Air 1995

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.

Wirestrike
Government of Canada,
Canadian Coast Guard
Bell 206L (Helicopter) C-GCHN
Margaree River, Nova Scotia
25 February 1995

Report Number A95A0040

Synopsis

The pilot of the Canadian Coast Guard helicopter departed East Margaree, Nova Scotia, on a fisheries surveillance flight with his daughter and two Department of Fisheries and Oceans officers on board. The flight was nearing completion and they were flying at a low altitude over the Margaree River when the helicopter struck a power line which spanned the river. The helicopter became uncontrollable and struck the ice-covered surface of the river. The pilot was fatally injured, and the three passengers were seriously injured.

The Board determined that the pilot did not see the power line in time to take avoidance action. Contributing to the accident were the pilot's decision to conduct the portion of the flight over the river at low altitude without having first completed a reconnaissance of the area for obstructions, and the absence of clearly defined procedures on the conduct of fisheries surveillance flights.

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1.0 Factual Information

1.1 History of the Flight

The Canadian Coast Guard helicopter had been flown to the East Margaree Airport from its base in Shearwater, Nova Scotia, on the morning of the occurrence. The helicopter was to be used to conduct a Department of Fisheries and Oceans (DFO)<1> surveillance patrol in the Cape Breton Highlands and Lake Ainsley area.

After arriving at East Margaree, the pilot met with two fisheries officers and discussed the mission. The pilot then departed East Margaree with his daughter and the two DFO officers on board the helicopter. After they had inspected several lakes in the Cape Breton Highlands, the helicopter was refuelled at Neil's Harbour, on the northeast coast of Cape Breton Island. The pilot then resumed the surveillance patrol and flew to the Lake Ainsley area, and then along the western coastline of Cape Breton Island to the mouth of the Margaree River.

The pilot followed the river upstream towards East Margaree. As the helicopter was being flown over the river at low altitude, it struck a power line which spanned the river. The helicopter became uncontrollable and struck the ice-covered surface of the river.
The pilot was fatally injured, and the three passengers were seriously injured.

The accident occurred at latitude 46.24'N and longitude 061.05'W<2>, at approximately 1321 Atlantic standard time (AST)<3> during daylight hours.

1.2 Injuries to Persons

<table>
<thead>
<tr>
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<th>Passengers</th>
<th>Others</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Serious</td>
<td>-</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Minor/None</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

1.3 Damage to Aircraft

The helicopter was destroyed.

1.4 Other Damage

The power line was severed. Approximately 100 homes in the local area were without electrical power until a temporary replacement power line was installed the following day.

1.5 Personnel Information

<table>
<thead>
<tr>
<th>Pilot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Pilot Licence</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
</tr>
<tr>
<td>Total Flying Hours</td>
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<tr>
<td>Hours on Type Last 90 Days</td>
</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
</tr>
<tr>
<td>Hours Off Duty Prior to Work Period</td>
</tr>
</tbody>
</table>

The pilot was qualified on Bell 206 helicopters and held a valid licence. He held a valid category 1 medical with the restriction "Glasses must be available." The pilot was wearing his glasses at the time of the occurrence.

The pilot had flown these DFO surveillance flights in the past.

1.6 Aircraft Information

| Manufacturer | Bell Helicopter Textron Inc. |
| Type | Bell 206L |
| Year of Manufacture | 1977 |
| Serial Number | 45136 |
| Certificate of Airworthiness (Flight Permit) | Valid |
| Total Airframe Time | 7,157 hr |
| Engine Type (number of) | Allison 250-C20B (1) |
| PropellerRotor Type (number of) | Semi-Rigid (1) |
Maximum Allowable Take-off Weight 3,950 lb
Recommended Fuel Type(s)       Jet A, Jet A-1, Jet B
Fuel Type Used                  Jet A

Documentation indicates that the helicopter was certified, equipped and maintained in accordance with existing regulations and approved procedures.

The weight and the centre of gravity were within the prescribed limits at the time of the occurrence.

1.7 Meteorological Information

1.7.1 Meteorological Information - Sydney

The Environment Canada weather reporting station closest to the accident site is Sydney, Nova Scotia, located 47 miles to the east.

The Terminal Forecast (FT) for Sydney was issued on 25 February 1995 at 1630 UTC and was valid for the period 1700 UTC to 1700 UTC the following day.

At the time of the accident, the following conditions were forecast: broken cloud at 2,000 feet above ground level (agl), visibility greater than 6 miles, and winds from 250° magnetic (·M) at 15 gusting to 25 knots. The following variable condition was forecast during the same period: scattered cloud at 2,000 feet agl, high scattered cloud with the visibility greater than 6 miles.

The Surface Actual (SA) report for Sydney taken at 1704 UTC was as follows: measured broken ceiling at 3,000 feet agl with a second overcast layer at 25,000 feet agl. The visibility was 15 miles and the winds were 270°·M at 16 gusting to 22 knots.

1.7.2 Meteorological Information - Margaree

Witnesses to the accident indicated that there was generally clear sky with good visibility. The wind was variable between 10 and 20 knots from the southwest. The sun was about 70° above the horizon and was overhead and slightly in front of the helicopter at the time of the occurrence.

The survivors described the visibility and flight conditions as very good. Turbulence was described as light.

1.8 Communications

The helicopter was equipped with serviceable very high frequency (VHF) and VHF-frequency modulated (FM) radio communication equipment. A continuous FM flight watch system was maintained between the helicopter and the Canadian Coast Guard (CCG) Operations Centre in Sydney, Nova Scotia.

There were no recorded radio transmissions from the accident helicopter just prior to the occurrence.

1.9 Pertinent Information

1.9.1 Eyewitness Observations

The distance from the mouth of the river to the location of the wire strike is approximately 2.5 miles. Witnesses along this portion of the river saw the helicopter descend to an estimated 100 feet agl at the mouth of the Margaree River and then fly up the river at this altitude.

1.9.2 Survivor Recollections

The DFO officer who was seated in the front left cockpit seat recalled that, during the flight up the Margaree River, a small evergreen tree on the river's ice-covered surface was attracting his attention. Such small evergreen trees are known by DFO officers to be used by poachers to prevent holes cut in
the ice from freezing. These holes are then used to set illegal fish nets under the ice surface.

The DFO officer could not recall any conversations in the aircraft during this short flight segment up the Margaree River. He recalled that, after overflying the small tree, the pilot completed a low-level 360-degree turn to the left. The pilot had completed the turn and had just initiated a climb when the helicopter struck the power line. The DFO officer only saw the power line after it had been struck by the helicopter. He recalled that, after the wires strike, the pilot tried to regain control of the helicopter until the impact with the ice-covered surface.

All three survivors stated that there was no evidence of a technical problem with the helicopter at any time prior to the wires strike.

1.10 Power Line

1.10.1 General Information

The power line was a 3/8-inch diameter, galvanized steel wire. Nova Scotia Power Inc. survey records indicate that the line was erected prior to 23 February 1940.

Immediately after the accident, a new aluminum power line was erected on the same poles. The following measurements were taken from the survey plan of the new power line:

- the total span of the power line between poles is 1,183 feet;
- the top of the pole on the west shore is 67.09 feet above datum elevation;
- the top of the pole on the east shore is 119.31 feet above datum elevation; and,
- the helicopter contact with the power line was estimated to be at an elevation of between 64 and 73 feet above the datum elevation.

The datum elevation is the Nova Scotia Control geodetic reference datum which is used on site survey plans.

Nova Scotia Power Inc. engineers indicated that the sag of the 3/8-inch diameter galvanized steel wire would have been lower than that of the newly erected aluminum conductor. The exact amount of sag of the original wire could not be determined.

1.10.2 Conspicuity of the Power Line

The power line was greyish-white in colour and provided little contrast with the ice-covered surface of the river and the higher snow-covered terrain in the background.

The power line was suspended from poles on either side of the river. Both of the supporting poles were surrounded by tall evergreen foliage and dense deciduous trees, and the cut-line normally associated with hydro lines had been overgrown with vegetation.

![Figure 1 - Location of the Power Line](http://www.tsb.gc.ca/en/reports/air/1995/a95a0040/a95a0040.asp)

The power line was not marked, nor was it required to be marked in accordance with existing regulations. In addition, the power line was not depicted on aviation navigation charts.
Following the erection of the new power line, investigators overflew the area at the approximate altitude flown by the accident helicopter. It was determined that, even with optimal vision and under ideal visibility conditions, the line and its support structure were extremely difficult to detect due to the camouflaging effect of the surrounding terrain and vegetation.

When overflown at an approximate altitude of 300 feet, the wire itself remained virtually invisible; however, the wire's support structure and the associated cut lines were visible on either side of the river.

1.10.3 Power Line Marking Requirements

The Canadian standards for marking of wires deemed a hazard to air navigation are contained in the Transport Canada publication TP 382E, Standards Obstruction Markings. According to these standards, wires higher than 300 feet above ground level require obstruction marking.

In certain circumstances, wires lower than 300 feet may be the subject of an aeronautical study to determine whether marking and/or lighting is necessary to increase the wire's conspicuity. Prior to undertaking such a study, the following factors are considered: the location of objects on high terrain; the surrounding topography; air traffic density; and the proximity of obstructions to water aerodromes and heliports.

As a rule, wires deemed to be a hazard to air navigation and to require marking would also be depicted on air navigation charts. No records were found of an aeronautical study having been conducted on this specific power line.

1.11 Wreckage and Impact Information

1.11.1 Power Line Impact

The helicopter was in a level attitude, about 70 feet above the river and at about the midpoint of the width of the river, flying at an estimated airspeed of 80 knots, when it struck the power line.

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![Figure 2 - Helicopter/Power Line Contact](image)

The power line contacted the front of the helicopter in the area of the bottom of the main windscrenn. The power line broke in two places: where it contacted the helicopter and where it joined onto the western pole. The broken section of the power line made contact with one main rotor blade and was then thrown forward. It was found 1,063 feet from the initial point of the power line contact.

1.11.2 Ground Impact

The helicopter was on a heading of 185·M when it struck the ice-covered surface in a nose- down, 15·right-banked attitude, 660 feet from the point of initial wire contact. The main lower fuselage section was torn away, and the fuel tanks were ruptured. After initial ground impact, the main cabin area slid forward 170 feet and the cockpit nose area was located 54 feet from the main cabin area. The total
wreckage trail extended 883 feet.

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

### 1.11.3 Aircraft Damage

There was no evidence of pre-impact airframe failure or engine malfunction. The engine was further examined at the regional wreckage examination facility in Moncton, New Brunswick, and it was determined that the engine was operating normally at the time of impact.

Six instruments were analyzed at the TSB Engineering Branch laboratory in Ottawa, Ontario; however, only three instruments were able to provide reliable information as to their readings at impact.

- Dual Tachometer Indicator - the power turbine pointer was indicating between 99% and 100%.
- Torquemeter - the pointer was indicating in the 50% to 52% range.
- Horizon Reference Indicator - the instrument indicated a 15° right bank.

The following six annunciator warning lamps were also examined: Low Rotor rpm, Engine Out, Engine Relight, Transmission Oil, Battery Hot, and Float Arm. It was concluded that these lamps were off at impact.

### 1.12 Medical Information

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

### 1.13 Fisheries Surveillance Operations

#### 1.13.1 Purpose of the Flight and Agencies Involved

The purpose of this flight was to monitor fishing activities in the Cape Breton Highlands and Lake Ainsley areas. The flight also included monitoring of the specific area of the occurrence site on the Margaree River because of a report to the DFO of illegal fishing activity.

The objective of DFO surveillance patrols is to gather intelligence with regards to any illegal activity, to obtain the identity of violators, and then to issue a warning and summons at a later time. It is not the normal practice to arrest a violator during the course of these patrols; however, DFO officers are armed and, in exceptional circumstances, are prepared to effect an arrest and transport the violator in the helicopter.

The two agencies involved in this operation were Transport Canada (TC) and the Department of Fisheries and Oceans (DFO). The personnel directly involved in the surveillance flight were the pilot from TC Aircraft Services and the two DFO fisheries officers. The helicopter was owned by the Canadian Coast Guard.

#### 1.13.2 Flight Requirement and Operations

The fisheries patrol requires that the pilot fly at an altitude that provides adequate obstacle clearance and an airspeed that allows the DFO officers to view any activity on the ground.

Generally, an altitude of 200 to 300 feet agl and an airspeed of about 80 knots is appropriate for the flight. Whenever an item of specific interest is located, the helicopter may be flown at lower altitudes and slower airspeed depending on the circumstances.

This operation is not part of the normal CCG flying duties. Rather, it is occasionally undertaken as an extra operation, usually on weekends, when requested by DFO. There is a Memorandum of Understanding (MOU) between TC and DFO concerning the charter of these surveillance flights. This MOU contains agreement between the two agencies on administrative matters; however, the MOU does not establish the terms of reference for the operational conduct of the flight.

#### 1.13.3 Standard Operating Procedures
There were no standard operating procedures (SOP) agreed to by the two agencies which would have delineated the duties of the persons involved in the surveillance flights, nor was any awareness training provided.

According to Degani and Wiener (1994)<4>, standard operating procedures enhance coordination between agents within the system and provide a common ground for agents who may be unfamiliar with one another's experience and requirements. Typically, the system involves company crew and agents; however, the system can be extended to include anyone directly involved in flight operations, as in this occurrence, law enforcement. These standard operating procedures provide the personnel with clear guidance for carrying out the operation. Adherence to such formal standard operating procedures is widely known to enhance the safety of flight operations.

In general, SOPs exist in order to specify, unambiguously, six items:

- What the task is.
- When the task is conducted (time and sequence).
- By whom the task is completed.
- How the task is done.
- What the sequence of actions consists of.
- What feedback mechanism is to be used to alert management of procedural weaknesses.

