gray colour. The left engine pistons had only slight amounts of light gray coloured carbon deposits, and the left engine exhaust system had light colour carbon exhaust deposits. The colouration of the left engine was consistent with an engine that had operated with a lean fuel/air mixture.

The right engine spark plugs exhibited medium brown combustion deposits. The right engine pistons had normal amounts of medium brown coloured carbon deposits. The inside of the right engine exhaust stacks ranged in colour from dark gray to light black to sooty black. The colouration of the right engine was consistent with an engine that had operated with a richer fuel/air mixture.
The colouration observed in the left engine, although different from the more typical colouration observed in the right engine, was considered to be within the range of what is observed in engines that are able to function normally.

1.12.3.2 Examination of Spark Plugs

The wear on the left engine spark plugs was considered to be excessive. The electrode gaps measured between 0.028 and 0.032 inches, where the normal gap should be between 0.016 and 0.022 inches. None of the spark plugs exhibited any evidence of pre-ignition or detonation. The spark plugs were sent to the TSB Engineering Branch for further testing and analysis (see TSB LP 155/96). The spark plugs were taken to Champion Aviation Products, Liberty, South Carolina, for testing under TSB supervision.

The spark plugs from the right engine tested satisfactorily. All of the spark plugs for the left engine failed to spark on the production test stand; however, they all sparked when tested on the cleaner/tester, which more closely duplicated actual operating conditions.

In-service performance of the spark plugs from the left engine would depend on the condition and adjustment of the engine. The testing did not lead to a definitive finding as to the performance of the spark plugs in the left engine.

1.12.3.3 Exhaust Temperature Determination

A metallurgical examination of the exhaust systems of both engines was conducted by the TSB Engineering Branch (see TSB LP 152/96). Samples taken from sections of the exhaust system that were crushed during the impact sequence were compared with samples crushed in the laboratory. This comparison gives an indication of whether the exhaust stack material was above or below a given temperature range at impact. From this information, conclusions may be drawn as to the operating condition of the engine at impact. The analysis gives best results when the samples are taken from crushed exhaust stacks close to the cylinder exhaust ports.

On the subject engines, both the intermediate and turbocharger pipes, although downstream, are typically hotter than the exhaust stacks; therefore, samples from these areas were also examined. When the subject exhaust material is deformed at temperatures below 600 to 800°F, it will form slip bands that can be detected metallographically. Material deformed at temperatures above that range will typically not form slip bands.

The metallurgical examination of the left engine exhaust sections suggests that they were crushed while at a temperature above the 600 to 800°F temperature range. The examination of the right engine exhaust sections suggests that they were crushed while at a temperature below the 600 to 800°F temperature range. However, the turbocharger microsections for the right engine suggest that they were above that range. As the results for the right engine are contradictory, the analysis is considered inconclusive with respect to the condition of that engine at ground impact. Note that the results of this metallurgical examination should not be considered definitive, as they are based on an as yet unproven experimental investigative technique.

1.12.3.4 Examination of Fuel System Components

Much of the information derived from the examination of the fuel valves and fuel panel was conflicting (see TSB LP 154/96). Bending and buckling of the airframe during the impact sequence subjected the control cables running between the fuel valves and the selectors on the fuel panel to random forces which may have repositioned the valves. In addition, the fuel panel was struck from the underside during the impact, which may have altered the positions of the selectors. The only valve found in a position that coincided with that selected on the fuel panel was the left fuel selector valve which was selected to the outboard tank.
During the examination of those fuel system components that could be tested, no discrepancies were noted which could have prevented normal operation. The configuration of the fuel system valves at impact could not be determined.

### 1.12.3.5 Examination of the Turbocharger Systems

During the disassembly examination of the engines, it was found that one blade was broken off the turbine wheel of the right engine turbocharger. The recovered components of the right turbocharger system were forwarded to the TSB Engineering Branch for examination to determine the mode and cause of the blade separation (see TSB LP 156/96). The left engine turbocharger system was also submitted, primarily to provide a comparison of damage patterns.

In a turbocharged engine, the exhaust flow is routed through a turbine wheel, which forces the turbine to rotate at high rpm. A shaft connects the turbine wheel directly to a fan, called a compressor, in the engine air intake. This system allows the energy from the exhaust to be used to provide high-pressure air to the engine intake, thus increasing the power of the engine, particularly at high altitude where the air is less dense. The type of engine on the accident aircraft is said to be "ground turbocharged," meaning that it depends on the turbocharger for some percentage of power, even at sea level. A "normalized" turbocharged engine, by contrast, does not need the turbocharger to produce full rated power at lower altitudes.

The turbocharger system is designed so that the amount of engine exhaust routed through the turbine wheel is automatically controlled. This is done by the positioning of an exhaust bypass "butterfly" type valve, called a waste gate, located in the exhaust system, upstream of the turbine wheel. The waste gate valve is loaded to the open position by two internal springs and one external spring; engine oil pressure, directed to a single acting actuator, moves the waste gate valve toward the closed position. The amount of oil pressure directed to the actuator is controlled by two separate controllers: the density controller and the differential pressure controller. The density controller senses the temperature and pressure of the airflow in the engine intake. The differential pressure controller senses the difference between engine manifold pressure and the air pressure between the compressor and the throttle valve. When fully open, the waste gate valve routes the exhaust flow directly out the tailpipe, away from the turbine wheel. When fully closed, the waste gate valve routes the exhaust flow through the turbine wheel, thereby driving the turbine. During most stages of operation the controllers modulate the position of the valve to drive the turbine at the speed required to meet the engine power selection. The system is designed to work with no input from the pilot.

It was determined that the right engine turbocharger had experienced a burst-type failure of the turbine wheel, resulting in separation of one blade. Burst-type failures are associated with high-speed rotation and/or exposure to excessive temperature. The turbine wheel was tested for metallurgical structure at the TSB Engineering Branch. Analysis of the chemical composition of the wheel material confirmed that it met the specifications quoted by the manufacturer. The pattern of damage and the metallurgical analysis indicate that a change in the microstructure, possibly related to exposure to abnormally high temperature during manufacture, repair or in service, was evident. It could not be established from this analysis whether this change in microstructure was recent and related to some in-service event or whether the difference existed since manufacture and only became critical, to the point of rupture, because of some factor such as an increase in the speed of the turbine wheel.

The separation of the blade resulted in an imbalance condition which caused the turbine wheel to contact the housing, and the shaft between the turbine wheel and the compressor to bend; the turbine wheel/compressor then stopped turning. Witness marks confirm the contact between the unbalanced, rotating turbine wheel and the housing. The examination of the right turbocharger and, in some cases, comparisons of indications between the right and left superchargers, revealed several items which support and collectively confirm that neither the turbine wheel nor the compressor was rotating at ground impact.
A light coating of oil was found on parts of the turbocharger assembly, including the turbine wheel shroud, indicating that oil pressure continued to be supplied to the centre housing, even though the turbine/compressor was not turning. When the shaft is not turning, the oil can escape by migrating along the shaft. There was a pattern of lead deposits in the right engine tailpipe that was produced by higher than normal heat. The time estimated for these conditions to develop is consistent with the amount of time between the pilot's first report of an engine-related problem and the time of the occurrence.

The Engineering Branch report (LP 156/96) describes the sequence of events considered to be most probable. This sequence starts with the aircraft departing normally on the accident flight and proceeding for some time in cruise flight conditions. An unidentified fault then occurs causing abnormally high temperature at the right engine turbocharger turbine wheel with a concurrent increase in wheel speed and manifold pressure. The wheel then experiences a burst type failure and one blade separates; the imbalance at high speed forces the turbine wheel into contact with the housing, bending the shaft so that the unit would jam and stop turning. This would reverse the effect on manifold pressure, which would drop suddenly.

The fault which first affected the turbocharger could also result in a high cylinder head temperature, the symptom first reported by the pilot. Subsequent stopping of the turbine/compressor would result in a rich fuel/air mixture, which could produce a rough-running engine, the next symptom described by the pilot. If the pilot were then to move the mixture control toward full rich, and the throttle toward full open, the resultant mixture could become so rich that stable combustion would not be possible. This would cause the engine to run rough, misfire, backfire, and lose further power.

The above sequence of events accounts for the turbine damage and the pilot's descriptions of the symptoms associated with the power loss; by contrast, a scenario that begins with the turbine wheel breaking while all other systems continued to operate normally does not account for the symptoms reported by the pilot.

1.13 Medical Information

An autopsy completed on the pilot showed that he died of extensive multiple traumatic injuries. Test results from the toxicological examination were negative. There is no evidence that incapacitation or physiological factors affected the pilot's performance.

1.14 Fire

There was no indication of a pre-impact fire, but witnesses described seeing a fireball associated with the impact. After the aircraft came to rest, it was consumed by a fuel-fed, post-impact fire. The local fire department, which had initially been called to the airport in anticipation of the arrival of the aircraft, was diverted to the site and arrived within four minutes of the crash. Fire-fighters extinguished the remaining fire.

1.15 Survival Aspects

The force with which the aircraft struck the ground was such that all occupants sustained fatal injuries at impact. The post-impact fire made examination of interior structures, such as seats or seat-belts, impossible. At the time of the occurrence, no ELT signal was heard at the Charlo FSS; however, the crew of an overflying aircraft heard an ELT signal. They reported to Moncton ACC that the signal lasted for about three minutes.

1.16 Tests and Research

Not applicable.

1.17 Organizational and Management Information
Telford Aviation Inc. is based in Waterville, Maine. At the time of the occurrence, the company was operating 19 aircraft, with 11 different types, ranging from helicopters to single- and twin-engine fixed-wing aircraft. They also conducted other aviation-related commercial activities, including major maintenance contracts and commercial retailing of aviation-related products. They had been in operation since 1982 and had no previous fatal accidents. They had a stable and experienced workforce and had not attracted any unusual attention from the regulatory authority.

The occurrence aircraft was operating under a pilot-self-dispatch system that placed the ultimate responsibility for decisions relating to operational issues on the pilot. This system of dispatch is allowed by the regulator and is typically used by operators engaged in charter operations. At Telford Aviation Inc., aircraft are assigned to charter flights by the same personnel who have the responsibility to handle bookings in response to requests from customers. They are not trained as dispatchers, nor is such training required by regulation. They assign aircraft to specific flights based on the number of passengers, any unusual baggage or cargo, the number of seats in the aircraft, and the operational range of the aircraft. These individuals have no specific training in calculating aircraft weight and balance nor in operational weight and balance considerations.

One specialty of the company is transporting hunting and fishing parties to and from eastern Canada. The company had flown the occurrence hunting party to Port Menier five days prior to the accident flight, on Tuesday, 15 October, using a Swearingen SA226-AT Merlin IV. The transfer of hunters is arranged in a manner that normally requires the aircraft to remain overnight in Port Menier. It was decided that, with the colder weather expected at this time of year, the Merlin IV could not be used because of the possibility of needing external power for engine starting. Such external power was not available in Port Menier. Based on the amount of baggage and cargo and the number of passengers, the company decided to use the Chieftain and the Caravan to retrieve the hunting party.

Regulatory monitoring of the company was the responsibility of the United States Federal Aviation Administration (FAA). Waterville, Maine, where Telford Aviation Inc. is based, is in the jurisdiction of the FAA office located in Portland, Maine. Inspectors from this office conducted periodic formal and informal inspections on the company through scheduled visits and through normal contacts concerning routine administrative issues. The level of oversight was sufficient to be in accordance with the FAA national work program, and was described by the FAA as meeting their standards for this type of operator.

The FAA inspectors from Portland described Telford Aviation Inc. as a good operator. However, they felt that as the regulatory authority, their level of overview was limited, given the number of operators for which each inspector was responsible, and the nature of the regulations for this type of operation. Inspectors described the level of overview expected for Part 135 operators as being at the lower end of the scale, and the governing regulations as being not as restrictive or as easy to enforce as those for, for example, scheduled carriers. FAA inspectors from Portland were not aware of the degree to which weight and balance was or was not being controlled by the operator.

1.18 Additional Information
1.18.1 Pilot Training

In coping with emergency situations, pilots rely on experience and training, first to decide on the best course of action, and second to have the skills to carry out the appropriate actions. Current FAA regulations for Part 135 on-demand charter operations require that a pilot pass an annual competency/proficiency check flight, during which the pilot must display proficiency in single-engine flight. This is done by simulating zero thrust on one engine at airspeeds that do not approach the minimum control speed and at aircraft weights significantly less than maximum gross weight. The total flight time on the pilot's most recent flight check was one
hour, of which 0.7 hours was airborne time. Other than his annual competency/proficiency check flights, the occurrence pilot did not complete any in-flight training on the Chieftrain after his initial training. There is no regulatory requirement for pilots to have any recurrent in-flight training.

1.18.2 Aircraft Performance

A study of the potential single-engine climb performance of the occurrence aircraft type under various conditions was conducted by the TSB Engineering Branch (see TSB LP 12/97). This study showed that, at the calculated gross weight, the aircraft was capable of maintaining a positive rate of climb on the power from one engine if flown in accordance with the following limitations: the operative engine at maximum continuous power, the inoperative propeller feathered, the cowl flaps closed, a five-degree bank toward the operative engine, and the gear and flaps retracted. However, the amount of excess thrust determined to be available was such that a deviation from these limitations would quickly put the aircraft in a performance situation where maintaining altitude would not be possible.

A twin-engine aircraft will experience a loss of directional control during flight with asymmetric power if the speed decreases below a certain speed. At that speed, the application of full rudder will not be adequate to overcome the power asymmetry. A typical loss of control in asymmetric flight starts with a gradual yaw and roll toward the engine with less power. If corrective action is not taken, the yaw and roll will reach a point where control of the aircraft is completely and suddenly lost. Prior to complete loss of control, control can be regained by increasing power on the low power engine, if possible, decreasing power on the high power engine, or by increasing airspeed. The pilot of an aircraft at low level may not be able to reduce power or increase airspeed without striking the ground. A loss of control caused by asymmetric power will usually result in a rapid, uncontrollable roll to an inverted attitude.

1.18.3 Flight Path and Ground Track

A study of the recorded radar data and the recorded communications between the aircraft and the controlling agencies was conducted by the TSB Engineering Branch (see TSB LP 148/96). This study included an attempt to determine the flight path and ground track of the aircraft. Information sources included the recorded communications, radar data, and witness information. For significant portions of the flight, the aircraft was operating outside of radar coverage. Using the information available, the most likely flight path and ground track were determined (see Appendix A). These depictions are based on the best available information and are consistent with known data; however, it cannot be stated with certainty that they depict the actual flight path and ground track of the aircraft.

Radar tracked the aircraft at 6,000 feet asl as it flew from Port Menier toward Charlo at an average ground speed of 175 knots. A comparison between theoretical performance and radar derived performance indicates that the aircraft was performing normally for the climb and initial cruise portions of the flight. The aircraft went out of radar coverage approximately 55 nm northeast of Charlo. At 1154, at a calculated distance of 26 nm from the Charlo beacon, the aircraft was cleared direct to Bangor. This would have required a slight course change to the left, and would track the aircraft over the Charlo airport.

There were no further radar returns recorded until approximately 22 minutes after radar contact was lost, when a further 72 seconds of data were recorded. As the aircraft was then in an area not normally covered by radar, the recording of this data was apparently the result of unusual atmospheric conditions. The additional 72 seconds of data start with the aircraft at about 3 nm northwest of Charlo airport. During the 72 seconds, the aircraft tracked toward the Charlo beacon at an average ground speed of 130 knots, on a track of 272 degrees magnetic, and descended from about 1,740 feet to about 1,340 feet.

Because the pilot had not reported or requested any deviation from the assigned IFR route or
altitude, it is assumed that the aircraft continued on course at 6,000 feet after radar contact was lost, and that the aircraft was still at 6,000 feet when the pilot first called Moncton ACC to report the engine problem. The depiction is also based on the assumption that the aircraft started to descend immediately after that call, and that the descent rate was a continuous 600 fpm; this rate of descent, over the known time, placed the aircraft at the known altitude when radar data was once again available. During this time, the pilot was inquiring about the Charlo weather and possible alternate airports. He was also obtaining information from the Charlo FSS and the Caravan pilot about the IFR approach into Charlo. It appears that the aircraft crossed over the Charlo airport, and then made a left turn to reverse course back toward the airport. This left turn and the resultant heading would put the aircraft in the area where it was heard by the witnesses east of the airport. It is also consistent with the time that the one witness called Charlo FSS to report hearing a malfunctioning aircraft. The aircraft then continued in a northeasterly direction before making a left turn to head toward the Charlo beacon. At this point, recorded radar is once again available, shown as a "series of radar hits" on the depictions at Appendix A.

A limited amount of data was available from the radar returns recorded as the aircraft was tracking toward the Charlo beacon. Resolution of the data suggests that, at 1,740 feet, the rate of descent was approximately 450 fpm, slowing to approximately 100 fpm approaching 1,340 feet. The final radar returns at 1,340 feet suggest 19 seconds of level flight; however, data resolution allows for a rate of descent of between zero and 310 fpm. During this time, the airspeed is seen to decrease from approximately 140 knots to approximately 110 knots at 1,340 feet; 110 knots is the best single-engine rate-of-climb speed. The remainder of the depiction assumes that the aircraft continued toward the Charlo beacon at an airspeed of 110 knots, descending at 310 fpm. If this assumption is accepted, then the Chieftain pilot would have made the call to the Caravan pilot, stating that he was at 1,100 feet and not able to maintain altitude, just before reaching the beacon and just after entering the top of the cloud/fog layer. Using the same assumption, the Chieftain pilot would have made the call "coming around the beacon..." at an altitude of 800 feet. Based on these assumptions, the aircraft would have been approximately 150 feet above a ceiling of 200 feet at the time of the last radio call. Since the scenario in the depiction assumes an inbound turn toward the localizer, the subsequent outbound-direction westerly track when the aircraft was below the ceiling suggests that the aircraft must have entered a high rate of turn near the time of the last transmission.

2.0 Analysis

2.1 Introduction

From a technical perspective, this analysis will examine the engine-related problem that was reported by the pilot and heard by witnesses and the information that is available to determine the nature of the problem. The operational aspects of this analysis will concentrate on the issues of pilot training, operational control by the company, overview by the regulatory authority, the pilot's decision making, and the pilot's actions in dealing with the loss of engine performance.

2.2 Technical Analysis

2.2.1 Introduction

The initial description of the mechanical problem, as related by the Chieftain pilot to the Caravan pilot, was that the cylinder head temperature on one engine was high, followed some minutes later by a rough running engine. As the aircraft was manoeuvring in the Charlo area, witnesses described hearing an engine that was backfiring, and not running with the sound of consistent power. Communication from the pilot indicates that he was dealing with a significant loss of engine power on one engine. Both engines were subjected to rigorous examination to determine if there were any mechanical deficiencies or operating conditions that would account for such a loss of power.
2.2.2 Left Engine

The left engine exhibited some potential for power loss. It showed signs of a lean fuel/air mixture and had badly worn spark plugs. However, several factors suggest that the left engine was operating normally. Misfiring spark plugs would lead to incomplete combustion causing low, rather than high, cylinder head temperatures. Excessively lean fuel/air mixture would result in a high cylinder head temperature, and could lead to detonation, pre-ignition and backfiring; however, there was no physical evidence that detonation or pre-ignition occurred. Damage to the left propeller suggests substantial engine power at impact. The spectral analysis showed a propeller speed that, when combined with the blade angle at impact, indicates an engine producing nearly full power. The exhaust stack analysis also supports a conclusion of normal power.

2.2.3 Right Engine

There is strong information that the right engine suffered a power loss prior to impact. The right turbocharger was not turning at impact. The sequence of events starting with an unidentified fault which caused the turbine speed and temperature to increase, would explain the symptoms described by the pilot and the witnesses. The initial overboost and lean fuel/air mixture would lead to a high cylinder head temperature. The subsequent seizing of the turbocharger would result in a rich fuel/air mixture, probably to the point where the engine would start to run rough, which was the next symptom described by the pilot. A seized turbocharger would also cause a significant drop in manifold pressure and engine power. If the pilot moved the mixture and throttle controls forward, and left them there, the fuel/air mixture could become so rich that stable combustion would not be possible. This would account for the rough-running, misfiring, and backfiring heard by the witnesses. Such symptoms are associated with an engine that is not producing much power. Damage to the right propeller suggests that the right engine was producing less power at impact than the left engine. The propeller blade angle and cooler temperature of the exhaust stacks are further indications that the right engine was producing less power than the left engine at impact.

2.3 Operational Analysis

2.3.1 Pilot Training

The circumstances of this occurrence would require a high level of pilot proficiency. The pilot was attempting to fly an aircraft into an unfamiliar airport that was at IFR weather minimums while the aircraft had a malfunctioning engine and was over its allowable gross weight. His workload would have been high. He had not had any recurrent in-flight training to prepare him to cope with such circumstances, nor did he have recurrent training to prepare him for flight at low airspeeds with asymmetric power.

2.3.2 Assigning the Chieftain to the Trip

The operator assigned the Chieftain to the charter based on its capability to seat the seven passengers who were to be picked up. There is no indication that weight and balance were considered. The individual who assigned the aircraft did not have any responsibility to determine the actual weights of the passengers, even though FAA regulations required that actual passenger weights be used. Actual weights should have been available, as the operator had flown the same passengers to Port Menier five days prior to the occurrence flight. If the actual weights had been taken into consideration, it would have been recognized that, in order to be below its maximum gross weight, the Chieftain could carry only 63 gallons of fuel. This amount of fuel would not have been sufficient to complete a non-stop flight from Port Menier to Bangor.

There is no indication that the regulatory authority had in place a surveillance program to
effectively monitor this operator with regard to weight and balance on charter flights.

2.3.3 Pilot Actions - Weight and Balance

There was no indication that the pilot completed a weight and balance calculation for the occurrence flight. If he had done so, it would have been evident to him that the aircraft would be over its maximum gross weight for take-off in Port Menier. Therefore, either the pilot was not considering weight and balance in his decision making or he was willing to accept the risks associated with the overweight condition.

When the pilot uplifted full fuel in Gaspé, it is likely that he was considering the probability of IFR weather for the return flight to Bangor the next day. Full fuel tanks would allow more options for an IFR alternate. The decision to fill the tanks indicates that he was not considering weight and balance, as even a quick calculation would have shown him that to be within weight limits when he loaded the seven passengers in Port Menier, the average weight of each passenger would have to be less than 150 pounds. This would be highly unlikely, given that the passengers were to be seven adult males.

It is not likely that, as he was preparing for the occurrence flight, the pilot would have considered off-loading fuel to bring the aircraft weight down. This would have been logistically difficult, as there are no fuelling or de-fuelling facilities in Port Menier. It is also not likely that he would have considered leaving passengers behind. Transferring passengers to the Caravan would not have been an option, as the Caravan was not approved for carrying passengers in IFR conditions. Also, the Caravan was fitted with only one passenger seat.

The pilot had the authority and responsibility to ensure that the aircraft was not over its maximum gross weight; however, the operator, by assigning the Chieftain to this flight, put the pilot in a position where significant alterations to the original mission would have been required to keep the aircraft within weight limits.

2.3.4 Pilot Actions - Dealing with the Engine Malfunction

When the pilot first indicated to Moncton ACC that he was experiencing an engine-related problem, the aircraft was 5 nm from the Charlo airport, and most likely still at 6,000 feet. Performance calculations indicate that the aircraft, even though overweight, should have been able to maintain a positive rate of climb, if flown in accordance with approved procedures. Despite this, the aircraft averaged a descent rate of about 600 feet per minute during the diversion to Charlo, and was significantly below the published minimum safe altitude for the IFR approach when it showed up on recorded radar just northwest of the airport.

The pilot's intentions with regard to rate of descent are not known. It is known that the aircraft was at an airspeed of approximately 140 knots when it came into radar coverage northwest of the airport. As the single-engine best rate-of-climb speed for the Chieftain is 110 knots, the speed of approximately 140 knots suggests that the pilot was not attempting to maintain altitude at that point. It appears that he did not attempt to conserve altitude, and that he did not discover that he could not maintain altitude until he slowed the aircraft to the best rate-of-climb speed approaching the beacon. This also corresponds to the altitude where continued descent would see the aircraft enter cloud at the top of the fog layer. At that point, the pilot did not have the malfunctioning engine secured or the propeller feathered. The pilot's decision to not secure the engine and feather the propeller could mean that he thought the remaining thrust from the malfunctioning engine would provide better performance than would be available with a feathered propeller.

The sound of an engine at high power can be heard during the final three transmissions from the aircraft. Engine noise could not be heard during the previous transmissions. This suggests that, as the aircraft was descending below 1,000 feet, the pilot selected full throttle on the functioning engine. At the same time, the propeller was determined to be at about 2,480 rpm,
suggesting that the pilot did not select it to full fine pitch. Full fine pitch is required to achieve maximum horsepower.

2.3.5 Effect of Overweight Condition

By the time the aircraft reached the area of the Charlo airport, its weight was calculated to be just above its maximum allowable for flight. Although its weight placed the aircraft just outside the performance envelope, calculations indicate that the aircraft was theoretically able to maintain altitude. However, the weight of the aircraft was such that there was little tolerance for any deviation from the parameters outlined for single-engine flight.

3.0 Conclusions

3.1 Findings

1. The pilot was certified, trained, and qualified in accordance with existing regulations.

2. Maintenance records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

3. The regulatory authority did not have an effective program in place to monitor weight and balance control by the operator.

4. There is no indication that the operator considered weight and balance issues before assigning an aircraft that could not complete the mission as planned without exceeding its maximum gross weight.

5. The pilot departed with an aircraft that exceeded its maximum approved gross weight. The excess weight had a detrimental effect on aircraft performance after the loss of power from one engine.

6. The turbocharger on the right engine seized in cruise flight, most likely as a result of a fault that exposed the turbine wheel to an increased temperature and/or speed condition.

7. The pilot had not received any in-flight training on emergency procedures after his initial type training, nor was such training required by regulation.

8. After the loss of power, the pilot apparently did not attempt to conserve altitude until reaching the top of the cloud/fog layer. As well he did not configure the aircraft for maximum performance after the loss of power from one engine.

9. The aircraft continued to descend until it reached an altitude where ground contact was imminent. The aircraft stalled, and asymmetric power caused the aircraft to roll inverted before it struck the ground in a vertical nose-down attitude.

3.2 Causes

There was a loss of power from the right engine, and the pilot did not conserve altitude or configure the aircraft for maximum performance following the loss of power. Control of the aircraft was lost, probably as the pilot was attempting to intercept the ILS for runway 13 during a low-level turn. Contributing factors were the overweight condition of the aircraft and the lack of in-flight emergency procedures training received by the pilot.

4.0 Safety Action

4.1 Action Taken

4.1.1 Pilot Training/Weight and Balance Issues
As with other accidents involving American registered aircraft in Canada, the TSB liaised with the National Transportation Safety Board (NTSB) during the course of this investigation. The TSB sent the NTSB a copy of the final accident report and highlighted the safety concerns relating to pilot training and weight and balance issues for their action as appropriate.

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 September 1997.

Appendix A - Supporting Depictions

The following figures depicted in this appendix are taken from LP 148/96:

Figure 1 Overview of Radar Data with Routing to Bangor

Figure 2 Not used

Figure 3 Estimated Ground Track (with selected transmissions)
Appendix A: Estimated Ground Track (with selected transmissions)
(Figure 3 of LP 14896)

Figure 4 Estimated Flight Path (with selected transmissions)
Appendix A: Estimated Flightpath (with selected transmissions)
(Figure 4 of LP 14896)

Figure 5 Estimated Profile of the Final Seconds of Flight
Appendix B - Weight and Balance

WEIGHT AND BALANCE CALCULATION

A96H0005 EEL RIVER CROSSING

20 OCTOBER 1996

TELFORD AVIATION INC.

PA-31-350 CHIEFTAIN N744W Serial No. 31-7952246

<table>
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<th>Item</th>
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<th>Moment</th>
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<td>616771.5</td>
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<tr>
<td>Pilot and Pax</td>
<td>407</td>
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<td>Seats 5&amp;6</td>
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<tr>
<td>Description</td>
<td>Value 1</td>
<td>Value 2</td>
<td>Value 3</td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
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<tr>
<td>Total No Fuel</td>
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<td>Fuel at Takeoff</td>
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<td>Total Weight at Take-off</td>
<td>7428</td>
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<tr>
<td>Fuel Used, Take-off to Impact</td>
<td>180*</td>
<td>148.0</td>
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<tr>
<td>Weight At Impact</td>
<td>7068</td>
<td>133.92</td>
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</tbody>
</table>

* In this calculation, fuel is divided equally between the inboard and outboard tanks. Actual distribution of the fuel on board during the accident flight was not determined.

MAXIMUM RAMP WEIGHT - 7045 lb
MAXIMUM TAKEOFF WEIGHT - 7000 lb
Forward C of G Limit - 126.0"
Aft C of G Limit - 135.0"
Amended Weight and Balance, 19 July 1996, N744W PA-31-350 Serial # 7952246
New Empty Weight: 4964
New Empty Weight C.G.: 124.2
Max T.O. Weight: 7000 lb
NEW USEFUL LOAD: 2036 lb
Appendix C - ILS Runway 13, Charlo, New Brunswick
Appendix D - List of Supporting Reports

The following TSB Engineering Branch Reports were completed:

LP 148/96 - Flight Simulation/Reconstruction;
LP 152/96 - Exhaust Temperature Determination;
LP 154/96 - Fuel Components Examination;
LP 155/96 - Components Examination;
LP 156/96 - Turbo-Charger Examination;
LP 12/97 - Climb Performance Analysis; and
LP 30/97 - Aircraft Performance Issues.

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

Appendix E - Glossary

ACC - Area Control Centre
ADF - automatic direction finder
ADT - Atlantic daylight saving time
asl - above sea level
C of G - centre of gravity
DME - distance measuring equipment
ELT - emergency locator transmitter
FAA - Federal Aviation Administration
FAF - final approach fix
FAR - Federal Aviation Regulations
fpm - feet per minute
FSS - Flight Service Station
g - load factor
gph - gallons per hour
hr - hour(s)
IFR - instrument flight rules
ILS - instrument landing system
KIAS - knots indicated airspeed
lb - pound(s)
NDB - non-directional beacon
NTSB - National Transportation Safety Board
nm - nautical miles
PMI - Primary Maintenance Inspector
rpm - revolutions per minute
TSB - Transportation Safety Board of Canada
TSO - time since overhaul
UTC - Coordinated Universal Time
VFR - visual flight rules
VOR - very high frequency omni-directional range
' - minute(s)
" - second(s)
- degree(s)

1. All times are Atlantic daylight saving time (Coordinated Universal Time minus 3 hours) unless otherwise noted.

2. See Glossary at Appendix E for all abbreviations and acronyms.
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
In-Flight Collision with Trees
GC-Air Nord Inc.
Beech A100 King Air C-GAVI
Peterborough, Ontario
08 February 1996

Report Number A96o021

Summary

The pilot was on a solo instrument flight rules (IFR) ferry flight in the Beech King Air A100 from Quebec City, Quebec, to Peterborough, Ontario. While the pilot was conducting the non-directional beacon (NDB) instrument approach (NDB RWY 09) at Peterborough, the aircraft struck trees in the area of the procedure turn. At the time that the pilot was cleared for the approach, the weather at Peterborough was 400 feet overcast and two miles visibility in light drizzle and fog. While the pilot was flying the approach, the ceiling and visibility lowered to 200 feet and one mile respectively. The minimum descent altitude on the approach was 1,200 feet above sea level (asl), 575 feet above the touchdown zone elevation (TDZE).

After the aircraft struck the trees, the pilot applied full power, retracted the flaps and landing gear, and commenced a climb. The pilot then advised air traffic control (ATC) of his situation, and, when he recognized that the aircraft right wing fuel tank was leaking fuel, he accepted radar vectors to the military aerodrome at Trenton, Ontario. The pilot safely landed the substantially damaged aircraft with the airport emergency rescue services deployed. The weather in Trenton when the aircraft landed was 100 feet overcast cloud with one and one-quarter mile visibility in drizzle and fog.

Ce rapport est également disponible en français.

Other Factual Information

The pilot held an Airline Transport Pilot Licence and had about 7,800 hours flying time, 4,500 hours on twin-engine aircraft.
The aircraft approached the Peterborough airport from the east and was cleared for an unspecified approach; the pilot elected to conduct the NDB RWY 09 approach. As the aircraft proceeded outbound from the Peterborough beacon, in descent to the procedure turn altitude of 2,600 feet asl, the pilot's instrument approach chart fell from his knee pad to the cockpit floor. He was using the Canada Air Pilot (CAP 4) instrument procedures booklet, which was not secured to his knee pad.

The pilot was unable to immediately recover the approach chart and continued to fly the approach in instrument meteorological conditions (IMC), from memory. The final approach fix crossing altitude was 1,800 feet asl; however, as the pilot turned to the final track intercept heading of 042 degrees magnetic in the procedure turn, he prematurely descended to 1,800 feet asl.

At this time, the pilot attempted to retrieve the approach chart, and the aircraft descended below 1,800 feet asl. As the pilot looked up, he saw tree tops which the aircraft struck at about 1,100 feet asl. The pilot immediately applied maximum power, raised the flaps and landing gear, and commenced a climb. He advised ATC that he was on the missed approach and requested clearance to Toronto, Ontario. The controller advised the pilot of the weather at Toronto and Ottawa, Ontario, and the pilot then elected to proceed to Ottawa. While on radar vectors for the on-course to Ottawa, the pilot advised the controller that the aircraft had struck trees during the approach into Peterborough and that the aircraft was leaking fuel. The controller suggested that the pilot could obtain a precision approach radar (PAR) approach at the military aerodrome at Trenton, and the pilot accepted radar vectors to Trenton.

After the landing in Trenton, inspection of the aircraft revealed damage to the right propeller, engine cowl, right wing leading edge, fuel tanks, right outboard flap, and the underside of the aircraft. There was evidence of several tree impacts in these areas and on the right main and nose landing gear.

During the approach at Peterborough, the pilot flew the aircraft with the autopilot heading mode engaged. The autopilot altitude hold mode was available, but the pilot did not use it.

**Analysis**

A single pilot, flying a non-precision instrument approach in IMC in this category of aircraft, is in a high workload situation that would require his full attention and flying ability. Although the pilot was using the autopilot in the heading mode selection, he was not using altitude hold and was manually flying and controlling the aircraft power and altitude during the approach.

When the CAP 4 containing the applicable approach chart fell to the cockpit floor, the pilot was unable to quickly retrieve it. He elected to continue the instrument approach from memory until he could retrieve the approach chart. Without reference to the approach chart, the pilot incorrectly descended 800 feet below the procedure turn altitude and
then attempted to retrieve the CAP 4. His attention was diverted away from flying the aircraft at a critical phase of the flight, and the pilot inadvertently allowed the aircraft to descend about another 700 feet until it struck the trees. Fortunately, the pilot was able to initiate an overshoot and land the damaged aircraft at a diversion aerodrome.

Findings

- While the pilot was conducting the approach procedure, the approach chart fell from his knee pad to the floor of the aircraft.

- Without reference to the approach chart, the pilot prematurely descended the aircraft to the final approach fix crossing altitude prior to establishing the aircraft on the inbound track.

- The pilot did not use the autopilot altitude hold mode while attempting to recover the approach chart.

- The pilot did not monitor the aircraft flight instruments while attempting to retrieve the approach chart, and the aircraft descended and struck trees.

Causes and Contributing Factors

The pilot did not adequately monitor the aircraft flight instruments while flying a non-precision approach in instrument meteorological conditions. Contributing to the accident was the pilot's decision to continue to fly the approach procedure from memory.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, Benoît Bouchard, and members Maurice Harquail and W.A. Tadros, authorized the release of this report on 09 October 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.

Control Difficulty
Tail Strike Air Canada Boeing 747-433
Combi C-GAGL Toronto/Lester B. Pearson
International Airport, Ontario
19 February 1996

Report Number A96O0030

Synopsis

The Boeing 747-433 Combi aircraft, operating as Air Canada flight 899, was on a scheduled passenger/freight flight from Toronto/Lester B. Pearson International Airport, Ontario, to Vancouver International Airport, British Columbia. As the aircraft was taking off, the underside of the tail struck the runway, and, during the climb-out, considerable nose-down stabilizer trim was required to trim the aircraft for flight. The strike was undetected by any crew member, and the flight continued to destination, where damage to the aircraft was discovered.

The Board determined that the underside of the tail struck the runway on take-off because the first officer rotated the aircraft too steeply and at an aircraft speed below the calculated rotation speed; the early rotation was facilitated by the far aft centre of gravity and the incorrect stabilizer trim setting. Contributing to the incident were an error in a recently modified aircraft loading computer application, incomplete validation of the modifications to the computer application, and the inability of the aircraft loading system to detect a gross calculation error.

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5.0 Appendices

   Appendix A - List of Supporting Reports
   Appendix B - Glossary

1.0 Factual Information

1.1 History of the Flight

The aircraft was scheduled to depart Toronto/Lester B. Pearson International Airport at 0845 eastern standard time (EST)(1) on a scheduled, non-stop flight to Vancouver International Airport. The aircraft was a Combi, configured to carry passengers and large loads of freight. Its load consisted of 243 passengers and 31,257 kilograms (kg)(2) of freight. The flight was delayed at the ramp 30 to 35 minutes while cargo was loaded. Push-back and taxi to runway 24 right were routine, and the aircraft was cleared for take-off at 0951 EST. The flight crew operated the aircraft in accordance with Air Canada standard operating procedures for taxi, pre-take-off, and the take-off roll. The captain monitored the take-off from the left seat with the first officer at the controls.

Flight data recorder (FDR) information showed that the nose of the aircraft started to pitch up slowly at about 120 knots indicated airspeed (KIAS)(3) without any elevator control movement. At about 134 KIAS, when the aircraft was about 5 degrees nose-up, there was a significant nose-up elevator movement, and the aircraft rotated more quickly, lifting off at 143 KIAS with a 13-degree nose-up attitude. Unbeknown to any crew member on board, the lower fuselage of the aircraft struck the runway during lift-off. Near full nose-down stabilizer trim was required to trim the aircraft on initial climb-out. Shortly after take-off, the flight crew advised company dispatch by radio that they believed, because of the way the aircraft was flying, that there was an error in the weight and balance of the aircraft.

When the aircraft was inspected at destination, it was discovered that the underside of the fuselage, in the tail area of the aircraft, had contacted the runway surface.

The incident occurred at latitude 43°40'N, longitude 079°37'W, at 0951 EST, during the hours

of daylight.

1.2 Injuries to Persons

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<td>-</td>
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<td>-</td>
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<td>253</td>
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<tr>
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<td>10</td>
<td>243</td>
<td>-</td>
<td>253</td>
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1.3 Damage to Aircraft

Damage to the aircraft consisted of scraping and minor buckling of the bottom of the aircraft fuselage tail area from aircraft station 2658 to station 2742. This area comprises the auxiliary power unit (APU) access doors and the area slightly aft of the doors.

1.4 Other Damage

None.

1.5 Personnel Information

1.5.1 General

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<tr>
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<th>First Officer</th>
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<td>Age</td>
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<td>ATPL</td>
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<tr>
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1.5.2 Captain

The captain was licensed and qualified in accordance with existing regulations. His licence was endorsed for the B747-200 in August 1991, and for the B747-400 in March 1992. His latest pilot proficiency and instrument check ride was completed on 27 January 1995. On his most recent pilot medical examination, 22 December 1995, he was assessed as fit, category I; his glasses must be available while flying. He was a qualified B747-400 company check pilot and was monitoring the first officer, who was undergoing company line indoctrination on the B747-400.

The captain arrived at the airport for duty about 0730 EST on the day of the occurrence. This was his first day of flight duty following five weeks off.

1.5.3 First Officer

The first officer commenced his company pilot ground school and flight simulator training for conversion to the B747-400 on 07 January 1996. He completed the simulator training and his pilot proficiency check ride on 09 February 1996. Prior to converting to the B747-400, he flew as a qualified first officer on the B767. His licence was endorsed for the B747-400 on 13 February 1996, and on his most recent pilot medical examination, 19 December 1995, he
was assessed as fit, category I; his glasses must be available while flying. He was licensed and qualified in accordance with existing regulations. The first officer completed a line indoctrination flight from Vancouver to Toronto on the day prior to the occurrence, arriving in Toronto at 2200 EST. He went directly from the airport to his hotel room and reportedly was in bed about an hour and a half after arriving in Toronto. On the day of the occurrence, the first officer arrived at the airport about one hour prior to the scheduled departure time for flight 899. The occurrence flight was his third of eight legs of line indoctrination training on the aircraft. It was his second take-off in the aircraft following his simulator training.

1.6 Aircraft Information

1.6.1 General

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<td>24998</td>
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<td>January 1991</td>
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<td>Engine Type (number of)</td>
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<td>Maximum Allowable Take-off Weight</td>
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<td>Fuel Type Used</td>
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The flight crew did not report, nor did the investigation detect, any failure or malfunction of the aircraft systems or components that would have contributed to the occurrence.

1.6.2 Aircraft Description

The Boeing 747-433 Combi aircraft was configured to carry a mix of passengers and freight. Passengers only are carried on the upper deck of the aircraft from aft of the cockpit to the leading edge of the wing. Passengers and freight are carried on the main deck, passengers from the nose of the aircraft to beyond the trailing edge of the wing and freight from the rear of the main deck passenger area to the tail of the aircraft. Freight only is carried below the main deck.
deck area in hold areas forward of the wing leading edge to aft of the nose landing gear, and aft of the wing trailing edge to the rear of the aircraft.

### 1.6.3 Weight and Balance

The maximum operational take-off weight of this aircraft is 328,600 kg, and the operational centre of gravity (C of G) limit is from 10.8% to 32.5% mean aerodynamic chord (MAC). A Toronto-based Air Canada certified station agent, assisted by a computer application called Automated Load Planning Air Canada (ALPAC), commenced planning the loading of flight 899 at 0645 EST. Load planning was routine and was completed by 0715 EST. Seven loaded cargo containers were placed in the aircraft main deck cargo area. Six of these containers exceeded the height of the cargo hold areas and could only be placed in the main deck cargo area of the aircraft. Total cargo weight in the main deck cargo area was 19,782 kg. The aircraft weight and balance information, computed by ALPAC, was given to the flight crew prior to the aircraft's departure.

A company load agent confirmed that the freight had been loaded on the aircraft in accordance with the ALPAC plan, and that the actual weight of the cargo was within acceptable tolerances of the ALPAC-computed weights used for the flight. Company load agents carried out a manual weight and balance calculation for the occurrence flight when the flight crew notified dispatch after take-off that they believed there was a weight and balance problem with the aircraft load. The manual calculation quickly confirmed the ALPAC application error, and the company took immediate action to ensure that no further flights were dispatched using the modified ALPAC application. The take-off weight of 286,500 kg was confirmed; however, the C of G was 35% MAC, while that computed prior to take-off was 22.3% MAC. FDR data showed the aircraft take-off weight as 286,783 kg. The aircraft actual C of G, at take-off, was aft of the aft limit of 32.5% MAC.

At the same time as the flight crew was reporting its difficulty with Flight 899, load agents preparing another Boeing 747 aircraft for dispatch experienced problems with the modified ALPAC application and were using the manual method of weight and balance calculations to investigate the reason for the problem.

### 1.6.4 Take-off Performance Data

The weight and balance information passed to the flight crew from the load agent was entered in an on-board computer which computed the aircraft take-off speeds and stabilizer trim setting position for take-off. The computed take-off speeds were automatically displayed on the aircraft instrument panel for take-off. The take-off speeds were not stored parameters in the FDR. The FDR data showed the stabilizer trim set at 5.9 units for the take-off, which is within the aircraft stabilizer trim setting range for take-off. The computed take-off speeds for conditions that existed at the time of the occurrence were \( V_1^{(4)} = 132 \) knots and \( V_R^{(5)} = 144 \) knots.

A "de-rate one" reduced engine power setting was used for the occurrence take-off, with 10 degrees of trailing edge flap extended.

### 1.6.5 Take-off Roll Technique

A characteristic of the Boeing 747 aircraft is that only light weight forces are exerted on the nose landing gear during the take-off run. The Air Canada Boeing 747-400 Aircraft Operating Manual, initial take-off procedure section, states that, for light weight and aft C of G conditions and for slippery runway conditions, the aircraft nosewheel should remain firmly in contact with the runway until just before \( V_R \), when any column push force should be relaxed.

Take-off and initial climb performance depend on rotating the aircraft at the correct speed and rate to the target rotation attitude. Rotating the aircraft too early, too rapidly, or too steeply may cause the aft fuselage to contact the runway. Aft fuselage contact will occur at a 12.5-degree nose-up pitch attitude with the aircraft wheels on the runway and the landing gear struts
The rate of rotation is related to the aircraft's acceleration; normally, the heavier the airplane, the slower the acceleration, and the slower the rotation rate. A 10-degree pitch attitude will normally be achieved in approximately three to five seconds with all engines operating, and lift-off will occur between 8.5 and 10 degrees nose-up attitude.

1.7 Meteorological Information

The weather at the time of the occurrence was as follows: scattered cloud based at 3,500 feet above ground level (agl), broken cloud at 5,000 feet agl, broken cloud at 10,000 feet agl, visibility 15 statute miles, wind from 150° magnetic at five knots, temperature -7°C, and dew point -13°C.

1.8 Aids to Navigation

None used.

1.9 Communications

Communication with air traffic control was routine and without difficulty. The flight crew contacted company dispatch by radio after take-off and reported the difficulty in controlling the aircraft on take-off.

1.10 Aerodrome Information

Runway 24 right is 10,500 feet long by 200 feet wide. The asphalt/concrete surface was bare and dry at the time of the occurrence.

1.11 Flight Recorders

The aircraft was equipped with an Allied Signal Universal Flight Data Recorder (FDR), model number 980-4100-AXUS. The FDR was removed from the aircraft when it arrived at destination in Vancouver, and was sent to the TSB Engineering Branch for analysis. Because the cockpit voice recorder (CVR) was continuously recording during the flight to Vancouver and the length of the recording loop is 30 minutes, no CVR data were available for the time of the occurrence.

On the occurrence take-off, engine power increased to and stabilized at 84% thrust. The pitch attitude of the aircraft gradually increased throughout the take-off roll without any control column movement from a zero (neutral) position. At about 120 KIAS, the pitch attitude and rate began to increase significantly without control column movement. There was slight control column forward movement as the aircraft accelerated through 132 KIAS, followed immediately by significant aft movement. As the aft control column movement peaked at 18 degrees aft, the aircraft pitch attitude increased to 13 degrees nose-up and the air/ground switch discrete toggled to air, indicating aircraft lift-off at 143 KIAS. A vertical acceleration spike of 1.13 g was recorded at the approximate time of lift-off. The aircraft pitch attitude continued to increase after lift-off, reaching approximately 18 degrees 13 seconds after lift-off. At this time, nose-down stabilizer trim movement from 5.9 units to 5.0 units was recorded, and the aircraft pitch attitude reduced to 16 degrees. About 16 seconds after lift-off, further nose-down stabilizer trim movements were recorded to 4.4 units, and the aircraft pitch attitude stabilized at 14 degrees nose-up for the climb.

FDR data from the previous take-off were analyzed and compared with data from the occurrence flight. The data from the previous take-off showed progressive forward control column movement throughout the take-off roll, peaking at minus 10 degrees prior to significant aft control column movement and the aircraft lifting off. After lift-off, only small movements of nose-down trim were recorded as the aircraft was established in the climb.

1.12 Wreckage and Impact Information
Not applicable.

1.13 Medical Information

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

1.14 Additional Information

1.14.1 Cockpit Workload Management

The company operations manual directs that the flight crew review the take-off speeds prior to take-off. On the take-off roll, the pilot flying (PF) advances the throttles and the pilot not flying (PNF) sets take-off power by 80 knots. The captain's hand remains on the throttles until \( V_1 \) speed is attained. If the captain detects any abnormality critical to aircraft safety before the aircraft attains \( V_1 \) speed, he assumes control of the aircraft and rejects the take-off. Company procedures for Boeing aircraft do not require that speeds be called out during the take-off roll; during this occurrence, there were no calls.

It is common practice in the aviation industry for the PNF to call out airspeeds as the aircraft accelerates on the take-off roll. Speeds called out on large aircraft are as follows: a speed well below \( V_1 \), confirming that the airspeed indicators are functioning and that take-off power is set and stabilized, \( V_1 \), and \( V_R \). When the PNF calls \( V_R \), the PF initiates rotation by smoothly moving the control column aft at a speed that will allow the aircraft to lift off at the correct speed and pitch angle.

1.14.2 Pilot Training

Although several take-offs were demonstrated to the first officer during his recent Boeing 747-400 simulator training, none was with the aircraft out of trim or out of balance. The only simulator training relating to an out-of-trim condition he could recall was carried out in conjunction with in-flight aircraft stabilizer problems.

1.14.3 Station Agent Training

Prior to beginning training to become a certified station agent, a candidate goes through a selection process of qualifying exams. The self-study exams cover basic ramp procedures, cargo procedures, and aircraft procedures. The candidate can also opt to take a self-study module on weight and balance for the DC-9 aircraft. Successful completion of the qualifying exams is followed by a six-week training course. The course covers basic ALPAC load training on narrow-bodied aircraft using both ALPAC and manual computations for weight and balance determination. The candidate is then examined on knowledge and theory and his or her ability to determine weight and balance using ALPAC and using a manual method. Candidates are examined and certified separately on each aircraft for which they prepare loads.

The certified station agent who handled the aircraft on the occurrence flight had more than 20 years of experience as a station agent.

1.14.4 Automated Load Planning - Air Canada (ALPAC)

ALPAC is a computer application, continuously under development by Air Canada, that assists certified load agents with the planning and positioning of cargo and baggage in all Air Canada aircraft. Some of the objectives of the application are to ensure that aircraft weight and balance limits are respected, dangerous goods are correctly loaded, pallets are positioned to allow unimpeded unloading at the destination, and the load is positioned to achieve the most fuel-efficient aircraft balance. The load agent enters into the computer particulars of each pallet; the application keeps a running total of the weights and calculates the moment change for the aircraft balance by applying a performance code which contains the arm for each pallet location.
For the B747-400 Combi aircraft, cargo is loaded onto pallets which are then loaded, as required, in the forward, aft, and bulk cargo holds below the main deck and in the main deck cargo area. Standard pallets are 88 inches by 125 inches (small pallet), and there is a new standard pallet that is 96 inches by 125 inches (large pallet). Air Canada uses the letter Q to designate a large pallet. Prior to 16 February 1996, the weight of the pallets was entered into the ALPAC application without indicating whether it was a small or large pallet. Air Canada found that when a large pallet was loaded in the aft hold of the B747-400 Combi aircraft, space was reduced and one less pallet could be loaded into the area. Therefore, for load planning purposes, Air Canada wanted the ALPAC application to be able to identify that a large pallet was in the aft hold. The computer company that maintains and develops the ALPAC application incorporated this modification at Air Canada's request, and tested the modified area of the application to confirm that it functioned properly before releasing it to Air Canada. Air Canada Engineering personnel also conducted a test to ascertain that the changed section of the application performed properly. The ALPAC application was modified to further automate loading on the B747-433 Combi and Airbus A340 aircraft. This modification was believed to affect only the A340 aircraft and the cargo hold of the B747 Combi aircraft, and not the main deck cargo area of the B747 Combi aircraft. Consequently, testing of the modified application was not carried out for the main deck cargo area of the B747 Combi aircraft, nor was testing of the entire application carried out before the modified application was put into operational service. On 16 February 1996, the modified application was loaded on the main computer for use by the load agents. The modified application was not monitored for accuracy after it was put in operational use. The flight crew did not perform any manual weight and balance calculations prior to take-off, nor were any required by company procedures. After the occurrence flight, it was discovered that when the smaller pallets were loaded into the main deck cargo area, ALPAC correctly calculated the weight and accounted for the moment changes. However, when large pallets were loaded in the main deck cargo area and their information entered into the computer, ALPAC properly added the weight to the total but did not account for any resulting moment changes. In order for the ALPAC application to account for the Q designator, changes were required to the performance codes for the pallet positions. No personnel from Air Canada or the computer maintenance company connected the initial application changes with the requirement to change the performance codes; therefore, these changes were not requested or made prior to the occurrence flight. From 16 February 1996 until the occurrence flight, nine B747-433 Combi aircraft flights were inadvertently operated with incorrect C of G calculations as a result of the ALPAC calculations. The flight crews of these flights did not report any difficulty in controlling the aircraft.

2.0 Analysis

2.1 Introduction

Neither aircraft airworthiness nor environmental conditions contributed to the cause of the occurrence. Therefore, the analysis will concentrate on the company computer application in use that affected aircraft operational data, and flight crew handling of the aircraft during the take-off roll.

2.2 ALPAC Computer Application

The ALPAC computer application had been used by company load agents for several years without any reported errors in calculations used for aircraft operational data. Load agents were confident with the application and accepted aircraft operational data computed by the application without question. Since the ALPAC-computed C of G for the occurrence flight fell within the operational limits of the aircraft, the agent accepted it and dispatched the flight. He passed the weight and balance information to the flight crew and they accepted the calculations, routinely, as they had in the past.

In this instance, an experienced load agent, thoroughly familiar with the loading of aircraft, accepted a computer-generated C of G calculation that located the aircraft C of G near the
centre of the flight envelope when the bulk of the freight, 63.3% of the total weight of the freight on board, was loaded in the very aft section of the aircraft. The actual C of G was beyond the aft limit of the flight envelope. The unquestioning acceptance by the load agent of computer-generated data demonstrates a degree of overconfidence that trained and experienced personnel have gained through the use of computers.

The ALPAC application in its entirety was not tested after the modification was completed, nor was it monitored after it was put in operation by the airline. In this instance, as with several previous flights, the ALPAC application correctly computed the weight of the aircraft but did not correctly compute the weight moment for the Q-designated pallets loaded on the main deck cargo area. The application is designed to display a computer screen warning to the load agent when aircraft operational limits are exceeded. In this instance, although the C of G was, in fact, aft of the rear limit, the computer data indicated that the C of G was positioned well within the limits; therefore, no warning was displayed. As well, there was no computer indication that the weight moment change was not being correctly computed when the load agent entered Q-pallet information.

2.3 Take-off Roll

Since the control column does not move without someone actually moving it, it was concluded that all control column movements, as recorded on the FDR, were inputs by the first officer. As the aircraft accelerated, the nose began to pitch up, gradually increasing with the control column in a near neutral position. The uncommanded nose pitch-up resulted from a combination of the aft C of G, the incorrect stabilizer trim setting (in that the stabilizer was trimmed for a nose-heavy aircraft although the aircraft was tail heavy), and the lack of control input by the first officer to keep the aircraft nosewheel firmly on the runway until rotation speed was attained.

The aft control column movement that started at 132 KIAS was considered to be the initiation of rotation by the first officer. The aircraft nosewheel was likely off the ground at this point, without any control input from the first officer. The uncommanded initiation of rotation likely influenced the first officer to continue rotation, even though the airspeed was about 11 knots below V_R. The aircraft lifted off below V_R with the nose pitched up 13 degrees, which caused the underside of the tail to strike the runway.

The captain, who was monitoring the first officer's take-off, did not take action to prevent the gradual, uncommanded increase in aircraft pitch attitude during the take-off roll, or to prevent early rotation of the aircraft. Once airborne, the captain told the first officer that the airspeed was low.

2.4 Silent Cockpit

Company policy for Boeing aircraft did not require the PNF to call out airspeeds on take-off, and none were called on this occurrence. Both pilots were accustomed to the silent cockpit take-off procedure. The first officer was not experienced on the B747-400 and may not have been accustomed to its characteristic lack of weight exerted on the nosewheel. The light weight on the nosewheel requires the pilot to make a conscious effort to keep the nosewheel firmly on the runway by applying forward control column movement (down elevator) until just before the aircraft reaches V_R.

The company's rationale for not calling out airspeeds is that it sees no requirement to call out normal information which is displayed to both flight crew. Any call made in this environment will therefore be addressing some abnormality. There are, however, some crew co-ordination and workload consequences arising from this procedure.

The PF must direct more of his attention to the airspeed indicator as V_1 and V_R are approached; he knows that the PNF will not be calling the speeds. This re-focusing of attention could be at the expense of time spent looking outside the cockpit or at other control and performance instruments.

As for co-ordination, a verbal call of V_R could help ensure that rotation takes place at V_R, and not before or after. The V_1 speed is less important in a normal take-off situation, but is critical
for determining pilot reactions to an engine failure. The absence of a verbal $V_1$ call could create some confusion between the pilots should a power loss occur at an airspeed close to $V_1$.

3.0 Conclusions

3.1 Findings

1. The flight crew was certified, trained, and qualified for the flight in accordance with existing regulations.

2. The occurrence flight was the first officer's second at-the-controls take-off since completing his pilot conversion training on the B747-400.

3. The first officer did not apply sufficient down elevator input to keep the aircraft nosewheel firmly on the runway during the take-off roll.

4. There was an uncommanded nose pitch-up during the take-off roll.

5. Airspeeds were not called out by the PNF during the take-off roll, nor were they required to be by the company.

6. The first officer rotated the aircraft too steeply and at an aircraft speed below the calculated rotation speed, and, as a result, the underside of the tail struck the runway.

7. The captain, who was monitoring the first officer's take-off, did not take action to ensure that the aircraft nosewheel remained firmly on the ground until rotation speed was attained, or to prevent early rotation of the aircraft.

8. The aircraft stabilizer trim setting was incorrectly set because of an incorrectly computed aircraft take-off $C$ of $G$.

9. The first officer's recent simulator training did not include an aircraft out-of-trim or out-of-balance take-off.

10. A recently modified computer application, ALPAC, used by load agents to plan loads and compute aircraft weight and balance, incorrectly computed the aircraft take-off $C$ of $G$.

11. The ALPAC-computed aircraft take-off $C$ of $G$ was near the centre of the aircraft flight envelope, while the actual $C$ of $G$ was beyond the aft limit.

12. The ALPAC application produced a large error in the aircraft $C$ of $G$ calculation; however, there was no defence in place to detect such a critical error in the application itself, at the aircraft loading stage, or in the flight crew confirmations of load and trim setting.

13. The modified computer application was not adequately tested before it was released for operational use.

14. The modified computer application was not monitored effectively for accuracy after it was placed in operational use.

3.2 Causes

The underside of the tail struck the runway on take-off because the first officer rotated the aircraft too steeply and at an aircraft speed below the calculated rotation speed; the early rotation was facilitated by the far aft $C$ of $G$ and the incorrect stabilizer trim setting. Contributing to the incident were an error in a recently modified aircraft loading computer...
application, incomplete validation of the modifications to the computer application, and the inability of the aircraft loading system to detect a gross calculation error.

4.0 Safety Action

4.1 Action Taken

4.1.1 Operator Action - Calling of Speeds on Take-off

On 15 July 1996, the operator amended its Boeing 747-400 aircraft operations manual to introduce verbal calls at speeds of 100 knots, \( V_1 \), and \( V_R \) during the take-off roll. The change in procedures will be applicable to all Air Canada aircraft and will standardize the company fleet operation with the procedures previously accepted for the operation of Airbus aircraft in the company fleet.

4.1.2 Operator Action - Weight and Balance

Since the occurrence, Air Canada has taken action to enhance the quality assurance procedures for its load control software. Weight and Balance introduced a position of Operational Control Manager and Technical/Training/Development, effective 01 June 1996. More direct control will be taken for software changes, software change specifications will be clearly defined, a full impact assessment will be made to identify all components affected by the change, test databases have been updated, follow-on testing will be done in "live mode", and positive confirmation of testing will be achieved. Although its focus is currently on load control software, Air Canada indicated that it is taking a more comprehensive look at the testing environment and procedures for all critical systems. Training lesson plans are being rewritten to strengthen load agents’ understanding of the relationship between the manual and ALPAC methods of determination of weight and balance. 

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 17 December 1996.

Appendix A - List of Supporting Reports

The following TSB Engineering Branch Report was completed:
LP 25/96 - FDR Analysis.
This report is available upon request from the Transportation Safety Board of Canada.

Appendix B - Glossary

ALPAC - Automated Load Planning Air Canada
agl - above ground level
APU - auxiliary power unit
ATPL - Airline Transport Pilot Licence
C of G - centre of gravity
CVR - cockpit voice recorder
EST - eastern standard time
FDR - flight data recorder
in - inches
kg - kilograms
KIAS - knots indicated airspeed
MAC - mean aerodynamic chord
PF - pilot flying
PNF - pilot not flying
TSB - Transportation Safety Board of Canada
UTC - Coordinated Universal Time
V₁ critical engine failure recognition speed, or take-off decision speed
VR rotation speed
° degree(s)
' minute(s)

1 All times are EST (Coordinated Universal Time [UTC] minus five hours) unless otherwise stated.
2 See Glossary for all abbreviations and acronyms.
3 Units are consistent with official manuals, documents, reports and instructions used by or issued to crew.
4 V₁ is defined by Transport Canada as "critical engine failure recognition speed"; the Boeing 747-400 Airplane Flight Manual defines it as "take-off decision speed."
5 Rotation speed.
6 A reduced power setting used for take-off when maximum thrust is not required.
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
Controlled Flight Path into a Tree
Aero Academy Ltd.
Cessna 172N C-GQVU
Centalia/Huron Airpark, Ontario 0.5 nm W
26 February 1996

Report Number A96O0034

Summary

At approximately 1830 eastern standard time (EST)\(^{(1)}\), the student and instructor pilot departed from London, Ontario, to fly night circuits at Centralia/Huron Airpark, about 22 nautical miles northwest of London. The student, who was in the left seat, was practising night visual approaches on his second night flight. On final approach during the third or fourth circuit to runway 10, the aircraft struck a tree. After the tree strike, the aircraft struck the ground in a steep, nose-down attitude and came to rest in an inverted position. The instructor, who received minor injuries, extricated himself from the aircraft and walked three kilometres to call for assistance. The student, who was seriously injured, remained in the aircraft until local authorities were able to remove him from the wreckage. The emergency locator transmitter (ELT) was activated during the impact but was not required by rescuers to locate the accident site. The accident occurred during the hours of darkness at approximately 1930.

Ce rapport est également disponible en français.

Other Factual Information

Records indicate that the aircraft was certified and maintained in accordance with existing regulations. There were no known or reported discrepancies with the aircraft, and an inspection of the aircraft at the site revealed no pre-occurrence abnormalities.

The Centralia/Huron Airpark is a certified aerodrome and is operated in accordance with applicable Transport Canada standards. The aerodrome is sometimes used for training because of its low traffic.
volume. The aerodrome elevation is 822 feet above sea level (asl). Runway 10 is an asphalt runway, 5,012 feet long by 100 feet wide. Medium intensity runway edge lights with three variable settings, runway threshold lights, and runway end lights are available. There is no approach lighting for the runway. The aerodrome is equipped with an aircraft radio control aerodrome lighting (ARCAL) system on frequency 122.8 megahertz. The runway lighting system was serviceable and in use at the time of the occurrence.

The weather was initially clear with unlimited visibility, and the winds were light and variable. During the flight, a high broken to overcast cloud layer formed, which reduced the ambient level of light from the partially concealed moon. The altimeter setting for London was 29.98 inches of mercury, and was correctly set on the aircraft altimeter.

The aerodrome and surrounding terrain is mostly level farmland, at about 825 feet asl, with farm buildings scattered in the area. Visual references in the vicinity of the aerodrome on a dark night are limited to the runway lights. The only other local reference at night is the small town of Crediton, where the instructor made the telephone call for assistance after the accident. The town is situated below the left downwind leg of the circuit for runway 10 but does not provide any useful glide path indication to an aircraft on a final approach at night. The student had a valid private pilot licence. According to his pilot logbook, he did not fly from August 1979 to May 1995. Between May 1995 and February 1996, the student accumulated 18.3 flying hours, excluding this flight. Between 14 November 1995 and 17 February 1996, the student flew 6.3 hours of instrument training, and acquired 5.0 hours of simulated instrument time. The student completed his first night training trip on 30 January 1996, and flew 1.1 hours in the circuit at London. The runways at the London aerodrome are 200 feet wide, and three of the four runways are equipped with either a visual approach slope indicator (VASIS) or a precision approach path indicator (PAPI) for final approach altitude guidance. Prior to the accident flight, the student had not flown a night circuit without the visual assistance of approach path/slope indicators.

The instructor held a valid commercial licence and was qualified for the flight in accordance with existing regulations. Prior to this flight, the instructor had flown about 6.8 hours with the student, including the student's first night flight at London.

The flight proceeded to the Centralia/Huron Airpark, and the student completed at least two and possibly three circuits prior to the tree strike. The first two approaches were flown with the landing light on, and the subsequent approaches were flown with the landing light off. During the first approaches, the student brought the aircraft in slightly high; on the occurrence approach, he was attempting to fly a shallower final approach when the aircraft struck the tree.

The tree was about 40 feet high, with branches about three inches in diameter, and it was located about 3,000 feet short of the runway 10 threshold. Impact marks on the tree and aircraft indicated that the aircraft struck the tree with the left wing. The normal height of an
aircraft on final approach at this point would be 300 to 400 feet above ground level (agl). During the occurrence approach, neither the student nor instructor pilot noted the aircraft's altitude, or the fact that the aircraft was too low, prior to the collision with the tree.

Transport Canada's *Instrument Flight Procedures Manual* describes a visual illusion known as "black-hole illusion" as follows:

During night visual approaches to runways in dark, featureless areas...the lack of ambient clues to orientation interferes with depth perception. Under these conditions, pilots often overestimate their altitude and, while concentrating on maintaining a constant visual angle of approach, ...

...[will fly along a descending]...arc which results in premature contact with the ground.

Black-hole illusion was studied, in 1968, by Drs. Kraft and Elworth of the Boeing Aerospace Company. They reviewed the circumstances of a number of major commercial jet accidents that occurred at night between 1959 and 1967, and noted certain similarities. These accidents occurred during night approaches over unlighted terrain or water, toward lighted cities. During their research, a series of night approaches were conducted in simulators without reference to an altimeter. The resulting data indicated that, under certain conditions, during an approach to land over dark terrain, even the most experienced pilots tend to visually overestimate their altitude and fly too low. If the unintended descent were to go undetected, the aircraft would crash short of the runway. The research demonstrated that the most relevant source of visual information for a pilot was the vertical angle subtended at the eye by the nearest and farthest lights. If, during a descent, a pilot were to maintain this vertical angle at a constant value, the aircraft's approach path would follow an arc that would contact the terrain short of the intended runway threshold.

**Analysis**

The aircraft struck a tree and subsequently the ground while descending well below the correct final approach path in controlled flight.

The ambient conditions and landing environment were such that both the instructor and student were likely affected by the black-hole illusion. The black-hole illusion would influence the pilots' perceptions of the aircraft altitude, and allow the pilots to unknowingly descend below a safe altitude if they did not make appropriate reference to the aircraft altimeter. In addition, the runway was only 100 feet wide, whereas the student had practised his previous night approaches and landings on a runway 200 feet wide, and the runway had no approach lights or final approach glide path indicator systems.

**Findings**

- The instructor and student were properly qualified and fit for the training flight.
Records indicate that the aircraft was certified and maintained in accordance with existing regulations, and there was no evidence found of any aircraft malfunctions that could have contributed to the accident.

The aircraft struck a tree at low level and crashed during a visual final approach at night to runway 10.

The ambient conditions and landing environment were conducive to black-hole illusion on final approach.

The final approach was flown without reference to the aircraft altimeter.

Causes and Contributing Factors

Neither the instructor nor the student monitored the aircraft's altitude during the night visual approach, and the ambient conditions and landing environment were conducive to black-hole illusion.

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 January 1997.

1. All times are EST (Coordinated Universal Time minus five 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**  
Broke Through Ice/ Sank in Water  
Aeronca 11CC Super Chief C-FNGV  
Sault Ste. Marie, Ontario 5 nm E  
23 March 1996

**Report Number A96O0048**

**Summary**

At approximately 0830 eastern standard time (EST)\(^{(1)}\), the pilot and one passenger departed from the ice surface of the St. Marys River, near the Sault Ste. Marie, Ontario, sea plane base (Partridge Point), in a ski-equipped Aeronca 11CC Super Chief aircraft. The purpose of the trip was to go ice fishing on Buck Lake, and they planned to return at about 1800. When the aircraft had not returned and was overdue, a search was initiated at 2035. The visual search was hampered by darkness; however, the next morning, a search aircraft reported a hole in the ice on the St. Mary's river just west of Bells Point. An inspection of this hole revealed the submerged aircraft in about 12 feet of water. The aircraft was situated on the bottom of the river in an upright position, facing west. Both the pilot and the passenger were found outside of the submerged aircraft and under the ice surface. Both of the occupants had succumbed to hypothermia and drowning.

*Ce rapport est également disponible en français.*

**Other Factual Information**

 Witnesses at Buck Lake confirmed that the aircraft had arrived and landed at about 0920 EST. The pilot and the passenger talked to two other ice fishermen who were at the lake and then set their ice fishing lines in the same vicinity. The pilot and the passenger were still fishing on Buck Lake at 1400 EST when the other fishermen departed the area. The day after the accident, one of the fishermen indicated that the pilot had told him that there had been some unspecified problem with the tail of the aircraft. The exact nature of the apparent problem was not known.
The aircraft was examined by Ontario Provincial Police divers with an underwater video camera. It was sitting upright on the bottom of the river, undamaged except for a minor dent in the engine cowl and a minor bend in the right wing fillet fairing. The propeller was undamaged.

Both seat-belts were found undone and both doors were open. The engine throttle was found pulled in the "idle" position and the carburettor heat control was found pulled fully back in the "hot" position. The magneto switch was found in the "both" position.

The ice in the vicinity of the sunken aircraft was estimated to be one to two inches thick around the hole and the water had a mild current. Such a thin layer of ice would not have supported the weight of either the pilot or the passenger. Thicker regions of ice were noted in other areas of the river. The water temperature was reported to be about one degree Celsius.

The pilot was certified and qualified for the flight in accordance with existing regulations. Both occupants displayed minor injuries, consistent with no or minimal impact forces. No potentially incapacitating medical conditions were evident in the pilot at the post mortem. Both the pilot and the passenger were wearing appropriate winter clothing for their fishing activity.

**Analysis**

During the investigation, there was no confirmed indication of any mechanical problem with the aircraft. The accuracy of a general reference to an unspecified problem with the tail of the aircraft, that had apparently occurred at sometime prior to the accident flight, was not determined; however, the departure from the St. Marys River and arrival at Buck Lake were normal and indicate the aircraft was operating correctly.

The aircraft apparently left from Buck Lake and returned to the St. Marys River sometime in the late afternoon. The position of the throttle, carburettor heat and magneto controls is consistent with normal engine operation at reduced power, such as would be expected for a normal landing.