1.14 Wire Strike Protection

1.14.1 Wire Strike Protection System (WSPS)

A WSPS is available for the Bell 206L helicopter under approved Supplementary Type Certificate (STC) SH4083SW. The system is engineered to prevent entry of a wire into the cockpit area, reduce the possibility of flight control damage during a wire strike, and decrease the chance of wires becoming entangled in the landing gear. The WSPS manufacturer states that the system has been demonstrated at angles up to 45° and at speeds as low as 4 mph, and that it is effective against multiple wire strikes.

![Wire Strike Protection System](image)

**Figure 3 - Wire Strike Protection System**

The system comprises three components: an upper and a lower cutter/deflector, and a windshield deflector/guide. Each is equipped with a high tensile steel sawtooth edge. The windshield deflector/guide serves to move the wire over the cockpit area and into the cutters.

The helicopter was not equipped with a WSPS, nor was one required by regulation.
1.14.2 Air Carrier Advisory Circular (ACAC) 0020

On 24 April 1991, Transport Canada Aviation, Flight Standards Branch, issued ACAC 0020, which addressed the issue of wire strike protection systems. The purpose of this circular was to advise operators of rotorcraft involved in low-level special-purpose operations of the effectiveness of wire strike protection systems.

This ACAC was based on Canadian Aviation Safety Board (CASB) Safety Recommendation 90-50, which recommended that:

The Department of Transport

(a) energetically promote the fitment of wire strike protection systems on all helicopters engaged in low-level special-purpose operations; and,

(b) develop appropriate legislation requiring the mandatory fitment of such equipment.

In response to the Board's recommendations, Transport Canada concluded that, because the fitment of a WSPS is not possible on all helicopters, installation of a WSPS will have to remain at the discretion of the operators. However, in its advisory circular, Transport Canada strongly urged helicopter operators to consider installation of a WSPS where possible, as the benefits greatly outweigh the costs of both equipment and crews in the event of a wire strike.

1.15 Low-Level Helicopter Flight Operations

The airspace below 300 feet agl is generally regarded by the helicopter pilot community as a hostile environment. Helicopter pilots are habitually cautioned about the increased risks of wirestrikes at these low altitudes and are warned not to venture into this airspace before taking measures to reduce the risk of a wirestrike. One such measure is the widely accepted practice of conducting an overflight of the area at a higher altitude to examine the area for the presence of obstructions, such as wires, prior to descending to low altitudes.

1.16 Passengers - DFO Surveillance Flights

On the morning of the occurrence, and in accordance with existing CCG directives, the pilot requested and received approval from the Coast Guard Operations Centre to bring his daughter along on the flight. The presence of the pilot's daughter was not essential for the conduct of the law-enforcement mission.

Sections 4.6.2, Coast Guard Flights, and 4.6.3, Hydrographic Flights, of the TC Aircraft Services Helicopter Flight Operations Manual (HFOM) address the carriage of passengers. Both sections state that passengers may be carried when their carriage will not interfere with the purpose of the flight.

There is no section in these flight manuals that deals specifically with the carriage of passengers on DFO surveillance flights.

1.17 Survival Aspects

1.17.1 Seat-Belts

The occupants' seat-belt buckles remained attached throughout the crash sequence. With the destruction of the cockpit/cabin area, the fuselage structures around the seat-belt attachments failed. The pilot and the two DFO fisheries officers were found lying on the ice outside of the cockpit/cabin area.

1.17.2 Fuel Spill

The fuel system incorporates three single-bladder type fuel cells, one located below and aft of the passenger seat and the other two located under each of the aft-facing passenger seats. All three fuel cells burst during the impact sequence and a significant quantity of fuel pooled in the vicinity of the final
resting place of the main wreckage and its occupants.

All persons on board were soaked by the pooled fuel, which resulted in substantial chemical burn injuries to the occupants.

1.17.3 Emergency Locator Transmitter (ELT)

The ELT was affixed to the bottom frame of the windshield, inside the cabin just in front of the passenger door. The ELT became detached from the helicopter during the crash sequence and was found on the ice in the "OFF" position. The ELT mounting location is approved by Transport Canada. TSB investigations of previous accidents with similar ELT mounting locations indicate that the ELT is vulnerable to becoming detached from the helicopter during the crash sequence.

Pilots and aircraft maintenance engineers indicated that, as part of their daily inspection, they check the security of the ELT but not the switch position. Evidence indicates that the ELT had been in the "OFF" position for some time prior to the accident flight.

1.17.4 Pilot Protective Helmets

Helicopter Directive Number AAFDB-9 of the TC HFOM addresses the use of protective helmets. This directive states as follows:

Effective immediately, for personal protection, all pilots and engineers shall wear protective helmets when engaged in helicopter operations. When justified, exceptions may be granted by AAFDB for medical and physical dimensions. In case of unserviceability, a headset will be worn until such time as the helmet can be repaired.

The pilot was not wearing his helmet during the flight. His helmet was unserviceable and had been sent to the TC repair facility in Ottawa four days prior to the accident. The pilot was wearing a headset in accordance with the above-mentioned directive. Additional helmets were available in the Coast Guard facilities in Shearwater. It was reported that it was highly likely that the occurrence pilot was not aware of the availability of these helmets.

The TC HFOM has no existing provisions for the wearing of helmets by passengers on specialty low-level flights.

The three survivors suffered varying degrees of head injuries. Although the pilot also suffered some head injuries, these head injuries were determined to be relatively minor.

2.0 Analysis

2.1 General

The aircraft records indicate that the helicopter was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The examination of the aircraft wreckage revealed no pre-impact control failures or engine malfunction. Based on this information and on the survivors’ recollections that there were no apparent mechanical problems prior to the occurrence, a control or other mechanical malfunction is not considered a likely factor in this occurrence. Similarly, in light of the known visibility and in-flight conditions, weather is not considered a factor either.

Several elements specific to this occurrence affected the pilot’s ability to see the unmarked power line during the low-level flight. The 3/8-inch diameter of the power line presented a very small visual target which, at a distance, even under ideal circumstances, would have been virtually invisible. The power line’s support structures were difficult to detect due to the surrounding foliage. Moreover, the greyish-white power line itself blended with the ice-covered river and snow-covered surrounding terrain.

Based on witness observations and survivor recollections, as well as the inconspicuousness of the power line, it was determined that the pilot did not detect the power line in time to take avoidance action. The analysis will explore several operational elements associated with this event.

2.2 Conduct of Low-Level Flight
It could not be determined why the pilot descended below the normal fisheries surveillance flight altitude of 200-300 feet during the final segment of the flight without first doing a reconnaissance of the area at a higher altitude.

There were no apparent operational requirements for the pilot to descend as low as he did without having first completed a reconnaissance of the area, nor did the pilot make any comments which would explain his intentions.

Had a reconnaissance overflight been conducted, it is possible that the power line or its associated support structure would have been observed and the flight profile could have been altered accordingly.

2.3 Fisheries Surveillance Operations

This surveillance operation involved two organizations. Each organization had its own role in the mission: Transport Canada to fly the aircraft safely and DFO to spot illegal activity and conduct related law-enforcement operations. While the two roles were quite distinct, they were closely linked and complemented one another.

Despite the relationship between the two roles, and the differences between them, the agencies did not meet to discuss operational requirements or to reach agreement on in-flight procedures.

In the case of the accident flight, had standard operating procedures been in effect for such elements as altitudes, airspeeds, and reconnaissance overflights prior to descents to low altitudes, the risks inherent within the mission would have been mitigated, ensuring a safer and more predictable operation.

2.4 Marking of Power Line

This power line was erected prior to 23 February 1940, and this occurrence was the first reported aviation accident related to the line. The fitment of markers on the power line would have made the line more visible and increased the possibility of it being detected by the pilot. Had an aeronautical study been conducted on this specific power line, it is likely that the power line would not have been marked for several reasons. The height of the power line above the Margaree River was well below the altitude expected to be flown by helicopters or fixed wing aircraft. In addition, that portion of the Margaree River is not on a visual flight route normally flown by helicopters or other aircraft, nor is the power line in the vicinity of an aerodrome or heliport.

2.5 Wire Strike Protection Systems

As ACAC 0020 recommends, the installation of WSPS equipment on helicopters engaged in low-level operations can only enhance the safety of the operation.

In this accident, the helicopter contacted the wire in a position where WSPS has been demonstrated to be effective. Had this helicopter been fitted with a WSPS, it is very likely that the power line would have been cut. In that event, the outcome of the occurrence would likely have been considerably less severe.

2.6 Passengers - DFO Surveillance Flights

The carriage of non-essential passengers is not specifically addressed in the TC HFOM; however, in general, passengers may be carried in the helicopter when their presence will not interfere with the purpose of the flight.

Notwithstanding the hazards posed by the law-enforcement nature of the flight, helicopter fisheries surveillance flights require that the helicopter be flown at low altitudes for extended periods. The carriage of non-essential passengers on such high-risk, low-level operations unnecessarily exposes additional persons to the dangers inherent in such operations.

3.0 Conclusions

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

The helicopter was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

There was no evidence of pre-impact airframe failure or engine malfunction.

The power line was not marked nor was it required to be marked by regulations.

The helicopter contacted the power line in the area of the bottom of the main windscreen.

No operational requirement or reason could be found that would explain why the helicopter was being flown as low as it was without first having overflown the area to ensure that the area was free of wires or other obstacles.

There was no formal agreement in place between TC and DFO establishing the terms of reference of the operation, nor was there communication between the two agencies regarding the risks associated with this type of operation.

No standard operating procedures for this type of surveillance operation were available to the pilot, nor was any awareness training provided.

The helicopter was not equipped with a WSPS, nor was one required by regulation.

Had this helicopter been fitted with a WSPS, it is very likely that the power line would have been cut.

The ELT became detached from the helicopter during the crash sequence and was found on the ice in the "OFF" position.

The pilot was not wearing his helmet during the flight.

3.2 Causes

The pilot did not see the power line in time to take avoidance action. The pilot's decision to conduct the portion of the flight over the river at low altitude without having first completed a reconnaissance of the area for obstructions, and the absence of clearly defined procedures on the conduct of fisheries surveillance flights were contributing factors in the accident.

4.0 Safety Action

4.1 Action Taken

4.1.1 ELT Arming

The ELT was found intact on the river surface with the function switch in the "OFF" position and intact. The absence of damage to the switch and the area surrounding the switch led to the conclusion that the ELT was in the "OFF" position prior to impact. It could not be determined when the "OFF" selection had been made.

Transport Canada pilots have been reminded to follow the Standard Operating Procedures regarding the confirmation of the ELT armed switch location. During a check, or training flight, the position of the switch would be a debriefing point if it were not checked.
4.1.2 Passengers - DFO Surveillance Flights

Helicopter fisheries surveillance flights require that the helicopter be flown at low altitudes for extended periods. The carriage of non-essential passengers on such high-risk, low-level operations unnecessarily exposes additional persons to the dangers inherent in such operations.

Transport Canada has issued instructions to preclude the carriage of passengers on board aircraft conducting specialty operations.

4.1.3 Wire Strike Protection Systems

In this accident, the helicopter contacted the wire in a position where WSPS has been demonstrated to be effective. The Board notes that devices are being developed to warn crews of wires and cables.

The installation of WSPS on all Transport Canada's helicopters will be completed within 15 months. By December 1995, each region will have at least one helicopter equipped with a WSPS.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 08 November 1995.

Appendix A - List of Supporting Reports

The following TSB Engineering Branch Report was completed:

LP 37/95 - Instrument Analysis.

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

Appendix B - Glossary

ACAC - Air Carrier Advisory Circular
agl - above ground level
AST - Atlantic standard time
CASB - Canadian Aviation Safety Board
CCG - Canadian Coast Guard
CPL - Commercial Pilot Licence
DFO - Department of Fisheries and Oceans
ELT - emergency locator transmitter
FM - VHF frequency modulated
FT - terminal forecast
hr - hour(s)
inc. - incorporated
knots - nautical miles per hour
lb - pound(s)
MOU - Memorandum of Understanding
mph - miles per hour
SA - Surface Actual Weather Report
SOP - standard operating procedure
STC - Supplementary Type Certificate
TC - Transport Canada
TSB - Transportation Safety Board of Canada
UTC - Coordinated Universal Time
VHF - very high frequency
WSPS - Wire Strike Protection System

- degree(s)
- M degrees of the magnetic compass
<1>See Glossary for all abbreviations and acronyms.

<2>Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

<3>All times are AST (Coordinated Universal Time [UTC] minus four hours) unless otherwise stated.

Air 1995

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

Risk of Collision Between
Delta Air Lines Lockheed L1011 N740DA and
British Airways Boeing 747 G-AWNH
North Atlantic
08 March 1995

Report Number A95A0046

Synopsis

British Airways flight 92 X-ray (BAW92X), a Boeing 747, was flying eastbound to London, England, along North Atlantic Track (NAT) Bravo at flight level 330 (FL330). At 1926 Coordinated Universal Time (UTC), the flight crew of BAW92X reported over St. Anthony, Newfoundland, with an estimate of 1950 UTC for the geographic fix of 53°00’N latitude, 50°00’W longitude (50 West); then, as instructed, they left the Gander Area Control Centre (ACC) frequency.

Delta Air Lines flight 49 (DAL49), a Lockheed L1011, was flying westbound on NAT Bravo to Cincinnati, Ohio, also at FL330. At 1936 UTC, DAL49 passed by 50 West. The flight crew contacted the Gander ACC at 1942 UTC, at which time they requested and received a clearance to climb to FL350. At approximately 1944 UTC, 225 nautical miles northeast of Gander, DAL49 passed about 1,800 feet above and one mile south of BAW92X, where the required separation was 2,000 feet vertically. There were no injuries to crew or passengers.