The lack of any substantial damage to the aircraft, combined with the minor injuries to the occupants from any impact forces, indicated that the aircraft was stopped or travelling at a slow speed when it broke through the ice. The fact that the seat-belts were undone, that both cabin doors were open, and that both occupants were found outside of the aircraft indicates that they had sufficient time to exit the aircraft as it sank, or that they were not in the aircraft when it started to sink.

With a water temperature of about one degree Celsius, the survival time in the water would have been very short. It would have been an extremely difficult task for both of the occupants to swim and get out of the water with the wet, heavy winter clothing they had on.
There were no known mechanical problems with the aircraft or any medical conditions of the pilot that were considered to be contributory to the accident.

**Findings**

- During the landing roll at slow speed or just after coming to a stop, the aircraft broke through a thin layer of the ice which covered the St. Marys River.

- Both the pilot and passenger, if still in the aircraft as it sank, were able to exit the aircraft, but were unable to get out of the water.

- The pilot and the passenger succumbed to hypothermia and drowning.

- The pilot was properly qualified and licensed.

- There was no evidence that mechanical problems contributed to the accident.

- The search for the aircraft was hampered by darkness and the fact that the aircraft had sunk in the water.

**Causes and Contributing Factors**

The Aeronca 11CC broke through a thin layer of ice on the St. Mary's river either at slow speed during, or stopped at the end of, the landing roll. Contributing to this fatal accident were the water temperature of one degree Celsius, and the winter clothing worn by the pilot and passenger which would have hampered their ability to swim and get out of the 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 05 May 1997.*

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

Loss of Control Spin
Trentair Aviation Ltd
Cessna 150 M C-GNCF
Peterborough, Ontario
27 June 1996

Report Number A96O0105

Synopsis

The pilot and passenger departed on a local flight, planned to last one hour. After the aircraft became airborne, it gained altitude momentarily; the pitch angle was then seen to decrease, and the aircraft descended to a height of approximately ten feet above the runway surface. The pitch angle increased again and the aircraft climbed to a height variably described as up to 200 feet above ground level before entering a gentle turn to the left. The angle of bank then abruptly increased, the nose pitched down sharply, and the aircraft descended to the ground in a steep, nose-down, left-wing-low attitude. The pilot was fatally injured, and the passenger received serious injuries.

Other Factual Information

The pilot was certified and qualified to conduct the flight in accordance with existing regulations. It could not be determined when the pilot had last practised, or received instruction pertaining to, precautionary and forced approach procedures or stall recognition, avoidance, and recovery. There is no regulatory requirement for recurrent training or examination subsequent to pilot licensing. There is no evidence that incapacitation or physiological factors affected the pilot's performance.

On 10 June 1996, an instructor and student were flying the occurrence aircraft on a training flight. They reported that while they were in level, cruise flight, the aircraft engine (Continental O-200-A) was running rough and it lost approximately 200 rpm. They returned to the Peterborough airport for an uneventful landing. The aircraft was taken to a maintenance facility and the defect was verbally reported. Maintenance personnel subsequently diagnosed that the carburettor was the source of the problem. They replaced the carburettor, tested
the engine, and returned the aircraft to service on 21 June 1996. Because many starts of the engine were conducted while troubleshooting the rough running, the starter clutch began to slip, and the engine starter drive unit was also changed on 21 June. After the starter drive unit was changed, neither the engine oil nor the oil screen was checked for contamination, nor is there any manufacturer or regulatory requirement for the check to be carried out. The occurrence flight was the first since the aircraft was returned to service.

At the accident site, the engine tachometer indicated approximately 2,100 rpm. The TSB's analysis of the instrument revealed that the pointer was captured during the impact sequence by the broken face glass, indicating that the engine was rotating at a minimum of 2,130 rpm. One witness to the accident indicated that, from the time the aircraft began its take-off roll, the engine sounded as though it was not operating smoothly. The Cessna Pilot's Operating Handbook states that "Any sign of rough engine operation or sluggish engine acceleration is good cause for discontinuing the takeoff."

No discrepancies were noted with the airframe, airframe systems, or propeller that would have contributed to the accident. Impact witness marks indicated that the ailerons were deflected in a full right-turn command position. The position of the elevators and rudder at impact could not be determined.

During the field examination of the aircraft, a substantial amount of ferrous material was discovered in the engine oil and engine oil screen. Accordingly, the engine was removed and taken to the TSB Engineering Branch for detailed examination. It was determined that the composition of the ferrous material was consistent with that of bearing material. The starter drive unit which had been removed on 21 June 1996 was examined. It was determined that the needle bearings in the starter drive gear assembly had failed prior to its removal and that wear ensued between the wheel stub shaft and the starter drive clutch gear. This wear produced metal contamination which was carried throughout the engine by the lubricating oil. Further examination of the engine revealed that some of these wear particles from the starter drive unit that was removed on 21 June had become lodged in the hydraulic lifters and rendered four of the eight lifters inoperative. Information from the engine manufacturer indicated that four inoperative lifters on two cylinders may reduce the engine power output by as much as 30 per cent.

The runway at Peterborough Airport was undergoing resurfacing at the time of the occurrence and a portion of it was closed. The take-off run available was 2,400 feet for aircraft operations. Ten degrees of flaps were extended for the take-off. Performance calculations for the aircraft operating at maximum gross weight, with ten degrees of flap extended, showed that, on the day of the occurrence, the aircraft would have required a ground roll of 811 feet, and in excess of 1,524 feet to climb to 50 feet above ground level. The estimated aircraft take-off weight was 1,619 pounds. The certificated maximum take-off weight is 1,600 pounds.
Analysis

The starter drive gear assembly needle bearings in the starter drive unit which was removed on 21 June 1996 failed prior to the unit's removal and allowed wear to occur between the drive clutch gear and the stub shaft. The wear metal contaminated the engine oil system, causing four of the eight engine hydraulic valve lifters to jam, disrupting valve operation and reducing the power output of the engine. The disrupted valve action would likely have resulted in a rough running engine and may have been interpreted by maintenance personnel as a problem with the carburettor. Based on the amount of wear and metal deposits, and the jammed lifters, the engine was probably not running smoothly or developing rated power from the time the power was advanced for take-off.

The pilot extended ten degrees of flaps for take-off, probably in order to shorten the take-off roll because of the shortened runway. The extended flap would have shortened the ground roll, but would have also degraded aircraft acceleration and climb performance after the aircraft became airborne. The engine was developing sufficient power for the aircraft to become airborne and climb slowly; however, once airborne, the pilot maintained a nose-high attitude, which prevented the aircraft from accelerating to a safe indicated climb airspeed. The airspeed continued to decrease to, or just above, the stall speed. Either the pilot began a left turn, or the aircraft yawed to the left because of the nose-high attitude, low airspeed, and engine power. The induced yaw would have caused the aircraft to roll (bank) left, and the pilot likely attempted to level the wings with the application of right aileron. The wing stalled and the aircraft entered an incipient spin at an altitude from which there was insufficient time to recover. The application of aileron control input at the point of stall would have enhanced the aircraft's tendency to enter a spin.

The following Engineering Branch reports were completed:

LP 91/96 - Instrument Examination; and

LP 141/96 - Aircraft and Engine Examination.

Findings

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

2. There is no regulatory requirement for recurrent training or examination subsequent to pilot licensing.

3. The estimated take-off weight of the aircraft was 1,619 pounds.

4. The needle bearings in the starter drive gear assembly which was removed on 21 June 1996 failed prior to the assembly's removal, resulting in contamination of the engine lubricating oil with wear metal.

5. Wear metal contamination collected in four of the eight engine
hydraulic valve lifters and restricted their operation.

6. After the starter drive unit was replaced on 21 June 1996, neither the engine oil nor the engine oil screen was checked for contamination, nor is there any manufacturer or regulatory requirement for the check to be performed.

7. The aircraft engine could not develop maximum rated power as a result of disrupted engine valve operation.

8. The pilot maintained an aircraft nose-high attitude after take-off, which prevented the aircraft from accelerating to a safe climb airspeed.

9. Either the pilot began a left turn or the aircraft yawed uncommanded to the left during climb-out, and the aircraft stalled.

10. The aircraft entered an incipient spin at too low an altitude for the pilot to recover.

11. The pilot likely attempted to correct the left banked attitude using right aileron control, which would have enhanced the tendency of the aircraft to enter a spin at the point of stall.

12. No discrepancies which would have contributed to the accident were noted with the airframe, airframe systems, or propeller.

**Causes and Contributing Factors**

The aircraft stalled and entered an incipient spin at an altitude from which there was insufficient height to recover. Disrupted engine valve operation caused less-than-maximum engine power output and contributed to the occurrence.

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 June 1997.

**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 Control (Stall)
Orillia Aviation Ltd
Cessna 150 C-GAXG
Orillia, Ontario
17 August 1996

Report Number A96O0153

Summary

The aircraft alternator had recently been replaced, and the pilot decided to test fly the aircraft before taking passengers on a planned local flight. At approximately 1515 eastern daylight time the aircraft took off from runway 22, climbed to about 500 feet above ground level, turned back and flew a low pass over runway 04. It then entered the downwind leg of runway 12, flew a low pass over the runway and made a turn back toward runway 30. At some point during, or prior to the last turn, some people reported a loud "pop" sound. The aircraft then made a single, continuous turn to align with runway 30. Descriptions of the flight path indicated that all turns were steep; bank angle descriptions varied between 60 and 90 degrees. During the final turn the aircraft stalled, descended, and struck the ground. The aircraft was upright and nose-down at the first point of impact; it then bounced, nosed-over and came to rest inverted. The pilot died as a result of injuries received during the accident.

Ce rapport est également disponible en français.

Other Factual Information

Weather conditions at the airport were reported as clear sky and calm winds, with the temperature between 24 and 26 degrees Celsius.

The Cessna 150 was owned by Orillia Aviation but had recently been under lease to another aviation flying school. The aircraft was returned to Orillia Aviation on 13 August 1996. At that time, to address an electrical problem, the alternator was replaced. No other problems or discrepancies were reported.
The aircraft was found, inverted, in the brush short of the threshold of runway 30. Impact marks in the soil showed that the aircraft was 94 metres from the runway when all three wheels touched down. It then bounced, nosed over and came to rest inverted, about 8 metres closer to the runway. The aircraft remained largely intact but the fuselage was broken to the left behind the baggage area. The nose landing gear strut had been bent straight backwards and the cockpit area was compressed. All flight control systems were intact and continuous. The wing flaps were found in the up position, which is contrary to the full flap position the pilot normally used for landing. The flap motor was tested and determined to have been operational at the time of the accident. The engine throttle was back at a low power or idle setting. Subsequent laboratory examination showed that the engine tachometer was indicating 2200 rpm at impact. When the engine was dismantled no defects were noted that would have prevented the engine from developing full power. However, the finger screen in the carburettor had been removed and a pipe fitting had been screwed directly into the carburettor. (It should be noted that these threads are not compatible.) It could not be determined when this had been done, but there was no contamination inside the carburettor bowl.

There was no mechanical explanation for the reported "pop" sound.

There was a small, post-crash fire that started in the engine compartment. Fuel, which was leaking from the fuel strainer bowl and the carburettor, had run along the engine tachometer cable into the cockpit area and this had caused a small amount of interior fire damage.

The Cessna 150 Pilot Operating Handbook indicates that the aircraft stalls in a wings-level attitude, with flaps up, at 46-47 knots indicated airspeed. In a 60 degree bank, the aircraft will have a stall speed of 66 knots; in a 75 degree bank, the aircraft will stall at 92 knots. TSB Engineering Branch examination of the airspeed indicator determined that it was indicating 50 knots when the aircraft struck the ground.

The pilot had been licenced as a private pilot since 1979, and had accumulated approximately 2,200 hours. His last aviation medical was on 9 August 1995, and he was assessed as fit for a category 3 medical. After the accident, it was learned that the pilot had been prescribed Prozac (an anti-depressant) in January 1994. This information had not been communicated to the Aviation Medical Examiner or to Transport Canada Civil Aviation Medicine. Had this information been communicated, the pilot's licence would likely have been suspended. On the day of the accident, the pilot was described as being alert and in good humour. Toxicological samples examined after the accident showed ethyl alcohol in the pilot's blood of 11 mg/100ml; by comparison, the legal limit for driving is 80 mg/100ml. Also found in the pilot's blood was fluoxetine (Prozac) of 0.025mg/100ml and a trace of chlorpheniramine (non-prescription antihistamine/decongestant). There was no evidence of putrefaction found during autopsy. The amount of alcohol is consistent with the pilot having had at least one alcoholic drink within eight hours prior to the flight.
To address the risks associated with alcohol and drug consumption, Canadian Aviation Regulation 602.03 specifies the following:

No person shall act as a crew member of an aircraft

(a) within eight hours after consuming alcohol;
(b) while under the influence of alcohol; or
(c) while using any drug that impairs the person's faculties to the extent that the safety of the aircraft is endangered in any way.

Analysis

When the aircraft was examined, the only discrepancy identified was the missing carburettor inlet screen, and this was not a factor in the accident. The aircraft flight controls were examined in detail and determined to have been fully functional at the time of the occurrence. Since the aircraft flight controls were intact and functional, the steep banked turns that caused the aircraft to stall during the turn to final were likely pilot-induced manoeuvres. The functional flight controls also mean that the pilot would have been able to recover from a stall, had there been sufficient altitude. The three landing gear marks at the beginning of the wreckage trail indicate that the aircraft was in a relatively wings-level, nose-down attitude when it hit the ground. In this attitude the aircraft's speed would have been increasing, and it is likely the pilot was in the process of recovering from the stall when the aircraft struck the ground.

The aircraft flaps were found in the fully retracted position, which was not consistent with the pilot's normal landing configuration. From this it can be concluded that the pilot was either intending to select full flap on final approach or that he had no intention of landing on this approach.

It is unlikely that the amount of ethyl alcohol found in the pilot's blood and urine would have, of itself, impaired the pilot's ability to handle the aircraft. There is no measurement of how the Prozac might have affected his performance nor is there any way to measure the combined effect of alcohol, Prozac, and the antihistamine. The specific air regulations regarding alcohol and drugs, applicable to all pilots, were enacted to minimize the negative affects of alcohol and drugs on pilots' flying skills.

The following Engineering Branch report was completed:

LP 121/96 - Instrument Analysis

Findings

- The carburettor fuel inlet screen had been removed, and the aircraft had been operated without the screen for an unknown period of time.

- The pilot had not revealed his prescription for, and use of,
Prozac at his last aviation medical.

- It is probable that the pilot had ingested alcohol within eight hours of the flight.

- The aircraft stalled during a turn to final approach, and the pilot was not able to recover before the aircraft struck the ground.

**Causes and Contributing Factors**

The aircraft stalled as the pilot was conducting a turn from downwind to final approach. The pilot was not able to recover from the stalled condition before the aircraft struck the ground.

*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.*

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
Losses of Separation between Air Ontario de Havilland DHC-8-301 C-GUON and Canadian Airlines International Douglas DC-10-30 C-GCPI
and between Air Canada Airbus A320-211 C-FDSN and Canadian Airlines International Airbus A320-211 C-FLSI
Toronto/Lester B. Pearson International Airport, Ontario
24 September 1996

Report Number A96O0196

Summary

At approximately 1309 eastern daylight saving time (EDT), an Air Ontario de Havilland DHC-8 (ONT331) was cleared to position on runway 24 right (24R). A loss of separation occurred approximately one minute later when a Canadian Airlines Douglas DC-10 (CDN02) was cleared to land on the same runway. At approximately 1334, a second loss of separation occurred when the same controller cleared an Air Canada Airbus A320 (ACA127) to position on runway 24R and subsequently cleared a Canadian Airlines Airbus A320 (CDN962) to land on runway 24R. In both instances the landing aircraft were instructed to overshoot, and both did so safely.

Ce rapport est également disponible en français.

Other Factual Information

The tower controller was working the combined controller positions of north tower and south tower. At 1308:51\(^1\), the controller cleared ONT331 to position on runway 24R, and, at 1309:37, he transmitted control instructions to the crew. He did not include take-off clearance in this transmission. The flight crew of ONT331 apparently attempted to contact the controller to ask if they had been cleared for take-off, but at the same time, the controller was communicating with the crew of an
aircraft landing on runway 24 left (24L), and the transmission from ONT331 was not heard by the controller. The transmission was not recorded. When the controller cleared CDN02 to land, he noticed that ONT331 was not departing and told the flight crew that their “take-off clearance was for now.” As CDN02 approached the threshold of 24R, the controller cancelled ONT331’s take-off clearance and issued overshoot instructions to CDN02.

At 1332, the controller cleared ACA127 to position and hold on runway 24R. About a minute later, while ACA127 was still holding, the controller cleared CDN962 to land on 24R. During the approach, the crew of CDN962 transmitted to the tower that “there’s an aircraft on the runway.” The controller immediately issued instructions to CDN962 to pull up and go around.

During the first occurrence, the shift supervisor was on his lunch break; however, there was an acting supervisor, and he noticed that ONT331 was not departing and that CDN02 was instructed to overshoot. Both the controller and the acting supervisor thought that a take-off clearance had been issued to ONT331 before CDN02 was cleared to land and that ONT331 was slow to depart. At the time of the second occurrence, the tower controller was working only the north tower position, and the supervisor was working the clearance delivery position. Staffing at the time of both occurrences was in accordance with unit policies.

After clearing an aircraft to position on an active runway, the controller involved in these occurrences generally slid the flight data strip for that aircraft partially out of its flight data strip holder. Lately, however, the flight data strips had not been of a uniform width, and some slid easily in and out of the flight data strip holder, whereas others required considerable force to slide. Because of this, the controller used an alternative reminder method if the flight data strip was difficult to slide, lifting the flight data strip holder part way out of the flight data strip bay. It could not be determined what method was used for the first occurrence. At the time of the second occurrence, the controller was unable to slide the flight data strip for ACA127 because the strip was wide and would not slide easily. The controller did not use any visual cue reminder method during the second occurrence. Although the tower controller scanned the threshold of runway 24R prior to issuing the landing clearance to CDN962, he did not visually acquire ACA127. The weather during both occurrences was reported as wind 360 degrees at 5 knots, visibility 2 statute miles in rain showers and mist, and clouds based at 700 feet above ground level. The threshold of runway 24R is approximately 1.5 miles from the control tower. Factors which can affect the ability of controllers to see aircraft on the threshold include the number and type of aircraft waiting for take-off on taxiways “B”, “H”, and “A” and the prevailing visibility. An additional factor in this instance was the paint scheme of ACA127, which was predominantly dark. Witnesses who were in the tower during the second occurrence stated that ACA127 was quite difficult to see at the threshold of runway 24R.
The control tower was equipped with monitors to display information from the airport surface detection equipment (ASDE). Controllers in the tower reported that the monitors sometimes displayed returns of non-existent aircraft, or did not display returns for aircraft which were in position on the end of runway 24R. Some of these anomalies were observed by investigators during the field phase of the investigation. Controllers stated that they checked the ASDE monitor after the second loss of separation, and there was no return for ACA127.

The controller involved in the occurrences reported that he had slept only two hours during the night before the occurrences, and that his sleep pattern had been similar during several previous nights. The controller stated that he knew he was tired before he started his shift, but he assessed himself as fit to perform his duties. Significant amounts of sleep loss can have deleterious effects on one’s performance, including decrements in vigilance, impairments of working memory, and increased errors in communication. People, especially those who are sleepy, often do not realize their actual level of fatigue, alertness, or performance.

**Analysis**

In the first occurrence, the controller cleared ONT331 to hold on runway 24R and did not issue a take-off clearance until after CDN02 had been cleared to land. The controller thought that he had issued a take-off clearance to ONT331 and was waiting for the flight crew to begin a take-off roll; the flight crew was waiting for a take-off clearance. Both the airport controller and the acting supervisor thought that a take-off clearance had been issued to ONT331 prior to the first loss of
separation and, therefore, did not realize that a significant, abnormal occurrence had taken place. For that reason, the controller was not removed from operational duty.

In the second occurrence, the controller cleared ACA127 to position on the active runway and forgot to issue the take-off clearance. He also forgot to use, or was unable to use, his visual cue, possibly because the flight data strip would not slide easily out of the flight data strip holder. With no visual cue to remind him that the aircraft was in position on the runway, a line of defence was lost. He did not visually acquire the aircraft in position on the runway during his scan of the area. It is possible that a combination of the lack of contrast between the aircraft and the background, traffic on an adjacent taxiway between the tower and the threshold, and meteorological conditions, in conjunction with the lack of a visual cue, resulted in the controller forgetting that he had placed the aircraft on the active runway. It is also likely that the ASDE did not display a return for ACA127.

The controllers on duty at the time of the occurrence stated that the combination of traffic on the adjacent taxiway, reduced visibility, and the predominant colour of the aircraft blending into the background made ACA127 difficult to see at the threshold of the runway. Although the airport is equipped with ASDE and the tower controllers are able to monitor the returns, the location and idiosyncrasies of the radar make it subject to displaying false or misleading information, or not displaying information at all. The controllers are aware of these characteristics and certainly, in the case of the second occurrence, the lack of information would be a critical lapse. The shift supervisor was working the clearance delivery position at the time of the second occurrence and was unable to perform supervisory duties.

It is very likely that the controller was fatigued as a result of an accumulated sleep debt stemming from several nights of disturbed and shortened sleep cycles. The fact that the controller thought he had cleared ONT331 for take-off when he had not, and forgot he had placed ACA127 on the threshold of runway 24R, appears to be consistent with these potential sleep-loss effects. Further, although the controller felt that he was fatigued prior to starting his shift, he believed that he would be able to perform his duties. This decision by the controller was consistent with the effects of fatigue, in that people often do not realize their actual level of fatigue, alertness, or performance.

Findings

- The control tower was staffed in accordance with unit policy.
- The controller had an accumulated sleep debt and was fatigued.
- In the first occurrence, the tower controller was working the north and south tower positions combined.
- The tower controller was aware that he had placed ONT331 in
The tower controller thought that he had cleared ONT331 for take-off on runway 24R when he had not.

CDN02 was cleared to land on runway 24R when separation from ONT331 was not assured.

The controller forgot about ACA127 after he cleared it to position on runway 24R.

There is no uniform method used by controllers as a visual reminder that they have placed an aircraft in position on an active runway.

The tower controller did not use any visual cue to remind himself that he had placed ACA127 on the threshold of runway 24R.

The shift supervisor was working the clearance delivery position at the time of the second occurrence.

A combination of factors made ACA127 difficult to see at the threshold of runway 24R.

### Causes and Contributing Factors

The two losses of separation occurred when, in each instance, the controller instructed the aircraft to position on the active runway and subsequently cleared an aircraft to land on the same runway when separation between the landing aircraft and the aircraft on the runway was not assured. Contributing to the two occurrences was the probable impairment of the controller's performance by sleep debt.

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 EDT (Coordinated Universal Time (UTC) minus four hours) unless otherwise stated.

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 Situational Awareness
Helijet Airways Inc.
Sikorsky S-76A (Helicopter) C-GHJL
Victoria Airport, British Columbia
13 January 1996

Report Number A96P0006

Summary

Helijet Airways flight 721 (JBA721) departed Vancouver on a scheduled flight to the Victoria Harbour helipad, British Columbia, with 2 pilots and 11 passengers on board. While en route, the pilots were advised that the Victoria Harbour weather was below landing limits. The pilots then chose to divert to the Victoria airport, where they conducted the "ILS/DME" (instrument landing system/distance measuring equipment) instrument approach to runway 09. At 1252 Pacific standard time (PST) they initiated the published missed approach procedure at the decision height, because of poor visibility in fog. The first officer, who was flying the helicopter at the time, had unintentionally allowed the airspeed to gradually reduce to about 40 knots during the latter stages of the approach; when he applied power to begin the missed approach climb straight ahead, the helicopter smoothly turned about 100 degrees to the right. This turn was not immediately detected by either pilot, and the helicopter continued on the climb out on the incorrect heading for about 30 seconds until the captain saw the heading deviation and instructed the first officer to correct course to the left, back to the published heading. The Victoria Terminal air traffic controller also noted the heading discrepancy and issued the pilot radar vectors to prevent a loss of separation with another aircraft on the same ILS approach to runway 09 at Victoria. The helicopter then continued to Vancouver and landed without further incident.

Ce rapport est également disponible en français.

Other Factual Information

The published ILS/DME approach to runway 09 at Victoria, dated 14
September 1995, was a conventional precision instrument approach procedure which incorporated a 3-degree glide path, an inbound track of 085 degrees magnetic, and a decision height of 255 feet above sea level (asl), 200 feet above ground level (agl). The missed approach procedure required an aircraft to climb straight ahead on the localizer to 5 DME from the airport, before turning left and climbing to 3,000 feet asl. By design, this flight path traversed mostly open water and some low-elevation islands. The approach procedure document used by the pilots at the time of the incident was correct and appropriate for the approach to runway 09. The instrument approach procedures and profile were not contributing factors in this incident.

The pilots were certified and qualified for the flight in accordance with existing regulations, and their work schedules and rest periods were in accordance with the approved company operations manual limitations. On this flight, the captain, although he was the pilot-in-command, was acting as the non-flying pilot in the left-hand seat. This division of flight deck duties is a common industry practice and, through appropriate crew resource management techniques, provides acceptable levels of competence during flight. The captain remains unequivocally in command at all times.

Before joining Helijet, the captain had accumulated about 4,500 hours of helicopter flight time engaged primarily in bush work and ab initio student instruction in smaller helicopters. Shortly after receiving his initial class 4 instrument rating qualification in 1992, he began flying as a first officer on the S-76 with Helijet, and he was upgraded to captain status in April 1995. Since joining the operator, the pilot had gained about 1,800 hours of flying experience on the S-76.

The first officer had a strong background in military helicopter operations, which included about 7 years in an instrument flying environment, and he had gained about 2,500 flight hours in both medium and large size helicopters. He had joined Helijet as a first officer in early 1995, and had accumulated about 500 hours on the S-76 since then.

The 1233 PST Victoria terminal weather observation was reported as 100 feet scattered, measured ceiling of 800 feet broken, 2,800 feet overcast, with 3 miles visibility in light rain and fog. At 1300 PST, 10 minutes after the incident, the only change to the weather was reported as 2,700 feet overcast.

At the time of the incident, Helijet had a Transport-Canada-approved, non-precision Loran approach procedure into the Victoria Harbour, which incorporated a step-descent profile leading to a missed approach point at 380 feet asl. The latter stages of this approach were usually flown at 60 to 70 knots indicated airspeed (KIAS), and the final segment of the approach to the missed approach point was conducted in straight and level flight. This approach profile had been used successfully in the past by the Helijet pilots flying into Victoria Harbour in conditions of limited visibility. The incident crew had recently flown the Loran approach to Victoria Harbour successfully, and both pilots had done so on other occasions.
The operator had established approved training and recurrency programmes which, in part, provided training, critique, and examination of several types of instrument approaches, including the Loran step descent to Victoria Harbour, and the ILS precision approaches to either Vancouver or Victoria airports.

Helijet regularly flew in the Vancouver area, and the pilot’s traditional proficiency, operational, and examination flying included ILS approaches which terminated at the designated missed approach point for the specific procedure. Because the airspace where the ILS approaches were established was so active, air traffic control (ATC) operational circumstances required the crews to expedite their ILS approaches at airspeeds which caused minimal disruption to larger, commercial aeroplanes, sometimes flying in the order of 140 KIAS. As a consequence of the ILS approaches being flown at these higher airspeeds, the S-76 pilots were rarely exposed to ILS profiles at the lower, more conventional helicopter airspeed of 70 KIAS. The handling characteristics of the helicopter at 140 KIAS are significantly different from those at 70 KIAS; however, both these high and low in-flight speeds are well within the certificated flight envelope of the helicopter. Neither pilot had flown an ILS in the S-76 at 70 knots.

The traditional procedure of practising sequential instrument approaches incorporated, by necessity, the practice of executing the missed approach procedure at each decision point; not often, therefore, did the helicopter proceed past the decision point with the intention of landing, and continue with the approach to touchdown. This often repeated practice of truncated approaches did not expose pilots to the flight characteristics of the S-76 in the slow speed regime during instrument approaches.

During the in-flight approach briefing, the pilots discussed the circumstances of the approach profile and, because of the marginal weather conditions at the time, decided to conduct the ILS at a reduced airspeed of 60 to 70 KIAS, in similar fashion to their recent successful Loran approach to Victoria Harbour. This decision was based on the premise that the slower airspeed would allow them more opportunity to acquire the required visual references at the missed approach point, and then to proceed in visually for landing. Once established on the localizer, the pilot-flying began to reduce airspeed to the discussed 70 knots; the helicopter, however, began to climb on the glide path because of the higher nose attitude required to slow down. In an attempt to regain the glide path, the pilot reduced collective pitch to descend, and the rate of descent increased to about 800 feet per minute.

At this stage the pilot-flying began to fixate on the glide-slope indicator, to the exclusion of the other cockpit instruments. The captain observed the low airspeed and cautioned the pilot-flying to move the cyclic forward to regain airspeed. The helicopter then arrived at the missed approach point height, and the captain called for the missed approach procedure to be carried out. The pilot-flying acknowledged, applied climb power, and began the transition into the climb. It was at this stage
that the aircraft turned right about 100 degrees without the pilots realizing it. The airspeed then began to increase, and, during the initial stages of the climb, the captain continued his pilot-not-flying duties. At 60 KIAS, he retracted the landing gear, and transmitted their intentions to ATC. During the initial part of the missed approach, however, the pilot-flying had not yet resumed his instrument scan and was disoriented. As a result, the captain chose to talk him through the procedure and provide constant feedback and direction. About 30 seconds after the helicopter had turned right, the captain became aware of the heading deviation and instructed the pilot-flying to turn left to regain the correct missed approach heading. About 50 seconds later, ATC issued radar vectors to JBA721 to ensure continued separation from another arriving aircraft.

Analysis

While both the incident pilots had seen and experienced the 70 KIAS Loran step-descent approach in the S-76, they had not experienced an ILS approach at that same airspeed. The most significant difference between the approach profiles is that the ILS is a descending flight path; the missed approach, therefore, is a constant-speed transition from descending flight to climbing flight. Aggravating the pilot's workload was the significant torque-related force turning the helicopter to the right as a result of the increase in collective pitch to begin the climb.

It is most likely that the pilot began to lose situational awareness as a result of his unfamiliarity with the low speed ILS approach profile. A combination of the high rate of descent, low airspeed, large power application, and significant nose attitude change led to aircraft handling characteristics that the pilots had not previously experienced. As a result, when the instrument scan of the pilot-flying broke down, he lost directional control and the helicopter turned right. The turn itself was not detected by either of the pilots, most likely because the effect was masked by other attitude changes and the lack of external visual references. The delay in the captain's detection of the heading error resulted from his preoccupation with the missed approach vital actions, and his having to talk the pilot-flying through the missed approach and recovery of his instrument scan.

Findings

- The pilot-flying lost situational awareness and unknowingly allowed the helicopter to turn 100 degrees away from the published missed approach procedure heading.

- The helicopter continued on the incorrect missed approach heading for about 30 seconds, until the captain realized the error and issued recovery instructions to the pilot-flying.

- The incident pilots had not previously flown ILS approaches at low airspeeds of about 70 knots.
• The operator had not included practice flying ILS approaches at low speed during in-flight training.

Causes and Contributing Factors

The helicopter flew off the published missed approach procedure because the pilot-flying lost situational awareness. Contributing to the incident was the crew's lack of low-speed ILS experience.

Safety Action Taken

Immediately after the incident, Helijet withdrew both pilots from flying duties, and had the pilots complete an instrument flying training, reassessment, and recertification programme. Following successful retesting by a Transport Canada air carrier inspector, both pilots returned to line flying.

Shortly after the incident, the Flight Safety unit at Helijet conducted a crew resource management (CRM) training seminar for all company pilots, during which the circumstances of this incident were used as a primary training module.

The Helijet training programme was modified to specifically include practising ILS approaches at both high and low airspeeds, and continuing approaches past the missed approach point more often. In addition, Helijet's standard operating procedures (SOPs) were modified to require a minimum airspeed of 75 knots on instrument approaches.

Helijet also introduced an additional annual instrument training flight for all company pilots to supplement the annual recurrent training already in place. This additional flight concentrates on basic and essential instrument flying skills, and aircraft handling and instrument scanning techniques.

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 February 1997.
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
Canadian Helicopters Limited
Eurocopter AS-350BA (Helicopter) C-GRGK
Revelstoke, British Columbia, 50 nm North
26 April 1996

Report Number A96P0064

Summary

The pilot departed the operator's Revelstoke base in the AS-350BA helicopter at 0750 mountain daylight time (MDT)(1) on Friday, 26 April 1996, and flew to the operator's base at Golden, British Columbia, to refuel and pick up two passengers. The three then departed Golden at 0900 MDT to begin a planned visual flight rules (VFR) flight to undertake snow-sampling operations at various locations in the mountainous area between Golden and Revelstoke. The helicopter did not return to Golden at the expected time, and the operator's base-pilot in Golden commenced an aerial search in the other company helicopter. The Kamloops flight service station specialist contacted the Rescue Coordination Centre in Victoria to advise them of the overdue aircraft. Search and rescue aircraft were dispatched from Canadian Forces Base Comox shortly thereafter and flew to the search area. After an extensive civilian and military search, the wreckage of the missing helicopter was found at about 1030 MDT the following day. The helicopter had crashed in mountainous terrain at about 6,200 feet above sea level; the three occupants were fatally injured and the helicopter destroyed. There was no fire.

Ce rapport est également disponible en français.

Other Factual Information

The pilot was on the fifth day of his tour at the Revelstoke base, and had last flown on Wednesday, 24 April 1996. The pilot was said to be a happily married man, and a quiet, compassionate, and meticulous individual. He was regarded as a conscientious pilot, well-respected by his peers and supervisors in the company, and had a positive,
had no significant outside pressures. There was no evidence that incapacitation or physiological or psychological factors affected the pilot's performance.

The pilot was licensed and qualified in accordance with existing regulations. He had considerable experience in both mountain flying and winter operations, as well as field-camp operations. His flying career included about 4,500 helicopter hours with the Canadian Forces in both Canadian and German operational and training spheres. Since joining Canadian Helicopters, he had accumulated about 1,500 hours on the AS350 helicopter, bringing his total helicopter experience to about 6,000 hours. His last operational and pilot proficiency examinations and flight tests were conducted in February 1996, and, as on previous occasions, were of a consistently high standard.

The pilot refuelled the helicopter himself, but the precise amount of fuel he added is not known. Had he refuelled the tank to its capacity of 540 litres, or about 940 pounds, at Golden, the aircraft weight at take-off would have been no more than 4,200 pounds. The maximum certificated weight for the helicopter is 4,630 pounds. Given that the pilot had recorded the journey's cumulative flight time up to the last landing as 1 hour and 35 minutes, the fuel consumed would have been about 490 pounds; the estimated take-off weight from Goldstream, the last landing site recorded in the pilot's flight log, would have therefore been less than 3,700 pounds. The longitudinal and lateral positions of the centre of gravity would have been within limits, regardless of the fuel load. Investigators at the accident site drained about 90 litres, or about 160 pounds, of fuel from the fuel tank. A test for water in the fuel revealed no contamination. Fuel quantity, quality, or delivery were considered not to have been factors in this accident.

The helicopter had a set of snow covers designed to cover the engine inlet, exhaust, and the main rotor blades. The pilot did not take this protective equipment from the Revelstoke base when he departed on Friday morning, nor was he required to have done so.