The Board determined that the controllers involved in this occurrence did not detect the traffic conflict between DAL49 and BAW92X prior to the risk of collision. Contributing to this occurrence were the controllers' loss of situational awareness created by complacency and a lack of vigilance during a period of low-traffic activity.

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1.0 Factual Information

1.1 History of the Flight

At 1926 Coordinated Universal Time (UTC) <1>, British Airways flight 92 X-ray (BAW92X)<2>, a Boeing 747, passed over St. Anthony, Newfoundland (NFLD), flying at flight level 330 (FL330) eastbound to London, England, along North Atlantic Track (NAT) Bravo. The flight crew called Gander Area Control Centre (ACC) with their position report and gave an estimate of 1950 for the geographic fix 53-00'N latitude, 50-00'W longitude (50 West). Gander ACC acknowledged the estimate and, at 1926:35, instructed the flight crew to change to another frequency.

Delta Air Lines flight 49 (DAL49), a Lockheed L1011, passed over 50 West at 1936, flying westbound at FL330 along NAT Bravo to Cincinnati, Ohio. At 1942, the flight crew of DAL49 contacted Gander ACC for the first time. The flight crew requested and received a clearance to climb to FL350.

As DAL49's first officer entered the new altitude into the aircraft's vertical navigation computer, he observed conflicting opposite-direction traffic at 30 miles on the Traffic Alert and Collision Avoidance System (TCAS). The crew expedited the climb in order to avoid the conflicting traffic.

DAL49 passed about 1,800 feet above and one mile south of BAW92X, where the required separation was 2,000 feet vertically. The two aircraft had been closing at a combined speed of 980 knots, and at 30 miles were less than two minutes apart. The occurrence took place at 52:25'N, 52:40'W at approximately 1944, during daylight hours. (See Appendix A.)

1.2 Injuries to Persons

1.2.1 Delta Air Lines Lockheed L1011 N740DA

Crew Passengers Others Total
Fatal  -  -  -  -
Serious  -  -  -  -
Minor/None 14  247  -  261
Total     14  247  -  261

1.2.2 British Airways Boeing 747 G-AWNH

Crew Passengers Others Total
Fatal  -  -  -  -
Serious  -  -  -  -
Minor/None 19  192  -  211
Total     19  192  -  211

1.3 Damage to Aircraft

There was no damage to either aircraft.

1.4 Other Damage

None.

1.5 Personnel Information

1.5.1 Air Traffic Controller Information

Controller Position          Oceanic Planner High-Level Domestic
Age                        43               30
Licence                    IFR  IFR
Medical Expiry Date       01 Aug 95  01 Feb 96
Experience
  ■  as a Controller

  ■  as an IFR Controller
       16 yr  5 yr

  ■  in Present Unit
       16 yr  5 yr
       16 yr  5 yr

Hours on Duty Prior to Occurrence 7  8
Hours Off Duty Prior to Work Period 9  8

Controller Position                     High-Level Domestic OJI High-Level Domestic Trainee
Age                        43               24
Licence                    IFR  IFR
Medical Expiry Date       01 Feb 96  01 Jun 96
Experience
  ■  as a Controller

  ■  as an IFR Controller
       12 yr  1 yr

  ■  in Present Unit
       12 yr  1 yr
12 yr    1 yr
Hours on Duty Prior to Occurrence    1    1
Hours Off Duty Prior to Work Period    12    48

Controller Position    Oceanic Controller
Age    26
Licence    IFR
Medical Expiry Date    01 Jun 95
Experience
  • as a Controller
  • as an IFR Controller    3 yr
  • in Present Unit    3 yr
  3 yr
Hours on Duty Prior to Occurrence    1
Hours Off Duty Prior to Work Period    12

1.6 Aircraft Information
Not pertinent.

1.7 Meteorological Information
Both aircraft were operating under instrument flight rules (IFR) in visual meteorological conditions (VMC) at the time of the occurrence. The crew of DAL49 had visual contact with BAW92X as it passed below their aircraft.

1.8 Aids to Navigation
There were no reported discrepancies with the navigational aids being used by the aircraft involved in this occurrence. In addition, there were no reported discrepancies with the equipment being used by the Gander ACC controllers.

1.9 Communications
Communications between the Gander ACC and the aircraft were reported to be normal before, during, and after the occurrence.

1.10 North Atlantic Tracks
Air traffic control over the North Atlantic Ocean is handled primarily from Gander, Newfoundland, and Prestwick, Scotland. Primary responsibility for the planning function of the eastbound flow, which predominates at night between 2300 and 0500 UTC, rests with Gander, and for the westbound flow, which predominates during the daytime between 1000 and 2100 UTC, with Prestwick.

In order to regulate the flow during peak traffic periods, discrete tracks and altitudes are instituted. Conflict detection on these tracks over the ocean, east of 50° west longitude, up to 52° north latitude, is provided by the Gander automated air traffic system (GAATS). By using GAATS, the planner is alerted to any conflict with other oceanic traffic when an aircraft's flight plan is entered into the computer. Conflict detection in domestic airspace is the responsibility of the controller and is achieved by utilizing radar, flight progress strips, and pilot position reports.

This risk of collision took place in a small area of domestic airspace where there is no radar coverage; the controller must rely on information from the flight progress strips to provide separation.
It is possible for as many as 400 aircraft to transit the Gander Domestic airspace during the peak four hours of eastbound or westbound flow. During the changeover periods from day to night tracks, traffic volume and controller workload is considerably reduced. This daily change in traffic volume is generally consistent and is anticipated by the controllers.

1.11 Flight Progress Strips

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 flight data. This data is updated manually by the controller from position reports received from aircraft. Flight progress strips are arranged in bays under fix designators corresponding to the geographic location of a navigational fix. A flight progress strip depicting an aircraft's route of flight and altitude is placed under the fix designator that will best indicate the geographic position of the aircraft so that potential traffic conflicts can be more easily recognized and accurately assessed.

In Gander ACC, flight progress strips for westbound aircraft are printed in red ink, while strips for eastbound aircraft are printed in black ink. For some time prior to the occurrence, there were only two aircraft flight progress strips under the St. Anthony fix designator. One strip was for the westbound DAL49 at FL330 and the other was for the eastbound BAW92X, also at FL330.

The ATC Manual of Operations (MANOPS), Appendix 2, explains flight progress strip marking for IFR operations. Section 1.1.8 describes the controller's on-going scan of the control data board as follows:

Scan the control data board by performing the following actions:

A. scan each bay individually rather than looking over the entire board;
B. in each bay, check altitude boxes to verify vertical separation;
C. if more than one aircraft is at the same altitude, check strips to ensure some other form of IFR separation exists;
D. follow individual flights through the sector, checking for conflicting, converging or crossing track situations, consistency in altitude and estimate data, and for correct posting.

1.12 Traffic Conflict Detection

There were four opportunities for different controllers in Gander ACC to detect the traffic conflict developing between DAL49 and BAW92X.

Procedures, standards, guidelines, and checklists are available for the controllers to ensure the safe separation of aircraft. The separation standard that should have applied in this case was 2,000 feet vertically between the two aircraft. Staffing in the Gander ACC during the occurrence met unit standards.

1.12.1 Oceanic Planner Controller

The first opportunity to detect the conflict occurred when the oceanic planner initially received the requested altitude, FL330, for BAW92X. He coordinated this altitude with Prestwick centre and entered the information into GAATS. GAATS did not show a conflict between BAW92X and DAL49 because DAL49's estimated time of arrival (ETA) for 50 West was earlier than BAW92X's ETA for 50 West. The planner did not check with the Gander oceanic controller to determine if FL330 was okay for BAW92X because he saw that the oceanic controller was busy with a trainee. The planner checked the ocean data board himself and, although the data showed a conflict with DAL49 already at FL330, he did not detect the conflict. He returned to his position and the flight progress strip for BAW92X was produced at 1901.

1.12.2 High-Level Domestic Controller
A second opportunity to detect the conflict occurred when the Gander high-level domestic controller received the flight progress strip in black ink for BAW92X about 1845 and put it on the control data board under the St. Anthony fix designator along with the flight progress strip in red ink for DAL49. He did not detect the conflict during his routine scan of the control data board prior to being relieved at the sector.

1.12.3 High-Level Domestic Controller Instructor and Trainee

The third opportunity to detect the conflict occurred when the high-level domestic radar controller was relieved by a high-level domestic on-the-job instructor (OJI) and his trainee about 1915. The relieving controllers followed the standard Gander ACC procedure of first standing behind the position to observe the traffic. Next the relieving controllers were briefed, and a data board check was performed by the controller at the position. The briefing is designed to follow a written checklist and includes altitude reservations, separation problems to be resolved, conflicts, and immediate control actions. The relieving controller then sits at the sector position while the controller being relieved stands behind the position and observes until the relieving controller is acclimatized to the sector.

Controllers regard the sector briefing as common sense, and they report that the written checklists disappear from the control positions within a matter of days or weeks. In this case, the relieving controllers reported that they did observe the sector and get a briefing, and that the relieved controller did stand behind them for some time. The traffic conflict between BAW92X and DAL49, the only two data strips under the St. Anthony fix designator, was not detected at this time. The controllers reported that the sector briefing pointed out that most of the traffic was over the tracks in the southern airspace of the Gander area. The sector's radar was displaying mostly traffic on the tracks in the southern, rather than northern, part of the airspace.

The OJI reported that the trainee sat in at the high-level domestic position after receiving the briefing, and the OJI observed the trainee do a data board check; the OJI also did a scan of the data board. Prior to the occurrence, the trainee was responsible for five or six aircraft at any one time that were transiting through his sector. This traffic volume was assessed as light to moderate. Review of the sector's audio tape recording for the 30 minutes prior to the occurrence indicated nine aircraft on the frequency and a period of almost seven minutes with no radio transmissions just prior to the occurrence.

At 1926, BAW92X contacted the Gander ACC trainee with a position report over St. Anthony. The trainee had already marked BAW92X's data strip when he accepted the handoff from west radar and, nine minutes later, he wrote the aircraft's progress report on the flight data strip. The aircraft reported maintaining FL330 and the trainee told the pilot to contact Gander Radio in 100 miles. The trainee did not detect the conflict on the two strips under the St. Anthony fix designator, the red one for DAL49 and the black one for BAW92X, both marked at the same altitude.

At 1942, DAL49 contacted the Gander ACC trainee and reported at FL330, with an estimate for St. Anthony of 2019. The trainee issued the aircraft a domestic clearance and asked the pilot of DAL49 what altitude they were requesting. At that point the controllers realized that both DAL49 and BAW92X were at FL330, on the same track and possibly in conflict. After confirming that DAL49 was at FL330, the trainee cleared the aircraft up to FL350. The clearance to DAL49 did not include an instruction to expedite the climb or any traffic advisory about the position of BAW92X.

1.12.4 Oceanic Controller

The fourth opportunity to detect the conflict occurred when an oceanic controller took over the ocean sector from the first oceanic controller and his trainee at about 1905. When the relieving controller did his data board check, he did not notice that the flight data strips for DAL49 and BAW92X indicated that the aircraft were at the same altitude, travelling in opposite directions, on the same track.

About 1915, a second strip for BAW92X was produced with a speed change and no change to the routing. The oceanic controller received this new strip and compared it with the BAW92X strip already on the board. Once again, he did not detect the conflict with DAL49. The oceanic controller also did not detect the traffic conflict during his routine scan of the data board.
1.13 Controller Situational Awareness

Studies have shown that controllers form a mental picture of air traffic that assists with the conceptualization and prediction of aircraft movement. Information used to develop this picture comes from radar displays, aircraft position reports, and the data from flight progress strips. Maintenance of the picture is essential for controller situational awareness and effective air traffic control.

David Hopkin, in his book *Situational Awareness in Complex Systems* (Embry-Riddle Aeronautical University Press, 1994), makes the following observations about situational awareness in air traffic control:

Situational awareness will be subject to the formation of habits, may be resistant to new evidence that appears to contradict what is already known, may be biased in the choice of what is relevant to it, and may be influenced, and perhaps overly influenced by memories which once recalled, may be treated as more relevant than they are.

All the major proposed forms of computer assistance for air traffic controllers in performing their tasks, and all the intended forms of automation in air traffic control that are envisaged to have some consequences for the controller, must affect situational awareness. The reason is that all aids require new learning of some kind and situational awareness is a function of learning. The expressed anxieties about some of the consequences for situational awareness of increased air traffic control automation, such as an increased propensity for the controller to lose the picture or reduced controller understanding of the picture, seem to have some justification.

1.14 Controller Vigilance

In 1990, the Canadian Aviation Safety Board (CASB), as a result of a special investigation into air traffic control services, stated that inattention or lack of vigilance appears to be contributory in approximately 50 per cent of all air traffic services (ATS) occurrences, and that these types of errors often happen during periods of light, non-complex traffic. Complacency and boredom were considered to contribute to the frequency of attention-related occurrences.

2.0 Analysis

2.1 General

Sixty minutes had elapsed between the time the oceanic planner determined that FL330 was an appropriate altitude for BAW92X and the time of the occurrence. There were four opportunities for individual controllers to detect the conflict and correct it. Normally, aircraft separation, conflict detection, and conflict correction take place routinely, regardless of the traffic volume.

2.2 Traffic Volume

During the late afternoon, the traffic activity that normally follows the daily westbound flow is at its lowest. Changeover in the main-flow direction will take place over the next few hours and the controller evening shift changes are also taking place. Controllers arrive at their positions anticipating few traffic problems, knowing that the main traffic volume will occur later in the evening. Relieving controllers anticipate that the controllers being relieved will have already resolved any potential traffic conflicts or will point out unresolved traffic conflicts for their immediate attention.

Considering the conditions that normally exist, the first few hours of the evening shift are the least demanding of the shift. This established routine can engender a complacent attitude, causing a lack of vigilance and leading to a loss of controller situational awareness.

2.3 Traffic Conflict Detection

2.3.1 Oceanic Planner

If the oceanic planner had completed an adequate check of the ocean board, he might have detected the presence of DAL49 already over the ocean at FL330. In that case, he would not have planned
BAW92X at the same altitude. Rather than checking the ocean data board himself, a more appropriate action for the oceanic planner might have been to interrupt the ocean controller and his trainee, or wait for an opportune moment, and discuss the altitude for BAW92X with him. The ocean controller, being more familiar with the traffic in his sector, might have been able to detect the conflict more easily than the planner.

2.3.2 High-Level Domestic Controller

When the high-level domestic controller received the flight data strip for BAW92X and placed it with the strip for DAL49 on the data board, he did not notice that both aircraft were at the same altitude. He did not detect the traffic conflict during the period that both strips were on his sector's data board. Given that the two differently coloured strips were the only two under the St. Anthony fix designator, it is likely that the high-level domestic controller's routine data board scan was ineffective.

2.3.3 High-Level Domestic OJI and Trainee

Although the controllers reported that a briefing was completed when the OJI and his trainee relieved the first high-level controller, the briefing did not include any information about the conflict between DAL49 and BAW92X. The data board checks performed by both the OJI and the trainee were ineffective, as neither detected the conflict at that time.

The trainee controller's mental picture of the air traffic and his situational awareness were inadequate. This is highlighted by his action of twice marking flight progress information on BAW92X's black data strip and failing to detect the traffic conflict, even though DAL49's red strip was the only other strip under the St. Anthony fix designator.

The section of domestic airspace where the occurrence took place does not have radar coverage. Even if radar coverage were available in this area, though, it is unlikely that the controllers would have detected the conflict, because the radar was centred to display the traffic on the tracks in the southern part of the airspace.

When the controllers detected the traffic conflict, they cleared DAL49 to climb without instructing the pilot to expedite, and they did not give a traffic advisory about BAW92X's position. It is possible that the actual air traffic picture deviated so greatly from the mental picture they had already developed that they did not give the most appropriate instructions to DAL49.

2.3.4 Oceanic Controller

If the controller who relieved the oceanic sector prior to the occurrence had done an adequate data board check, he would have detected the traffic conflict. When the oceanic controller received the second data strip for BAW92X with the speed change, he saw that it was not a routing change, assumed that the route was already free of traffic conflict, and did not check it against the other strips on the ocean data board. The oceanic controller did not detect the conflict during his routine scan of the ocean data board either.

2.4 Controller Situational Awareness

It is likely that the failure of the involved controllers to maintain their situational awareness was due to the development of a complacent attitude during a period of low traffic activity. Contributing to this complacent attitude was a reliance on automated systems, such as GAATS, and other controllers to detect potential traffic conflicts. This complacent attitude led to a lack of vigilance and less compliance with established procedures and checklists. When a traffic conflict does develop during a period of low traffic activity, as occurred on this occasion, it is less likely to be detected than it would be during a period of peak traffic activity.

Adherence to established procedures and the use of written checklists by the controllers would likely have resulted in earlier detection and resolution of the conflict, and would have reduced the risk of collision.
2.5 Traffic Alert and Collision Avoidance System

The crew of DAL49 decided to expedite the climb to FL350 after the first officer observed conflicting opposite-direction traffic at 30 miles on the TCAS. This decision was based solely on the TCAS information and resulted in the two aircraft achieving 1,800 feet vertical separation when they passed. Without an ATC instruction to expedite the climb and without the information provided by TCAS, the crew of DAL49 probably would have performed a slower en route climb, resulting in less vertical separation with BAW92X when they passed.

3.0 Conclusions

3.1 Findings

- All the controllers involved in this occurrence were qualified and current at their positions.
- All equipment available to the controllers was serviceable and being used.
- Staffing in the Gander Area Control Centre met unit standards.
- The traffic volume was assessed as light to moderate with normal complexity.
- The oceanic planner did not detect a traffic conflict with DAL49 when he planned the altitude for BAW92X.
- The first high-level domestic controller occupying the sector did not detect the traffic conflict between the two aircraft.
- The OJI and high-level domestic radar trainee who relieved the sector did not detect the traffic conflict between the two aircraft.
- The oceanic controller who occupied the ocean sector during the time prior to the occurrence did not detect the traffic conflict.
- When the risk of collision was detected, DAL49 was not instructed to expedite the climb to FL350, and no traffic information was passed.
- The crew of DAL49 decided to expedite their climb based on TCAS information about opposite direction traffic.
- DAL49 passed about 1,800 feet above and one mile south of BAW92X.
- Established procedures and written checklists for flight data board scans and sector briefings were not effectively followed.

3.2 Causes

The controllers involved in this occurrence did not detect the traffic conflict between DAL49 and BAW92X prior to the risk of collision. Contributing to this occurrence were the controllers' loss of situational awareness created by complacency and a lack of vigilance during a period of low traffic activity.

4.0 Safety Action
4.1 Action Taken

4.1.1 Transport Canada

Previous TSB investigations have shown that controller inattention, lack of vigilance, or loss of situational awareness are major factors in loss of separation occurrences. Therefore, subsequent to a risk of collision between two A320 Airbus aircraft in December 1993 (A93C0208), the Board recommended that:

The Department of Transport sponsor research into methods for maintaining reliable controller vigilance in an increasingly automated ATC work environment.

(A94-28, issued December 1994)

In response, Transport Canada (TC) indicated that research would be conducted on the most effective communication, focusing, and distraction-control techniques for air traffic controllers, and relevant training programs would be implemented. Additionally, TC has started research into other areas that affect controller vigilance and into programs designed to optimize controller health and performance.

To address the issue of controller situational awareness in the short term, the Board recommended that:

The Department of Transport provide training for Canadian controllers similar to crew resource management (CRM) training for pilots.

(A94-29, issued December 1994)

In response, TC indicated its intention to develop a decision making course for controllers (similar to the pilot decision making (PDM) courses) which would include a discussion of the various factors that affect situational awareness.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 03 January 1996.

Appendix A - Occurrence Location Diagram
Appendix B - Glossary

ACC - Area Control Centre
ATC - air traffic control
ATS - Air Traffic Services
BAW92X - British Airways flight number 92 X-ray
CAB - Canadian Aviation Safety Board
DAL49 - Delta Airlines flight number 49
ETA - estimated time of arrival
FL - flight level
GAATS - Gander Automated Air Traffic System
IFR - instrument flight rules
MANOPS - Manual of ATS Operations
N - north
NAT - North Atlantic Track
NFLD - Newfoundland
OJI - on-the-job instructor
TC - Transport Canada

1926 BAW92X reported by St. Anthony at FL 330.
1936 DAL49 reported by 50 West at FL 330.
1943 DAL49 was cleared to FL 360.
1944 The aircraft passed with 1,800 feet vertical separation.
TCAS - Traffic Alert and Collision Avoidance System
TSB - Transportation Safety Board of Canada
UTC - Coordinated Universal Time
W - west
yr - year (s)
50 West 53'00' North latitude 50'00' West longitude
° degree(s)
' minute(s)

<1> 1All times are Coordinated Universal Time (UTC) unless otherwise noted.
<2> 2See Glossary for all abbreviations and acronyms.

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.

Runway Overrun
Royal Aviation Inc.
Boeing Company 727-217 C-GRYR
St. John's, Newfoundland
11 May 1995

Report Number A95A0093

Synopsis

The Royal Aviation Boeing 727, flight 4529, landed on runway 11 at St. John's, Newfoundland. The aircraft initially touched down with about 3,500 feet of runway remaining and overran the runway end by 300 feet before coming to a full stop. No evacuation was initiated and there were no injuries to the passengers or crew.

The Board determined that the crew continued with the landing when there was insufficient runway remaining to stop on the runway surface. Contributing to the overrun were ineffective landing technique, excessive altitude and airspeed over the runway threshold, and the use of inappropriate approach limits for a new captain.

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2.0 Analysis

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3.0 Conclusions

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5.0 Appendices

Appendix A - Aerodrome Chart
Appendix B - List of Supporting Reports
Appendix C - Glossary

1.0 Factual Information

1.1 History of the Flight

Royal Aviation (ROY) <1> flight number 4529, a Boeing 727-217, was on a sub-charter flight from Toronto, Ontario, to St. John's, Newfoundland, via Halifax, Nova Scotia. The aircraft arrived in Halifax at 1247 Coordinated Universal Time (UTC)<2>, but the departure from Halifax was delayed due to the poor weather in St. John's. The weather in St. John's subsequently went above approach-ban limits of 1/4 mile, and ROY4529 departed Halifax. On board were 3 flight crew, 5 flight attendants, and 154 passengers.

On arrival at St. John's, the aircraft was vectored and cleared for a straight-in instrument landing system (ILS) approach to runway 11. During the approach, the flight crew acknowledged the tower report indicating the wind from 010 degrees<3> at 20 knots and the runway visual range (RVR) reading of 2,800 feet. The flight crew reported seeing the runway lights at minimums, at which time the aircraft was
slightly left of the runway centre line. The aircraft subsequently drifted to the right of the centre line, and the touchdown was delayed while the aircraft was being realigned. On touchdown, the speed brakes deployed automatically, the captain used firm braking action, and the normal thrust reverse was selected. Shortly thereafter, the flight crew saw the end of the runway approaching, and both the captain and first officer applied maximum braking. Maximum reverse thrust was also applied. The aircraft could not be stopped on the paved runway surface, and came to rest 300 feet beyond the end of the runway. The incident occurred at 1518, during the hours of daylight.

The crew notified the St. John's control tower that the aircraft had overrun the runway, and the tower activated the emergency vehicle response. The crew assessed that there was not a requirement to carry out an emergency evacuation. There was only minor aircraft fuselage damage, and there were no injuries.

1.2 Injuries to Persons

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<td>-</td>
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</table>

1.3 Damage to Aircraft

The two pod-mounted engines were substantially damaged because of debris blown upward during the runway excursion. The No. 1 tire on the left main gear blew during the landing roll, and there was minor damage to flaps and fairings.

1.4 Other Damage

Some runway end lights and approach lights were damaged as a result of the aircraft excursion.

1.5 Personnel Information

1.5.1 General

<table>
<thead>
<tr>
<th></th>
<th>Captain</th>
<th>First Officer</th>
<th>Second Officer</th>
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<tbody>
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<td>Age</td>
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<tr>
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<td>CPL</td>
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</tr>
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<tr>
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Hours on Duty Prior to Occurrence: 6 6 6
Hours Off Duty Prior to Work Period: 20 48 72

1.5.2 Captain's Work History

The captain joined Royal Aviation on 27 April 1992 as a second officer on the Boeing 727. He subsequently was upgraded to a first officer on the Boeing 727 and Lockheed L1011 aircraft. On 09 May 1995, he successfully completed his captain's route check on the Boeing 727.

At the time of the occurrence, the captain held an Airline Transport Pilot Licence (ATPL) endorsed for Boeing 727 and Lockheed L1011, a Group 1 instrument rating, and a Category 1 medical. The incident flight was his first flight as a captain on the Boeing 727. The captain had received at least the minimum of 25 hours line indoctrination training before completing a route and line check ride. The captain's training met company and Transport Canada requirements.

1.5.3 First Officer's Work History

The first officer joined Royal Aviation in December of 1993 as a flight engineer on the Lockheed L1011. On 19 December 1994, he successfully completed a route check as a Boeing 727 first officer.

He held a Commercial Pilot Licence endorsed for Boeing 727, a Group 1 instrument rating, and a Category 1 medical. He also held an Aircraft Maintenance Engineer (AME) licence.

1.5.4 Second Officer's Work History

The second officer joined Royal Aviation in November 1994, and on 22 December 1994, he successfully completed a route check as a Boeing 727 second officer. He held an ATPL endorsed for second officer on the Boeing 727, a Group 1 instrument rating, and a Category 1 medical.

1.5.5 Flight Attendants

There were five cabin crew working on Royal Aviation Flight 4529. The in-flight director (IFD) was responsible for cabin safety and cabin service, and for coordinating the duties of the other four flight attendants.

The IFD had three years experience as a flight attendant and had been an IFD on the Boeing 727 for one year.

The other four flight attendants had recently completed the company's flight attendant training program in April 1995. The incident flight was their first flight as crew members on the Boeing 727 aircraft.

1.6 Aircraft Information
The aircraft documentation indicated that, for the occurrence flight, 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.

An analysis of the blown No. 1 tire conducted by the TSB Engineering Branch determined that the tire did not rotate during the landing and that plies had been worn away in the central area of the tread. The analysis also determined that the remaining plies were insufficient to contain the tire pressure, causing the fully inflated tire to burst. The nylon material in the tire also showed signs of smearing, which is a common indication after a wet runway landing.

The antiskid was selected to "ON" prior to the landing, and the flight crew reported that the antiskid "INOP" lights did not illuminate at any time during the incident. Maintenance checks of the brake/anti-skid and hydraulic systems conducted after the incident determined that these systems were serviceable.

The reason why the wheel locked could not be determined.

### 1.7 Meteorological Information

During the three hours prior to the aircraft's departure from Halifax, the St. John's Surface Hourly Weather Reports (SA) reported 100 feet obscured ceilings and 1/8 of a mile visibility. The following special weather observations (SPs) were issued for St. John's:

1317: Ceiling 200 feet obscured and 1/4 of a mile visibility.