The pilot had not made any comment to the engineering personnel at Golden that morning about any deficiencies with the helicopter. A review of the aircraft maintenance documents revealed that the helicopter was certificated and maintained in accordance with existing regulations, and no evidence was found of any outstanding defects.

The helicopter was equipped with an emergency locator transmitter (ELT) beacon, mounted in the forward section of the instrument pedestal, near the pilot's left anti-torque pedal. This particular installation did not provide convenient access to the ELT. No ELT signal had been received; first responders at the accident site found the ELT switch in the OFF position. The TSB Engineering Branch examined the ELT and found no evidence that the switch had been struck, despite considerable case damage. It was therefore concluded that the switch had not been jarred off during impact, and that the ELT had not been armed before the accident flight. Engineering laboratory tests revealed that the internal 'g-switch' in the ELT had been triggered,
but that the transmitter crystal had been recently split, presumably by the impact forces of the accident; such damage would have immediately rendered the unit unserviceable. It could not be determined when, or why, the ELT was turned OFF, or why the pilot did not set it to ARMED before the flight.

The French aviation regulatory agency, Direction générale de l'aviation civile (DGAC), had issued an Airworthiness Directive (AD), number 93-067-066(B), dated 12 May 1993, which limited flight in falling snow in all AS350 helicopters which do not have one of the approved, optional engine intake accessory kits installed. At the time of the accident, C-GRGK did not have either kit installed and, to avoid risk of engine flameout when flying in falling snow, the following limitations were applicable:

- when visibility was greater than 1,500 metres, flight was authorized;
- when visibility was less than 800 metres, flight was prohibited; and
- when visibility was between 800 metres and 1,500 metres, the total flying time in falling snow was limited to 10 minutes. This time limit included the time required to leave all snowy conditions, irrespective of the visibility.

Transport Canada (TC) Continuing Airworthiness Branch issued a letter to all AS350 helicopter owners, dated 07 January 1994, which referred to the DGAC AD and which "clarifies the restrictions on flight in snow imposed by the subject airworthiness directive (AD)." The letter stated in part that;

"The AD does not supersede any approved AFM (Aircraft Flight Manual) Supplements that allow in their Limitations Sections cancellation of the flight in snow limitations of the basic AFM."

The letter further stated that;

"TC has accepted the DGAC approval for flight in snow with the Sand Filter kit, or with the Protection of the Air Intake Against Induction of Snow kit installed in accordance with the Flight Manual Supplements ...

The TC letter made no further interpretation of the in-flight time restriction of 10 minutes.

During the course of the investigation, discussions with other Canadian operators of the AS-350 helicopter revealed fundamental differences in their interpretations of the in-flight time restriction imposed by the AD. The operator had interpreted the restriction to imply that the total of 10 minutes flight was inviolate, and that the helicopter had to be on the ground for engine intake inspection within that time; another operator deemed that the AD flight time restriction was cumulative in effect, and
that the helicopter could fly in snow at various times during flight for a total of 10 minutes before landing for inspection; yet another interpretation was that the 10-minute limit was on a per-instance basis and that, providing the 10-minute limit was not exceeded on any one occasion, the helicopter could fly in and out of snowing conditions indefinitely.

A witness, who was located at the 4,600-foot level in the same valley as the accident site, saw a helicopter flying low, moving slowly up the valley towards the Goldstream landing site at about 1320 MDT. He reported that the weather conditions at that level were poor, with heavy, falling snow, and low ceiling. These conditions reportedly did not improve significantly for several hours, until about 1700 MDT. The witness did not see or hear the helicopter subsequently take off. Without an observer, the weather conditions at the Goldstream landing site, about two miles away and 2,000 feet higher up the mountainside, are unknown. According to people familiar with the local weather circumstances and seasonal patterns, it is common at that time of the year for frequent and localized weather cells to move across the area, creating well-defined snow squalls in otherwise clear, sunny skies. Visibility in these rapid squalls is often reduced to less than 100 feet.

Recent human tracks were found at five of the seven proposed landing sites, indicating that the accident helicopter had recently landed there. An examination of the site notes taken by the snow-sampling team confirmed that they had worked at those sites, and established their sequence; the pilot's personal flight record notebook confirmed the flight times to the sites, and the landing sequence. A collective review of these records reveals that the helicopter had landed at the Goldstream site at 1325 MDT, after having landed at four other sites.

The three people on board the helicopter were experienced outdoor campers, had sufficient provisions to stay overnight in the field, and none had urgent or pressing requirements to return to Golden that Friday night. At the time of landing at Goldstream, they still had about seven hours of daylight at their disposal to work, wait if necessary, and depart for the remaining site, or to return to Golden.

The accident site is about 300 feet lower in elevation than the Goldstream landing site, and at a distance of about 1,500 feet down the valley. The terrain slopes at about 30 degrees and is moderately populated with tall conifers. Two large trees on the periphery of the accident site had been topped and exhibited clear evidence of rotor blade strikes at about 50 feet above the snow surface; a larger tree, about 18 inches in diameter, had been snapped off at the surface and had fallen back onto the helicopter at impact. Other smaller trees exhibited scrape marks and gouges consistent with helicopter fuselage and skid contact. There were areas that were clear of trees adjacent to the accident site which may have been suitable for an emergency landing.

The helicopter wreckage was contained to the impact point and all components were accounted for. Impact marks and aircraft wreckage characteristics revealed that the helicopter had struck the ground in a
nose-low, right-side-down attitude with a high rate of descent and low main rotor rpm. At surface impact, the helicopter had collided head-on with the large tree, which then passed through the cabin area and struck the main transmission gearbox, breaking the front main transmission mounts and the forward hydraulic servo. The tail boom assembly had snapped off at the fuselage attachment bulkhead, and it exhibited damage consistent with separation at low rotor rpm; the tail rotor assembly exhibited similar low-rpm damage. The three main rotor blades were intact and attached to the head; the damage patterns were consistent with impact with the surface at low torque and low rotor rpm. None of the drive train components exhibited evidence of engine power at impact. Except for the known tail boom separation, flight control continuity was confirmed for the collective, cyclic, and anti-torque controls.

The throttle lever in the cockpit was found in the "stop", or aft, position; the main fuel flow valve on the engine fuel control unit (FCU) was in the corresponding closed position; and the throttle cable fitting at the engine had been bent at impact. The TSB Engineering Branch examination of the bent end fitting on the fuel flow control cable revealed damage that was consistent with the cable having been forced into the fitting while the fitting was bending or after the fitting was bent. Since the bending occurred at impact, it was concluded that the throttle lever was forced into the aft, closed position as a result of the impact forces when the helicopter struck the ground. The fuel lever was found snapped off at the quadrant in the open, or normal in-flight, position but the frangible witness wire was intact; the associated fuel shut-off valve was found open.

The Turbomeca Arriel 1B engine was taken to an approved engine overhaul facility for a detailed examination and test cell run. The examination revealed no evidence of either mechanical deficiency or significant rotation at impact. The engine was test run and met the engine manufacturer's specifications. The engine FCU was examined, tested, and stripped down; it was unremarkable and met all specifications and tolerances.

The main rotor gearbox was disassembled and examined. With one exception, all components were unremarkable. When the main rotor shaft was removed from the gearbox upper housing unit, the locking key which couples the phonic wheel to the shaft fell out from the machined key-way. Closer examination revealed that the retaining roll-pin, which normally holds the key in place in the phonic wheel key-way slot, had been sheared. TSB Engineering Branch microscopic examinations of the key, the phonic wheel, and associated bearings determined that, although the key had been partly in place in the key-way slot, there had been no slippage between the components during service life. As a result, it was concluded that the mis-set key was not a contributing factor in this accident. It was, however, the focus of a study and review of the installation procedures for this component.

All three occupants were wearing seat-belts and shoulder harnesses; the pilot was also wearing a flight helmet. The impact forces at ground contact were high, and the occupiable volume of the cabin was
compromised by the large tree which the helicopter struck at ground impact. The accident was not survivable.

Analysis

In general, in the event of an uncommanded engine deceleration in flight, the indications to the pilot would have been similar to those resulting from an engine flame-out, and would have given the pilot the same operational options. Such a deceleration would have been caused by a malfunction of the engine’s fuel control unit (FCU). The engine run in the test cell after the accident repeatedly demonstrated consistent, specification engine performance, and normal function and performance of the FCU. The FCU examination and disassembly revealed no abnormalities, and demonstrated again that the FCU was functioning correctly. It is possible that foreign matter had entered the FCU at some time, caused it to malfunction, and yet became dislodged at impact; however, the undisturbed fuel samples taken before and during the first engine run contained no discernible contaminant, nor was any significant contaminant found at FCU disassembly. Given the success of the test cell runs and the FCU examinations, and in the absence of any contaminant found in the fuel system, it is unlikely that contamination of the FCU caused an uncommanded deceleration and led to the accident. Since no causal mechanical deficiencies with the engine or helicopter were found, this analysis concentrates on the operational factors of this accident.

As a result of the engine examination, it was concluded that the engine was not delivering significant power at impact, although capable of doing so. As well, the damage to the rotor system is consistent with low torque and low rpm at impact. Although the engine throttle control was found in the closed position, there is evidence to conclude that it was moved by impact forces.

Consequently, snow ingestion remains as the most likely reason for the engine stopping in flight. It was not possible to determine either the time of take-off from Goldstream or the duration of the flight prior to the engine stoppage. It is possible that (a) the helicopter flew into adverse snow showers and accumulated sufficient snow to flame out the engine, or that (b) unseen by the pilot, snow had accumulated inside the engine intake while the helicopter was on the ground at Goldstream, and slipped into the engine during in-flight manoeuvring and caused the flame-out. It is also possible that a combination of the above occurred.

A sudden loss of engine power would have committed the pilot to conduct an autorotative descent and landing over inhospitable terrain, and possibly in adverse weather conditions. The in-flight circumstances immediately preceding the engine stoppage could not be determined; however, when the helicopter struck the trees during the last stage of descent, the main rotor rpm would have been reduced and, if the rpm had already decayed, likely would have rendered the helicopter uncontrollable, leading to inevitable impact with the surface.

The TC Airworthiness letter dated 07 January 1994 which sought to
clarify the DGAC AD restrictions on flight in falling snow, did not either identify the possibility of, or resolve, the ambiguity in the AD, nor did it further interpret the in-flight time restriction of 10 minutes. That Canadian operators of the AS-350 helicopter independently interpreted the AD with fundamental differences in their application of the in-flight time restrictions indicates that the AD is ambiguous and unclear, that it leads to misinterpretation, and is not applied uniformly.

The following Engineering Branch reports were completed:

- LP 67/96 - Systems Examination;
- LP 77/96 - Control and Drive Systems Examination.

**Findings**

- Records indicate that the helicopter was certificated and maintained in accordance with existing regulations, and no evidence was found of any pre-impact failure or malfunction which could have contributed to the accident.

- The actual weather conditions at the accident site or the last known take-off location are unknown.

- Conditions of falling snow and reduced visibility were reported in the vicinity at about the time of the accident.

- The helicopter engine flamed out in flight, likely as a result of snow ingestion.

- The pilot was committed to an autorotative descent and landing into inhospitable terrain.

- The helicopter struck trees during the final stage of descent for undetermined reasons.

- The ELT was not ARMED for this flight for undetermined reasons.

- The DGAC AD pertaining to flight in falling snow is ambiguous, and leads to misinterpretation.

- The locking key which coupled the phonic wheel to the main rotor shaft had been incorrectly installed; it was concluded that this did not contribute to the accident.

**Causes and Contributing Factors**

The engine flamed out, likely as a result of snow ingestion. It could not be determined why the helicopter struck trees during autorotative descent. Contributing to the accident were the inhospitable terrain and
likely adverse weather conditions.

**Safety Action**

On 20 May 1996, Eurocopter France, the manufacturer of the AS-350BA, issued a service letter, number 1270-00-96, to all operators of Eurocopter helicopters on the subject of "Protection and Operation of Helicopters in Snowy Conditions." The letter served to explain and emphasize the precautions to be taken to prepare for flight a helicopter that had been parked out in the open in (falling) snow.

Since the accident, the operator has installed the engine particle separator kit in all its AS-350 helicopters. As a result of this installation programme, the AD pertaining to flight in snow no longer applies to any of their AS-350 helicopters.

Since the anomaly concerning the drive shaft key was identified, the maintenance division of the operator has issued internal instructions to highlight the possibility of misalignment of the components at re-assembly, and to increase awareness of the potential danger of misalignment.

In December 1995, following a review of TSB data for occurrences from 1984 to 1995, the TSB forwarded an Aviation Safety Advisory to TC concerning the high incidence of ELTs being found in the unarmed position during accident investigations. The Advisory asked TC to consider emphasising the importance of arming ELTs prior to flight, and as well, for TC to consider a mandatory requirement for the arming of ELTs. In response, TC indicated that a rule requiring mandatory arming of ELTs was not appropriate. However, the former ELT ANO (Series II, Number 17) has now been replaced by the Canadian Aviation Regulation (CAR) 605.38, which in part requires the ELT to be armed if so specified by the flight manual, operating manual, or pilot handbook. Since the accident, TC has prepared articles on the importance of ensuring that ELTs are armed prior to flight, and they have appeared in the COPA, Vortex, Maintainer, and Aviation Safety newsletters.

An Aviation Safety Advisory letter was sent to TC advising of the ambiguity that exists in Airworthiness Directive 93-067-066(B) with respect to the limitations for flight in falling snow.

*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 17 September 1997.*

1. All times are MDT (Coordinated Universal Time minus six hours) unless otherwise noted.
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
Buffalo Narrows Airways
de Havilland DHC-3 Otter C-GDOB
Terrace, British Columbia 30 nm e
09 May 1996

Report Number A96P0082

Summary

The single-engine, float-equipped DHC-3 Otter departed Ketchikan, Alaska, at 0905 Pacific daylight time (PDT) on 09 May 1996 with a pilot and co-pilot on board. They were on a visual flight rules (VFR) ferry flight to Dawson Creek, British Columbia, en route to Buffalo Narrows, Saskatchewan. After a refuelling stop and weather briefing at Prince Rupert, British Columbia, the aircraft departed eastbound along the published Telkwa Pass VFR route. When the aircraft did not arrive at Dawson Creek, it was reported overdue. The next day, an extensive search for the missing Otter was commenced and wreckage was located by search and rescue aircraft at 1930 PDT, 30 miles east of Terrace, in the Telkwa Pass. The aircraft had struck mountainous terrain and was destroyed. Both occupants were fatally injured.

Ce rapport est également disponible en français.

Other Factual Information

The pilot-in-command, who was also the owner of Buffalo Narrows Airways, had just purchased the aircraft from Taquan Air in Ketchikan. He and his associate, also a licensed pilot and current on this aircraft type, intended to ferry the Otter to their base of operations in Buffalo Narrows, Saskatchewan. The pilot-in-command had about 10,000 hours total flight time, and the co-pilot had about 5,000 hours. Both pilots were experienced on the Otter, both held valid licences, and both had once held instrument ratings. Neither pilot, however, had significant experience flying in mountainous terrain.

Witnesses observed the pilot-in-command in the left-hand seat and the
co-pilot in the right-hand seat during the take-off from Seal Cove, the water aerodrome at Prince Rupert. The aircraft was not equipped with rudder control pedals on the right-hand side, nor were they required by regulation. Pathological examinations identified injury patterns to both occupants which were consistent with high speed impact. The injuries to the pilot's hands and feet were not consistent with the characteristic injury patterns normally identified with manipulating the flight controls at impact. The co-pilot, however, did exhibit injuries consistent with manipulating the flight controls at impact. Nevertheless, during the impact sequence, the occupants tumbled several thousand feet down the mountainside, and the observed injury patterns were not considered as definitive evidence to positively identify which pilot was at the controls. Although it would have been possible for the pilots to have exchanged seat positions while in flight, there is no conclusive evidence that they had done so.

The aircraft had just been completely rebuilt by Taquan Air, and it was flown on a one-hour test flight prior to this ferry flight. The cargo on board the Otter at take-off from Ketchikan included all the known technical records for the aircraft, and spare aircraft parts for the floats and landing gear assemblies. As well, there were eleven 5-gallon plastic gasoline containers. Ten of these were filled with fuel and one with aircraft engine oil. The containers were reportedly not restrained by either a cargo net or tie-down devices. The pilot checked the aircraft fuel tanks for water before the aircraft departed Ketchikan.

Based on the amount of cargo carried on board at the time of departure from Ketchikan, the centre of gravity of the aircraft was estimated to have been within the prescribed limits, and the aircraft weight was estimated to have been close to the maximum allowable of 8,000 pounds. Neither the draft of the floats before the aircraft began to water taxi nor the length of the take-off run was excessive.

The pilot landed at Prince Rupert to clear Canadian Customs, refuel, and obtain a weather briefing. The aircraft was refuelled with 100 octane low-lead aviation gasoline, and the forward, centre, and aft fuel tanks were filled to capacity. Following the accident, the distributor of the aviation fuel at Seal Cove tested the fuel source and found no evidence of water or other contamination.

The Prince Rupert flight service station (FSS) specialist provided the pilot with a comprehensive weather briefing, covering both the Skeena River and Telkwa Pass published VFR routes through the mountains. Although the weather forecast called for visual meteorological conditions (VMC) on both routes, the specialist recommended that the pilot take the Skeena River VFR route so that he could use lower en route altitudes if he encountered adverse weather. The pilot expressed his preference to fly the Telkwa pass because it was significantly shorter.

Reduced visibility in snow showers was forecast because of convection-type activity. During the briefing, the FSS received a pilot report (Pirep) which indicated that the Telkwa Pass route was open at that time. The ceiling in the pass was reported to be 6,500 feet above
sea level (asl), 3,500 feet above ground level at the highest point in the pass. The visibility was reduced occasionally to 10 miles in light snow showers. A video recording, taken by the pilot who made the Pirep two and one-half hours before the Otter entered the Pass area, showed good visual meteorological conditions. Light turbulence was also evident in the recording.

The occurrence flight departed Seal Cove at 1307 PDT, and the pilot reported to the Terrace FSS at 1416 PDT that he was 10 miles south of Terrace at an altitude of 4,500 feet asl. The FSS specialist advised the pilot that the current Smithers weather, 30 miles further east along the flight-planned route, was as follows: estimated broken ceiling at 6,500 feet asl; visibility 25 miles; temperature 6 degrees Celsius; dew point -8 degrees Celsius; wind 120 degrees magnetic at 7 knots; altimeter setting 30.27 inches of mercury; nine-tenths towering cumulus cloud coverage; and virga and rain showers in all quadrants.

At 1429 PDT, the pilot reported his position to the Terrace FSS as 15 miles east of Terrace. He advised that they were encountering light snow showers and asked if there were any current Pireps which might indicate the extent of this shower activity; there were no recent reports available. No other radio communication from the flight was received by the Terrace FSS. An emergency locator transmitter (ELT) signal from the aircraft was later received by a search and rescue satellite (SARSAT).

Aerial reconnaissance did not establish the initial point of impact; however, the aircraft's engine was located at 7,000 feet asl, snagged in a rock outcropping on a 60-degree slope. It had apparently fallen down the steep terrain from a higher elevation.

Other pieces of wreckage, including two floats, part of a wing, other small aircraft pieces, and the plastic fuel containers, were located further down an avalanche slide area. Most of the wreckage was not visible, likely because it had been buried in snow or loose rock. The bodies of the pilot and co-pilot were found at about 4,000 feet asl, at the base of the slide area.

Only a small amount of wreckage was found at the accident site, and there was clear evidence of recent avalanche activity. The accident site was considered extremely hazardous because of the risk of avalanche or rock slide, and a ground examination of the limited wreckage was therefore not undertaken by accident investigators; however, a limited aerial examination was conducted. The accident site was overflown several times during the summer after the snow had melted, but no additional wreckage was discernible.

Because of the hazardous nature of the site and the complete loss of the technical records which were on board the aircraft at the time of the accident, it was not possible to complete a technical investigation of the aircraft wreckage or aircraft documentation. There was no direct evidence found to suggest an in-flight breakup of the aircraft.

Analysis
The absence of aircraft wreckage and documentation precludes an analysis of the technical aspects of this accident. This analysis, therefore, concentrates solely on the operational aspects.

The high impact speed is indicative of either a loss of control followed by a rapid descent into terrain or controlled flight into unseen terrain. Given that the pilot reported encountering snow showers within 15 miles of the accident site, it is possible that the weather continued to deteriorate and may have adversely affected the pilot's ability to maintain visual contact with the terrain.

Findings

- The weight and centre of gravity of the aircraft at the last take-off were estimated to have been within the prescribed limits.

- The pilot was certified, trained, and qualified for the flight in accordance with existing regulations.

- Marginal visual weather conditions existed in the vicinity of the accident site.

- It is possible that deteriorating weather affected the pilot's ability to maintain visual contact with the terrain.

Causes and Contributing Factors

It was not determined why the aircraft struck terrain; however, it is likely that the contact occurred during conditions of reduced visibility.

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 19 February 1997.

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
Main Rotor Strike
Pemberton Helicopters Inc.
Bell 206B II, C-GJPK
Squamish, British Columbia 10 nm East
26 June 1996

Report Number A96P0105

Summary

The British Columbia Ministry of Forests, Forest Service division, chartered the Bell 206B helicopter, serial number 1206, to fly two inspectors to various logged areas to conduct an aerial and surface inspection. The helicopter pilot was to land and let the inspectors out of the helicopter at a clearcut so they could inspect it from the ground. The terrain was sloped at angles ranging from 15 to 25 degrees and was transected by a decommissioned logging road.

The pilot attempted to off-load his passengers while touching down on one skid on the off-level road. The skid had just touched down when the pilot determined that the site was not suitable, and he had just decided to reject the landing when he detected a vibration in the cyclic control. The passengers heard a bang. The pilot immediately raised the collective control and brought the helicopter up 10 feet. He then turned about 270 degrees to the right in an attempt to find a more suitable landing site. The vibrations increased in intensity during the turn, and the pilot noticed that the main rotor speed was decaying. He attempted to land on the off-level road; however, on touchdown, the helicopter rolled over, coming to rest almost upside down. The front-seat passenger received a cut to the head from flying debris and the rear-seat passenger was bruised; the pilot was not injured. The helicopter was substantially damaged. All occupants were able to exit from the helicopter with some help from each other. One passenger climbed up the slope and radioed for help. A helicopter was dispatched to the site with a first-aid attendant.

Ce rapport est également disponible en français.
Other Factual Information

Helicopters are frequently used during logging operations and pilots often use the access roads as landing sites. Ministry of Forests regulations require logging companies to dig up the access roads used by the logging trucks when the logging operation is terminated so that the area can return to its natural state more quickly. Both air and ground checks are conducted as part of the required final harvesting inspections. The area of mountainside where the accident took place had been logged and the access road on this cut block had been decommissioned. In combination with the steep slope of the terrain, this left no suitable place for a helicopter to make a normal landing.

The pilot decided to attempt to disembark the passengers by placing one skid on the ground to stabilize the helicopter while the passengers exited. The site at which the pilot was attempting this hovering landing was a mound of gravel on the former logging road. Upon closer examination, however, the pilot felt that the site was not sufficiently stable for disembarking the passengers, and he had just made the decision to reject the landing when the bang and vibration were noted. There was a suitable landing site within one mile of this area, and the pilot had been planning to land there if he found no means of dropping off his passengers at this location.

The hovering landing technique of placing one skid on the ground to stabilize the helicopter while holding the other skid level, without actually landing, is a recognized practice when embarking and disembarking properly briefed passengers on off-level terrain. The passengers had only been briefed for an exit following a normal landing, however, and exiting a helicopter when some or all of its weight is still supported by main rotor lift involves different techniques and considerations on the part of the passengers and the pilot. That the passengers had not been briefed was another factor in the pilot's decision to reject the off-level, hovering landing.

The approach to the site was made parallel to the road; to the left of the helicopter was higher terrain containing tree stumps. On examination, the tree stumps were found to exhibit numerous cuts and marks as a result of the logging operation, and it was not possible to determine if any of the stumps had been struck by the main rotor blades. One stump, however, was within the plane of the main rotor and was high enough to have been struck by the blades as the helicopter touched down on one skid.

The main rotor shaft sheared during the accident sequence, and the main rotor hub, with parts of the blades still attached, was found 45 feet from the wreckage. Wood fibres were found lodged in a blade tip, and chordwise scratches were etched into the bottom surface of the blade. The other blade tip was not found.

The pilot had begun working for the company two-and-a-half months before the accident. He had accumulated over 3,000 hours of flying experience since starting his flying career in 1991. He held the appropriate licences and ratings.
The pilot was wearing his seat-belt, shoulder harness, and a helmet. Shoulder harnesses were available to both passengers but neither was wearing one at the time of the accident. Air Navigation Order (ANO) Series II, Number 2 requires that a shoulder harness be available and be worn by every person on board during special purpose operations such as this aerial survey work.

The passengers were familiar with helicopter operations; both had been passengers on numerous similar flights. They reported that they were uncomfortable with the area the pilot had chosen to land as they had expected to exit the helicopter after a normal landing. They did not communicate their discomfort to the pilot.

The helicopter was not equipped with an emergency locator transmitter (ELT) on this particular flight because it had been removed for maintenance that morning. ANO Series II, No. 17, the *Emergency Locator Transmitter Order*, permits operation of aircraft without an ELT provided the aircraft remains within 25 nautical miles of the aerodrome of departure. The area in which the helicopter was operating was within 25 nautical miles of the point of departure. The lack of an ELT did not cause any delay in the rescue of the helicopter's occupants because the inspectors were carrying Forest Service two-way radios.

**Analysis**

A bang, vibrations, and a loss of rotor speed are typical symptoms of a main rotor strike. Although no clearly identifiable rotor strike marks were found on the stumps in the area of the attempted landing site, the marks and the trapped wood fibres on the main rotor blade tip are consistent with a rotor strike, likely against a stump that protruded into the area of the rotor disk.

It is likely that, when the pilot approached the decommissioned road, his attention was focused on evaluating the suitability of the landing surface and he did not recognize that a stump extended into the main rotor disk area. Although the helicopter was airborne, the vibrations and the decaying main rotor speed which resulted from the strike forced the pilot to land immediately. The helicopter touched down on the steep sloping terrain and rolled over.

**Findings**

- The pilot attempted an off-level, hovering landing at an unsuitable site.
- The main rotor blade likely struck a stump, causing vibrations and the main rotor speed to decay.
- The pilot was forced to land on steep sloping terrain, which caused the helicopter to roll over.
- The passengers were not wearing the available shoulder harness.
harnesses.

Causes and Contributing Factors

The pilot was attempting a hovering landing at an unsuitable site when the main rotor blades likely struck a stump. The pilot was subsequently forced to land on steep sloping terrain, which caused the helicopter to roll over.

Safety Action Taken

Following this accident, the BC Ministry of Forests took the following actions:

- Forestry inspectors were coached to be more vocal in situations where they felt uncomfortable;

- A memo was issued to employees reminding them of the policy requiring the wearing of shoulder harnesses during flights; and

- A new policy was established requiring that an ELT be carried on board any aircraft chartered by the Ministry regardless of the circumstances.

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 05 March 1997.

Updated: 2002-10-06
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
Loss of Control - Stall
Piper PA-28-151 Warrior C-GHWH
Nelson, British Columbia 30 nm East
07 July 1996

Report Number A96P0112

Summary

The Piper aircraft, C-GHWH, departed the Nelson airport, British Columbia, at about 1225 Pacific daylight saving time (PDT)(1) in support of a Canadian Forces search and rescue (SAR) mission. The aircraft was part of the Civil Air Search and Rescue Association (CASARA) assignment. The crew, consisting of a pilot, a navigator, and an observer, were tasked to search an area east of Nelson and west of Cranbrook for a recently missing Piper PA-28 aircraft. At 1300, the accident pilot broadcast on the radio that all search operations were normal. At about 1340, an observer on board a Canadian Forces SAR aircraft spotted smoke coming from a downed aircraft, later identified as C-GHWH; it had been destroyed by the crash and post-impact fire, and the three occupants were fatally injured. There were no witnesses to the accident. The object of the SAR mission, missing PA-28 aircraft C-GNXV, was found later the same day; it had crashed in mountainous terrain north of Nelson. (Refer to TSB file number A96P0111.)

Ce rapport est également disponible en français.

Other Factual Information

The weather in the vicinity of the accident site was reported to be clear, about 10 degrees Celsius, with the winds from the northwest at 20 knots. The only reported turbulence in the accident area was near mountain peaks. There are few surface features in the mountains to provide pilots with reliable clues as to local wind speed and direction. Several search pilots reported smooth flight conditions in the mountain valleys and cirques, although one stated that he encountered a smooth updraft of approximately 1,000 feet per minute.
The wreckage was located at the 5,800-foot level on a 35-degree slope of Snowcrest Mountain. The aircraft had struck the ground at low speed, in a flat attitude relative to the surface. The burned-out aircraft was surrounded by small trees, and the fire had spread about 150 feet up the hill. An examination of the wreckage did not reveal any conclusive evidence of the direction of flight before impact; however, the orientation of the fuselage at rest facing towards the end of the valley suggests that the aircraft had been flying in that direction. Ground scars revealed forward movement of less than 3 feet after impact, and there was no damage to any of the surrounding trees.

The aircraft fuselage was largely consumed by a fuel-fed, post-crash fire. Both wings were essentially intact and in position, as was the empennage. Severe fire damage precluded the recovery of any cockpit instruments or switches that could have yielded any useful information. The flaps were found set at the first notch (10 degrees). All primary flight control cables and control surfaces were found intact. There was no evidence found of any airframe failure or system malfunction prior to impact, and the pilot had given no indication of any problems when he radioed in at 1300 PDT.

The engine was taken to the TSB regional wreckage examination facility for examination; no evidence of pre-impact failure was found. The propeller damage was consistent with the characteristic damage patterns of a propeller being powered at impact.

A review of the available aircraft records indicated that the aircraft was certificated, equipped, and maintained in accordance with existing regulations and approved procedures. The aircraft weight at take-off was estimated to have been at or near the maximum gross weight, and the centre of gravity of the aircraft was estimated to have been within the prescribed limits at the time of departure.

The pilot was licensed and qualified for the flight in accordance with existing regulations, and there was no evidence that physiological factors affected his performance. The pilot had previous experience on CASARA missions, and was trained and qualified in accordance with the CASARA standards.

The type of search pattern used during this particular aerial search is known as "contour searching." The recommended procedure is to maintain a constant altitude above the contours of the mountainous terrain, starting at the peak and working down the mountain. The CASARA training manual advises that contour searching in mountainous terrain is considered to be one of the most dangerous and difficult types of visual searches. The CASARA pilots in British Columbia receive both classroom and airborne training in the various search profiles, and the accident pilot had taken this type of training.

The pilot's assigned search area was to have been flown at a height of 1,000 feet above the contours; this height would have afforded the searchers an effective visual searching range of one mile. The pilot had been assigned a 500-foot altitude restriction in his morning search area. At the time that the accident aircraft was to have been transiting
to the search area, another search pilot saw it heading in the opposite direction. When questioned, the accident pilot replied that he did not have enough altitude to enter the mountainous search area, and that he was trying to gain altitude before entering the search area.

The aircraft manufacturer's performance charts for the PA-28-151 indicated that the maximum climb performance at the density altitude of 6,400 feet computed for the occurrence site was approximately 370 feet per minute, at the best rate-of-climb speed of 87 mph. The turning radius of the aircraft at this higher density altitude would have been greater than that at sea level for the same indicated airspeed.

Analysis

Mechanical malfunction was not considered a likely factor in this accident because no evidence was found of any airframe, engine, or system malfunction or failure prior to impact, and the pilot had given no indication of any problems when he radioed in at 1300.

The aircraft's flight path and altitude prior to the occurrence are not known. The evidence of the aircraft's rather flat attitude relative to the sloped surface of the mountain and the low speed at impact, the short wreckage trail, and the wreckage damage patterns are all consistent with the aircraft stalling and entering an uncontrolled descent to the ground during a turn at a low height from which recovery was not possible. Because there were no witnesses to the accident, it could not be determined why the aircraft stalled and crashed to the ground.

Findings

- The pilot was certified and qualified for the flight in accordance with existing regulations.
- There was no evidence of any airframe, engine, or system malfunction or failure prior to impact.
- There were moderate to strong winds and reported updrafts in the area at the time of the accident.
- The aircraft was operating at a density altitude which adversely affected the aircraft's rate-of-climb and turn radius.
- The aircraft crashed in an uncontrolled, stalled flight condition, probably from a low altitude, for reasons undetermined.

Causes and Contributing Factors

The aircraft stalled and crashed to the ground for reasons undetermined.

Safety Action

The British Columbia chapter of CASARA held an executive meeting on
20 July 1996. It was resolved at that meeting that any aircraft involved in close contour searches of mountainous terrain must have engines with a minimum power rating of 200 horsepower.

*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 05 March 1997.*

1. All times are PDT (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 150, C-FLYU
Powell River, British Columbia
21 July 1996

Report Number A96P0132

Summary

The Cessna 150, with the pilot and one passenger on board, departed from the Powell River Airport, British Columbia, at about 2030 Pacific daylight savings time for a local sightseeing trip. It was the pilot's intention to fly overhead a house where friends had gathered for a social occasion. The house was located within a housing subdivision, one-half mile southwest of the airport. The pilot approached the house at a low height above the ground, rocked the wings, and entered a steep, left turn. The turn was completed and, as the wings levelled, witnesses heard the engine stop and saw the nose of the aircraft pitch down slightly. There was then a momentary recovery to level flight from the nose-down attitude, followed by an abrupt aerodynamic stall. The aircraft then descended in a steep nose-down attitude, striking the side of a house and the ground. Both occupants were fatally injured. The aircraft was substantially damaged. There was no fire.

Ce rapport est également disponible en français.

Other Factual Information

The pilot was licensed and qualified for the flight in accordance with existing regulations, and there was no evidence that physiological factors affected his performance.

The weather conditions reported at the time of the accident were 4,000 feet scattered, visibility 25 miles, temperature 22 degrees Celsius, and calm winds.

A review of the available aircraft records indicated that the aircraft was certificated, equipped, and maintained in accordance with existing regulations and approved procedures. The weight and centre of gravity
of the aircraft were estimated to have been within the prescribed limits.

An examination of the wreckage revealed no evidence of any pre-existing mechanical deficiencies which could have contributed to the accident. The wings contained a quantity of fuel and had been separated from the fuselage by the rescue crews to reduce the risk of fire. Because the fuel lines had been disrupted and the carburettor crushed at impact, the pre-impact serviceability of the fuel delivery system could not be determined.

Witnesses heard the engine sound stop abruptly immediately prior to the aerodynamic stall. One witness, an experienced pilot, observed the propeller windmilling just prior to the stall; another witness observed that, after the stall and the instant before impact, the propeller appeared to have stopped. Witness estimates of the height of the aircraft while it was manoeuvring above the houses vary from 80 to 200 feet.

The aircraft engine was taken to the TSB Regional wreckage examination facility for examination. No evidence of pre-impact failure was found, nor was anything found which could explain the power loss. The exhaust pipe was bent and crushed during the impact. The engine rpm tachometer and a portion of the exhaust pipe were sent to the TSB Engineering Branch Laboratory for examination. It was concluded that the exhaust pipe was below operational temperatures when the crushing and bending occurred. The examination of the tachometer found that the engine rpm at impact may have been between 300 and 1,000. This rpm range is not necessarily indicative of an operating engine, because a propeller can "windmill" in descending flight, being driven by the airflow without engine power driving it. The damage to the propeller was consistent with the damage patterns characteristic of a propeller that was not powered at impact.