1410: Ceiling 200 feet overcast and one mile visibility.

1441: Ceiling 200 feet overcast and 3/4 of a mile visibility.

The regular SA for St. John's issued at 1500 was as follows: ceiling indefinite 200 feet overcast, 5/8 of a mile visibility in drizzle and fog, temperature and dew point 4 degrees Celsius, and wind 350 degrees true at 16 knots.

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<td>Type and Model</td>
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<tr>
<td>Fuel Type Used</td>
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</tr>
</tbody>
</table>

The flight crew received the 1500 SA from the automatic terminal information service (ATIS), and, while the aircraft was on approach, the St. John's control tower reported that the RVR for runway 11 was 3,000 feet. Prior to landing, the flight crew acknowledged the latest St. John's control tower-reported winds and RVR as follows: wind 010 degrees at 20 knots and a 2,800 foot RVR for runway 11.

At 1525, seven minutes after the incident, the visibility was 1/2 mile and the wind was 350 degrees true at 14 knots, gusting to 21 knots.

1.8 Aids to Navigation

Runway 11 at St. John's is serviced by an ILS. At the time of the occurrence, the ILS was reported to have been functioning properly.

1.9 Aerodrome Information

St. John's Airport is situated on the southeast coast of Newfoundland, at a reference point elevation of 461 feet above sea level (asl). The airport has three runways; runway 11/29, used by the occurrence flight, is 8,500 feet long by 200 feet wide.

Runway 11, an ILS category 1 runway, is equipped with centre-row category 1 high-intensity approach lights, green threshold lighting, white centre-line lighting for the entire 8,500-foot runway length, and red runway-end lighting. At the time of the incident, the runway light strength was selected to the maximum intensity, level 5.

The reciprocal runway, 29, an ILS category 2 runway, is equipped with centre-row, category 2, high-intensity approach lights, green threshold lighting, touchdown zone lighting, white runway centre-line lighting for the first 5,500 feet, alternating red and white for the next 2,000 feet, and red centre-line lighting for the remaining 1,000 feet. The runway end lighting is also red.

1.10 Flight Recorders

The aircraft was equipped with a four-track Fairchild A100 cockpit voice recorder (CVR) and a four-track Sundstrand 573A 82-parameter digital flight data recorder (FDR). The CVR recorded the pilot, co-pilot, and flight engineer audio channels, as well as the cockpit area microphone channel. Hot microphone channels were not recorded. The quality of the CVR recording was good, and the recording covered the time from approximately 10 minutes prior to descent until about one minute after the aircraft came to a stop off the end of the runway.

The flight data on the FDR was of good quality. The FDR recording did not include ILS glide slope or localizer information, nor any other navigation information that could have provided precise aircraft position. Radar data, obtained from the Gander Area Control Centre, and mathematical analysis of derived groundspeed were used to determine the aircraft's longitudinal position in relationship to the runway (see LP 65/95). The aircraft's lateral position with respect to the runway centre line was determined from crew communications and
aircraft-heading and roll-attitude data. ILS interception and tracking information was based on crew communications.

1.11 Flight Path Reconstruction

The flight path reconstruction, based on CVR, FDR, radar, and crew information, revealed a number of factors regarding the transition, touchdown, and roll-out phases of the occurrence landing.

On arrival in the area of St. John's, ROY4529 was cleared to the Oscar non-directional beacon (NDB) in anticipation of an ILS approach to runway 11 at St. John's.

As part of the approach briefing, and based on the 1410 ATIS winds, 154 knots indicated airspeed (KIAS) was set on the approach speed bug, and 147 KIAS was selected as the threshold-crossing speed.

The descent and approach toward the Oscar NDB was normal, and, after receiving the 1500 St. John's SA, the crew reviewed the missed-approach procedure. Subsequently, ROY4529 was assigned heading 090 degrees, cleared to 2,100 feet asl, and then cleared for the straight-in ILS runway 11 approach. Shortly after levelling the aircraft at 2,100 feet, the captain disengaged the autopilot, electing to fly the approach manually. Based on the CVR data, the localizer and glide slope were captured normally and no significant problems with the approach to minimums were noted.

During the final stages of the approach, at approximately 150 feet above decision height (DH), the aircraft was maintaining 165 KIAS, on a heading of 098 degrees, with a rate of descent of 900 feet per minute (fpm), and slightly left of the runway centre line. When the first officer made the "one-hundred-above" call, the aircraft was in a seven-degree right-bank turn.

When the first officer called the runway lights visual, the aircraft was at about 600 feet asl or 140 feet above the runway touchdown zone elevation (TDZE), at 168 KIAS, on a heading of 106 degrees, with a rate of descent (sink rate) of 1,000 fpm and slightly left of the runway centre line. Nine seconds before threshold crossing, the captain reduced the aircraft's high descent rate.

Glide slope deviation was not a recorded parameter on the FDR. Although the CVR did not indicate deviation from the glide slope, the increased descent rate approximately nine seconds prior to threshold crossing was indicative of a fly down correction for deviation above the glide path.

On a typical ILS approach, the aircraft descends on a three-degree glide path, reaching DH about 1/2 mile from the threshold. On the incident flight, the aircraft descended through DH just prior to the threshold crossing.

The aircraft crossed the runway threshold at 165 KIAS, 110 feet above TDZE, and on a heading of 109 degrees, drifting to the right of the
runway centre line.

A left turn to 103 degrees, using up to 12 degrees of left bank, was required to return the aircraft to the runway centre line, which occurred at about nine seconds and 1,800 feet after runway threshold crossing.

The 50-foot call was made 12 seconds and 2,500 feet beyond the threshold. Engine throttles were reduced from 75 per cent N1 to idle thrust, about 14 seconds after threshold crossing. Touchdown was determined to have occurred at 147 KIAS, and approximately 22 seconds and 5,100 feet after threshold crossing.

Just after touchdown, the armed speed brakes (spoilers) deployed automatically and the thrust-reversers were unlocked. The captain applied firm braking and selected normal thrust reverse. About eight seconds later, the captain called "coming up," at which time the runway end came into view. Maximum reverse thrust was selected by the captain, and both the captain and the first officer applied maximum braking.

As the aircraft approached the runway end, it was tracking slightly to the right of the runway centre line. Tire marks originating from the No. 1 main tire were observed on the last 55 feet of runway; these marks extended off the end of the runway, two feet to the right of the runway centre line. Maximum reverse thrust and braking were maintained until the aircraft came to rest about 300 feet beyond the runway end and 21 feet to the right of the runway extended centre line.

1.12 Survival and Evacuation

1.12.1 Decision Not To Evacuate

As the aircraft departed off the end of the runway, there was significant noise from the engines as well as vibrations from the aircraft rolling over the unprepared surface. Once the aircraft was stopped, the captain assessed that an evacuation was not necessary because he saw no fire warnings or other abnormal indications in the cockpit and because he did not see any obstacles in the aircraft's path during the runway excursion. Shortly after the aircraft came to rest, the IFD entered the cockpit, informed the captain that there was a burning smell and some smoke in the cabin area, and asked if an emergency evacuation was to take place. The captain was aware that a significant amount of debris had been blown around by the thrust reversers during the overrun and assumed that some of the debris had probably been ingested by the engines; he looked back into the cabin area and decided not to evacuate, and told the IFD that it was smoke from the brakes.

The emergency response vehicles arrived at the aircraft approximately two minutes after the aircraft had come to rest, and the response personnel confirmed that there was no evidence of fire.

The flight crew advised the tower that buses would be required to disembark the passengers. About 20 minutes later, the right rear cabin...
door was opened by a flight attendant to provide some fresh air while awaiting the buses. About 45 minutes passed before passenger disembarkment and transport to the airport terminal started. The cabin crew disembarked with the last passengers.

1.12.2 Cabin Attendant Response

The decision to carry out an aircraft evacuation is normally made by the captain, and, once the decision has been made, the flight crew is to advise the cabin crew using prescribed signals.

The IFD, who was sitting in an aft-facing jump seat at the forward left side of the aircraft, reported that, on noticing the aircraft pass considerably more runway side lights than usual before touchdown, he was mentally preparing for an abnormal situation to develop. As the aircraft stopped, he told the flight attendant who was sitting adjacent to him to prepare for the emergency evacuation signal. The abnormal sights and sounds during the landing overrun, the lack of an immediate evacuation call or other notification by the flight crew, and the presence of smoke and a burning smell in the cabin area prompted the IFD to enter the flight deck and request direction as to whether an emergency evacuation was to take place. Based on the captain's decision and in response to several passengers who had released their seat-belts with the intention of standing up, the IFD yelled to the passengers to remain seated, advising them that the smell was only the brakes. Shortly after the IFD advised the passengers to remain seated, the first officer, on the direction of the captain, made a public address announcement for the passengers to remain seated.

The IFD also instructed the other flight attendants to remain at their respective exits and to remain ready for an evacuation in anticipation that such a direction might be given.

Emergency procedures training is provided for flight crews and cabin crews; however, no mutual training is conducted between the two crews, a procedure recommended by Transport Canada. The flight and cabin crew did not debrief after this incident took place.

1.13 Company Weather Limits For New Captains

The company's operations manual (OM) states that the limits published in the Canada Air Pilot (CAP) or appropriate publication must be increased by 100 feet and 1/2 mile until such time as the captain has completed 100 hours on type as captain. The company operates under a pilot self-dispatch system, and the minimum requirement to conduct an approach is 1/4 mile visibility.

Although the captain had 2,400 hours on the Boeing 727, this was his first flight as captain. The captain recalled reading about the higher minimum limits for new captains, but the crew had not considered these limits during the flight. The second officer was unaware of the new-captain higher minimum limits. All flight crew members reported that at no time in their company training were the new-captain limits discussed.
The CAP limits for the St. John's ILS approach to runway 11 are 200 foot ceiling and 1/2 mile visibility (RVR 2,600 feet). Therefore, the landing limits for a new captain, when landing on runway 11, are 300 feet and 1 mile visibility. When the occurrence aircraft was positioned to land, the reported weather was 200 feet overcast, visibility 5/8 mile.

1.14 Airspeed Bug Settings

The Royal Aviation 727 Operating Manual (AOM), Normal Procedures, Section 3, Page 5, provides direction as to how flight crews are to determine the airspeed bug settings for approach and landing as follows:

Ref This is the speed for a specific flap configuration which provides adequate stall margin for landing. It is the basis for computing target and threshold speeds.

Target This is the speed which the approach is flown (sic). It is equal to the Ref speed plus 1/2 the steady headwind component plus the full gust value.

Threshold This is the speed crossing the threshold. It is equal to Ref speed plus the full gust value.

If the approach is flown in a no-wind condition, the minimum target speed is Vref + 5 knots, and the threshold speed is Vref. This section also states that under certain circumstances, such as terrain induced turbulence, it is acceptable to add half the steady wind value plus the gust without calculating the headwind component.

For the approach and landing into St. John's, the flight crew calculated the speeds based on the landing weight and flap configuration Ref speed of 137 knots, and the ATIS 1410 Special surface winds of 030 degrees at 15, gusting to 25, knots. Using half the steady wind (7 knots) and all of the gust (10 knots), the crew calculated the bug speeds to be 154 knots for the target speed and 147 knots for the threshold speed. The CAP approach diagram for runway 11 at St. John's advises flight crews to anticipate moderate to severe turbulence.

1.15 Approach Procedures

1.15.1 Cockpit Workload Management

The company does not have a standard or procedure for the use of the autopilot when conducting IFR approaches, nor are there regulations or manufacturer's guidance on this issue. However, industry norms dictate that available automation should be used when making approaches in poor weather, specifically because the use of cockpit automation improves the accuracy of the approach and facilitates the transition to the runway landing by reducing pilot workload.

Another technique used by some carriers to enhance the transition from an IFR approach to a visual landing is the pilot-monitored approach.
This technique uses traditional flying techniques, wherein the pilot flying (PF) is responsible for maintaining the aircraft on the approach course and descent profile, while the pilot not flying (PNF) monitors the PF's approach. However, in a pilot-monitored approach, the PNF is also responsible for scanning outside the cockpit for the runway environment, and when the necessary visual runway references are acquired, the PNF takes control and lands the aircraft. This technique reduces the workload and better enables the PNF to maintain situational awareness and to be better oriented with the landing environment when the PNF takes control to land the aircraft.

In this occurrence, the approach was being conducted in cross-wind, low ceiling, and low visibility conditions. The captain disconnected the autopilot before the aircraft descended below 2,100 feet asl to fly the approach manually. FDR data and pilots' statements indicate that the runway lights were sighted just as the aircraft reached decision height; at that point, the aircraft was not aligned with the centre line, and the airspeed was 11 knots above the desired speed. In addition, the captain introduced a correction which caused the aircraft to drift right of the centre line.

1.16 Additional Issues

1.16.1 Transition to Landing

The ILS approach is designed in such a manner that, if the aircraft follows the glide slope and localizer, the touchdown point for the aircraft will be approximately 1,000 feet beyond the threshold of the runway. Consequently, when acquiring the appropriate runway visual references, the pilot should transition to visual references and maintain the approach profile to touchdown.

The company's Boeing 727 Operating Manual directs that, during the approach phase, the pilot is to fly a well executed approach with the airplane positioned on the glide path and runway centre line and at the speed recommended for existing conditions. The pilot is further directed that, during the flare phase, the pilot should not allow the aircraft to float or drift; and during the touchdown phase, the pilot should get the wheels on the runway at approximately 1,000 feet from the approach end of the runway. The airplane should be flown firmly onto the runway at the aiming point, even if the speed is excessive.