To provide pilots with a reasonable altitude buffer to manoeuvre in the event of an emergency, Air Regulation 534(2)(a) requires, in part, that no person shall fly an aircraft over a built-up area of any city or town at an altitude less than ":1,000 feet above the highest obstacle within a radius of 2,000 feet from the aircraft."

Analysis

The reports of the windmilling and then stopped propeller, the damage to the propeller, and the sudden loss of engine sound, combined with the evidence provided by the exhaust pipe damage and engine tachometer markings, are all consistent with a loss of engine power before impact. However, the reason for the power loss could not be determined.

The loss of engine power causes neither an aircraft to stall, nor a pilot to lose control of the aircraft. The accident aircraft, however, was operated at a low height above ground when the power loss occurred, and it likely stalled when the pilot tried to prevent the aircraft from descending any lower. Without sufficient height above the houses, the pilot could not recover from the stall.
Had the aircraft been higher above the ground when the engine lost power, the pilot would have had greater opportunity to recover from the stall, and to attempt an engine restart or to carry out a forced landing in a more suitable area.

The following TSB Engineering Branch reports were completed:

- LP 106/96 - Tachometer Examination;
- LP 107/96 - Exhaust Stack Temperature.

Findings

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

- The aircraft was certificated, equipped, and maintained in accordance with existing regulations and approved procedures.

- The weight and centre of gravity were estimated to have been within the prescribed limits.

- There was no evidence of any pre-existing mechanical defects which could have contributed to the accident.

- The aircraft was operated at a low height above ground when the engine lost power for undetermined reasons.

- The aircraft stalled, likely as a result of the pilot attempting to maintain height.

Causes and Contributing Factors

The pilot was flying the aircraft at less than 1,000 feet over a built-up area. The operation of the aircraft at low altitude did not permit him to recover from the stall following the loss of engine power.

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 January 1997.
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
In-flight Engine Fire and Separation
Air North
Douglas DC-4(C54A-DC) C-FGNI
Bronson Creek, British Columbia
14 August 1996

Report Number A96P0175

Summary

The DC-4 aircraft (serial number 10389) was on a visual flight rules flight from Bronson Creek, British Columbia, to Wrangell, Alaska, with a crew of three and about 16,600 pounds of cargo on board. The departure from the remote mining strip was uneventful until the aircraft approached 1,500 feet above sea level, when the crew heard a whining noise in their headsets. Believing that the whining was caused by an inverter problem, they switched inverters, but the problem persisted. Electrical instrument indications in the cockpit then became erratic, and the number 2 engine, on the left wing, began to misfire; its fire warning light in the cockpit illuminated briefly, but without the accompanying bell. The captain confirmed visually that the number 2 engine was on fire and the crew carried out the engine fire drill; however, the fire did not extinguish. The captain commenced a right-hand turn to return to the Bronson Creek airstrip, and announced to the crew that the number 2 engine had separated from the wing. The captain applied maximum power to the three remaining engines; however, the aircraft began to lose altitude. Both pilots held the rudder and aileron controls at full right deflection in an attempt to prevent the aircraft from yawing or rolling to the left. The aircraft was shaking violently at that time, and the crew members were unable to read any of the engine or flight instruments. At about 50 feet above ground level, just short of the Iskut River, the pilots closed the throttles. The aircraft descended rapidly, and the burning left wing struck a tree just as the fuselage contacted the surface of the river. The three occupants escaped the burning aircraft, and the first officer and load master swam to safety. The captain is missing and is presumed to have drowned. The aircraft was destroyed.

Ce rapport est également disponible en français.
Other Factual Information

The accident site is located in the Iskut River, at 56°41.57 North and 131°06.22 West, 1.2 nautical miles (nm) from the Bronson Creek airstrip. The crew escaped the partially submerged cockpit by jumping into the river out the right-hand side, the captain and first officer through the cockpit window, and the load master through the crew door.

Helicopters from Bronson Creek were at the site in less than 10 minutes, and rescuers located the first officer and load master on the south shore of the river. They began to search for the captain almost immediately; three helicopters and three vessels were involved. The RCMP and search and rescue personnel continued to search the river downstream of the accident for two additional days, but did not find the captain.

The number 2 engine and propeller were found about 2.3 nm from the crash site. The engine was recovered and transported to the TSB Regional wreckage examination facility. Sections of the firewall and the engine mounts were subsequently sent to the TSB Engineering Branch for further examination.

Portions of the burned-out left wing and the number 1 engine have since been recovered by salvage crews; however, the strong river current and fluctuating water levels have prevented further recovery of the aircraft wreckage or engines. Therefore, the technical content of this report concentrates on the available airframe and engine records, and the physical examination of the recovered number 2 engine.

The flight crew was licensed and qualified in accordance with existing regulations, and both pilots had successfully completed their recurrent training on the DC-4 aircraft in September 1995. The captain had accumulated a total of about 12,500 hours of flying time, including 1,500 hours on type, while the first officer had accumulated a total of about 2,900 hours of flying time, including 420 hours on type. The crew had been on duty for about five hours, and this was their third flight of the day.

The aircraft operation at Bronson Creek involved flying ore concentrate from the mine to nearby Wrangell, where it was taken by surface transportation to a smelter. The flights were normally of short duration, usually conducted at near-maximum gross weight for the aircraft, and were flown in mountainous terrain. Flight operations were demanding for both pilots and aircraft because they involved repetitive, short, and arduous flights. As a result, the ageing DC-4 aircraft required, and received, intense maintenance attention.

Available aircraft records indicate that the 51-year-old airplane was maintained in accordance with existing regulations. It had accumulated 50,754.8 hours total airframe time, and the last 50-hour inspection had been completed on 05 August 1996. Four days before the accident, the carburettor and the fuel pump were changed on the number 2 engine.
At the time of take-off, both the aircraft weight of about 61,900 pounds and the centre of gravity were within the prescribed limits. A DC-4 performance graph (circa 1946) for one engine inoperative indicates that the aircraft should have been able to maintain a rate-of-climb of 550 feet per minute. This performance prediction was based on a new airframe and specification engines. No graph is available for the situation where an engine falls off the aircraft, thereby inducing unpredictable factors such as increased airframe drag, sudden weight and balance changes, and profoundly detrimental aerodynamic effects. As well, the theoretical performance figures do not account for the effect of airframe ageing and a service life of more than 50 years and 50,000 flight hours.

The natural tendency of an aircraft, under conditions of asymmetric thrust, is to roll and yaw towards the engine that is not producing thrust. Control inputs are required to offset this tendency, but if the airspeed of the aircraft falls below the speed for minimum control in the air (VMCA), flight control inputs alone will not be sufficient to prevent the yawing moment, and control of the aircraft will probably be lost if the pilot does not reduce asymmetric thrust. VMCA for this aircraft with an engine physically separated from the aircraft is unknown.

The number 2 engine was a Pratt & Whitney R2000-7M2 (serial number P-108882) reciprocating radial engine, and had a Hamilton Standard 23E50-473 propeller (serial number FC-3492). The engine had accumulated 1,241 hours since its last overhaul, and 19.8 hours since its last inspection; the propeller had accumulated 2,314.6 hours since its last overhaul, and 19.8 hours since last inspection. The propeller, which had separated from the engine, was examined at the site, and no evidence of pre-existing failure or malfunction was found.

Control cables for both left-wing engines were routed down the left wing, and the cables for the number 1 engine passed behind the number 2 engine. These two engines shared common cable pulley brackets in the vicinity of the number 2 engine; the physical separation of the number 2 engine from the wing, therefore, would have affected the number 1 engine controls since the pulley brackets would have been disrupted.

The examination revealed that the number 2 engine and firewall had separated from the wing when the aluminum support channels failed. These channels, located aft of the firewall, held the steel fittings that attached to the engine mounts, and these steel fittings were still attached to the detached engine. The two inboard aluminum channels exhibited "broom-strawing" patterns, melting, and other damage consistent with exposure to high heat, while the outboard channels showed evidence of mechanical stress.

Examination of all available engine and nacelle components revealed that the fire was in the engine compartment, between the firewall and the accessory section of the engine. The components that were located on the inboard, upper side of the accessory section evidenced the greatest heat concentration; this area is adjacent to the engine mounting structure which had melted in several minutes. There were no
signs of intense heat in the lower outboard area of the firewall, indicating that the fire was localized. Potential fuel sources were identified in the upper, inboard area of the firewall, and included several pressurized fuel lines which carried fuel for engine priming and for cockpit indications, and a hydraulic line carrying pressurized hydraulic fluid from the pump to airframe hydraulic systems. Potential sources of ignition for the fire include electrical solenoids, the starter motor, the generator, and exhaust components. However, the actual ignition source could not be identified.

The engine fire extinguishing system is mechanically controlled by the pilots, and consists of selector valves, discharge handles, and four 15-pound carbon dioxide bottles which can be discharged in pairs. There are 17 fire-detecting thermocouples on each engine, as well as 6 thermocouples for the inboard nacelle, and a distribution ring through which the carbon dioxide is delivered to the separate engine sections.

Analysis

Because further recovery of the aircraft wreckage was not possible, this analysis concentrates on the technical aspects of all available airframe and engine records, and the examination of the number 2 engine.

The flight crew were required to deal with multiple emergencies in a short period of time. The flight control difficulties experienced by the pilots are consistent with a significant loss of engine power on the left wing. The physical separation of the number 2 engine from the aircraft likely affected the power output from the number 1 engine, because the departing engine probably interfered with the controls for that engine. The sudden loss of power, and the combination of the significant aircraft weight and balance changes, the impaired aircraft handling characteristics, and the deteriorating in-flight performance would have raised the VMCA to a value above that which the aircraft was able to maintain. Under these circumstances, the crew was forced to reduce power on the engines to maintain control of the aircraft, and had no alternative but to force-land the aircraft.

The sequence of events that led to the accident began with the engine fire, and the electrical malfunctions were the result of wiring burned by the fire. The intense fire damage to the engine and firewall obliterated any evidence which could identify the cause or the source of the fire. The source of a rapid and destructive fire involving the firewall and engine accessories is usually fed by fuel or hydraulic fluid. It is probable that a hydraulic or fuel line became loose or broke and sprayed fuel or hydraulic fluid under system pressure into an area, and that the fluid was ignited by one of the several sources of ignition in that area.

The following Engineering Branch report was completed:

LP 137/96 - Electrical Fire Analysis.

Findings
The crew was certified and qualified for the flight in accordance with existing regulations.

Aircraft records indicate that the aircraft was maintained in accordance with existing regulations.

The aircraft weight and centre of gravity at take-off were within prescribed limits.

An intense, localized fire behind the number 2 engine caused the engine to separate from the aircraft.

The physical separation of the number 2 engine probably interfered with the controls to the number 1 engine.

With maximum power applied to the remaining engines, the pilots could not maintain altitude or directional control because the aircraft speed was below VMCA for that configuration.

The captain was missing following the crash landing and is presumed drowned.

**Causes and Contributing Factors**

The number 2 engine separated from the aircraft as a result of an intense fire in the wing. The loss of the engine rendered the aircraft uncontrollable, and the pilots were forced to land in the river.

*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 9 September 1997.*
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
Controlled Flight into Terrain
Harbour Air Limited
De Havilland DHC-3 Otter C-GCMY
Alliford Bay, British Columbia 18 nm S
18 August 1996

Report Number A96P0178

Summary

The float-equipped, turbine-engine, DHC-3 Otter departed from Tasu, British Columbia, at about 1940 Pacific daylight saving time (PDT), with the pilot and two passengers on board, on a charter, visual flight rules (VFR) flight to Alliford Bay, 26 nautical miles to the north. When the aircraft did not arrive at destination, the operator initiated a search. The aircraft wreckage was located the following day, 18 nautical miles (nm) south of Alliford Bay, in rugged terrain at an elevation of 1,700 feet above sea level (asl). The aircraft was destroyed, and there were no survivors.

Ce rapport est également disponible en français.

Other Factual Information

The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. There was no evidence of any pre-impact mechanical or structural failure. The weight and centre of gravity of the aircraft were within the prescribed limits. The pilot was qualified for the flight. There was no evidence that physiological factors affected the pilot's performance.

The aircraft had left Alliford Bay at 1836 PDT and flown to Tasu, on the south end of Newcombe Inlet, to pick up two passengers. As was the informal practice when route weather information was required, the Harbour Air flight dispatcher had called the Sewell Inlet logging camp, located two thirds of the way along the flight-planned route, and requested weather information. There was no weather reporting station at Sewell Inlet and no values of ceiling or visibility were provided to the
Harbour Air dispatcher or recorded elsewhere. The dispatcher was advised by an employee at the campsite that there was light drizzle at this location, and that the visibility was restricted by fog.

The 2000 PDT Environment Canada actual weather report for the Sandspit airport, 6 nm east of Alliford Bay, was as follows: sky condition 900 feet scattered, 2,800 feet scattered, estimated ceiling 4,700 feet broken, 10,000 feet overcast, visibility 15 miles in light rain showers, temperature 14 degrees Celsius, dewpoint 11 degrees Celsius, wind 240 degrees magnetic at 6 knots, and altimeter setting 29.86 inches of Mercury.

At about 1940 PDT, the aircraft departed from Tasu for the 20-minute flight back to Alliford Bay. A witness reported seeing the Otter flying north from Newcombe Inlet and into the valley where it was later found. The witness recalled that, at his position 4 nm south of the accident site, there had been a heavy rain shower lasting several minutes, which had diminished to a light drizzle when the aircraft flew overhead. He was unable to estimate the ceiling or cloud cover at the time.

The pilot's planned route was to leave Tasu heading toward the north end of Newcombe Inlet, cross some low terrain for about two miles, and then turn eastward through a valley to Sewell Inlet en route to Alliford Bay. Just north of the turn-off to Sewell Inlet, there is a valley leading northward into a box canyon where the terrain rises abruptly to 3,350 feet asl. The two valleys are similar in appearance and both have a creek and a road following the valley floor. The aircraft flew past the valley leading to Sewell Inlet, continued north into the valley leading to the box canyon, and subsequently struck the side of the valley at 1,700 feet asl.

Wreckage damage and impact scars indicated that the aircraft was in controlled, wings-level flight and on a heading of about 210 degrees magnetic when it struck the ground. At the accident site, there was characteristic evidence that the engine was delivering power, and the speed at impact was estimated to have been about 80 miles per hour. The Pratt & Whitney PT6 A-135 turbine engine was later examined at the engine manufacturer's facility in Montreal; it was concluded that the engine was operational at the time of impact, and that it was capable of producing maximum rated power. The power setting at the time of impact was not established.

**Analysis**

It is probable, because of low visibility in fog and light drizzle, that the pilot made a navigational error and inadvertently entered the valley to the north rather than turning to the east toward Sewell Inlet. The aircraft heading at impact, 150 degrees off the required heading, indicates that the pilot had turned the aircraft around. This reversal of course could have been made because the pilot recognized that he was in the wrong valley or because he began to encounter adverse weather conditions.

Because the aircraft struck the terrain in a wings-level attitude,
indicating no last-second evasive manoeuvring by the pilot, it is likely that the pilot's forward visibility was restricted and that he did not see the ground in time to avoid impact. If the weather observed by the witness, 4 nm south of the accident site, had prevailed in the valley at the time of the accident, it is likely that the aircraft would have entered the clouds prior to it reaching the crash elevation of 1,700 feet. Once the aircraft was in cloud, the pilot would have had no other option than to climb to avoid the high terrain. It is probable that the pilot delayed his decision to reverse course until he was unable to avoid the weather.

Findings

- The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

- The aircraft weight and centre of gravity were within the prescribed limits.

- No pre-crash airframe failure or engine defect was found.

- The pilot was certified, trained, and qualified for the flight in accordance with existing regulations.

- The pilot probably made a navigational error because of restricted visibility in fog and light drizzle and inadvertently entered the valley toward the north.

- The pilot reversed course because he recognized that he was in the wrong valley or because he began to encounter adverse weather conditions.

- It is probable that the pilot delayed his decision to reverse course until he was unable to avoid the weather.

- It is probable that the pilot entered cloud and did not see the ground in time to take evasive action.

Causes and Contributing Factors

The pilot probably made a navigational error because of restricted visibility in fog and light drizzle and entered the wrong valley, and he delayed his decision to reverse course until he was unable to avoid the weather.

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 14 May 1997.
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.

Collision with Water
Wayco Aviation
Cessna 180J C-FRLI
Knot Lake, British Columbia
07 September 1996

Report Number A96P0201

Synopsis

The pilot departed Nimpo Lake, British Columbia, in the float-equipped Cessna 180J aircraft at about 1020 Pacific daylight saving time (PDT) for a 25-minute visual flight to Knot Lake, 35 nautical miles southwest. This was the pilot's second flight of the day, the first being to another lake located in the vicinity of Knot Lake. When the aircraft had not returned to Nimpo Lake by 1330 PDT, the company owner took off from Nimpo Lake in a Beaver aircraft to conduct an aerial search. He heard the signal from an emergency locator transmitter (ELT) near Knot Lake; however, he could not locate the source. He then returned to Nimpo Lake and notified the Rescue Coordination Centre (RCC). The missing aircraft was found later that day on Knot Lake, partially afloat and sinking. The pilot had been fatally injured, and his body was recovered from the submerged aircraft the next day by RCMP divers.

Other Factual Information

The purpose of the flight was to pre-position a client's personal belongings and equipment at Knot Lake. At the time of the accident, the aircraft contained 175 pounds of belongings, a 70-pound outboard motor, 40 pounds of outboard motor gasoline, and the 190-pound pilot. The weight of the fuel in the aircraft tanks was estimated to have been 200 pounds. The aircraft weight at take-off was estimated at 2,600 pounds; the maximum allowable weight was 2,950 pounds. A cargo net was available to secure the cargo, but it is not known if it was used on this flight.

The aircraft was equipped with shoulder harnesses; however, the RCMP divers reported that the pilot was wearing only the lap belt when they removed him from the aircraft. The medical investigation revealed
that he had received a severe head laceration and had drowned. Toxicological testing excluded the presence of alcohol and drugs.

The aircraft sank to the bottom of the east side of the lake in about 35 feet of water, and it is probable that the point of water impact was nearby. The RCMP divers reported that the fuselage was damaged, although, with underwater visibility of less than one metre in the heavily silted lake, they were unable to determine the extent of that damage. They reported that both floats were separate from the aircraft, that the left wing had separated from the aircraft and was missing, and that the propeller and the engine mounts were bent. The described damage is consistent with the characteristics of damage resulting from a cartwheeling impact with the water. Because of the winter freeze-up, the aircraft was not recovered.

The aircraft maintenance log-books contained no evidence of deficiencies relevant to the circumstances of the accident. The aircraft journey log-book was in the aircraft and was not recovered. Records show that the aircraft had flown a total of 6,965.5 hours, the engine had been overhauled at 1,470.4 hours, and the wing and tail bolts were last inspected on 06 July 1996.

The pilot began his employment as an office manager for Wayco Aviation in June 1996. He flew occasional trips as a co-pilot until 23 August 1996, when he was assigned to pilot-in-command flying duties. The pilot had a commercial licence with multi-engine and float endorsements, a class one instrument rating, and a valid medical certificate. At the time of the accident, he had about 850 total flying hours, of which 212 hours were on float-equipped aircraft. He had flown about 20 hours with the company before the accident and had landed at Knot Lake on at least seven other occasions.

The pilot's employer had flown with him a number of times and considered him to be a competent pilot, as did other company pilots who had flown with him. Those who had seen him the night before the accident reported that he went to bed early. Those who saw him in the morning observed that he appeared rested and that nothing in his manner was out of the ordinary.

Wayco Aviation pilots are able to obtain an aviation area weather forecast by calling a "1-800" number. It is not known if the pilot used this service before the occurrence flight; however, as it was his second flight into the area that day, he would have had first-hand knowledge of the local weather.

Persons fishing at the north end of Knot Lake, about a mile from the accident site, saw the accident aircraft fly overhead from north to south. They estimated that the aircraft was five seconds from landing when they lost sight of it behind a spit of land, but they did not see the accident. They reported that the surface of the lake was very rough and that whitecaps were present. There was no one found who had witnessed the accident.

The Wayco Aviation company owner reported that when he was at the
accident site about two hours after the accident occurred, the cloud base and the visibility were suitable for operations at the lake. He described the location on the lake where the accident pilot apparently chose to land as being at the confluence of two airflows, one from the prevailing south wind and one caused by air flowing down a glacial ravine onto the lake from the west. He said that the mixing of these two airflows often created an area of hazardous turbulence. He noted that the air was turbulent and the water rough, and that, although the Beaver aircraft was better suited to rough-water landings than was the Cessna 180, he had to carefully select a landing area and then exercise caution during the landing.

The pilot who found the missing aircraft often flew to Knot Lake, and he, too, reported that landing conditions are often hazardous when the described wind conditions are present. He arrived at the accident site about three hours after the accident occurred and saw water spouts up to 60 feet in height rising from the lake surface. He said that he would not have landed had he not spotted the missing aircraft in the water.

Analysis

The aircraft damage described by the RCMP divers is typical of damage that occurs when an aircraft has cartwheeled on the water after having struck the water with a wing tip. However, why and in what attitude the aircraft struck the water was not determined. It is probable that the pilot encountered turbulence and lost control of the aircraft during an attempted landing.

It was not determined if the pilot's head injury was the result of him either striking the aircraft or being struck by loose cargo during the crash sequence. It was also not determined if the severity of the pilot's injuries would have been reduced had he been wearing the available shoulder harness.

Findings

1. The pilot was not wearing the available shoulder harness.

2. The aircraft was maintained in accordance with existing directives.

3. Strong winds known to cause hazardous turbulence were present in the area at the time of the accident.

4. It is probable that the pilot encountered turbulence and lost control of the aircraft during an attempted landing.

Causes and Contributing Factors

The aircraft struck the water and crashed, probably because the pilot encountered turbulence and lost control of the aircraft during an attempted landing.

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 14 May 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
Transmission Spindle Mount Failure
Transwest Helicopters Ltd.
Bell 214B-1 (Helicopter) C-GTWH
New Denver, British Columbia 10 nm SE
16 October 1996

Report Number A96P0231

Summary

The Bell 214B-1 helicopter (serial number 28017) was engaged in heli-logging operations 10 nautical miles southeast of New Denver, British Columbia. At about 1500 Pacific daylight saving time (PDT)\(^1\), the helicopter was just beginning to pick up two logs when the pilots heard a loud bang from the rear of the aircraft; the helicopter continued flying briefly and then began to rotate in a clockwise direction. Ground witnesses who heard the loud bang observed that the tail rotor stopped turning. The pilot assessed that he had experienced a tail rotor failure and carried out the associated emergency procedures. He landed the helicopter at the edge of the logged area near a stand of small trees and beside a gully. The main rotor blades struck the trees, and the helicopter rolled over into the gully. The co-pilot was seriously injured, and the pilot received minor injuries. The ground crew assisted the pilots in evacuating the aircraft and then put out a small fire in the engine area. The helicopter was substantially damaged.

*Ce rapport est également disponible en français.*

Other Factual Information

Records gathered during the investigation reveal that the pilot was certificated and qualified in accordance with existing regulations. He had returned to work the day prior to the accident after two weeks off. On the day of the accident, flying had begun at about 1030; a two-hour break had commenced about an hour later while the ground crew moved their equipment to a new logging area. The heli-logging operation had been underway in the new area for about 1½ hours before the accident.
Each pilot was wearing a flying helmet, but neither pilot was wearing his available shoulder harness. It was not practicable for the pilots to wear shoulder harnesses because the pilots needed to lean to the side of the cockpit and look down through an open door or bubble window to continually observe the longline, the load, the tail rotor clearance, and the ground.

An examination of the helicopter at the accident site revealed that the tail rotor drive shaft had sheared aft of the main rotor transmission gearbox at the point where the drive shaft enters a protective tunnel underneath the engine. The helicopter was transported to the operator's base for further examination. The left, upper transmission spindle mount (PN 214-030-606-005) was found to have broken and the fracture showed characteristics of fatigue. The broken transmission mount was sent to the TSB Engineering Branch Laboratory for microscopic examination.

It was found that fatigue cracking had occurred at the radius between the barrel and the shoulder portion of the spindle. The crack had continued to grow as a result of alternating stages of fatigue and overload until a critical stage was reached when the spindle failed. Neither the originating cause nor the time interval for the crack propagation could be determined. There was no evidence of a manufacturing defect, and the spindle met all specified dimensional criteria.

The transmission spindles installed in the Bell 214B are replaced on the basis of their condition and, therefore, have an unlimited service life. As a result, the spindles are not monitored by a component tracking system, and the complete service histories of these parts could not be determined. Upon initial delivery from the Bell Helicopter Textron Incorporated (BHTI) factory, the spindles were attached to a main rotor transmission with a different serial number. That transmission was later involved in an accident that caused a sudden main rotor stoppage, which would have imposed high stress loads on the spindles.

Because of the lack of component documentation, it could not be determined if the occurrence spindles were the same spindles as were on the transmission at the time of the previous accident. Both occurrence spindles showed evidence of reworking at some time in their service life.

The Bell 214B helicopter main rotor transmission requires an overhaul every 2,500 hours of service life. A newly overhauled transmission had been installed on the accident helicopter on 17 April 1996, and records show that the helicopter had flown 810.3 hours since. The BHTI Component Repair and Overhaul (CRO) manual requires that the spindles be examined both visually and with a magnetic particle inspection (MPI) process during the overhaul.

The overhaul of the complete transmission was carried out by Transwest Helicopters in their own maintenance facility, and
components requiring a non-destructive testing (NDT) process were sent to an independent, approved testing facility. The operator had purchased a time-expired, lower transmission case unit from another helicopter operator; they separately purchased an upper case with the spindles already attached, and sent it to the NDT contractor for inspection. The transmission upper case is constructed of aluminum and requires a different NDT process than the MPI that the spindles require. The records relating to the overhaul of this transmission do not indicate that the spindles received any MPI process. The maintenance check sheets used during the transmission overhaul were based on the CRO manual, and use of the sheets had been approved by Transport Canada. A review of the check sheets reveals that at least three different technicians had been involved in the overhaul.

An overhaul of the transmission requires cleaning, disassembly, inspection, repair as necessary, and reassembly of many components. Accordingly, the instructions contained in the CRO manual for the transmission overhaul were long and complicated. To help simplify and maintain control over the process, several overhaul organizations developed additional NDT check sheets to indicate which parts require NDT, and the type of NDT required. The helicopter manufacturer, BHTI, does not include such a check sheet within their CRO manual, nor is it required by regulation. At the time of this accident, Transwest Helicopters did not utilize such a check sheet; however, they developed and implemented their own additional NDT check sheet shortly after the occurrence.

Analysis

The failure of the transmission spindle mount would have allowed the transmission to pivot and become misaligned. This movement placed a bending load on the tail rotor drive shaft which rapidly led to failure. That the helicopter did not rotate clockwise immediately after the bang suggests that the noise was made by the instant failure of the spindle, while the failure of the tail rotor drive shaft was progressive and secondary.

The root cause of the spindle failure could not be determined. The indications of rework on the spindles suggest that they had been damaged earlier, perhaps in the earlier accident. The alternating bands of fatigue and overload cracking identified during the laboratory examinations suggest that the crack propagated slowly during normal operations and advanced quickly during overload such as large torque spikes.

Although the time interval from crack initiation to final failure could not be calculated, it is likely that the crack existed at the time of the transmission overhaul because of the earlier damage. It could not be determined if the crack would have been detected had the spindle received the MPI that was required. Omission of the MPI, however, reduced the chances of early detection.

The MPI process was omitted as a result of several factors relating to the control of the transmission overhaul. That the upper case was
purchased separately, and was sent out for NDT inspection with the spindles attached, created the confusion, since this was not the standard procedure. Furthermore, the overhaul was not supervised by one individual, but was carried out by three people working independently.

The overhaul instructions in the CRO manual were necessarily long. The use of an additional check sheet, identifying the components that require NDT, may have prevented the omission of the MPI. Many companies have recognized the need for an additional NDT check sheet, but since the CRO manual does not include one, each company must develop its own.

The following TSB Engineering Branch Laboratory report was completed:

LP 165/96 - Spindle Failure Analysis.

Findings

- The spindle failed as a result of fatigue; the origin of the failure is unknown.

- According to available component records, the spindle did not receive the required magnetic particle inspection at the last overhaul.

- The omission of the magnetic particle inspection was the result of a lack of maintenance supervision during the overhaul process.

- The failure of the spindle allowed the transmission to move, thereby creating bending loads on the tail rotor drive shaft which rapidly caused it to fail.

Causes and Contributing Factors

The tail rotor drive shaft broke as a result of the bending loads caused by the transmission misalignment when the spindle mount failed.

Safety Action

Following this accident, Transwest Helicopters amended its transmission overhaul procedures and facilities. This included adding hangar space to include an overhaul facility, making a full-time technician responsible for the overhauls, and amending the company overhaul manual to include additional NDT check sheets clearly identifying the level of inspection required for each component.

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

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

Capsizing at Take-off  
Cessna U206F C-GNUG  
Rivière des Prairies, Quebec  
20 July 1996

Report Number A96Q0114

Synopsis

The float-equipped Cessna U206F (serial number U20602795), with six persons on board, was to make a pleasure flight from Rivière des Prairies, Quebec, to the Gouin Reservoir. The seaplane started its take-off run on a water surface agitated by strong cross-winds from the right. The aircraft lifted out of the water at very low speed, travelled about 1,000 feet before taking off, and fell back on the water in a pronounced nose-up attitude. The pilot-owner continued with the take-off, and the aircraft lifted out of the water a second time. The left wing then struck the surface of the water; the left float dug into the water, and the aircraft capsized. The pilot told the passengers to unfasten their seat-belts as the aircraft rapidly filled with water. He then went toward the rear to try to open the two cargo doors to let the occupants out. A man who had witnessed the accident immediately proceeded to the site to assist the occupants. He opened the left front door, and the female passenger evacuated the seaplane. A child followed soon afterward. As they had no life jackets, these two persons clung to the floats until the other rescuers arrived. The first fire-fighters and police officers arrived at the site about 15 minutes after the accident. The pilot and the other three passengers drowned inside the aircraft.

Other Factual Information

The pilot was qualified for the flight. He had about 1,350 flying hours, including about 1,000 hours on type.

The water surface used for the take-off was a river about 1,000 feet wide bordered by trees. At the time of the take-off in a westerly direction, the winds were from the north with gusts estimated at 20 knots. Before the take-off, witnesses had mentioned the strong cross-winds to the pilot. The exact take-off speed could not be determined.
The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. There was no evidence found of any airframe failure or system malfunction on take-off. The aircraft had no known deficiencies before the flight and was being operated within its load and centre of gravity limits. Examination of the aircraft after it was removed from the water revealed that the forward leaf of the rear cargo door had been forced.

The aircraft was equipped with a Robertson short take-off and landing (STOL) kit. It was also equipped with a Flint Aero wing-tip auxiliary tank kit. These two kits increase lift and reduce the stall speed of the aircraft. Owners modify their seaplanes with these kits to be able to take off and land on water over shorter distances and to increase the maximum take-off weight of the seaplane.

The Robertson kit uses modified flaps and ailerons. When the pilot extends the flaps, the ailerons also deploy by small increments to 16 degrees, producing the equivalent of 25 degrees of flap. This increases camber over a larger part of the wing, which improves wing lift at low speed. However, the upward travel of the ailerons, which normally rise on the side of the turn, is limited to approximately the neutral position, and this reduces the roll efficiency and roll control of the aircraft. Flight manual supplements are published for the Robertson and Flint Aero kits. There was no evidence found that these flight supplements had been inserted in the aircraft flight manual as required by aviation regulations. There was no official flight test conducted to evaluate the changes in performance of the modified aircraft, and it is not required by the present regulations.

The pilot had the five passengers—one man, one woman, and three children—board via the left front main door. The pilot sat in the left front seat and had the passengers sit as follows: the man in the right front seat; the woman in the second row seat behind the pilot with her two-year-old daughter on her lap; the six-year-old child in the seat to the right of the woman, in line with the forward leaf of the right rear cargo door; and the nine-year-old child in the only seat at the right rear, in line with the aft leaf of the cargo door. There are no regulations regarding passenger distribution on this type of aircraft.

On board the aircraft, the pilot used the intercom to give the passengers a safety briefing. All were wearing headphones and a microphone. During the investigation, the woman said that she removed her headphones to tend to the children and that she did not hear the safety briefing given by the pilot. The content of the pilot's safety briefing could not be determined.

Although there were life jackets on board the aircraft, none of the occupants was wearing one at the time of the accident. Wearing a life jacket is not mandatory; however, in report SA9401 entitled A Safety Study of Survivability in Seaplane Accidents, the TSB recommended that Transport Canada require that all occupants of seaplanes wear a personal flotation device during the standing, taxiing, take-off, and approach and landing phases of flight (A94-07).
The pilot used 20 degrees of flap, as suggested in the flight manual for the Cessna U206F seaplane. For a take-off in strong cross-wind conditions, the Cessna U206F flight manual suggests using the minimum flap required for the take-off distance available. The flight manual does not specify any cross-wind take-off limitations because the limitation depends on pilot skill instead of aircraft capability.

For a normal take-off with an aircraft fitted with a Robertson kit, the flight manual supplement suggests 20 degrees of flap. The only reference to cross-wind take-offs in the Robertson supplement relates to the STOL take-off procedure, when the flaps should be extended to 25 degrees. The suggestion is that 5 knots be added to the take-off speed for every 10 knots of wind speed.

Several experienced bush pilots stated that they extend the flaps to 10 degrees instead of 20 degrees when taking off in strong cross-wind conditions with a Cessna U206F equipped with a Robertson kit and a Flint Aero wing-tip kit. They indicated that the seaplane attains a higher take-off speed in this configuration; also, the ailerons are more effective in cross-winds because they do not lower completely and their upward travel is less restricted.

When the flaps are extended to 20 degrees, strong winds cause the seaplane to lift out of the water and take off prematurely. The aircraft is still at low speed, close to the stall speed. If the winds are gusting, the seaplane can stall and fall back on the water when the gust subsides.

The Cessna U206F is equipped with two doors: the left front main door, next to the pilot seat, and a double cargo door in the right rear. The forward leaf of the cargo door is in line with the second row of seats, and the aft leaf is in line with the rear row of seats. All seats face forward. The Cessna U206F is certified in this configuration with its two doors in accordance with Part 3 of the Civil Air Regulations (CAR), and is consequently approved by Transport Canada.

When the flaps are extended to 20 degrees, the forward leaf of the cargo door on this type of aircraft can open only about 8 cm, and this makes it difficult to fully open the aft leaf of the cargo door. Pilots and operators of this type of aircraft are aware of the difficulty, but it is not mentioned in the aircraft owner's manual. In this accident, there was no evidence found that the two leaves were opened, despite the evidence that the forward leaf of the cargo door was forced from the inside.

The Cessna U206F Stationair owner's manual describes the operation of the cargo door in the section entitled Cargo Door Emergency Exit as follows:

If it is necessary to use the cargo doors as an emergency exit and the wing flaps are not extended, open the forward door and exit. If the wing flaps are extended, open the doors in accordance with the instructions shown on the red placard which is mounted on the forward cargo door.