A pilot's decision to continue the approach and landing after reaching DH is based on a number of factors. Any significant deviation from the final approach profile should be cause for considering a missed approach. Also, the pilot must have and maintain the runway visual, have sufficient visual cues to continue the landing, and have sufficient runway remaining to bring the aircraft to a complete stop.

The company's OM states, in part, that a missed approach shall be initiated when, in the opinion of the pilot-in-command, a safe landing cannot be accomplished within the touchdown zone (the first 3,000 feet of runway) and the aircraft stopped within the confines of the computed...
stopping distance.

1.16.2 Aircraft Performance

In calculating the landing performance, the flight crew factored in a wet runway condition and calculated the required landing distance to be 6,000 feet for the aircraft weight at the landing field temperature.

Analysis of the FDR data indicated that the aircraft crossed the threshold 110 feet above ground level (agl). The published threshold crossing height (TCH) for the approach to runway 11 is 57 feet agl.

The aircraft manufacturer analyzed the FDR information and compared it with the simulated (predicted) results and with the certification flight tested deceleration values. The results are as follows:

At 154 knots, the bugged target speed, the predicted total landing distance using certified flare parameters for a wet runway is 5,500 feet.

At 165 knots, the speed that was flown, the predicted total landing distance required was 6,010 feet.

At the speeds and conditions at the time of the incident, the predicted ground roll-out distance from touchdown to stop was 3,750 feet. If the tire blowout had occurred immediately at touchdown, the predicted ground roll-out distance would have increased by 160 feet to 3,910 feet.

FDR data indicate that the aircraft touched down about 5,100 feet beyond the threshold and had an approximate ground roll-out distance of 3,800 feet.

1.16.3 Pilot Training

Although low ceiling approaches and cross-wind landings had been independently demonstrated during the flight crew simulator training, minimum visibility approaches combined with strong cross-winds were not. During company simulator training for new captains, instrument approaches were flown with reference to the published CAP limits. The higher company limits for new captains were not discussed during training or line indoctrination.

2.0 Analysis

2.1 Introduction

Although the failure of the No. 1 main tire resulted in decreased aircraft braking effectiveness and a slight increase in the landing distance required, it was primarily the delayed touchdown that resulted in insufficient runway remaining to stop the aircraft. Therefore, the analysis will concentrate on the approach profile and the captain's decision to continue with the landing.

2.2 Approach Information
When ROY4529 departed Halifax, the St. John's weather was a 200-foot ceiling and 1/4 mile visibility. Since the company operates under a pilot self-dispatch system and the minimum requirement to conduct an approach is 1/4 mile visibility, the captain's decision to depart was procedurally correct.

The 1410 ATIS reported that the visibility had increased to one mile. However, the weather updates after the 1410 ATIS report and the RVR for runway 11 reported by the tower before the aircraft reached DH indicated that the visibility at St. John's was deteriorating.

The captain disconnected the autopilot and continued with a manual approach before descending below 2,000 feet asl. With the deteriorating weather conditions and the gusty cross-wind conditions on final approach, the captain would have been less heavily tasked if he had maintained the aircraft on autopilot and completed a coupled instrument approach. This would have allowed him to spend more time monitoring the approach and preparing for the transition to visual for landing.

When the captain saw the runway and realized that the aircraft was left of the runway centre line, he corrected to the right. This right turn, combined with the left cross-wind, caused the aircraft to drift to the right of the runway centre line. It is likely that when the captain saw the runway, he automatically turned towards it and corrected too far to the right. This, in effect, removed the crab that was maintained for the cross-wind conditions and resulted in the aircraft drifting from the desired track.

At the estimated time of threshold crossing, the aircraft was descending through an approximate altitude of 110 feet agl. This indicates that the aircraft had deviated above the glide slope at some point during the approach. Nine seconds before threshold crossing, the captain reduced the rate of descent of the aircraft; this is likely when the aircraft went above the glide slope.

2.3 New Captain Limits

The captain continued with the approach to runway 11, even though the reported St. John's weather was below the company weather limits for new captains.

The captain never consciously considered the higher minimums for new captains in his decision to continue the approach. During his simulator training, approaches were flown referencing CAP limits and not the higher limits for new captains. It is probable that on the incident flight, the captain referenced the CAP limits.

Training conducted in a simulator is the best opportunity for a company to check a pilot's proficiency, including flying the aircraft down to CAP minimum approach limits. These are the minimum limits that the pilot will be expected to perform to on a normal basis.

Had the captain observed the higher limits during the approach to
runway 11, he would have begun a missed approach procedure when he reached those limits. His options then would have been flying a second approach and, if unable to land, flying to his alternate airport.

The intent of the higher limits for new captains is to provide a safety margin until they have acquired experience as a captain on the aircraft type.

### 2.4 Runway Lighting

The aircraft approached St. John's from the west; therefore, runway 11 provided a straight-in approach to the airport. Since the prevailing winds, although gusty, were approximately 90 degrees to the runway, a landing on runway 29 would not have appeared more favourable and would have taken more time.

The lighting on runway 29 includes touchdown zone lighting, and the last 3,000 feet of runway centre-line lighting is marked with a change from white to red lighting. If the crew had used runway 29, the additional lighting might have aided the crew in better identifying the touchdown zone and the runway remaining.

### 2.5 Approach Airspeed

The captain and first officer set their airspeed bugs prior to the descent to St. John's. The approach was flown at a speed 11 knots faster than the bug speed of 154 knots, and the aircraft crossed the threshold at a speed 18 knots faster than the threshold crossing speed of 147 knots. Approaches flown at speeds above bug speed can result in the aircraft floating and a delayed touchdown.

The captain did not start reducing engine approach power until the aircraft's deviation from the centre line was corrected and the aircraft was 2,500 feet past the threshold. The pilot reported that the aircraft floated during the flare. The wind was effectively 90 degrees to the runway, and the absence of a headwind component would have caused the aircraft to float further than anticipated. Had the pilot been more firm in landing the aircraft, even with the excessive threshold crossing speed, the floating distance could have been reduced.

### 2.6 The Landing

The aircraft was to the right of the centre line as it crossed the threshold, and a 12-degree left bank was required before the aircraft was positioned to continue the landing flare. This manoeuvre, coupled with a speed higher than the bug speed and a higher-than-published threshold crossing height, consumed runway and delayed the flare.

The captain believed that there was sufficient runway remaining and continued with the landing. However, because visibility was poor and there was no category 2 runway lighting to rely on, the flight crew members were unaware of the runway distance that had already been overflown. They were also unaware of the runway remaining when the aircraft touched down.
The absence of a headwind, the aircraft's extra height over the threshold and excessive airspeed, and the lack of firm landing techniques contributed to a long float and a delayed touchdown. The result was insufficient runway remaining to stop the aircraft.

The runway end came into sight only after the thrust reversers were deployed; the crew correctly assessed that it was impractical and unsafe to attempt a go-around.

### 2.7 Cabin Attendant Response

The IFD was prepared for an emergency evacuation signal from the flight crew and had briefed the adjacent flight attendant prior to getting up from his jump seat. When the signal was not given, he correctly responded by approaching the cockpit for instructions. Although all of the other cabin attendants were inexperienced, their recent training prepared them to focus on their crew duties.

### 3.0 Conclusions

#### 3.1 Findings

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

- The incident flight was the captain's first flight as pilot-in-command since his upgrade to a Boeing 727 captain, two days earlier.

- The captain flew the ILS approach without the assistance of the autopilot.

- The aircraft target speed flown throughout the approach was 11 knots above the bug speed.

- The aircraft crossed the threshold at a speed 18 knots above the required threshold crossing speed.

- When the crew saw the runway, the aircraft was slightly left of the runway and above the glide slope.

- While the captain was manoeuvring the aircraft to get back on the runway centre line, the touchdown was delayed.

- The flight crew was not aware of the aircraft location in relation to the end of the runway at touchdown because of the limited visibility.

- The captain was not firm with the touchdown, which resulted in an excessively long float; the touchdown occurred 5,100 feet...
after threshold crossing.

- The No. 1 main tire blew during the landing because of non-rotation.

- The brake/anti-skid and hydraulic systems were found to be serviceable after the incident. The reason for the No. 1 wheel lock-up could not be determined.

- Because the captain was new, his minimum approach limits were to be higher than the CAP limits by 100 feet for the ceiling and 1/2 mile for the visibility.

- At DH, the captain called landing when the reported meteorological conditions for a landing on runway 11 were below the limits for a new captain.

- The CAP limits were referenced during company flight crew simulator training; the higher limits for a new captain were not referenced.

3.2 Causes

The crew continued with the landing when there was insufficient runway remaining to stop on the runway surface. Contributing to the overrun were ineffective landing technique, excessive altitude and airspeed over the runway threshold, and the use of inappropriate approach limits for a new captain.

4.0 Safety Action

4.1 Action Taken

4.1.1 Operator Action

Subsequent to the occurrence, the operator indicated the following:

a) crew experience is now reviewed prior to pairing crews;

b) weather limits for new captains are now stressed during recurrent training and will be enforced;

c) crew resource management (CRM) training is now integrated into recurrent training;

d) coupled approaches in low visibility are now included in simulator training;

e) standard operating procedures (SOPs) have been amended to enhance consideration of usable runway, type of approach, lighting,
and visual aids;

f) ground school lectures and line indoctrination now place greater emphasis on landing performance field limits, landing speeds, and wind additives; and

g) combined cockpit and cabin crew training will be conducted once a year.

4.1.2 Crew Resource Management

The flight crew of the accident aircraft did not make use of the autopilot during the approach, nor did they use runway 29, which had better lighting. Use of either of these resources might have prevented the runway overrun.

The effective use of all available resources, including equipment, is an integral part of proper CRM. The flight crew had not received training in CRM, nor were they required to. The new Canadian Aviation Regulations, to be promulgated in 1996, will require all airline flight crews to take such training.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 04 April 1996.*

Appendix A - Aerodrome Chart

Appendix B - List of Supporting Reports

The following TSB Engineering Branch Reports were completed:

LP 65/95 - FDR/CVR Report; and

LP 70/95 - Tire Damage Analysis.

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

Appendix C - Glossary

agl - above ground level
AME - aircraft maintenance engineer
AOM - aircraft operating manual
asl - above sea level
ATIS - Automatic Terminal Information Service
ATPL - Airline Transport Pilot Licence
CAP - Canada Air Pilot
CPL - Commercial Pilot Licence
CRM - crew resource management
CVR - cockpit voice recorder
DH - decision height
FDR - flight data recorder
fpm - feet per minute
hr - hour(s)
IFD - In-flight Director
KIAS - knots indicated airspeed
knots - nautical miles per hour
ILS - instrument landing system
lb - pound(s)
NDB - non-directional beacon
nm - nautical miles
OM - Operating Manual
PF - pilot flying
PNF - pilot not flying
ROY - Royal Aviation
RVR - runway visual range
SA - surface hourly weather report
SOP - standard operating procedure
SP - special weather observation
TCH - threshold crossing height
TDZE - touchdown zone elevation
TSB - Transportation Safety Board of Canada
UTC - Coordinated Universal Time
Vref - reference speed

<1>See Glossary at Appendix C for all abbreviations and acronyms.
<2>All times are Coordinated Universal Time (Newfoundland daylight saving time plus two and one-half hours) unless otherwise noted.
<3>All headings are in degrees magnetic unless otherwise noted.

Updated: 2002-10-06
The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Loss of Separation
between Canada 3000
BOEING Company 757 C-FOOH and
American Airlines Inc
BOEING Company 767 N322AA
Natashquan, Québec
16 September 1995

Report Number A95A0167

Synopsis

Canada 3000 (call sign Elite 5516), a Boeing 757, was westbound at flight level (FL) 370 from Denmark to Toronto via REDBY, Natashquan. American Airlines (AAL 53), a Boeing 767, was westbound at FL390 from Scotland to Chicago, also via REDBY, Natashquan. Canada 3000 (Elite 5512), a Boeing 757, was westbound from London to Montreal at FL370 via Gander, MIILS. (See figure 1.)

The Gander area control centre (ACC) controller issued a frequency change to Elite 5512 after the radar hand-off to Moncton ACC. However, Elite 5516 took the frequency change, contacted the Moncton ACC and requested clearance for a climb to FL390. The Moncton controller trainee cleared Elite 5516, which was still in Gander ACC airspace and not displayed on his radar, to climb to FL390.

The Gander controller observed on the radar display that Elite 5516 was climbing above FL370 and conflicting with AAL 53 already at FL390. The controller attempted but was unable to contact Elite 5516, so gave AAL 53 a 50° right turn to resolve the conflict. A loss of separation occurred when Elite 5516 came within three miles of AAL 53, at the same altitude. The required separation between the two aircraft was 2000 feet vertically.

Other Factual Information

Elite 5512 and Elite 5516 were both in the same Gander ACC sector, monitoring the same frequency. A review of the Gander ACC communications tape indicated that the Gander controller instructed Elite 5512 to contact Moncton ACC on frequency 132.8 MHz. The first officer of Elite 5516 responded quickly, said "28 thanks" and switched to Moncton on 132.8 MHz. An aircraft's identification or call-sign must be included in any radio transmission. The crew of Elite 5512 had not heard nor acknowledged the instruction for them to contact Moncton on 132.8 MHz.

Elite 5516 contacted the Moncton ACC controller on 132.8 MHz, and the first officer requested and received clearance to climb to FL390. During the hand-off from Gander ACC and the climb to FL390, the captain of Elite 5516 was not on the flight deck. The Canada 3000, Boeing 757,
Standard Operating Procedures (SOP) manual requires that the other flight crew member confirm important directions, such as altitude changes, before they are complied with.