The following instructions were on the sign on the inside of the forward leaf of the cargo door of the aircraft:
EMERGENCY EXIT OPERATION

- ROTATE FORWARD CARGO DOOR HANDLE FULL FORWARD THEN FULL AFT.
- OPEN FORWARD CARGO DOOR AS FAR AS POSSIBLE.
- ROTATE RED LEVER IN REAR CARGO DOOR FORWARD.
- FORCE REAR CARGO DOOR FULL OPEN.

This investigation included an ergonomic assessment of the double cargo door using the criteria prescribed in Part 3 of the CAR and military criteria for ergonomics. According to the criteria used in the ergonomic assessment, one emergency exit must generally be designed to be easy to use, easily accessible, free of obstructions, and easy to find and open in the dark. On this type of Cessna, the forward leaf of the cargo door must be opened to allow the aft leaf to open. The handle used to unlatch the cargo door forward leaf is accessible to passengers seated in the middle row of seats, but is harder to reach for passengers seated in the rear row. If the flaps are extended to 20 degrees, as they were in this accident, the flaps allow the forward leaf of the cargo door to open only slightly, and this impedes occupant evacuation. The handle used to unlatch the aft leaf of the cargo door, which is mounted in the upright frame member of the leaf itself and is in line with the backrest of the right-hand second row seat, is difficult to reach for the passenger occupying that seat. In addition, when the handle is lowered to the open position, it strikes the slightly open forward leaf, which prevents the aft leaf from opening. The handle must be raised in order to open the aft leaf, but here again, the latch may re-engage.

The criteria used for the ergonomic assessment state that the emergency exits must open quickly, within three seconds, and all occupants must be able to evacuate the aircraft within 60 seconds using only half the emergency exits available. Ground tests showed that even with the flaps retracted, it was not possible to open either leaf of the rear cargo door within three seconds or to evacuate six adults within 60 seconds.

Following an accident in 1984 at Salone Lake (report No. 84-Q40031), the Canadian Aviation Safety Board forwarded an Aviation Safety Advisory to Transport Canada indicating that the rear double cargo door of the Cessna 206 was hard to open. No measures were taken to have the doors modified. In March 1991, the Cessna Aircraft Company issued a service bulletin, SEB91-04, to improve the cargo door latch mechanism on the Cessna 206 and U206. This service bulletin advised adding a return spring to the aft cargo door handle and installing two new placards. One was placed on the forward cargo door, and one on the aft cargo door pointing out the handle location. The changes reduced by one the steps to be taken to open the two cargo doors but did not eliminate the jamming of the forward cargo door against the flaps when they are at 20 degrees down. The owner of the aircraft did not comply with this service bulletin. The service bulletin was not
mandatory, as it did not affect the airworthiness of the aircraft.

The ergonomic assessment of the rear cargo door was conducted during the day in favourable light conditions. In the accident, the seaplane was inverted in the water and remained totally submerged. The female passenger reported that the water was murky and that it was hard to see anything under water.

A study relating to escape and survival from aircraft ditching states that the rotation of the body underwater and loss of gravitational reference makes disorientation inevitable for survivors prior to escape from an inverted aircraft. In addition, the darkness produced by water flooding into the aircraft aggravates the disorientation. Survivors who were questioned in this study reported experiencing confusion, panic, and disorientation in the occurrences. The study concludes that only those who have experienced disorientation in an underwater trainer understand the problem and know how to deal with it to get out and survive. Early in the summer preceding the accident, the Association des pilotes de brousse du Québec held a training session on exiting an aircraft under water. At the training session, pilots (belted in the seat of an aircraft) were dropped in a pool and had to try to evacuate the aircraft. The pilot of the accident Cessna was unable to attend this annual training session.

The deaths of the pilot and three passengers were attributed to drowning. There was no evidence that incapacitation or physiological or psychological factors affected the pilot's performance.

**Analysis**

The investigation revealed that the seaplane was maintained in accordance with existing regulations and approved procedures. There was no evidence found of any airframe failure or system malfunction on take-off.

The pilot was experienced on this type of aircraft. By all indications, before embarking on the flight, the pilot assigned the passengers seats in the aircraft in an arrangement that he considered most effective and most agreeable for them. However, children were seated near the exit door, and there is a strong possibility that having an adult near the emergency exit would have facilitated evacuation.

The pilot gave the passengers a safety briefing, but some passengers were distracted and did not hear it clearly. The emergency exit instructions were on the sign on the cargo door, but the pilot did not demonstrate how to operate the two leaves of the cargo door to ensure that the passengers knew how they operated and to facilitate opening the door in an emergency; however, such a demonstration is not mandatory under the regulations. The pilot did not ask the passengers to wear life jackets for take-off, nor is this mandatory under the aviation regulations.

There are no limitations for take-offs in cross-wind conditions because they depend on pilot skill. The pilot took off in strong cross-wind
conditions and used 20 degrees of flap, as indicated in the Cessna U206F manual and the Robertson kit supplement. However, the pilot could have used 10 degrees of flap like some pilots with experience on this type of aircraft. The effectiveness of the ailerons, which was diminished by the Robertson kit installed on the seaplane and the use of 20 degrees of flap, did not allow the pilot to maintain roll control during the take-off; the strong right cross-winds lifted the right wing of the aircraft, which then rolled to the left.

While the aircraft was overturned in the water, the pilot went to open the rear cargo door. By all indications, the pilot and the other occupants became disoriented in the murky water, and no one was able to find the handle of the cargo door forward leaf to open it. The damage observed on the cargo door forward leaf suggests that one of the adults tried to force it open.

The system for opening the two leaves of the rear cargo door is complex and difficult to operate under normal conditions, but opening the leaves is even more difficult if the flaps are extended for a take-off or landing. This makes the rear cargo door practically unusable, and as a result, the left front main door is the only usable emergency exit for all occupants. Findings

1. The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

2. The weight and centre of gravity of the aircraft were within the prescribed limits.

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

4. The pre-flight briefing given by the pilot was not heard by all passengers.

5. The content of the pilot's briefing could not be determined.

6. The passenger distribution was such that it was not easy for the occupant seated in line with the cargo door to open the door in an evacuation.

7. Opening the leaves of the rear cargo door of a Cessna U206F is complex and difficult if the flaps are extended to 20 degrees; it is even more difficult when the seaplane is submerged and overturned.

8. The damage to the forward leaf of the cargo door suggests that one of the adults tried to force it open.

9. The pilot did not ask the passengers to wear their life jackets during taxiing and take-off, nor is it mandatory to do so under the aviation regulations.

10. The Robertson and Flint Aero flight supplements do not mention the position of the flaps on the Cessna U206F seaplane for a take-off from water in strong cross-wind conditions.
11. The pilot used 20 degrees of flap to take off from water in cross-wind conditions.

12. The pilot was unable to maintain roll control of the seaplane during a take-off from water in strong cross-wind conditions.

13. The pilot was unable to attend the annual optional training on evacuating a submerged aircraft.

14. Service Bulletin SEB91-04, to improve the cargo door latch mechanism, had not been incorporated in this aircraft.

Causes and Contributing Factors

The pilot was unable to maintain control of the aircraft, equipped with Robertson and Flint Aero kits, during a take-off with 20 degrees of flap in strong cross-wind conditions. The distribution of the passengers and the complexity of opening the leaves of the rear cargo door with the flaps extended to 20 degrees contributed to the difficulty of the evacuation.

Safety Action

Subsequent to this accident, and based on the TSB investigation process, Transport Canada (TC) expressed its concern about the adequacy of the emergency exit of the Cessna U206 aircraft to the FAA in a letter dated 27 November 1996. TC acknowledged that, "While incorporation of the Cessna modification kit improves the situation somewhat, it does not, however, resolve the basic problem - the Cessna U206 emergency exit procedure, when the flaps are down, remains a multi-step procedure that can be difficult to execute under emergency conditions." TC encouraged the FAA to make the Cessna modification (SEB91-04) mandatory for in-service aircraft. The letter further states that should production of the U206 resume, TC would strongly recommend that the FAA require Cessna to incorporate a solution which eliminates the interference problem between the flaps and the emergency exit. The TSB understands that TC has not received a response to date regarding this concern.

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 29 July 1997.

Appendix A - Diagram of Cabin (from the Cessna U206F Owner's Manual)
INTERNAL CABIN DIMENSIONS
FOR CARGO LOADING

FLAPS AT 20 DEGREES

CABIN HEIGHT
MEASUREMENTS

DOOR OPENING
DIMENSIONS

<table>
<thead>
<tr>
<th>CABIN DOOR</th>
<th>WIDTH (TOP)</th>
<th>WIDTH (BOTTOM)</th>
<th>HEIGHT (FRONT)</th>
<th>HEIGHT (REAR)</th>
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<td>37&quot;</td>
<td>45&quot;</td>
<td>38&quot;</td>
</tr>
<tr>
<td>CARGO DOORS</td>
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<td>49&quot;</td>
<td>39½&quot;</td>
<td>37½&quot;</td>
</tr>
</tbody>
</table>

REAR DOOR POST BULKHEAD
CARGO TIE-DOWN (HNG 10)
FACE OF INSTRUMENT PANEL

CABIN WIDTH
MEASUREMENTS

FIREWALL
CABIN STATIONS (CARGO WT 600LBS)

NOTES:
1. Use the forward face of the rear door post as a reference point to locate C.G.
   center. For example, a box with its center of weight located 12 inches aft at
   the rear door post would have a C.G. error of 0.0690.6 + 78.3 = 80.9 inches.
2. Minimum allowable floor loading, 200 pounds/total area. However, when
   surfaces with small or sharp support areas are empennage, the installation of a 1/4"-
   thick plywood floor is highly recommended to protect the aircraft structure.

Updated: 2002-10-06

Important Notices
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
Fire on Take-off
Piper Apache PA-23 C-FYXT
Saint-Mathias Aerodrome, Quebec
10 March 1996

Report Number A96Q0034

Summary

After a training flight, the pilot owner, accompanied by his instructor, landed the Piper PA-23 at the Saint-Mathias aerodrome, Quebec, to refuel. After refuelling, which took approximately 30 minutes, the pilot taxied the aircraft for a flight to the Beloeil airport, Quebec. Prior to take-off, the pilot did a run-up of about five minutes. During the initial climb, shortly after take-off, at a height of about three feet above ground level, the instructor, who was sitting in the right-hand seat, observed smoke emanating from the rear of the right engine. He told the pilot to land the aircraft immediately. The pilot landed the aircraft on the runway ahead, and the aircraft came to a stop in a ditch located at the end of the runway.

The two occupants evacuated the aircraft quickly and without any difficulty. Shortly thereafter, the local firefighters arrived and extinguished the fire that had broken out under the aircraft's right nacelle, where fuel was running onto the ground. No one was injured.

Ce rapport est également disponible en français.

Other Factual Information

The crew was certified and qualified for the flight according to existing regulations.

The gravel runway measured 2,000 feet long by 50 feet wide. The aircraft landed with the landing gear down and locked. The fuel selector was in the "Main" position during take-off and during the inspection of the aircraft.

Examination of the aircraft confirmed that the source of the fire was
under the right nacelle in the area occupied by the fuel supply selector for the right engine, the fuel filter, and the auxiliary fuel pump. The damage caused by the fire ran from the right engine, near the firewall, towards the back of the firewall. The spar had been completely destroyed by the fire and no longer supported the wing.

Examination of the electrical system did not reveal any sign of a short circuit. No circuit breaker had disconnected from the electrical system.

A single line in the hydraulic system was ruptured. The line was not actuated during the take-off run and was not in an area where a fire could have started in the event of a leak of hydraulic fluid.

The fire consumed the fuel filter and its adjacent parts as well as the fuel lines for selecting the tanks.

The fuel system was at the centre of the source of the fire. The auxiliary pump, also located in this area, fell off onto the ground during the fire. This pump is normally supposed to be fastened to the structure by two bolts and nuts, but only one retaining bolt was in place. The other retaining point did not show any trace of a bolt having been present before the fire. Further, the fitting that connected the fuel supply to the pump was not fully tightened, and fuel could leak out. The fuel filter was supposed to be fastened to the pump fitting, but no trace of the filter was found. The retaining points of the auxiliary fuel pump did not show any sign of electrical arcing.

The aircraft was certified and maintained in accordance with existing regulations and approved procedures. It was not fitted with a fire indicator, nor is one required for this type of aircraft.

**Analysis**

As the aircraft was not fitted with a fire indicator, the presence of the instructor permitted fast detection of the fire and interruption of the take-off.

No trace of the fuel filter was found. The absence of the filter, which should have been connected to the auxiliary fuel pump which fell to the ground during the fire, coupled with the observed fuel leak, would seem to indicate that the filter was consumed by the fire, and that it was improperly installed. The fitting that connected the filter to the pump was not tight enough to prevent the possibility of a fuel leak.

The pump and the filter should have been held in place by two retaining bolts. As one bolt was missing and no part of it was found, it is impossible to determine whether the bolt broke off or came undone on a previous flight, or how long it had been missing.

Further, as the auxiliary fuel pump was fastened to the structure by only one bolt instead of two, the weakness of the installation of the pump and the filter, which connects to the pump at the fitting, might have contributed to causing a fuel leak.
The considerable damage in this area of the aircraft, however, made it impossible to determine exactly what factor initiated the fire in the fuel.

It was difficult for the pilot to stop the aircraft on the runway itself because the runway is only 2,000 feet long.

Findings

- The fire broke out at the rear of the right nacelle in the area occupied by the filter, the auxiliary fuel pump, and the fuel selector.

- The auxiliary fuel pump had only one retaining bolt holding it to the structure instead of two.

- The fitting attaching the fuel filter to the auxiliary fuel pump inlet was not fully tightened and it was possible for fuel to leak.

- The fuel filter was consumed by the fire, and no debris was found.

Causes and Contributing Factors

A fuel leak in the connection between the auxiliary fuel pump and the fuel filter allowed a fire to start in the right nacelle during take-off. The absence of one of the fastening bolts from the auxiliary fuel pump and an inadequately tightened fitting are factors that may have contributed to the fuel leak.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, Benoit Bouchard, and members Maurice Harquail and W.A. Tadros, authorized the release of this report on 12 September 1996.

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
Controlled Flight into Terrain
Les Transports Aéro 2000 Inc.
Piper PA-31 Navajo C-GRPM
Nouveau-Québec Crater, Quebec
30 May 1996

Report Number A96Q0076

Summary

The Piper Navajo PA-31 (serial number 318012021), belonging to Les Transports Aéro 2000 Inc., with three passengers and one pilot on board, was on a charter visual flight rules (VFR) flight from Kangiqsujuaq, Quebec, to Kuujjuaq, Quebec. At 1056 eastern daylight saving time (EDT), the pilot contacted the Kuujjuaq flight service station (FSS) by radio and reported that he had taken off eight minutes earlier and planned to overfly the Nouveau-Québec crater. That was the last message received from the pilot. When the aircraft failed to arrive at destination at the expected time, a search was initiated. The next day, a ground search team found the aircraft. The Navajo struck the eastern slope of the Nouveau-Québec crater while in straight and level flight. The four occupants of the aircraft were fatally injured in the accident.

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 received his airline transport pilot licence (aeroplane) on 31 January 1989. He passed a pilot proficiency check (PPC) on 15 June 1995. His licence validation certificate was current; he was required to wear prescription lenses while flying. The pilot was very familiar with the area he was overflying.

The twin-engine aircraft was certified, equipped and maintained in accordance with existing regulations and approved procedures. The last flight entered in the aircraft journey log-book was made the day before the accident. No deficiencies were reported or logged in the
aircraft log-book. The aircraft had been declared airworthy 15 days earlier following a 150-hour inspection. The pilot was strict regarding the maintenance of his aircraft and did not hesitate to report deficiencies to the head of maintenance during his journeys. He had not reported any particular problems since departing Quebec City. The aircraft had the instrumentation required for instrument flight. C-GRPM was not equipped with a radio altimeter or ground proximity warning system (GPWS), nor was the aircraft required to be equipped with these instruments. The aircraft was equipped with a global positioning system (GPS).

The aircraft departed Quebec City on 27 May 1996 for a charter flight lasting several days. On 29 May 1996, the aircraft landed at Kangiqsujuaq as planned for a one-night layover. On the morning of 30 May, prior to the flight, the pilot telephoned the Kuujjuaq FSS for current weather conditions and the destination forecast. He obtained the regular weather observation for 1000 hours and the terminal forecast. The observations indicated favourable conditions for VFR flight. The pilot then filed a VFR flight notification with the FSS specialist. The pilot neither requested nor received the area forecast (FA) for the planned route. However, the area forecast summarized conditions in the crater area as favourable for visual flight.

The flight was to be made in two legs. The aircraft was first to follow a heading of 250 degrees true at a cruising speed of 170 knots for 52 nautical miles (nm) and overfly the Nouveau-Québec crater to allow the passengers to photograph the area, then proceed southeast for 250 nm to Kuujjuaq. The planned route led the aircraft over a vast expanse of snow-covered, treeless tundra that was scattered with rocks and largely uninhabited. The terrain at this location slopes upward and consists of hills with elevations of 1,600 to 2,000 feet above sea level.

There is no FSS at the Nouveau-Québec crater. The closest FSS is at Kuujjuaq, located about 250 nm southeast. A weather analysis was done by the Weather and Environmental Services Office of Environment Canada in Quebec City. According to the study, the extreme northern region of Quebec was under the influence of a trough, located over Hudson Bay, which caused mixed precipitation during the afternoon and evening of 30 May. At the time of take-off, the ceiling at Kangiqsujuaq was approximately 1,100 feet above ground level and visibility was at least 10 miles. Inland, the clouds were broken to overcast from 1,500 to 2,000 feet above sea level. Surface winds were from the south to southwest at 15 to 25 knots, and from the west at 20 to 25 knots 2,000 feet above sea level. Moderate mechanical turbulence was associated with winds at this velocity. In addition, satellite photographs revealed mountain wave turbulence. Again according to the study, visibility at the different observation stations was over six miles. However, in the area of the crater, visibility was severely reduced or near zero in drizzle and fog on high terrain and slopes exposed to the south and southwest winds. Light to moderate rime or clear ice and freezing drizzle could be encountered in flight if the temperature was near freezing.

At the accident site, the altimeter setting was estimated at 29.72 in. Hg.
The aircraft was equipped with two aneroid altimeters that indicated the same altitude. The pilot's altimeter, on the left, was set at 29.76 in. Hg, and the right-hand altimeter showed 29.72 in. Hg.

The crater is located in an area of uncontrolled airspace. It is perfectly circular in shape, 3.4 km in diameter, and is surrounded by a mountainous ridge rising 2,156 feet above sea level. The immediate perimeter of the crater consists of rolling terrain with an average elevation of 1,700 feet above sea level. The eastern slope of the crater has a gradient of 15 degrees. Regulations require that, for flights in uncontrolled airspace, visibility in flight must be at least one mile, and aircraft must be outside the clouds when flying less than 700 vertical feet above land or water.

It was determined that the aircraft was in a slight nose-up attitude (about 5 degrees) on a heading of 277 degrees true when it struck the eastern slope of the crater about 1,920 feet above sea level, on a snow-covered uphill slope, with an impact trajectory of 251 degrees true. The aircraft bounced and continued its course in the air for 247 feet, rolling left on its longitudinal axis until the left wing struck the ground. The aircraft continued its course and continued rolling until it came to rest on its back 650 feet west of the initial point of impact. C-GRPM was found 2,100 feet above sea level and 200 feet south of the summit.

The aircraft started to break up on the initial ground impact; pieces of the aircraft were distributed on both sides of the main wreckage trail. The forward upper section of the fuselage and the cockpit sustained substantial damage when the aircraft fell back to the ground on its back. The flaps and landing gear were retracted at the time of ground impact. Examination of the wreckage revealed no evidence of any airframe failure, flight control problems, electrical problems, power loss, or fire during the flight or on the ground. There was fuel in the tanks, and some fuel spilled out on the ground. Weight and balance were within limits. The marks made by the propellers on initial impact indicate that the engines were running at the same rpm, and the ground speed of the aircraft was about 154 knots.

Examination of the faces of the airspeed indicators and the turn and bank indicator provided no reliable information. Examination of the instrument panel revealed the following: the master switch was at ON after the impact; all circuit breakers were at ON; the horizontal situation indicator (HSI) indicated 285 degrees; the weather radar was on "Standby"; and the emergency avionics switch was at OFF.

A fixed automatic emergency locator transmitter (ELT) was installed at the base of the aircraft vertical stabilizer. It was installed five months before the accident. The ELT was serviceable but did not activate on impact. On installation, the selector switch was selected OFF and subsequently was not set back on ARM.

The GPS was recovered and sent to the manufacturer for examination to determine the readings it provided during the flight. The GPS electronic memory contained the names and geographic coordinates of
Several waypoints, including some on the final approach courses of runways for which no instrument approach is published. The crater was identified as WPT CRTER at latitude 6116'406"N, longitude 07342'823"W. The exact position of the Nouveau-Québec crater is in fact 2.5 nm east of the coordinates entered in the GPS. It was determined that, after take-off, the pilot pressed twice on the push-button "D" (direct route) to go to WPT CRTER.

One passenger was sitting in the co-pilot's seat and was wearing a seat-belt; one passenger was sitting, without a seat-belt, in the right-hand seat of the first row facing the rear of the cabin. The third passenger was sitting in the left-hand seat of the second row and was wearing a seat-belt. As a result of the impact forces, the second-row seat separated from the floor, projecting its occupant toward the front of the cabin.

The deaths of the three passengers were attributed to severe multiple trauma sustained in the impact. An autopsy was performed on the body of the pilot. Toxicological test results were negative. The autopsy revealed that the pilot suffered from coronary arteriosclerosis with 60% to 70% stenosis of each coronary artery. The pilot's death was nonetheless attributed to severe multiple trauma sustained in the accident, although the relatively serious coronary arteriosclerosis may have contributed to his death. The pilot's last medical examination, in February 1996, and his last electrocardiogram, in June 1995, did not detect the pilot's cardiovascular condition. The pilot told the civil aviation medical examiner he had never had a cardiovascular disorder and had never been treated for this type of problem or any other health problems. There was no evidence that incapacitation or physiological factors affected the pilot's performance.

A CFIT (controlled flight into terrain) accident is an accident in which an aircraft inadvertently strikes the terrain, water or an obstruction without the crew being aware of the impending mishap. According to TSB statistics, two-thirds of the aircraft involved in accidents in sparsely populated regions of Canada were piloted by one pilot. In many CFIT accidents, pilots tried to see the ground to fly visual, even where the flight was conducted in cloud, at night, in whiteout conditions, or in other conditions that precluded visual flight. Over half of these CFIT accidents occurred during VFR flight. In February 1996, the pilot had attended a Transport Canada presentation on CFIT accidents. The presentation included an analysis of the conditions conducive to this type of accident and suggested strategies to avoid them.

Whiteout (also called milky weather) occurs over an unbroken snow cover and beneath a uniformly overcast sky. Sunlight is dispersed and diffused through cloud and reflected back in all directions by the snow cover. The space between the ground and the clouds appears to be engulfed in a uniformly diffused white glow. Depth perception is impossible, as the milky white of the sky blends with the snowy white of the ground, completely obliterating the horizon as a spatial reference line.

Analysis
On departing Kangiqsujuaq, the pilot knew that the current weather conditions and the conditions forecast for Kuujjuaq were favourable for VFR flight. But the crater is in a largely uninhabited region, and the pilot was unaware that the weather quickly deteriorated west of Kangiqsujuaq and that the weather at the crater was poor. In fact, visibility in that area was reduced, and the mountainous ridge surrounding the crater was probably hidden by cloud. Also, the atmospheric conditions at the time and the local topography were conducive to whiteout. The pilot continued flight in adverse weather in which he risked losing the visual references necessary for avoiding obstructions.

The hypothesis of an engine failure or aircraft system malfunction, or both, was eliminated, because the examination of the aircraft revealed no deficiencies and no distress calls were received. Also, if an emergency situation had occurred in flight, all passengers would likely have been found in their seats with their seat-belts fastened. There was no evidence found of any emergency or aircraft malfunction prior to impact.

The aircraft struck the ground on the planned route, 2.5 nm east and one minute's time of flight from the waypoint entered in the GPS. All indications are that the pilot did not know his actual position in relation to the crater. The pilot was evidently using the information provided by the GPS to go directly to the crater; since the coordinates entered in the GPS for the crater were incorrect, the pilot was unaware of the actual position of the aircraft, and evidently arrived at the crater one minute sooner than he expected.

The pilot encountered adverse weather conditions and probably used the GPS to lighten his workload. Two possibilities were examined: either the pilot descended to break out of the clouds and see the crater, or he flew under the clouds so he could see the ground and fly visual. The theory that he tried to descend below the cloud base was considered unlikely, however, as it would have been unusual for the pilot to descend to an altitude below the crater summit and below the safe altitude for the area. Also, if the pilot had attempted such a manoeuvre, it is highly probable that the aircraft would have struck the ground in a nose-down attitude.

Instead, it appears that the pilot, who knew the area well, was trying to fly visual, by using the GPS, to arrive over the crater in visual meteorological conditions (VMC). However, the pilot encountered reduced visibility and whiteout conditions, where there was a considerable risk that he would lose visual contact with the ground due to the prevailing weather conditions.

The slight nose-up attitude and the heading of the aircraft, about 25 degrees greater than that of the route planned and that of the breakup trajectory, suggest that the pilot initiated a climb and an uncoordinated right turn just before colliding with the ground. Therefore, it is reasonable to believe that the pilot evidently did not have the required visual references and did not see the ground in time to avoid it.
The aircraft was not equipped with a radio altimeter or GPWS. These devices could have warned the pilot that the aircraft was dangerously close to the terrain; however, these devices were not mandatory.

Although the autopsy report determined that serious coronary arteriosclerosis may have contributed to the pilot's death, there was no evidence that his performance was affected by physiological factors. In fact, the aircraft attitude and heading on impact indicate that the pilot was not affected by any incapacitation that could have prevented him from controlling the aircraft.

The Nouveau-Québec crater is a unique terrain feature located in an inaccessible region. It could not be determined why the pilot decided to continue the flight in adverse weather. However, it is probable that his knowledge of the area, the proximity of the crater, and the information provided by the GPS influenced the pilot's decision.

Findings

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

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

- The pilot was unaware of the current weather conditions in the crater area.

- While the pilot was en route toward the crater, weather conditions deteriorated; the pilot continued flight and evidently used the GPS.

- Visibility was reduced, and the atmospheric conditions and local topography were conducive to whiteout at the accident site at the time of impact.

- In the moments preceding the impact, the pilot evidently did not have the visual references required to avoid obstructions.

- Because incorrect coordinates were entered in the GPS, the crater's actual position was 2.5 nm east of the position indicated by the GPS, and the pilot evidently arrived at the crater about one minute sooner than he expected.

- The ELT selector switch was at OFF.

- The aircraft was not equipped with a GPWS, nor was one required under existing regulations.
The pilot suffered from relatively serious coronary arteriosclerosis which was not detected by routine medical examinations.

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

Causes and Contributing Factors

The pilot continued flight in adverse weather and may have lost situational awareness due to incorrect information provided by the GPS. The pilot evidently did not have the visual references required to avoid striking the eastern slope of the Nouveau-Québec crater.

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 April 1997.

Updated: 2002-10-06
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
Loss of Wheels on Landing
Inter-Canadien Fokker F-28 Mk1000 C-FCRI
Quebec/Jean Lesage International Airport, Quebec
09 June 1996

Report Number A96Q0083

Summary

The Fokker F-28 aircraft (serial number 11043) (Inter-Canadien flight 1661) was on the downwind leg for a landing on runway 06 at Jean-Lesage international airport, Québec, Quebec. During the approach, the crew lowered the landing gear and prepared to land. Shortly after touchdown, the crew felt side-to-side oscillations. The captain, who was flying the aircraft, applied heavy braking; the oscillations stopped, but then began again. The captain modulated the braking to try to reduce the oscillations, but without success. The inboard wheel of the right main landing gear strut separated from the landing gear, followed shortly thereafter by the outboard wheel of the same main gear. The crew noted the aircraft's change in attitude, and the captain applied the left wheel brake to keep the aircraft on the runway, while controlling the nose wheel. When the aircraft came to rest, on the runway, the order to evacuate was given, and the passengers evacuated the aircraft by the service/emergency door and the emergency exits located over the wings. There were no injuries during the evacuation.

Ce rapport est également disponible en français.

Other Factual Information

The flight crew was certified and qualified for the flight in accordance with existing regulations. The pilot had obtained his Fokker F-28 type rating on 24 April 1996 and had a total of 125 flying hours on type. The copilot had obtained his type rating on 02 May 1996 and had a total of 70 flying hours on type.

The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The aircraft's weight and centre of gravity were within the prescribed limits. The flight crew operated the aircraft in accordance with Inter-Canadien standards and approved procedures.

The crew of two pilots and two flight attendants had come on duty at around 0730 eastern daylight time (EDT)\(^1\), and had carried out the customary checks. Flight 1660 left Dorval, Quebec, at 0830 for Québec, Sept-Îles, Quebec, and Wabush, Newfoundland. From that point on, the flight was called flight 1661 and retraced its route to return to Dorval.
When flight 1661 left Sept-Îles for Québec, all the aircraft systems were operating normally, and the captain was flying the aircraft. The flight was somewhat behind schedule when it left Sept-Îles, but was to land in Québec at 1550 as scheduled. The weather report for Québec indicated a few clouds at 3,000 feet and winds from 050 degrees magnetic at 6 knots.

According to the crew, when on short final for runway 06, the aircraft was showing a reference speed of 116 knots (V_{\text{ref}}), with the flaps extended 42 degrees; the aircraft touched down at a speed of 113 knots. The flight attendants described the touchdown as firm, and the pilots described it as soft. The oscillations began shortly after touchdown. The cockpit voice recorder (CVR) information shows that the approach proceeded without incident.

The flight data recorder (FDR) data show that on touchdown the indicated speed was 125 knots, higher than on previous flights. Also, after touchdown there was a two-second delay before the thrust levers were placed in the idle position. The oscillations began about four seconds after touchdown. Runway 06 is 9,000 feet long. The oscillation marks began 1,800 feet from the runway threshold and were 630 feet long (see Appendix A). They are essentially parallel S-shaped marks made by the right landing gear. The second series of S-marks began 4,257 feet from the runway threshold and continued for a distance of 83 feet. During this second series of marks (19 seconds after touchdown), the inboard wheel separated from the right landing gear, followed by the outboard wheel; the speed at that time was 64 knots. The aircraft continued on the landing gear strut for another 340 feet before coming to rest on a heading of 96 degrees magnetic, 4,680 feet from the threshold of the 9,000-foot runway. During this time, the two tires continued to roll; both crossed taxiway Alpha before coming to rest, one 7,045 feet from the runway threshold and the other 7,708 feet from the runway threshold. There was no fire during the occurrence.

The Québec tower controller alerted the emergency services as soon as the crew advised of the occurrence. The emergency vehicles headed for taxiway Alpha to go up runway 06. They had to stop for a few seconds because they were told that the aircraft's tires were about to cross taxiway Alpha.

After the aircraft came to rest and the check-list was completed, the captain gave the order to evacuate the aircraft. The flight attendant responsible for the forward exits was not able to open the left forward main door because the opening mechanism electric assist had been lost, and because the aircraft was leaning to the right, requiring additional force to open the door. The emergency exits over the wings and the right forward emergency exit were quickly opened. The evacuation was completed within a reasonable time. Approximately 80 per cent of the passengers used the right forward exit; the other passengers used the exits over the wings. A survey of a number of passengers indicated that the evacuation was orderly, in spite of the element of surprise surrounding the incident. However, a number of passengers were determined to take their hand baggage with them, and some were successful.

After the passengers had been evacuated, the crew opened the left forward main door and exited the aircraft. The passengers were evacuated to the runway edge and then transported to the air terminal.

Each main landing gear unit on the F-28 is equipped with an upper and a lower torque link, mounted behind the landing gear and connecting the lower strut to the main strut. Because it is hinged at a central point (the apex), the torque link allows the lower strut to move up and down while keeping the landing gear wheels in proper alignment. Each landing gear unit has an inboard wheel and an outboard wheel.
The TSB Engineering Branch examined the aircraft's right landing gear unit. The failure of the landing gear upper torque link was attributed to mechanical overload. The failure of the landing gear upper torque link was attributed to the overload extension of three small zones of precracking at a location known to have been previously associated with fatigue crack formation. The zone between the precracking and overload revealed fine microstriations consistent with loading having occurred at higher-than-normal service loads. This indicates that the precracks only served to locate the initiation of the overstress fracture.

The clearances between the upper torque link pin and the bushes in the upper torque link attachment lugs on the main fitting, between the upper torque link pin and the bushes in the upper torque link, between the lower torque link pin and the bushes in the lower torque link attachment lugs on the sliding member and between the lower torque link pin and the bushes in the lower torque link exceeded their respective in-service wear limit. Two days before the occurrence, a crew had reported strong vibrations from the landing gear. After checking the landing gear in accordance with the Fokker F-28 Maintenance Manual, the maintenance unit judged that the landing gear met standards.

The shock absorber was found to contain 10.7 litres of hydraulic fluid, whereas the amount specified in the manufacturer’s Component Maintenance Manual is 13.3 litres. After other shock absorbers were checked and volume calculations were done by the Dowty company (the manufacturer), it was shown that there was an error in the maintenance manual, and that the actual capacity of the shock absorber was in the area of 10.7 litres of hydraulic fluid. The quantity of liquid measured in the examination thus matches the shock absorber’s actual capacity, and the manufacturer stated that it would make the necessary changes to the maintenance manuals.

The examination by the TSB Engineering Branch found that the nitrogen pressure in the landing gear shock absorber was 325 pounds per square inch (psi). Because of its type of air operations, Inter-Canadien may land at several airports in the same day, at outside (operating) temperatures varying considerably from airport to airport. According to the Fokker, F-28 Maintenance Manual, the nitrogen pressure which should be applied when servicing at 15 degrees Celsius varies between 205 psi (for operating temperatures of 15 degrees Celsius) and 376 psi (for operating temperatures of minus 40 degrees Celsius). At low operating temperatures, the nitrogen pressure of 205 psi should not be used because it does not provide sufficient stroke and the shock absorber may bottom under certain
conditions.

Previous investigations of torque link failures on this aircraft type have often identified, as contributing factors, insufficient hydraulic fluid or excessive nitrogen pressure in the shock absorber. High nitrogen pressure has the effect of keeping the strut extended longer during the landing, thus reducing the mechanical advantage of the torque links in keeping the landing gear wheels in proper alignment.

A number of FDR data items found in investigations of similar accidents were studied to determine whether non-deployment of lift dumpers could have been the only cause of similar occurrences in Canada. When the lift dumpers are deployed, the weight is transferred from the wings to the wheels, and the upper and lower torque links regain their mechanical advantage. For the lift dumpers to deploy automatically, the system must be engaged, the engine thrust levers must activate the lift dumper microcontacts (between 65 HP and 80 HP), and one pair of wheels must be rolling at more than 50 knots. Research has shown that non-deployment of the lift dumpers is not the only cause of this type of occurrence. Other factors, such as excessive indicated speed on landing, can also slow the weight transfer to the landing gear, preventing the torque links from exerting their mechanical advantage and favouring the appearance of oscillations.

Analysis

The flight crew was certified and qualified for the flight in accordance with existing regulations. The weather conditions were favourable for the flight as planned.

During the evacuation, the main door could not be opened by the flight attendant because of the additional force required when the aircraft was leaning and the electric assist had been lost. The evacuation was orderly and was completed in a reasonable time, but not all the available exits could be used. The determination of a number of passengers to take their hand baggage with them could have had serious consequences if the evacuation had not gone so smoothly.

Two days before the occurrence, vibrations had been reported to the company's maintenance unit. The aircraft had been returned to service after an inspection found that everything was within standards. However, the laboratory examination showed that there was excessive wear on the attachment between the lower torque link and the lower strut, and that the nitrogen pressure in the cylinder was high, so that the landing gear strut remained in the extended position for a longer time.

On landing, the lift dumpers could not deploy quickly because the thrust levers had not been pulled sufficiently to activate the microcontacts. Late deployment of the lift dumpers and the higher landing speed are conditions which contribute to the development, the amplitude and the duration of oscillations. The extension of the landing gear strut reduced the mechanical advantage necessary for the torque links to keep the landing gear wheels in line with the aircraft's longitudinal axis. The main landing gear upper torque link therefore failed in overload, and the right main landing gear wheels separated from the aircraft.

The following laboratory reports were completed:

    LP 76/96 - FDR/CVR Analysis
    LP 79/96 - MLG Linkage Examination
    LP 84/96 - Effect of Lengthening F-28 Torque Links

Findings
- The main door of the aircraft could not be opened by the flight attendant.

- A number of passengers were determined to take their hand baggage when they evacuated the aircraft, and some were successful.

- Strong vibrations of the aircraft’s main landing gear had been reported two days before the occurrence.

- The clearances between the upper torque link pin and the bushes in the upper torque link attachment lugs on the main fitting, between the upper torque link pin and the bushes in the upper torque link, between the lower torque link pin and the bushes in the lower torque link attachment lugs on the sliding member and between the lower torque link pin and the bushes in the lower torque link exceeded their respective in-service wear limit.

- The upper torque link failed in overload.

- Fatigue cracking of sub-critical dimensions served to locate the initiation of the overload fracture.

- The nitrogen pressure within the cylinder was higher than the standard.

- The lift dumpers were deployed late.

- The aircraft’s actual landing speed was higher than \( V_{\text{ref}} \).

**Causes and Contributing Factors**

The upper torque link failed in mechanical overload. Contributing to the failure was the high nitrogen pressure in the main landing gear, the late deployment of the lift dumpers, the high landing speed, and the exceeded in-service wear limits found between the upper and lower torque link pins and the respective bushes.

**Safety Action**

**Action Taken**

Dowty, the landing gear designer, acknowledges that there is an error on page 9 of *Component Maintenance Manual* 32-10-03, and that it is now changing the manual to correct the error. The manual will be amended by removing the figure 13.306 as the quantity of hydraulic fluid. Also, the document explains that the company is studying the data relating to the occurrences of 09 June 1996 and 01 November 1995, which are similar cases, involving Canadian Regional Airlines Ltd.

In early August 1996, the Fokker company issued a letter to all F-28 operators concerning the main landing gear. It notified operators of the publication of bulletin SB F28/32-151. This bulletin is in two parts: modifications to the maintenance program and the introduction of a damper for the torque links. Shortly after, the Netherlands issued Airworthiness Directive BLA 1996-103 indicating that bulletin SB F28/32-151 was mandatory.

Since the F-28 aircraft from Canadian Regional Airlines Ltd encounter considerable
differences in ground temperatures during the same flight, Fokker sent them a facsimile in October 1996 indicating that a pressure of 290 psi should be used in the landing gear during the winter. Fokker also plans to publish another pressure figure for the summer.

Inter-Canadien confirmed the implementation of seven changes, dealing mainly with maintenance and staff 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 22 April 1998._

**Appendix A - Québec Airport (not to scale)**

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

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Updated: 2002-10-06

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Important Notices
Report A96Q0126

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 Landing/Loss of Control
First Air DHC-6 Series 300 C-GNDN
Iqaluit, Northwest Territories 85 nm NW
12 August 1996

Report Number A96Q0126

Summary

First Air 064, a DHC-6 Twin Otter (Serial No. 427), took off from Iqaluit, Northwest Territories (NWT), at 1258 Coordinated Universal Time (UTC)\(^1\) on a charter flight to Markham Bay, Lake Harbour, and back to Iqaluit. The aircraft was carrying six barrels of Jet B fuel to be delivered to Markham Bay, an off-strip landing site. At 1300, just after he took off, the captain told the Iqaluit Flight Service Station (FSS) specialist that the estimated time of arrival (ETA) for Markham Bay would be 1335. At approximately 1345, the crew informed First Air dispatch that they were landing at Markham Bay. After touching down, the pilot attempted an overshoot. During the attempt, the aircraft struck the ground about 200 metres past the end of the landing area, got airborne again, cleared a ridge, then crashed onto a rocky beach. A helicopter located the airplane 629 metres from the beginning of the landing area, partially submerged in water. The two pilots, the only occupants, received fatal injuries in the crash.

The accident occurred during daylight hours at 1347, as per the clock of the airplane, at latitude 63°40'N and longitude 071°39'W. There were no witnesses to this accident.

\(\text{Ce rapport est également disponible en français.}\)

Other Factual Information

The captain and the first officer were certified and qualified for the flight in accordance with existing regulations. The captain had accumulated a total of 3,813 hours, of which 2,028 were on Twin Otter aircraft. He was hired by First Air in February 1991, promoted to captain on the Twin Otter in June 1995, and had flown 395 hours as captain on the Twin
Otter at the time of the occurrence. Company policy stipulates that the captain, rather than the first officer, is to land the aircraft on a short strip like Markham Bay. The first officer was hired in February 1995 and had accumulated a total of 2,724 hours, of which 1,000 were with First Air on Twin Otter and Beechcraft aircraft.

Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and procedures. The airplane was loaded, under the supervision of the captain, with six barrels of Jet B fuel. The take-off weight at Iqaluit was calculated to be 12,862 pounds, and the landing weight at Markham Bay to be 12,412 pounds. The maximum authorized take-off weight is 12,500 pounds and the maximum authorized landing weight is 12,300 pounds. As both the take-off weight and landing weight were outside of the aircraft's flight envelope, the take-off centre of gravity and landing centre of gravity could not be determined.

The cargo was secured in the fuselage by the use of straps, tie-down rings, and Brownline tie-down tracks. Examination of the tracks revealed that the fasteners used to attach the straps to the tracks had torn free on impact. Four drums were found inside and two were found outside the fuselage. None of them had moved into the cockpit.

Autopsies on the pilots were performed by the Forensic Pathology Unit, Office of the Coroner for Ontario. The cause of death for the captain was determined to be head and neck injuries. The cause of death for the first officer was determined to be head and neck injuries, complicated by drowning. The autopsy report revealed injuries to the first officer's left leg, ankle, and foot. These types of injuries are commonly found on pilots who were flying the aircraft and were at the controls at the time of impact. The toxicology analysis was performed by the Center of Forensic Sciences. The testing for the presence of common drugs and alcohol was negative for each crew member. There was no evidence that incapacitation or physiological factors affected the crew's performance.

Markham Bay is located 85 nm northwest of Iqaluit and 69 nm north of Lake Harbour. There is no weather information available for Markham Bay, and pilots use weather information from Iqaluit and Lake Harbour. At 1300 and 1400, the reported weather at Iqaluit was as follows: visibility 30 statute miles, a few clouds at 26,000 feet, wind calm, temperature 9 degrees Celsius, and dew point 3 degrees. At 1400, the reported Lake Harbour weather was as follows: visibility 15 statute miles, scattered cloud at 1,500 feet with a second layer at 25,000 feet, wind calm, temperature 12 degrees Celsius, and dew point 2 degrees. The helicopter pilot who found the wreckage confirmed that there was no wind and no cloud around Markham Bay.

The Markham Bay off-site landing surface is composed of loose, small-to-medium gravel with three shallow, obliquely transverse wash-outs located along its length. The area was well known by the captain, as he had landed there on several occasions. The length of the landing site is 209 metres on a heading of 032 degrees magnetic. The actual landing area is marked by four, red 45-gallon drums placed at each
corner of the landing strip. Past the end of the landing strip, there is a
depression with water in it, rising rocky terrain, a ridge, and then
descending terrain to the waters of Hudson Strait.

During the landing attempt, the airplane made four separate sets of
marks along the landing area. The first three sets of marks showed no
evidence of braking, but the last set of marks showed evidence of
heavy braking and skidding towards the right by approximately five
degrees. The last marks also showed evidence of nosewheel digging
and steering input. The brakes were released 12 metres after the end
of the runway, and a new heading of 044 degrees magnetic was
established. The airplane became airborne 34 metres further on, past
the end of the landing area, where there was a downslope of 11
degrees. There were no more marks for over 185 metres, then the right
main gear was torn off when it hit a rock. Small flakes of metal and
paint were found in a large area around the gear, but no other
significant pieces were found. The airplane managed to continue over a
ridge and came to rest on the other side, 629 metres from the
beginning of the landing area.

The airplane struck the sea bed right wing first with a nose-down
attitude of at least 60 degrees. On impact, the right wing moved
backward and buckled the fuselage. The imprint of the flaps on the
fuselage indicated a flap setting of 20 degrees, which is the normal flap
setting for a short field take-off. The flap setting was later confirmed by
the actuator length and flaps selector position. The right engine and
propeller were torn from the firewall and were found approximately 10
metres to the left, behind the main wreckage. The firewall fuel shut-off
valve was in the open position. The left wing failed forward and inward
toward the fuselage. Cuts in the fuselage aft of the captain's seat were
made by the left propeller. The left engine and propeller remained
attached to the wing.

A continuity check of the rudder, rudder trim, elevator and elevator trim
control cables, and associated bellcranks and pushrods was
completed. The aileron and aileron trim cables failed in overload as the
wings tore free from the fuselage, but continuity was established from
the failures through the fuselage to the control column and through the
wings to the associated bellcranks, pushrods, and flight controls.

Both engines were disassembled, under TSB supervision, at the Pratt
& Whitney Canada facility. The engines displayed light impact damage
and minimal compression damage, as well as slight torsional damage
to the exhaust duct. Circumferential rubbing and scoring were
displayed by the internal rotating components due to impact loads and
external distortion, and were considered an indication that the engines
were producing power at impact. There was no indication of any
anomalies observed during the examination that would have precluded
normal engine operation.

Both propellers were disassembled at the TSB Engineering Branch. No
pre-impact anomalies which would preclude normal propeller operation
were noted with either propeller. The analysis of the information
gathered during the examination indicated that the propellers were
rotating and absorbing power from the engines at the time of impact. The blade angle markings indicated a high power setting, at, or close to, full power. When a decision is made to abort the landing, the power levers are advanced to obtain take-off power, and the flaps are retracted to 20 degrees.

During examination of the right engine, it was found that the inboard isolation mount, one of three attachment points for the engine, was broken. All of the mounts from both engines were removed and forwarded to the TSB Engineering Branch for more detailed examination. The analysis determined that fatigue cracking had preceded the separation of the broken mount, and that four of the remaining five mounts also had fatigue cracks. It was not conclusively determined whether the broken mount failed before or during the accident sequence.

The TSB had recently conducted a failure analysis of a right-engine inboard isolation mount from the same model of aircraft. The pilot of that aircraft was questioned to help assess the probable effect of such a failure on the operation and performance of the powerplant. He indicated that there was no noticeable effect on movement of the engine or propeller controls or on aircraft performance or handling.

On short runways, pilots use a short-field landing technique. The Twin Otter Manual states that in standard conditions using a short-field technique, a ground roll of 515 feet (157 metres) would be necessary to stop the airplane at maximum landing weight when using 37.5 degrees of flaps (full flaps), an approach speed of 70 knots, full brakes on a hard surface, and full reverse thrust. Moving the throttles into reverse can only be achieved after the propeller levers have been moved into full forward position.

The flaps actuator needs between 16 and 23 seconds to move from 37.5 degrees to 20 degrees of flap, if there is no air load on the flaps. Assuming an averageairspeed of between 52 knots (stalling speed at maximum gross weight and 37.5 degrees of flaps) and 56 knots (stalling speed at maximum gross weight and 20 degrees of flaps), the flaps had 17 to 19 seconds to retract from the time the airplane landed and the crew applied brakes until the aircraft reached the location where it crashed. At Markham Bay, only the last set of marks showed signs of braking for a measured distance of 88 metres.

**Analysis**

There were no witnesses to the occurrence. The crew was qualified and certified for the flight. The weather conditions were not considered to be a factor in this occurrence. The aircraft's weight was determined to have been above the maximum take-off weight and the maximum landing weight.

Company policy requires the captain to do all landings at any off-site landing strips. When the airplane departed Iqaluit, the captain was speaking on the radio, a function normally performed by the pilot not flying. The injuries to the first officer's left leg, ankle, and foot suggest
that he may have been at the controls at the time of impact. However, given that the first officer was in the right seat and the initial impact forces were more severe on the right side of the aircraft, it is possible that the first officer's additional injuries were a result of the impact forces and not of his being at the controls of the aircraft. Examination of the off-site landing area revealed that there were signs of nosewheel steering input at the fourth set of tire marks. Because the steering lever is located on the hub of the captain's control wheel, either the captain was flying the aircraft at the time of the occurrence, or he was attempting to take control of the aircraft. Notwithstanding the above, it could not be determined with certainty who was at the controls of the aircraft.

The four sets of imprints on the landing strip at Markham Bay indicate that the aircraft bounced into the air three times during the landing attempt, and that the pilot flying the aircraft had difficulty controlling the aircraft on landing. In order to bounce on three different occasions, the airplane needed a speed in excess of the normal landing speed. Excessive speed can come from a higher than normal speed on final approach for the landing or from power application during the landing sequence. The use of full flaps during the approach, in addition to the use of brakes and reverse thrust on landing, will decrease the aircraft's landing speed and shorten the landing roll. It was not possible to determine what flap setting was used for the approach or if the pilot used reverse thrust on landing. The fact that the flaps were at 20 degrees and the engines were developing maximum power indicates that the pilots were likely attempting an overshoot using a short field take-off flap setting.

The airplane became airborne 34 metres after the crew released the brakes; the point at which they released the brakes is likely when they decided to overshoot. The fact that the aircraft became airborne in such a short distance is likely the result of the aircraft having a high residual airspeed, a take-off speed close to stall speed, and the downslope terrain. Controlling the aircraft is more difficult at such a low airspeed. The weight condition and the low airspeed did not allow the aircraft to gain sufficient height to clear the obstacle located 185 metres after lift-off. When the landing gear hit the rock and the airplane went over the ridge, the small margin between flying and stall speed was removed. The airspeed decreased below the stall speed and the aircraft fell nose down into the waters of Hudson Strait.

The following Engineering Branch reports were completed:

- LP 142/96 - Occurrence Investigation - Regional Support;
- LP 143/96 - Engines and Propellers Examination; and
- LP 094/96 - Engine Mount Failure.

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

**Findings**

- The crew was qualified for the flight.
- It could not be determined with certainty who was at the controls of the aircraft.

- The aircraft was loaded under the supervision of the captain.

- The aircraft's weight was determined to be above the maximum take-off weight and the maximum landing weight.

- The flaps were found set to 20 degrees at the accident site.

- The inboard isolation mount of the right engine was broken; the time of failure could not be determined.

- The aircraft stalled when going over the ridge.

### Causes and Contributing Factors

For unknown reasons, a decision was made to overshoot even though insufficient runway remained for acceleration, take-off, and climb. Likely contributing directly to the decision to overshoot was the difficulty in controlling the aircraft on touchdown.

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 UTC (local time plus four hours) unless otherwise noted.
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
Loss of Control and Runway Excursion
Propair Inc.
Swearingen SA226-TC C-GKFS
Puvirnituq, Quebec
23 October 1996

Report Number A96Q0176

Summary

Propair flight 450, a Swearingen SA226-TC (serial number TC-215E) with 13 persons on board, was on a charter flight from La Grande Rivière, Quebec, to Puvirnituq, Quebec. The co-pilot was in the right-hand seat and was flying the aircraft. Following an instrument approach to runway 19, the aircraft broke through the cloud layer and the co-pilot switched to visual for the final approach. As soon as the nose gear touched down on landing, the aircraft veered left. The co-pilot applied full right rudder and throttled back to GROUND IDLE in preparation for reversing thrust. A short time later, the pilot-in-command took the controls of the aircraft and left the throttle levers on GROUND IDLE. He then observed that the aircraft was drifting further to the left and that, even when he applied full right rudder, he was unable to correct the drift. As a last resort, he pressed the PARK button for the nosewheel steering system, but the aircraft continued its course toward the runway edge and crashed at the bottom of the embankment. The investigation established that the aircraft left the runway about 2,000 feet from the threshold after turning left 90 degrees relative to the runway centre line. The nose gear and main landing gear separated from the aircraft when the aircraft fell from the runway shoulder to the bottom of the embankment.

One passenger sustained minor injuries. All occupants evacuated the aircraft without difficulty via the emergency exits. The occurrence happened during daylight.

Ce rapport est également disponible en français.

Other Factual Information
According to the crew, the weather at the time of the landing was as follows: sky overcast at 1,900 feet, no precipitation, visibility over 15 miles, and winds from 140 degrees magnetic at 15 knots.

The runway is 5,000 feet long by 100 feet wide, and has a gravel surface. The surface is hard-packed and rough. The runway has shoulders about 30 feet wide and is built up in places. Where the aircraft left the runway and came to rest, there is a drop-off of about 6 feet from the level of the runway. At the time of the landing, the runway was wet, but the surface was uniformly compacted and hard. There was no standing water that could have affected aircraft braking.

The crew members were certified and qualified for the flight in accordance with existing regulations. The pilot-in-command had 1,050 flying hours on type and the co-pilot had 350 flying hours on type. Both pilots were familiar with gravel runway operations. Neither pilot had taken a course on cockpit resource management (CRM). CRM relates to the interaction between flight crew members during the flight. CRM training helps pilots and other members of the crew to communicate better, so as to ensure a better coordinated and more effective response in an emergency. The benefits of this training and its contribution to the advancement of aviation safety are well known in the industry. CRM training is not mandatory for commuter airlines.

The aircraft is equipped with a variable authority nosewheel steering system. An electrically controlled hydraulic servo-valve is used to steer the nosewheel. System controls include a switch to test system operation to the left and right, an ARM switch to ready the system for activation, and a PARK button. These switches are mounted on a panel in the cockpit to the left of the pilot-in-command. One switch of the nosewheel steering system is mounted on the left throttle lever, and is hard to reach from the co-pilot's seat. To activate the nosewheel steering system, the button on the left power lever must be depressed or the right speed lever retarded to LOW, while the system is armed. Nosewheel steering is then controlled by the rudder pedals. But if the system detects a malfunction or if the nosewheel is more than 3 degrees from the rudder pedal position, the system will not activate. Because of the sensitivity of the steering at higher speeds and the effectiveness of the rudder, the company recommended to its pilots that they not use the nosewheel steering system at speeds exceeding 60 knots. However, according to Fairchild Aircraft Incorporated, the steering is available and can be used to correct a drift when all other means fail. The nosewheel steering system is not used for normal take-off and landing procedures; rather, it is used to facilitate ground manoeuvres at low speed. The PARK button is used for tighter turns; the system increases nosewheel deflection from 10 degrees to the right or left to 60 degrees to the right or left. To activate the PARK button, the nosewheel steering system must be armed and the button on the left power lever must be depressed or the right speed lever retarded to LOW.

On the final approach and in accordance with the pre-landing checks, the pilot-in-command engaged the nosewheel steering ARM switch. On landing, the main gear touched down at about 110 knots and,
according to the co-pilot, the nosewheel touched down about two seconds later. As soon as the nosewheel touched down, the aircraft started to veer left. The co-pilot immediately applied full right rudder, and throttled back to GROUND IDLE so that he could then move the levers to reverse thrust to correct the drift to the left, but he did not use the brakes. He did not tell the pilot-in-command he was having difficulty keeping the aircraft straight. The pilot-in-command took the controls at about 80 knots and left the throttle levers on GROUND IDLE so as not to use the reverse thrust, in accordance with the standard operating procedures for gravel runways. He was surprised at the amount of force he had to apply to the right rudder pedal to try to straighten the aircraft. He did not try to engage the nosewheel steering system. As a last resort, he pressed the PARK button on the nose gear steering wheel and applied full reverse thrust, but the aircraft continued its course toward the embankment at the edge of the runway and crashed at the bottom.

The marks made by the aircraft tires on the gravel runway surface confirm that there was no skidding and no significant application of the brakes before the aircraft left the runway. The distance between the nose gear and left main gear was measured at 2 metres, while the distance between the nose gear and right main gear was 2.8 metres. This confirms that the nose gear was in fact deflected left during the landing roll. No sign of failure was found on the tires or brakes. The blades of both propellers were found at the same reverse pitch angle. The nose gear bent backward on impact. Part of the hydraulic servo-valve that is mounted in the nose gear and controls nosewheel steering fractured on ground impact. It was not possible to analyze the hydraulic fluid in the hydraulic servo-valve because the fluid had leaked out.

Examination of the wreckage and aircraft controls revealed no malfunctions which could have contributed to the accident. The nosewheel steering system was sent to the TSB Engineering Branch Laboratory for analysis. The hydraulic and electronic components, including the hydraulic servo-valve, were forwarded to the manufacturer, Fairchild Aircraft Incorporated, for testing. Test results revealed no pre-impact damage which could have contributed to drifting.

When the aircraft was certified, the maximum demonstrated cross-wind component was 20 knots at a 90-degree angle to the runway. No cross-wind limitations are recommended by the manufacturer. Limits are left to the discretion of the operator or pilot, and depend on the skill and experience of the individual. According to the company chief pilot, a 15-knot cross-wind from 45 degrees is considered negligible for this type of aircraft.

The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The aircraft had no known deficiencies before the flight. It was being operated within the prescribed limits for weight and centre of gravity. The Airworthiness Directives applicable to the aircraft were completed in accordance with existing regulations. In May 1995, the manufacturer issued Service Bulletin SB226-32-058, which proposed the optional replacement of the
hydraulic servo-valve in the nosewheel steering system to improve system operation. Note that users are not required to comply with service bulletins. The manufacturer's index of service bulletins, which was revised in February 1996 and was in the operator's possession, indicated that SB226-32-058 had not been issued. A printing error was made by the manufacturer, but it has since been corrected. The bulletin was in fact among the operator's records, but the hydraulic servo-valve had not been changed. The history of this type of servo-valve shows that contamination of the hydraulic fluid can degrade operation of the servo-valve and cause a situation similar to the accident described here.

Emergency procedures for a nosewheel steering malfunction are provided in the aircraft manual. These procedures state that in the event of an uncommanded deflection of the nosewheel, directional control of the aircraft must be maintained using any or all of: the rudder pedals, brakes or power. In addition, the nosewheel steering system must be switched off.

According to the company chief pilot, the emergency procedures for a nosewheel steering malfunction, particularly the emergency procedure for uncommanded nosewheel deflection, were unclear and were not well understood by his pilots and several other pilots experienced on this type of aircraft. He also reported that there are no memorized checklist items indicating the actions to take in the event of an uncommanded nosewheel deflection, and that it is difficult, if not impossible, to refer to the manual when this type of emergency arises.

The emergency exits were used for the evacuation because the main door of the aircraft was jammed.

Analysis

In this accident, the aircraft's left turn on landing may be attributed to several factors. The possibility that the left brake locked up on landing was eliminated, and the runway condition was not a factor. A 15-knot cross-wind from 45 degrees can be controlled easily with the rudder pedals and was considered negligible for this type of aircraft. Application of full right rudder, as described by the crew, should have corrected the drift of the aircraft, but it did not. An aircraft may also turn because of a deflection of the nosewheel. Although such a deflection was not confirmed by analysis, the elimination of all other factors indicates that the nosewheel probably was deflected to the left during the landing. The investigation consequently focused on the actions of the crew during the landing, because the aircraft was maintained in accordance with existing regulations and the tests and analyses revealed no other malfunctions.

On the landing, the system was armed and could be used. The nosewheel touched down at a speed of about 110 knots, and the aircraft suddenly veered left. As use of the system was not recommended at speeds over 60 knots and the button used to engage the system was hard to reach from the co-pilot's seat, the co-pilot tried to correct the drift with the right rudder pedal, without telling the pilot-in-
command that he had difficulty maintaining directional control of the aircraft. As he was preparing to apply reverse thrust at about 80 knots, the pilot-in-command took the controls of the aircraft. The pilot-in-command was surprised at the amount of force he had to apply to the right rudder pedal. He did not attempt to use the nosewheel steering system, but that would have been impossible without first centring the rudder pedals because they were clearly over three degrees from the nosewheel position. Also, the pilot-in-command did not use reverse thrust because the runway surface was gravel. The marks on the runway indicate that there was no significant braking. The pilot-in-command was unable to maintain directional control of the aircraft, which continued its course to the left and exited the runway.

The servo-valve was serviceable, but it was not possible to analyze its hydraulic fluid. The manufacturer merely suggested that the servo-valve be replaced and forgot to list the service bulletin in the bulletin index; consequently, the servo-valve of the aircraft was not replaced, but replacement was not mandatory. Publication of a service bulletin implies that the airworthiness of the aircraft is not in jeopardy; it is reasonable to believe, however, that replacement of this servo-valve might have prevented the accident.

The lack of clarity and understanding of the emergency procedures and the lack of communication between the co-pilot and pilot-in-command did not facilitate directional control of the aircraft during the landing roll. Had there been memorized checklist items for the emergency procedure to be followed in the event of an uncommanded nosewheel deflection, and had the co-pilot told the pilot-in-command that he was having difficulty keeping the aircraft straight and was going to use the thrust reversers to bring the aircraft back on course, the pilot-in-command might have used reverse thrust and would not have been surprised at the amount of force he had to apply to the rudder pedal to maintain directional control of the aircraft. In addition, the pilot-in-command might have made greater use of the brakes and propellers and disarmed the nosewheel steering system to maintain directional control of the aircraft, as specified in the user manual approved by the Federal Aviation Administration (FAA). A CRM course would likely have had a beneficial effect on the crew and the actions they took in this occurrence.

The following laboratory report was completed:

LP 168/96 - Swearingen Nosewheel Steering System.

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

**Findings**

- 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 pilot-in-command and co-pilot were certified and qualified for the flight in accordance with existing regulations.

The co-pilot did not tell the pilot-in-command that he had difficulty controlling the aircraft on the landing roll.

The marks made by the aircraft tires on the runway surface confirm that there was no skidding and no significant application of the brakes before the aircraft left the runway.

The blades of both propellers were found at the same reverse pitch angle.

Examination of the wreckage, and the tests on components, revealed no pre-impact malfunctions that could have contributed to the sudden deflection of the nosewheel to the left.

The hydraulic servo-valve was serviceable, but its hydraulic fluid could not be examined.

The manufacturer's index of service bulletins, which was revised in February 1996, indicated that Service Bulletin SB226-32-058 had not been issued. This bulletin proposed the optional replacement of the hydraulic servo-valve in the nosewheel steering system. The operator had SB226-32-058 in its possession, but the hydraulic servo-valve had not been changed. Replacement of the servo valve might have prevented the accident.

The nosewheel was probably deflected left on the landing, for reasons that could not be determined.

The members of the crew had not received CRM training.

There are no memorized checklist items indicating the actions to take in the event of an uncommanded nosewheel deflection.

Causes and Contributing Factors

The aircraft left the runway during the landing roll because the nosewheel was probably deflected left, for reasons that could not be determined. Contributing to the accident were a lack of communication in the cockpit and the actions taken by the crew to maintain directional control of the aircraft.

Safety Action

After this accident, the company took the initiative of sending all its
pilots on a CRM course.

The Board made two recommendations in 1995, A95-11 and A95-12, to Transport Canada (TC) on CRM training requirements for all operators and aircrew involved in commercial aviation. TC responded by mandating CRM training for all airline operations. However, Air Taxi (CAR 703) and Commuter (CAR 704) operations are still not required to have mandatory CRM training, even though these operators are involved in the majority of occurrences where the lack of CRM is a factor. In the last two years there have been at least two other occurrences involving Air Taxi or Commuter operators where poor crew coordination may have contributed.

In addition an Aviation Safety Advisory has been forwarded to Transport Canada to review the appropriateness of the emergency operating procedures pertaining to a loss of directional control on the ground for Swearingen SA-226 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 19 November 1997.

Updated: 2002-10-06

Important Notices
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.

Loss of engine power/stall
Cessna 177RG Cardinal C-GWNW
Airdrie, Alberta
12 March 1996

Report Number A96W0055

Synopsis

The pilot departed from runway 34, Calgary International Airport, on a visual flight rules (VFR) flight to Villeneuve Airport, Alberta, at about 1100 mountain standard time (MST). He climbed to 4,500 feet above sea level (asl) to clear the zone, and initiated a climb to his cruise altitude of 8,500 feet asl. As the pilot reached about 5,000 feet asl, the engine rpm smoothly dropped to idle. Attempts to regain normal power by movement of engine and fuel system controls were unsuccessful. The pilot declared an emergency, extended the landing gear, and established a 65 mph glide. Air Traffic Control (ATC) advised the pilot that Airdrie, behind him, was the closest airport to his location. The pilot made a left turn back toward Airdrie, but was unable to make it to the airport. The pilot selected a secondary road, running east-west toward Airdrie, for an emergency landing. While banking to the west to align with the road, he noticed a set of power lines and planned to clear them; however, he then noticed a second set of power lines and checked back on the elevator controls. While manoeuvring, the pilot heard the stall horn beeping and noticed that the aircraft was drifting south of his intended landing area. The left wing then dropped and the flight controls were initially unresponsive before the aircraft began a steep descent. The pilot attempted to flare during the dive. The aircraft struck the ground hard in a nose-low attitude, bounced twice, the right main wheel broke off, and the nose gear collapsed. The aircraft left the road and came to rest in the ditch against a barbed wire fence. The pilot sustained serious injuries. He turned off the master switch and called 911 from his cell phone. Police and ambulance personnel arrived shortly thereafter, and the pilot was evacuated to a Calgary hospital.

Other Factual Information

The aircraft fuselage was heavily damaged during the impact, with indications of high vertical loads evidenced by the collapse of the
cockpit floor under the pilot's seat. The flaps were found in the retracted position. The pilot was not wearing the shoulder harness installed in the aircraft. There was evidence of rotation on the propeller blades, prior to one blade becoming jammed into the lower cowl. At the request of the injured pilot, the emergency locator transmitter (ELT) had been selected to the manual ON position by a passer-by. The aircraft was reported to have been leaking fuel after the occurrence.

Examination of the aircraft showed that the impulse spring (part no. 10-51324) in the magneto (Teledyne Continental Motors (TCM)/Bendix model D4LN-2021) had broken. The engine (Textron Lycoming IO-360A1B6D) in this aircraft is equipped with a single-drive, dual magneto. The impulse coupling is a spring-loaded device that mechanically retards the spark advance to assist starting. Failure of this spring would allow the common drive of the dual magneto to move in the direction that would retard the spark. This would affect both ignition systems and could cause a significant power loss if the resulting spark timing was near top dead centre (TDC). A search of the Service Difficulty Report (SDR) data base determined there had been 58 other reports of the failure of this spring, five in this model dual magneto, with similar power losses reported. A detailed examination of the broken spring by the TSB Engineering Branch found evidence of an intergranular pre-crack region, indicating an environmentally assisted fracture. Examination determined that the magneto breaker points were pitted and gapped incorrectly, resulting in weak spark output when the magneto was bench tested, although this is not believed to be a causal factor in the occurrence.

Airworthiness Directive (AD) 78-09-07 R3, pertaining to this aircraft, requires inspection of the impulse coupling for excessive wear at 500-hour intervals. A survey of the aircraft logs and records determined that this AD had never been complied with. The engine log indicated that the engine had accumulated 758.1 hours since overhaul in 1983. The AD requires compliance with Bendix Service Bulletin (SB) 599B, which has been superseded by TCM mandatory SB (MSB) 645. This MSB adds requirements for inspection of riveted impulse couplings at 100-hour intervals, and replacement of the impulse spring if the impulse coupling is disassembled for inspection; inspection is possible without disassembly.

The aircraft was being maintained by a freelance aircraft maintenance engineer (AME), who was a close acquaintance of the pilot. The AME had last certified the aircraft on 03 February 1996, at 2,290.3 airframe hours. The AME indicated that he had obtained a listing of the ADs required for this aircraft from an American aircraft sales publication called The Aircraft Bluebook. The book was examined and AD 78-09-07 R3 was not included in the list of ADs for the Cessna 177RG. A disclaimer printed in the lower margin of the AD notes section of this book reads: "NOTE - this AD note listing is intended as a guide only and should not be relied upon as conclusive evidence of AD applicability on any particular aircraft."

The pilot has held a private pilot licence since 1986 and has flown a total of about 600 hours, 468 hours of which were on type. He had
obtained a night endorsement in 1989. The pilot had not performed a forced landing, practice or actual, since his initial flight training. His valid Class III medical required glasses or contact lenses to be worn. Medical examination of the pilot, following the occurrence, indicated crush damage to vertebra that required immediate surgery.

The weather at the time of the occurrence was reported as scattered cloud at 4,000 feet, broken ceiling at 8,000 feet, temperature 5 degrees Celsius, dew point -1 degree Celsius, visibility 40 miles, and the wind from 350 degrees true at 13 gusting to 18 knots. The Transport Canada Aeronautical Information Publication (AIP) section AIR 2.1 - Crosswind Landing Limitations chart indicates that, as a general rule, the maximum crosswind component for this aircraft in an 80-degree crosswind is about 14 mph. The pilot felt that local fields were too rough and soft to use for a forced landing, and decided to land on a road. The topography in the area of the occurrence consists of level pasture or stubble fields at an elevation of about 3,648 feet asl. The ground was reported to be soft, from a recent snow thaw, but would have been suitable for a forced landing.

The Cardinal RG Owner's Manual supplied by the manufacturer states that the stall speed is 66 mph CAS (flaps UP, power OFF) and 57 mph CAS (flaps DOWN, power OFF). Section III, Emergency Procedures, describes the following forced landing procedure:

EMERGENCY LANDING WITHOUT ENGINE POWER, if all attempts to restart the engine fail and a forced landing is imminent, select a suitable field and prepare for the landing as follows:

1. Airspeed---85 MPH (flaps UP) 75 MPH (flaps DOWN)
2. Mixture---IDLE CUT-OFF
3. Fuel Selector Valve---OFF
4. Ignition Switch---OFF
5. Landing Gear---DOWN (UP if terrain is rough or soft)
6. Wing Flaps---AS REQUIRED (30 degrees recommended)
7. Doors---UNLATCH PRIOR TO TOUCHDOWN
8. Touchdown---SLIGHTLY TAIL LOW
9. Brakes---APPLY HEAVILY

Analysis

A comparison of the forced landing procedure used by the pilot in this occurrence and the procedure recommended by the manufacturer in the Owner's Manual indicates that the pilot did not establish the correct glide speed, select flap, or secure the engine following the loss of power. The pilot would have been at about 1,500 feet above ground level (agl) at the time of the power loss, and would have had adequate
time to prepare the aircraft for a forced landing. The wing drop, initially unresponsive flight controls, and then a rapid descent are typical of an aerodynamic stall; the possibility of a stall would have been less with flap selected to the recommended 30 degrees. The drift to the south of the selected road on final approach was a result of the crosswind. The successful execution of a power-off, forced landing on a narrow road in gusty, maximum crosswind conditions would likely exceed the skill level of the average private pilot. A forced landing into wind in a level, stubble field probably would have resulted in less damage or injury. The aircraft damage pattern, including the collapsed floor under the pilot's seat, is evidence of the high vertical G impact forces that resulted in the back injuries experienced by the pilot.