During the occurrence, the Moncton ACC Heath Point Sector was staffed with a controller trainee who was being supervised by an on-the-job instructor (OJI). The traffic volume during the occurrence was assessed as light with normal complexity. All equipment available and used by the controllers was functioning properly. The radar display was configured to display data tags only for the aircraft targets transiting through the Heath Point Sector, such as Elite 5512; the track for Elite 5516 and AAL 53 was outside the Heath Point sector.

The controller trainee had a target displayed as Elite 5512 on his radar when Elite 5516 established radio contact. The controller trainee asked Elite 5516 to confirm 5516 and not 5512. The pilot replied that their aircraft was Elite 5516, but there was another Elite, 5512, airborne as well. The controller trainee believed that the Elite 5512 target displayed on his radar was in fact Elite 5516 and the aircraft to which he was talking. He did not use any additional means to confirm aircraft identification. The controllers reported that sometimes the aircraft identification data displayed on the radar is erroneous.

The controller trainee checked that there was no traffic confliction for the radar target displaying the Elite 5512 data tag and cleared Elite 5516 to climb up to FL 390. During the period that the controller trainee accepted the hand-off and cleared Elite 5516 to climb, his OJI was momentarily distracted by a group of former Transport Canada employees that was being given a tour of the Moncton ACC. When the OJI returned his attention to what the controller trainee was doing, he noticed that the Elite 5512 target had not started to climb. The radar's "all" function was selected to display all aircraft targets, and the OJI saw the Elite 5516 target over Natashquan climbing. The OJI immediately instructed the controller trainee to clear Elite 5516 back down to FL 370, which he did.

In 1990, the Canadian Aviation Safety Board (CAB), as a result of a special investigation into air traffic control services, stated that inattention or lack of vigilance appears to be contributory in approximately 50 per cent of all ATS occurrences, and that these types of errors often happen during periods of light, non-complex traffic.

Analysis

The controller trainee's OJI was responsible for the ATC service being provided in the Heath Point sector of Moncton ACC. The presence of the tour group in the ACC diverted the OJI's attention, and he missed the trainee controller's identification of Elite 5512 as Elite 5516.

When the first officer of Elite 5516 told the controller trainee that there was another Elite, 5512, airborne, the controller should have been alerted to the possibility of an aircraft identification problem. The use of another means of aircraft identification, such as having the crew squawk ident on their transponder, would have revealed the discrepancy, and eliminated any doubt before issuing a clearance for the aircraft to climb. The controller trainee had experienced aircraft data errors on the radar display in the past, and he incorrectly assumed that the aircraft handed-off to him was the one displayed on his radar.

The traffic volume and complexity at the time of the occurrence was well within the capabilities of the controller trainee to handle. The OJI felt that constant monitoring of the controller trainee was not required and might possibly decrease his confidence. It is possible that the period of light, non-complex traffic contributed to a complacent attitude in both the OJI and his controller trainee.

The first officer of Elite 5516 should have transmitted the aircraft's full call sign when he acknowledged the Gander controller's instruction to change to Moncton Centre. The Gander controller probably would have heard the wrong aircraft identification, advised Elite 5516 of their error, and instructed the correct aircraft, Elite 5512, to contact Moncton ACC. Had the captain
of Elite 5516 been present when the hand-off and clearance to climb were received, he may have detected the case of mistaken identity.

Findings

1. Elite 5516 acknowledged and acted on ATC instructions to change to Moncton Centre that were directed to Elite 5512.

2. The first officer of Elite 5516 did not use his aircraft's call sign when he acknowledged the hand-off to Moncton centre.

3. The traffic volume during the occurrence was assessed as light with normal complexity.

4. The controller trainee did not confirm that the aircraft he saw on his radar, Elite 5512, was the aircraft with which he was communicating, Elite 5516.

5. The controller trainee cleared Elite 5516 to climb when the aircraft was not in his area of control responsibility.

6. A tour group in the Moncton centre distracted the OJI from his responsibility to properly monitor the controller trainee.

Causes and Contributing Factors

A loss of separation occurred because the OJI was not properly monitoring the controller trainee when the trainee cleared Elite 5516 to climb. Contributing to the occurrence were the following: the trainee did not properly identify the aircraft; the first officer of Elite 5516 used improper phraseology; and, the Gander controller did not confirm the identification of the aircraft that read back the clearance.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 28 February 1996.
Figure 1 Position of aircraft at 1458 ADT

Figure 2 Position of aircraft at 1501 ADT
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
Bearskin Lake Air Services Ltd.
Beechcraft A100 C-GYQT
Big Trout Lake Airport, Ontario - 3 mi NW
21 February 1995

Report Number A95C0026

Synopsis

The Bearskin Lake Air Services Ltd. Beechcraft A100 was on a regular scheduled flight, under visual flight rules, to Big Trout Lake Airport, Ontario, with nine passengers and a crew of two on board. The crew were flying the aircraft over a lake about four miles northwest of the airport for a landing on runway 14 when whiteout conditions were encountered. The aircraft descended in controlled flight into the frozen surface of the lake. The crew and several passengers sustained serious injuries. Rescuers from the local community reached the aircraft about two hours after the crash and all eleven survivors were rescued within four hours.

The Board determined that, while the crew were manoeuvring the aircraft to land and attempting to maintain visual flying conditions in reduced visibility, their workload was such that they missed, or unknowingly discounted, critical information provided by the altimeters and vertical speed indicators. Contributing factors were the whiteout conditions and the crew's decision to fly a visual approach at low altitude over an area where visual cues were minimal and visibility was reduced.

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The crew of the Beechcraft A100, C-GYQT, were conducting a scheduled flight from Sioux Lookout, Ontario, to Big Trout Lake, Ontario, as Bearskin (BLS)<1> 324. BLS 324 departed Sioux Lookout with nine passengers and a crew of two at 1133 central standard time (CST)<2> and arrived in the vicinity of Big Trout Lake at approximately 1240. The captain briefed an instrument approach with a circling procedure to runway 14. On descent to the radio beacon, the crew reportedly encountered flight visibilities of one mile and were in visual contact with the ground. When the aircraft was less than five miles<3> from the airport, the crew heard a position report from another aircraft completing an approach to the airport. To ensure safe separation from the aircraft ahead, the captain elected to fly under visual flight rules to the southwest of the airport.

Air Traffic Services radar data was obtained from the Big Trout Lake radar source. The radar data indicated that the crew descended to about 150 feet above ground level (agl) approximately 4.5
miles from the end of the landing runway and maintained 200 to 300 feet agl for some 50 seconds prior to impact. Immediately prior to impact, the radar data indicated that the aircraft was about 3 1/2 miles from the runway at about 300 feet agl and descending at more than 1,200 feet per minute.

Throughout the approach, the first officer flew the aircraft visually with occasional reference to his instruments, while the captain navigated and maintained terrain clearance by visual reference to the terrain and issued instructions to the first officer. At approximately five miles from the runway, the crew turned onto the extended centre line of the runway and received a radio report from the other aircraft of local visibilities of less than 1/2 mile. The aircraft flew inbound over a wide expanse of lake, and the captain lowered the flaps in preparation for landing. Shortly thereafter, the captain became concerned with the reducing visibility and looked in the Company Approach Procedures binder that he held on his lap. The captain was aware of the danger of whiteout and intended to revert to instrument flight if whiteout were encountered. He had not previously removed the approach chart for Big Trout Lake and clipped it in the approach chart holder because he had discovered that the binder rings were broken and taped shut when he had performed his initial approach briefing. He intended to provide new approach information to the first officer so that a full instrument approach could be initiated from their current position. When the captain looked up from the binder, he observed the altimeter indicating a descent through 1,000 feet above sea level (asl) and called to the first officer, "Watch your altitude." Before a recovery could be initiated, the aircraft struck the frozen surface of the lake and bounced into the air. The captain initiated a recovery and then, concerned with the airworthiness of the aircraft, reduced power and attempted to land straight ahead. The aircraft crashed onto the frozen surface of the lake about 3/4 mile beyond the initial impact location.

All passengers and crew survived the accident. However, the crew and several passengers sustained serious injuries. Rescuers from the local community reached the aircraft about two hours after the crash and all survivors were rescued within four hours. The more seriously injured were experiencing the effects of hypothermia when rescued.

The accident occurred at 1248 CST, approximately three miles northwest of Big Trout Lake Airport, at latitude 53·49'N, longitude 089·53'W, at an elevation of 690 feet asl.

1.2 Injuries to Persons

<table>
<thead>
<tr>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Serious</td>
<td>2</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Minor/None</td>
<td>-</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>9</td>
<td>11</td>
</tr>
</tbody>
</table>

1.3 Damage to Aircraft

The aircraft was damaged beyond economical repair.

1.4 Other Damage

The aircraft's main fuel tanks ruptured on impact, and the resulting fuel spill contaminated the snow in the area of the impact.

1.5 Personnel Information

<table>
<thead>
<tr>
<th></th>
<th>Captain</th>
<th>First Officer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>29</td>
<td>27</td>
</tr>
<tr>
<td>Pilot Licence</td>
<td>ATPL</td>
<td>CPL</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
<td>01 Jul 1995</td>
<td>01 Mar 1995</td>
</tr>
<tr>
<td>Total Flying Hours</td>
<td>5,000</td>
<td>2,300</td>
</tr>
<tr>
<td>Hours on Type</td>
<td>1,500</td>
<td>800</td>
</tr>
<tr>
<td>Hours Last 90 Days</td>
<td>195</td>
<td>210</td>
</tr>
</tbody>
</table>
The crew was certified and qualified for the flight in accordance with the existing regulations.

The company has followed a policy of having all of their pilots receive crew resource management (CRM) training. The captain had received CRM training, but the first officer, who was a relatively new hire, had not received the training.

1.6 Aircraft Information

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Beech Aircraft Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>King Air A100</td>
</tr>
<tr>
<td>Year of Manufacture</td>
<td>1974</td>
</tr>
<tr>
<td>Serial Number</td>
<td>B-189</td>
</tr>
<tr>
<td>Certificate of Airworthiness (Flight Permit) Valid</td>
<td></td>
</tr>
<tr>
<td>Total Airframe Time</td>
<td>13,739 hr</td>
</tr>
<tr>
<td>Engine Type (number of)</td>
<td>PT6A-28 (2)</td>
</tr>
<tr>
<td>Propeller/Rotor Type (number of)</td>
<td>Hartzell HC-B4TN-3 (2)</td>
</tr>
<tr>
<td>Maximum Allowable Take-off Weight</td>
<td>11,500 lb</td>
</tr>
<tr>
<td>Recommended Fuel Type(s)</td>
<td>Jet-A, Jet A-1, Jet B</td>
</tr>
<tr>
<td>Fuel Type Used</td>
<td>Jet B</td>
</tr>
</tbody>
</table>

A review of available records indicated that the aircraft was equipped and maintained in accordance with existing regulations and approved procedures except for the following two discrepancies:

i. the propeller synchrophaser had been removed from the aircraft because of unserviceability, but this action had not been logged in the Journey Log; and,

ii. the radar altimeter (radalt) had been declared unserviceable [non-specific] in the Journey Log and subsequently logged in the Deferred Items Log section of the Aircraft Journey Log. However, the radalt had not been placarded unserviceable in the cockpit, as per the placarding requirements outlined in the company Maintenance Control Manual. The captain was aware of the unserviceability, and the radalt was not used during the approach. The radalt was found with its switch in the OFF position and the bug set at approximately 1,050 feet.

1.7 Meteorological Information

Big Trout Lake is served by an Automated Weather Observation System (AWOS) and a voice generation system. The AWOS provides up-to-the-minute weather information to the pilot via radio. Meteorologists use AWOS observations in the production of aerodrome and area forecasts.

The weather forecast for Big Trout Lake, issued at 0500 CST, and obtained by the crew prior to departure, indicated that for their time of arrival, there would be an occasional sky condition of 3,000 feet overcast with visibility greater than six miles in light snow. The weather forecast issued at 1100, just prior to their departure, was substantially the same. This forecast was amended at 1227 to an occasional sky condition of 1,000 feet overcast with visibility of one mile in light snow. However, the weather the flight encountered was localized and corresponded more closely to the visibility reports from the AWOS.

The AWOS report received by the crew before they began their approach procedures was made at 1212 and indicated that the cloud was scattered at 900 and 2,100 feet agl and the visibility was 1.3 miles in light snow. The weather report available from the AWOS by radio broadcast as the crew began their approach was made at 1239 and indicated that the sky was clear below 10,000 feet with visibility of 9/10 of a mile in light snow. The temperature was -14° Celsius, and the altimeter setting...
was 29.96 inches of mercury.

From the observations taken at the AWOS over the period of the occurrence, the visibility dropped from 9/10 of a mile at 1239 to 1/2 mile at 1300. The winds were from the south at 13 to 15 knots. The AWOS did not report any obscured or partially obscured ceiling in the precipitation.

### 1.8 Aids to Navigation

The airport is served by a non-directional beacon (NDB) located approximately 0.6 nautical miles (nm) west of the runway; the frequency of the NDB is 328 kilohertz (KHz), which was tuned to the aircraft's automatic direction-finder (ADF) radio. An interim Transport Canada Approved Company Instrument Approach Procedure, dated 07 November 1994, provides a circling approach to the runway with a minimum descent altitude of 1,280 feet asl and an advisory visibility of two miles. The elevation of the airfield specified by the chart is 777 feet. Company instrument approach procedure charts are issued on 8½- by 11-inch paper and are kept in three-ring binders by the company. The one binder provided in the occurrence aircraft was broken and the individual charts could not be easily removed by the crew. The captain placed the binder on his lap during the approach.