The risk of fire would have been reduced had the pilot secured the aircraft fuel and electrical systems prior to ground impact, as described in the Forced Landing section of the Owner's Manual. As the pilot did not complete these checklist items, and in consideration of the fuel leak at the occurrence site, the risk of fire was high. Because of the immobility of the pilot, a fire would have had serious consequences.

The failure of the magneto impulse spring resulted in a loss of engine power. Completion of the impulse coupling inspection requirements contained in the missed AD (78-09-07 R3) and the referred SBs probably would have resulted in replacement of the impulse spring, if the coupling was disassembled.

The following Engineering Branch report was completed:

LP 49/96 - Examination of Magneto Impulse Spring.

Findings

1. The pilot was properly licensed and qualified for the flight.

2. The magneto impulse spring failed in flight, which resulted in a loss of engine power.

3. The pilot did not extend the flaps during the forced landing, which would have lowered the stall speed.

4. The aircraft fuel and electrical systems were not secured during the forced landing procedure, resulting in a risk of fire.

5. The pilot stalled the aircraft while attempting a forced landing.

6. The aircraft landed hard and the cabin floor under the pilot's seat collapsed, which resulted in back injuries to the pilot.

7. The pilot was not wearing the shoulder harness installed in the aircraft.

8. AD 78-09-07 R3 had never been complied with.

Causes and Contributing Factors
While attempting a forced landing following a loss of engine power, the pilot stalled the aircraft on final approach. The pilot's failure to maintain adequate airspeed or extend the flaps during the forced landing is considered to be a contributing factor. The loss of engine power was caused by the failure of the magneto impulse spring.

**Safety Action Taken**

Subsequent to this accident, the TSB forwarded an Aviation Safety Advisory to TC indicating that confusion may exist concerning the compliance criteria of AD 78-09-07. The TSB suggested that TC may wish to request the FAA amend AD 78-09-07 to clearly require compliance with TCM mandatory SB 645.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, Benoît Bouchard, and members Maurice Harquail and W.A. Tadros, authorized the release of this report on 27 August 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/Ice
Canadian Helicopters Limited Western Division
Bell 206B JetRanger (Helicopter) C-FZSI
Mould Bay, Northwest Territories 9 SM S(T)
26 April 1996

Report Number A96W0072

Summary

The Bell 206B helicopter, serial number 647, departed the Mould Bay Airport, Northwest Territories, at 0729 mountain standard time (MST)\(^1\) on a visual flight rules (VFR) flight to Sachs Harbour and Inuvik. The pilot was expected to meet a Twin Otter aircraft at an en route fuel cache located 140 statute miles south of Mould Bay, near Mercy Bay, at about 0900. The helicopter did not arrive at Mercy Bay, and, at approximately 1000, the Twin Otter flight crew began an air search along the direct track to Mould Bay. They located burned and scattered helicopter wreckage on sea ice approximately nine miles south of the Mould Bay weather station. A ground party was quickly dispatched from the weather station in a tracked snow vehicle. They reached the accident site at approximately 1500 and determined that the wreckage was that of the missing helicopter. The pilot had sustained fatal injuries.

Ce rapport est également disponible en français.

Other Factual Information

Mould Bay is an Arctic sea bay on the east coast of Prince Patrick Island. It is oriented north-south, and is surrounded on three sides by barren hills which are up to 900 feet high. The bay is approximately 20 miles long and about 8 miles wide at the south end, where it opens into Crozier Channel. The accident site was located near the south end on the direct track between the Mould Bay Airport and the Mercy Bay fuel cache. The Mould Bay weather station is a remote high Arctic weather station located on the north shore of Mould Bay.
The helicopter had been chartered by a polar research company to retrieve sea buoys and move an ice camp approximately 300 miles northwest of Mould Bay. The pilot had flown the helicopter from Inuvik to Mould Bay on 18 April and had reached the ice camp on 19 April. He operated out of the ice camp for four days and returned to Mould Bay on 23 April. The helicopter was released by the client for the return flight to Inuvik on the morning of 26 April.

The area forecast for Mould region, issued at 0430 MST on 26 April, indicated that VFR conditions would generally prevail during the planned flight period. Sky conditions were forecast to be scattered cloud at 2,000 to 3,000 feet above sea level (asl), with tops at 5,000 feet. Visibilities were forecast to be greater than six statute miles, with occasional visibilities four to six miles in light snow. Local stratus ceilings of 300 to 800 feet above ground level (agl) and visibilities of ½ to 4 miles in fog and light snow were anticipated in areas of on-shore upslope flow. The pilot had telephoned the Sachs Harbour Community Aerodrome Radio Station (CARS) prior to departure, and determined that good VFR weather conditions existed in Sachs Harbour.

The Mould Bay 1400 UTC (0700 MST) AUTO5 SA\(^2\) reported the sky condition as clear below 10,000 feet; visibility greater than 9 statute miles; temperature -18 degrees Celsius; dew point -21 degrees Celsius; and winds 360 degrees true at 4 knots. Similar conditions were reported one hour later. Weather station personnel estimated the sky condition to be 500 to 1,000 feet overcast and the visibility to be 1 to 4 miles when the helicopter left Mould Bay. The Twin Otter had departed Mould Bay for Mercy Bay at 0900 MST; the flight crew reported that on departure the sky condition was 500 feet overcast and the visibility was 1 to 4 miles. Because of the obvious differences between the weather information provided by eyewitnesses and that provided by the AWOS, it is considered that the AWOS at Mould Bay was not accurately recording actual weather conditions at the time of the accident.

The pilot obtained his commercial helicopter licence in 1993, and had accumulated approximately 1,500 hours of flight experience. He was raised in Sachs Harbour and reportedly was very familiar with Arctic terrain and climate. He had frequently hunted and snowmobiled in Arctic whiteout conditions. He had been employed seasonally for several years to herd reindeer near Tuktoyaktuk, Northwest Territories, with a Robinson R-22 helicopter. Private and commercial training records indicate that the pilot had received a total of 10.6 hours of dual instrument training prior to acquiring his commercial helicopter licence. The pilot was not endorsed for night or instrument flight, and there was no evidence that he had acquired additional instrument training following the issue of his commercial helicopter licence.

Post-mortem examination and a review of medical records yielded no evidence of incapacitation or physiological or psychological factors which could have adversely affected the pilot's performance. Tests for the presence of common drugs were negative.

Records indicate that the helicopter was certified, equipped, and
maintained in accordance with existing regulations and approved procedures. It was equipped with the basic flight instrumentation necessary for instrument flight. The flight instruments were mounted in the centre of the instrument panel, to the left of the pilot's position and above the radio console.

The wreckage trail indicated that the helicopter was travelling in a southerly direction when it struck the ice, in an approximately 40-degree nose-down and 45-degree left-bank attitude. The airframe disintegration was extensive. The airframe fuel cell and three 10-gallon kegs of jet fuel, which are presumed to have been located in the cabin of the helicopter, ruptured during the accident. The ice surface was scorched and sooted for most of the length of the wreckage trail. 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 Transport Canada Aeronautical Information Publication (AIP) describes whiteout as an atmospheric optical phenomenon of the polar regions in which the observer appears to be engulfed in a uniformly white glow. Neither shadows, horizon, nor clouds are discernible, and the sense of depth and orientation is lost. Whiteout occurs over an unbroken snow cover and beneath a uniformly overcast sky. Whiteout may be encountered when flying over large frozen bodies of water at some distance from shore. The AIP recommends that pilots avoid such conditions, unless they have suitable aircraft instruments and they are sufficiently experienced.

Entry into a whiteout condition, which can occur in weather conditions which are considerably better than the minimum required for VFR flight, requires an immediate shift to instrument flight. A subtle absence of visual reference may be the first clue to a whiteout, and any delay in recognition may precipitate disorientation. Knowledge and experience, understanding the cause and effect of whiteout, and maintaining sufficient instrument skills to avoid disorientation may be the best defences against whiteout accidents.

The Canadian Helicopters Flight Operations Manual cautions against attempting to fly VFR in whiteout conditions, and advises pilots to be alert at all times to the danger of inadvertently entering these conditions. The Canadian Helicopters recurrent VFR training curriculum did not provide for basic instrument training, nor was there any regulatory requirement for the company to conduct this type of recurrent training.

Spatial disorientation is the false perception and/or interpretation of aircraft attitude with regard to horizontal and gravitational references. Pilots with little instrument time are particularly susceptible to spatial disorientation when they encounter conditions where there are no external visual attitude references.

There are two philosophies with regard to training to prevent helicopter accidents which occur because of inadvertent loss of outside visual
One philosophy is to equip helicopters with the basic instrumentation necessary for instrument flight, and to provide recurrent basic instrument training to VFR pilots. This would enable the pilot to maintain control of the helicopter long enough to return to visual flight should whiteout or other instrument meteorological conditions (IMC) be encountered. Some operators believe this may impart a false confidence to VFR pilots and encourage deliberate entry into instrument conditions because of improved instrument skills. Obstacle clearance may be as great a hazard as loss of control during transient VFR/IFR/VFR flight at low altitude. A second philosophy is to provide training which emphasizes early recognition and complete avoidance of potential IMC, without providing recurrent instrument training. This would encourage the pilot to avoid using meagre instrument skills to cope with whiteout and other IMC. Proponents of this philosophy stress diverting, turning back, or landing before loss of visual reference occurs.

The helicopter was fitted with a global positioning system (GPS) receiver. GPS is an inexpensive and accurate navigation system, which is especially helpful for VFR flight in featureless terrain and in areas of compass unreliability. GPS permits direct line navigation for optimal fuel efficiency and nearly eliminates the risk of getting lost. The benefits provided by GPS may be mitigated by the tendency to increase risk taking in other areas, such as attempting VFR flight in poor weather. This tendency is known as risk compensation. Data recovered from the GPS indicated that it was operating at impact.

The helicopter was equipped with a high frequency (HF) radio. The vernier HF antenna tuner was mounted on the left wall of the instrument centre console. The position of the vernier control and the indicator needle required that the pilot look and reach left and downward to tune the HF antenna. The research company routinely provided flight following on 5680 KHz, and the pilot had advised a Mould Bay operator that he would contact him on 5680 about five minutes after take-off. Approximately five minutes after take-off, an HF carrier-only transmission was heard for three to five seconds, indicating that the pilot may have been tuning the HF antenna. There was no subsequent communication with the pilot. The accident site was located approximately five minutes (air time) from the Mould Bay Airport.

The helicopter was equipped with a Pointer Sentry C-4000 emergency locator transmitter (ELT) which was mounted on the right side of the vertical control tube tunnel that is located in the centre of the cabin. The ELT was torn from the mount and the antenna lead at impact. The case was penetrated and the switch circuitry sustained damage which prevented signal transmission.

### Analysis

At the time the pilot departed the Mould Bay Airport, marginal VFR weather conditions prevailed, with the ceiling and visibility estimated to be 500 to 1,000 feet overcast and 1 to 4 miles in fog and light snow. In these conditions, a whiteout probably would have existed over the eight-mile-wide expanse of sea ice on Mould Bay. Wreckage
examination indicated that the helicopter was banked left and descending when it struck the ice, indicating that it was out of control. The severe breakup of the helicopter and the scattered wreckage trail are typical of numerous whiteout accidents. It is probable that the pilot lost visual reference because of the whiteout conditions, became disoriented, and lost control of the helicopter. It is possible that the pilot was tuning the radio at the time of the occurrence, which would have contributed to his disorientation.

Because of its ease of use and accuracy, GPS encourages straight-line tracking. The data retrieved from the GPS following the crash and the location of the accident site on a direct line between the departure airport and destination indicate that the GPS was functioning and that the pilot was using GPS as his primary method of navigation. His decision to initiate and continue flight into weather conditions which were conducive to whiteout might have been influenced by the availability of GPS, by the favourable area forecast, and by the fact that he knew the weather was good in Sachs Harbour.

The AWOS at Mould Bay was not accurately recording actual weather conditions at the time of the accident; however, this was not considered to be a factor in the occurrence.

The following Engineering Branch reports were completed:

- LP 59/96 - Instrument Examination;
- LP 58/96 - Servo Actuators Examination.

**Findings**

- The pilot was certified and qualified for flight in accordance with existing regulations.
- Records indicate that the helicopter was certified, equipped, and maintained in accordance with existing regulations and approved procedures.
- It is probable that the pilot lost visual reference and became disoriented over sea ice during whiteout conditions.
- The pilot had limited instrument flying experience.
- Because of impact damage, the ELT did not transmit.
- The AWOS at Mould Bay was not accurately recording actual weather conditions at the time of the occurrence; however, this was not considered to be a factor in the occurrence.

**Causes and Contributing Factors**

The pilot lost control of the helicopter after continuing flight into whiteout weather conditions, probably because he became disoriented.
Safety Action

As a result of this accident, Canadian Helicopters Western Division has reviewed its training policy and has incorporated emergency procedure training into the VFR recurrent training curriculum. This training will stress the hazards of "pushing" weather and stress avoidance of weather conditions which may result in whiteout. This training will also prepare the pilot to maintain straight and level flight, climb and descend, and complete a 180-degree turn with reference to the instruments should visual cues be lost.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail and W.A. Tadros, authorized the release of this report on 11 December 1996.

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

2. Reported by an automated weather observation system (AWOS).

Updated: 2002-10-06

Important Notices
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.

Loss of Control
Spiral Cessna 150 C
FQZC Bellis, Alberta
16 September 1996

Report Number A96W0178

Synopsis

The pilot of the Cessna 150 was on a night visual flight rules (VFR) flight from Spirit River, Alberta, to St. Paul. Prior to his departure, the pilot phoned the Grande Prairie Flight Service Station (FSS) to receive a weather briefing and file a flight plan. When the pilot filed his flight plan (at about 2030), he was told that his flight plan would be opened in 10 minutes unless the FSS specialist heard anything different. The aircraft departed at 2040 mountain daylight saving time (MDT) for the planned four-hour flight. No radio transmissions from the aircraft were heard by Grande Prairie or any other FSS along the route.

At 2310, witnesses in their house heard the whine of an aircraft engine followed by a loud thump. They went outside to search the area around their farm, but it was raining too hard to see anything so they went back inside their house and called the police. Later the police began a search that continued throughout the night until 0930 the next morning, when the aircraft wreckage was located about one-quarter mile from the farm house. The pilot was fatally injured.

Other Factual Information

The aircraft was equipped with a global positioning system (GPS) navigation receiver, and the pilot was familiar with the operation of the unit. The pilot had used the aircraft's radio several times on his flight into Spirit River; there was no evidence to indicate that the radio was unserviceable. The propeller blade damage and twist were consistent with considerable power being produced at the time of impact. The aircraft systems were examined to the degree possible, and no evidence of a malfunction was found. A review of the journey and technical log-books after the accident showed that the aircraft was maintained in accordance with existing regulations and approved
procedures, and there were no deferred unserviceabilities.

The accident site was on the direct track from Spirit River to St. Paul. The aircraft struck the ground in a right-wing-low, nose-down attitude. During the break-up sequence, pieces were scattered along a 170-foot wreckage trail. The airspeed indicator face shows a needle impact mark indicating a speed of over 190 mph. The ground scars and the wreckage distribution indicate that the aircraft was in a high-speed spiral dive on ground impact.

The emergency locator transmitter (ELT) switch was in the "ARM" position and the external antenna was broken off. No signal was reported, and when the ELT (Pointer Centrum Model C4000) was checked, no signal was being transmitted. After the switch was recycled, the ELT functioned normally. It was not determined why the ELT did not function properly on impact.

An advisory circular entitled *Pilot's Spatial Disorientation*, issued by the U.S. Federal Aviation Administration, explains the hazards of disorientation as a result of loss of visual reference with the ground. The circular states the following:

Surface references and the natural horizon may become obscured, although visibility may be above visual flight rule minimum. Lack of natural horizon or surface reference is common on overwater flights, at night, and especially at night in extremely sparsely populated areas, or in low visibility conditions.

The accident location was in a sparsely populated farming area where the lack of ground lights would have precluded good surface references.

The pilot began his flying training in August 1995 and received a private pilot licence on 02 May 1996. The pilot then enrolled in a commercial pilot course during which he received a night endorsement on 27 August 1996. The pilot had a total of 130 flight hours, 126 on the Cessna 150/152 aircraft and 4 on the Cessna 172RG. During the instruction for his licence and night endorsement, the pilot received a combined total of 11 hours of simulated instrument training. The training, as outlined in the Transport Canada *Flight Instructor Guide*, is designed to provide the pilot with a basic understanding of instrument flying. The training included straight-and-level flight, climbs and descents, turns, and unusual attitudes. The pilot was tested on these exercises as part of his private pilot flight test. The training for the night endorsement was similar, but no flight test was required. The majority of the instrument training was conducted using all the aircraft instruments available with an outside-view limiting device. The night training received by the pilot was conducted around the city of Edmonton, a heavily populated area with lots of ground lights. None of the training was conducted in actual instrument conditions.

At the time of the occurrence, a quasi-stationary maritime cold front extended from a low pressure system in northwestern Alberta and crossed the northeastern portion of the province. The flight planned
route from Spirit River to St. Paul crossed the cold front in the vicinity of Smoky Lake. The weather conditions along the route went from clear skies with a few clouds around the Spirit River area, to VFR ceilings within 60 to 90 nm west of the cold front, to low ceilings with poor visibilities in rain and fog in the vicinity of the cold front. To the east of the cold front, VFR stratocumulus ceilings were reported across much of the region.

The pilot called the FSS on the afternoon of 16 September for a weather briefing. He only asked for and received the weather conditions for the St. Paul area. Approximately 45 minutes before departure, the pilot called for an updated weather briefing. He was given the actual reported weather for Slave Lake (100 nm west of the cold front), Cold Lake (70 nm east of the cold front), and Lloydminster (80-90 nm east of the cold front) as well as the terminal forecast for Cold Lake. The pilot was told of marginal weather with stratocumulus ceilings and rain showers from Slave Lake along the remainder of the route to his destination. The terminal forecast for Cold Lake (40 nm from St. Paul) between 2200 to 0200 was for weather conditions as low as three miles in fog and rain with ceilings of 800 feet above ground level.
Analysis

No radio transmissions from the aircraft were reported; therefore, it could not be determined if the pilot attempted to contact the Grande Prairie FSS after take-off. It is possible that the pilot felt that he did not have to call the FSS to open his flight plan, or he may have been flying too low to communicate along the route.

Weather conditions were good when the pilot departed Spirit River, but deteriorated as the pilot proceeded along his route. In the vicinity of the front, with lower cloud and reduced visibility in fog and rain, and over a sparsely populated area at night, surface references and the natural horizon would have become obscured. The pilot would have been forced to fly using the aircraft's instruments; however, his instrument time was limited to the training environment, and he likely had never flown in cloud or in conditions where the horizon was not visible. The pilot likely found it difficult to fly the aircraft on instruments, became disoriented, and lost control of the aircraft. The aircraft entered into a spiral dive from which the pilot did not recover.

Findings

1. The weather briefing indicated that the weather was marginal for the intended flight.

2. The pilot did not make radio contact with any FSS facility en route.

3. The pilot attempted to continue visual flight in deteriorating weather conditions.

4. The accident occurred at night, in a sparsely populated area, and in low visibility conditions.

5. The pilot was licensed and qualified for the flight, but it is likely that he had not previously flown in conditions that required flying solely by reference to the aircraft instruments.

6. It could not be determined why the ELT did not function properly at the time of impact.

Causes and Contributing Factors

The pilot continued flight into deteriorating weather conditions, probably became disoriented, and lost control of the aircraft. The aircraft entered a spiral dive from which the pilot did not 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 14 May 1997.

1. All times are MDT (Coordinated Universal Time minus six hours)
unless otherwise noted.

Updated: 2002-10-06

Important Notices
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
Engine Failure/Forced Landing
Trans North Turbo Air Ltd.
McDonnell-Douglas 369D (Helicopter) C-GDMP
Fire Lake, Yukon
23 September 1996

Report Number A96W0185

Summary

The helicopter, serial number 610993D, had completed moving a diamond drill, and the pilot was transporting a driller's helper to connect sections of water hose on the steep mountainside. At about 1630 mountain daylight time (MDT)\(^{(1)}\), during the climb-out after the first hose connection was completed, the pilot felt that the cyclic control was not responding correctly. He yelled to the helper to "hang on," then descended rapidly and attempted to toe in on the steep talus slope of the mountain. The main rotor blades struck the hillside, cut off the tail boom, and broke away. The helicopter rolled onto its right side and began sliding down the slope, tearing off the cabin roof and the front of the "doghouse," or transmission cowl. The helper, who was not wearing his lap belt, was thrown out of the helicopter onto the rocky slope. The helicopter then rolled over onto its left side, and continued to slide backward down the slope. The pilot, who was wearing a helmet, was hanging inverted and his head was being dragged against the rocks as the helicopter slid backward. The helicopter finally came to rest on its side. The injured helper tried to assist the seriously injured pilot out of the front seat but was only able to unfasten the pilot's lap-belt. The helper crawled up the slope and yelled to the driller for help. When the helper returned to the helicopter, the pilot had crawled out of the cabin. Moments later, first-aid assistance arrived. The driller reportedly turned off the helicopter's electric start (fuel) pump. The two occupants of the helicopter were evacuated by aircraft to hospitals for treatment.

*Ce rapport est également disponible en français.*

Other Factual Information
The driller's helper indicated that at the time the pilot yelled "hang on," the helicopter was jumping around as if in turbulence and was yawing from side to side. He also observed that the engine out warning light was illuminated. The helper had not fastened his lap belt because he planned to be in and out of the helicopter frequently while hooking up water hose connections.

The helicopter came to rest at about 5,000 feet above sea level (asl)(2) on the mountainside. The weather conditions at the site were reported as overcast with light snow falling, visibility ½ mile, temperature of minus three to minus four degrees Celsius, and wind from the south at five mph. It had been snowing throughout the day.

Examination of the helicopter did not reveal any mechanical discrepancies or evidence of fuel contamination. The pilot reported that the helicopter contained between 100 and 150 pounds of Jet B fuel at the time of the occurrence.

The engine (Allison 250 C20B) compressor had been damaged by debris, and was found to be contaminated with a fine, grey powder that, after further analysis, was determined to be bentonite, a drilling mud product. The bentonite was found in the particle separator and around the bleed valve outlet in a manner that suggested it had been deposited while wet. The engine was internally examined at the manufacturer's facility and bentonite was found throughout the axial and centrifugal compressor sections as well as in the combustion chamber, where it formed several hard, baked lumps. Literature on bentonite describes it as a colloidal clay which has the property of being hydrophilic (water-swelling), with some varieties absorbing as much as five times their own weight in water. It is characterized by a sticky nature and soapy feel, and is highly absorbent. Discussions with the engine manufacturer regarding the effect of this unusual contamination indicated that, although they had not encountered this specific material previously, they had observed worse cases of deposits from atmospheric pollution that had resulted in a loss of compressor efficiency of about 14 per cent. This condition can typically result in below-specification engine power checks, and high turbine outlet temperature (TOT) during lifting operations. An engine power check had been conducted on 14 September 1996, about 45 hours prior to the accident, at which time the engine exceeded standard specifications. It was determined that bentonite was not being used at the accident drilling site, suggesting that the material may have been ingested elsewhere, at an earlier time. The actual source of this material and its effect on engine performance was not determined.

The engine, fitted with a substitute compressor, was successfully test run without any indication of power fluctuations or uncommanded decelerations. The only significant discrepancy noted prior to the run was a bleed valve that was slow to move to the closed position when tested with regulated air pressure. Manual exercise of the bleed valve resulted in normal operation. The binding appears to have been a post-occurrence event, related to the material found on and around the valve. Some of this material had adhered to the valve stem when it was
in the closed position and had contaminated the stem guide bearing area.

The pilot had a total of over 13,000 hours, with over 8,000 hours on helicopters. He had flown the McDonnell-Douglas (formerly Hughes) 369 for over 2,600 hours in similar operations, and would be considered highly experienced.

While conducting vertical reference work, the pilot had removed the left door and was not using the available shoulder harness. The pilot was operating with the engine auto-relight system ON and the engine anti-ice OFF. The estimated weight of the helicopter at the time of the occurrence was 2,048 pounds, and the hover ceiling out of ground effect (HOGE) performance was estimated at 15,800 feet. The pilot indicated there was no snow buildup on the exterior surface of the helicopter, but inspections of the plenum for snow accumulation were not conducted as the helicopter was refuelled while running during the work.

The helicopter manufacturer's Flight Manual, "Normal Procedures" (Section IV), 4-6 "Actions Before Take-off," states the following requirement: "Use engine anti-icing when OAT is below 5 degrees Celsius (41 degrees Fahrenheit) and visible moisture is present." The engine anti-ice system prevents ice buildup on the engine inlet support struts which could break off and damage the compressor blades.

The Flight Manual, Limitations, (Section II), Chapter 2.3, Flight Restrictions, states the following:

Flight operation is permitted in falling or blowing snow only if the Automatic Engine Reignition Kit and Engine Failure Warning System are installed and operable. Whenever the helicopter has been parked outside or has been in flight during falling snow, determine that the engine inlet area and all helicopter exterior surfaces are completely free of accumulated ice and snow. In addition, open the plenum chamber door and visually determine that the inlet screen or particle separator (if installed) have not become clogged with ice and snow. This inspection and removal of ice and snow shall be accomplished prior to the next flight.

Discussions with other operators of McDonnell-Douglas 369D helicopters indicate that they had also experienced numerous losses of engine power (flame-outs) in falling snow, and had installed optional engine air deflector kits, which eliminated the problem. The kit consists of a plate that covers the normal air intake on the "doghouse" and prevents snow from directly entering the particle separator. Installation of this kit is currently not mandatory.

On 30 September 1982, the Allison Engine Company issued a Commercial Service Letter warning of engine flame-outs due to snow or ice ingestion on the Allison 250 series engines. The letter states:

Owners, operators and pilots are warned that helicopters
using this engine in falling or blowing snow, or icing conditions, require special equipment. Snow or ice can build up on aircraft parts, inlet ducts or plenum chambers and break loose in "slugs". Slugs of snow or ice entering the compressor of these engines can cause flame-out. Helicopter manufacturers use different approaches to prevent slugs of snow or ice from being ingested by the engine. Some of these devices include special particle separators, reverse inlet scoops, and various types of inlet screens. Additionally, some helicopters utilize auto-reignition kits to relight the engine in the event that a flame-out occurs. It is the responsibility of the owner, operator and pilot to determine that the helicopter is properly equipped and the devices are in proper working order for operation in conditions where snow and ice can build up on the aircraft. It is also very important to inspect the engine inlet area on the pre-flight check when the aircraft has been exposed to an ice, snow, or sleet storm. Accumulations of ice and/or snow can collect in remote areas of the engine inlet air flow path. Removal of these accumulations is necessary, especially downstream of the protective devices, to prevent a possible flame-out caused by the break-off of these accumulations during flight.

Analysis

The information gathered indicates that the pilot experienced a flame-out and an automatic relight while climbing after lift-off. This would have caused a loss of main rotor rpm, and would have resulted in the cyclic control response problem reported by the pilot. Although the engine compressor contamination observed could result in decreased power output, it would not be expected to cause a flame-out. The most likely cause of engine flame-out in this occurrence would be the sudden dislodging of an accumulation of snow in the air intake plenum, which is consistent with the experiences of other operators of this model helicopter. The successful elimination of snow-induced flame-out on other similar helicopters following installation of an air deflector kit, indicates that the installation of such a kit on this aircraft probably would have prevented the occurrence.

The pilot made the decision to attempt a forced landing on the slope because he believed that any problems with the flight controls may have become more critical if he tried to fly downslope to flatter ground. The pilot's helmet was effective in reducing the severity of his head injuries during the forced landing. The unsecured passenger would probably have sustained fewer injuries if he had been wearing his lap belt.

The following Engineering Branch reports were completed:

   LP 138/96 - Compressor Contamination
   LP 139/96 - Engine Investigation

Findings
The helicopter had been operating in light falling snow during the day.

The helicopter was not fitted with an optional engine air inlet deflector kit.

The sudden loss of engine power (flame-out) was most likely the result of snow ingestion.

The engine compressor was contaminated with bentonite, but this would not be expected to cause a flame-out.

The passenger was not wearing his seat-belt, and was thrown out of the helicopter during the forced landing.

The pilot's helmet was effective in reducing head injury.

The pilot had not selected the engine anti-ice ON, as required by the flight manual.

Causes and Contributing Factors

The helicopter experienced a sudden loss of engine power (flame-out) during climb-out, likely as the result of the dislodging of a snow deposit in the air inlet plenum. A contributing factor was that the optional engine air intake deflector kit had not been installed on this helicopter.

Safety Action

Action Taken

Subsequent to this occurrence, a TSB Aviation Safety Advisory was forwarded to Transport Canada, suggesting a review of the MD 369 Series requirements for flight in falling/blowing snow with a view to validating the adequacy of the existing limitations, and to assess the safety benefit gained from having a requirement of installing an air deflector kit as part of these limitations.

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 7 August, 1997.

1. All times are MDT (Coordinated Universal Time minus six hours) unless otherwise noted.

2. Units are consistent with official manuals, documents, and instructions used by or issued to the crew.
Updated: 2002-10-06

Important Notices
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
Aircraft Broke Through Ice
Bell 206L-1 LongRanger (Helicopter) C-GZAA
Snare River, Northwest Territories
23 October 1996

Report Number A96W0204

Summary

The helicopter, serial number 45537, was chartered by Environment Canada, Water Survey Branch, to conduct hydrometric measurements at sites in the vicinity of the Snare River, 110 miles north of Yellowknife, Northwest Territories. The pilot and two technologists departed Yellowknife at 0925 mountain daylight saving time (MDT) and arrived at the first site one hour later.

High water levels had flooded the landing site, so an alternate drop-off site was found on a small ice-covered bay nearby. The pilot manoeuvred the helicopter close to shore and remained in a hover, with the skids resting lightly on the ice, while the technologists got out and checked the ice surface. They signalled to the pilot that the ice was okay. The pilot bumped the helicopter up and down twice to further test the ice strength. Both technologists walked to the left rear cabin door to unload equipment, when suddenly, without warning, the helicopter broke through the ice. Both technologists slid into the four-foot-deep water.

The pilot applied power and lifted the helicopter out of the water; however, the tail rotor had separated, and he had no tail rotor control. The helicopter rotated clockwise, rolled right and sank. The pilot was submerged, and evacuated the helicopter with assistance from one of the technologists. The second technologist was fatally injured when struck on the head by a portion of a main rotor blade after, or as, the blade fractured. The helicopter was substantially damaged.

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 had approximately 21,000 hours total flying time, of which approximately 10,500 hours was on Bell 206 helicopters. The pilot and technologists had worked together previously conducting water surveys. The procedure they used to check the ice had been carried out before with success.

Records indicate that the helicopter was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The company had equipped the helicopter with two emergency locator transmitters (ELT). The ELT mounted on the lower left front side of the cockpit remained above the water level and activated at impact. The second ELT, mounted on the centre post behind the cockpit seats, was submerged and did not emit an audible signal. The gross weight of the helicopter at the time of the occurrence was approximately 3,200 pounds, which was within limits.

Visual flight conditions existed at the time, with an estimated overcast of 700 feet above ground level (agl), 10 miles visibility, wind from the southeast at 6 to 10 knots, and temperature minus 5 degrees Celsius.

The initial plan was for the pilot to remain in a hover, with the skids resting lightly on the ice, while the technologists exited, checked the ice, and unloaded an axe and chain-saw. The pilot would then lift off and remain airborne while they prepared an area for landing. After the technologists checked the ice and signalled that the ice was okay, the pilot decided to shut down to conserve fuel and eliminate the need to divert to a distant fuel cache for refuelling. The helicopter broke through as he reduced power to ground idle and set the full weight of the helicopter onto the ice.

The helicopter was equipped with high skid gear which provided approximately 11 feet of clearance between the main rotor blade and the ice surface. The bear paws mounted on the rear of the helicopter's skids broke through the ice first, and the tail rotor blades struck the ice surface. The tail rotor gear box separated and the helicopter began a clockwise rotation. The main rotor blades struck the ice as the helicopter rolled to the right and one blade separated 45 inches from the blade attachment bolt at the yoke. The technologist's body was found in the water at the nose of the helicopter. A smear on the detached blade, 10 feet 8 inches from the tip, indicates that the technologist was struck after, or as, the blade separated from the helicopter.

The load-bearing capability of ice is dependent on its quality, thickness, and temperature. It is not possible to determine ice thickness from the air; however, the colour of the ice will usually provide some indication of ice quality. Ice colour will vary from clear blue to grey to white, with clear blue being the strongest.

The Treasury Board of Canada's *Handbook of Occupational Safety and Health* provides a rule of thumb of "one inch of clear blue ice for every
thousand pounds" to determine the required thickness of fresh water ice. A "Caution" follows the above quote - "Ice that is less than six inches (15 cm) thick should not be used for any crossing. Because of natural variations, thickness may be less than two inches (5 cm) in some areas." For loads that are stationary, as would be the case for a helicopter landing and shutting down, the weight bearing capacity of the ice should be decreased by a factor of 50 per cent.

Moving water under the ice can affect ice thickness and may not be apparent from the surface. A small stream, hidden from view under the ground cover foliage, fed into the bay below the ice layer. The ice was grey in colour and approximately three inches thick where the helicopter broke through.

The helicopter was equipped with a watertight emergency kit with a mirror, matches, and flares secured on the outside under plastic wrap, to facilitate access to these essential items in an emergency. The survivors made use of the emergency kit after the occurrence; however, duct tape used to secure the kit was very difficult to remove with cold hands in freezing temperatures.

The helicopter, on a flight notification, was not expected to return to Yellowknife until late in the day. However, the survivors used a portable satellite phone to call the Water Survey office in Yellowknife. A rescue team, including RCMP members and a nurse, arrived at the scene around 1300 MDT. Without the satellite phone to report the emergency and the prompt response by the rescue team, the survivors would likely have been stranded overnight and not been rescued until the following morning. Both individuals were suffering from hypothermia when rescued about three hours after the accident.

Analysis

The pilot and technologists were experienced in working together as a team. When they arrived at the hydrometric site and found the intended landing site covered with water and ice, they had to formulate an alternate plan to accomplish the project.

The pilot assessed the ice surface characteristics in the bay and judged that he could drop the men off safely from a hover, while maintaining lift on the main rotor. Although the indications on the surface appeared favourable, there was no reliable means to determine the ice thickness and strength from the air. After the technologists exited the helicopter and checked the ice, they signalled the pilot, which reinforced his assessment of the ice condition, and he decided to shut down.

The load-bearing capability of the ice was exceeded when the pilot set the full weight of the helicopter on the ice in preparation for shutdown, and the two technologists moved to the outside of the left rear door of the helicopter to unload their equipment. The small stream feeding into the bay likely had a detrimental effect on the ice thickness and quality.

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

- Records indicate that the helicopter was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

- The ice-covered bay was an alternate drop-off site because the original landing site was under water.

- The load-bearing strength of the ice was not sufficient to support the total weight of the helicopter, equipment, and personnel.

- The main rotor blades fractured when they hit the ice, and an outer portion of one of the blades struck one of the technologists.

- The stream feeding into the bay likely affected the thickness and quality of the ice.

- The survivors were rescued expeditiously because of the availability of the satellite phone.

Causes and Contributing Factors

The thickness and quality of the ice at the drop-off site was not sufficient to support the weight of the helicopter.

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 29 July, 1997.