The aircraft was equipped with a global positioning system (GPS), which was not an approved navigation aid for instrument flight rules (IFR) navigation, and was used by the crew as a backup navigation aid.

### 1.9 Communications

The airport is located in uncontrolled airspace. An aerodrome traffic frequency (ATF) is designated within a 5 nm radius below 3,700 feet asl. Prior to descent into Big Trout Lake, the captain communicated on the company frequency with another Bearskin flight that had departed Big Trout Lake about 30 minutes earlier. The crew of the departing flight reported the weather as one mile in snow, with snow showers to the west. On arrival at Big Trout Lake, the captain communicated on the ATF with the crew of another company who were flying a right-hand visual approach to runway 14.

### 1.10 Aerodrome Information

Big Trout Lake is a certified airport operated by the Ontario Government. The airport elevation listed in the Canada Flight Supplement dated 08 December 1994 and used by the occurrence crew is 738 feet. This elevation is 39 feet lower than the elevation specified on the Company Approach plate. The elevation specified on the Company Approach plate is based on a more recent survey and is the correct airport elevation for Big Trout Lake. Runway 14/32 is gravel and 3,900 feet long by 100 feet wide. A RAMP radar site is located approximately 1,700 feet west of the threshold of runway 14.

### 1.11 Flight Recorders

The aircraft was not equipped with any flight recorders, nor was there any regulatory requirement for the aircraft to be so equipped.

### 1.12 Wreckage and Impact Information

The initial impact occurred on the frozen surface of Big Trout Lake approximately 3.4 nm northwest of the airport on the extended centre line of the runway and approximately 3.1 nm northwest of the RAMP radar site. The belly luggage pod was destroyed on first impact and the contents were strewn onto the ice. The trail of baggage and luggage pod debris was oriented on a heading of approximately 140° magnetic (M). Snow, which fell and was compacted by the wind after the occurrence, obliterated any potential evidence of wing or propeller strikes in the initial impact area.

The second (main) impact site was located on the ice surface of the lake approximately 2.7 nm northwest of the airport, slightly to the left of the extended centre line of the runway. The aircraft crashed while in a left bank, nose-low attitude, on a heading of approximately 071°M. The nose and the underside of the fuselage were crushed and the fuselage was buckled in several places; however, the main shape of the cabin was retained and all windshields and windows maintained their integrity. The left wing attachment fittings were broken, and the left wing was buckled in several
places. The top surface of the right wing appeared undamaged; however, the rear spar of the right wing was fractured, and the right inboard flap cables were stretched and internal sleeves displaced by the forward movement of the right wing during the impact. The rear fuselage was wrinkled and buckled in several areas and both rear horizontal stabilizer attachment brackets were broken, which allowed the stabilizer to move freely.

The landing gear were in the retracted position, and the flaps were extended to the 30° position. All primary flight controls were attached, and the continuity of controls was verified. The wings and horizontal stabilizer had a slight accumulation of rime ice along the leading edge. The strips of rime ice were about 1 to 1.5 inches wide and up to 1/8 inch thick. In several places, the thin strips of rime ice had been covered with oil during the impact sequence.

Both engines were displaced to the left by the downward and forward motion of the aircraft during the impact sequence. The propeller of the left engine was found approximately 150 feet behind the aircraft at the start of the second impact wreckage trail. All four blades of this propeller were still in the hub. Three of the four blades were severely curled along 3/4 of their respective lengths. Examination of the propeller mounting flange revealed that the mounting bolt threads had failed. All of the bolts were found in the propeller shaft mounting flange on the engine. The propeller and gearbox of the right-hand engine were detached as a unit and became trapped under the engine against the fuselage. The right propeller blades were severely curled in a manner similar to the left propeller blades. This evidence is consistent with the engines providing high power as reported by the crew.

All seats, with the exception of the crew seats and the bench seat at the back of the aircraft, had been removed by rescuers. Three seat-belt attachment fittings had broken during the impact. The captain's seat pan was badly deformed and the mounting structure under the seat was broken. The seat track attachments maintained their integrity, but the vertical seat posts had failed as the cabin floor was driven upwards. The shoulder harnesses from both of the pilot seats had been cut by rescuers, leaving only three or four inches of shoulder harness material at the inertia reel. The bulkheads separating the crew from passengers had also been removed by rescue personnel.

1.13 Medical Information

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

1.14 Fire

There was no fire either before or after the occurrence. Emergency response services (ERS) were not available.

1.15 Survival Aspects

1.15.1 First Aid Kit

Air Navigation Order (ANO) Series II, No. 11, the Aircraft First Aid Kit Order, requires that aircraft be equipped with first aid kits for the treatment of injuries likely to occur in flight or in minor accidents. One of the passengers was a nurse who treated the survivors using the aircraft first aid kit. She reported that the first aid kit was not adequate to deal with the injuries that the passengers received. In particular, there was a critical lack of pressure dressings to stop bleeding. The nurse improvised and used packed snow to control bleeding.

1.15.2 Survival Kit

ANO Series V, No. 12, the Sparsely Settled Areas Order, specifies the type of emergency equipment that must be carried on aircraft operating in the sparsely settled region of Canada. The order permits exceptions for air carriers as authorized in the air carrier's operations manual. The Bearskin Lake Air Services Operations Manual, which was approved by Transport Canada, exempted this flight from the requirement to carry a winter sleeping bag for each person on board.
All personal baggage and equipment was lost when the baggage pod was crushed during the initial impact. A small survival kit carried in the aircraft cabin contained some foil (space) blankets that were used to protect the most seriously injured. However, the nurse reported that hypothermia occurred in the two most seriously injured survivors who were immobile.

### 1.15.3 Emergency Locator Transmitter (ELT)

ANO Series II, No. 17, the *Emergency Locator Transmitter Order*, requires that information concerning the location and operation of the emergency locator transmitter be made available to the passengers by means of a readily visible placard located in the aircraft's cabin or by other equivalent means. After the crash, the passengers had difficulty understanding the placard and could only follow its instructions with the aid of the seriously injured captain. The crew members and the passengers had difficulty ascertaining if the ELT had activated automatically during the crash. When they attempted to activate the ELT manually, they also had difficulty in determining if it was activated. Eventually, the crew turned on the aircraft electrical power to hear the ELT tone on the aircraft radio. The ELT did function correctly, and a search and rescue aircraft was dispatched and evacuated the passengers and crew to Winnipeg.

The ELT is manually activated by a small toggle switch accessible through a push-in access panel approximately the size of a quarter coin. The access panel is located on the exterior of the aircraft fuselage just forward of the starboard stabilizer. The location is identified by a placard. The on/off positions of the toggle switch were difficult to identify when viewed through the small access panel.

### 1.16 Tests and Research

#### 1.16.1 Altimeters

The aircraft was equipped with three pressure altimeters and one radar altimeter. The aircraft was not equipped with either allaltimeter reference markers or an altitude alerting system. The radar altimeter was not functional and not used by the crew. The pressure altimeter on the captain's side of the instrument panel was an encoding altimeter and required aircraft electrical power to function. Encoding altimeters provide the aircraft's altitude to air traffic control (ATC) radars via the aircraft's transponder. The pressure altimeter on the co-pilot's side of the instrument panel was not an encoding altimeter and did not require aircraft power to operate. The co-pilot's altimeter used a different static source than the captain's altimeter. The third pressure altimeter was a blind encoding altimeter and was not intended for crew use during flight. The blind encoding altimeter used the same static source as the co-pilot's altimeter. A switch was used to select either the captain's encoding altimeter or the blind encoding altimeter to provide the aircraft's altitude to ATC radars via the transponder. The selector switch was positioned to provide the blind encoding altimeter altitude to ATC radars at the time of the occurrence.

On the day following the accident, at approximately 1230, TSB investigators noted that the co-pilot's altimeter read 960 feet asl, and that the altimeter's sub-scale was set to 29.96 inches of mercury. The reading of the captain's altimeter was not considered valid since electrical power had been interrupted; however, the subscale was noted as set to 29.96 inches of mercury. The subscale settings of both altimeters corresponded to the altimeter setting transmitted by the Big Trout Lake AWOS at the time of the occurrence.

At the time that TSB investigators observed the co-pilot's altimeter reading of 960 feet asl, the Big Trout Lake AWOS altimeter setting was 29.69 inches of mercury. An Atmospheric Environment Service (AES) specialist in barometry used the preceding data to compute the altitude that the altimeter would have indicated if the correct altimeter setting, 29.69 inches of mercury, had been set on the co-pilot's altimeter. The computed altitude that the co-pilot's altimeter would have indicated for the atmospheric conditions at the time of the TSB observation was 710 feet asl, approximately the elevation of the lake surface.

The captain's and co-pilot's altimeters were tested and found to be working within required accuracy limits. At test altitudes of 500 and 1,000 feet, the captain's altimeter indicated 500 and 1,010 feet, and the co-pilot's altimeter indicated 500 and 990 feet.
1.16.2 Vertical Speed Indicators

Both the captain’s and co-pilot’s vertical speed indicators were tested and found to be calibrated in accordance with national standards and functioning well.

1.16.3 Horizontal Stabilizer Trim Actuator

The horizontal stabilizer trim actuator was tested and performed within acceptable parameters.

1.16.4 Passenger Seat-Belts

Two seat-belt attachment fittings from the occurrence aircraft and two new, similar fittings from the air carrier were subjected to strength testing. The applicable testing standard for seat-belt fittings is Federal Aviation Administration (FAA) Technical Standard Order C22. This standard requires that the belt fittings be designed to withstand loads of at least 1,500 pounds. All four fittings were tested to destruction under conditions specified in the standard; the two fittings from the occurrence aircraft failed at 1,596 and 2,218 pounds, and the two new fittings failed at 1,972 and 2,180 pounds.

1.17 Organizational and Management Information

The company has published standard operating procedures (SOPs) for the guidance of pilots of the Beech A100, Beech 99, and Metro aircraft. The amount of guidance provided in the Beech 99 and the Metro SOP with regard to approach procedures is significantly greater than that provided in the Beech A100 SOP. For example, the Beech 99 and Metro SOPs specify the approach briefing in detail and direct that both pilots have their approach charts displayed for the approach. The Beech A100 SOP does not have such specific guidance. The Beech 99 and the Metro SOPs discuss missed approach procedures and specify that, “The captain may also elect to carry out the missed approach at any time he may feel it is unwise to continue.” There is no discussion of the missed approach procedure in the Beech A100 SOP. Company SOPs are not mandatory and do not require approval by Transport Canada. (See Section 4.1.)

1.18 Additional Information

1.18.1 Whiteout

The Transport Canada Aeronautical Information Publication (AIP), section Air 2.14(b), describes whiteout as an extremely hazardous visual flight condition. Whiteout occurs over an unbroken snow cover and beneath a uniformly overcast sky. Because the light is so diffused, the sky and terrain blend imperceptibly into one another, obliterating the horizon. The horizon, shadows, and clouds are not discernible, and sense of depth and orientation is lost; only very dark, nearby objects are discernible. In addition, the AIP indicates that whiteout can result from blowing snow and falling snow.

The real hazard in a whiteout is that pilots do not suspect the phenomenon because they may be in clear air. In many whiteout accidents, pilots have flown into snow-covered surfaces unaware that they have been descending, and confident that they could see the ground. Consequently, when pilots encounter the whiteout conditions described above, or even suspect they are in such conditions, they should immediately climb if at low level, or level off and turn towards an area containing sharp terrain features. Pilots should not continue the flight unless they are prepared to cross the whiteout area using instruments, and have the skills to do so.

1.18.2 AWOS Visibility and Ceiling

Transport Canada issued an Aviation Notice, dated 02 February 1995, in response to user concerns with the performance of some AWOS sensors. The Aviation Notice included an interim operational caution as follows:
If aviation users encounter an AWOS report of clear below 10,000 feet (CLR BLO 100) when precipitation and reduced visibilities are also reported, it is a definite indication that this is an erroneous sky condition report. An analysis of minute-to-minute data at some sites indicates that this condition may persist, in some cases, for over an hour. Version 5.2 of the ceilometer algorithm has, in laboratory tests, almost eliminated false reports of this nature. This algorithm will be deployed as soon as possible after satisfactory field testing. Please consult NOTAM [Notice to Airmen] for the latest information on this subject.

NOTAM 940461 for Big Trout Lake was contained in the weather package carried by the crew. This NOTAM stated the following:

CYTL AWOS. If aviation users encounter an AWOS ceilometer report of "CLR BLO 100" when reduced visibility, precipitation or surface obscuration are present, it is a definite indication that this is an erroneous sky condition report. In the event of any discrepancy between AWOS ceiling or visibility and that observed by a pilot in the vicinity, operations may be based on the ceiling, runway visibility or flight visibility as provided by pilot report.

1.18.3 AWOS Altimeter Setting

The crew of the Bearskin flight that had departed Big Trout Lake about 30 minutes prior to the occurrence reported that they had received an inaccurate AWOS altimeter setting. They set their altimeters to the aerodrome elevation while they were on the ground, but initially could not remember the resulting subscale setting. Several days later, they recalled a subscale setting that would have resulted in an altitude reading of about 100 feet high. The co-pilot's altimeter from the aircraft used by this crew was tested. It was found to be functioning correctly and well within calibration limits. At test altitudes of 500 and 1,000 feet, this altimeter indicated 490 and 980 feet. The crew of another aircraft had landed minutes before the occurrence and did not report any discrepancy with the AWOS altimeter setting. Both crews used a field elevation of 738 feet, obtaining the elevation from data stored in their respective GPS data bases. The information stored in the GPS data base is based on the Canada Flight Supplement.

The AWOS altimeter setting provided is the lower reading of two sensors. If a discrepancy of 0.04 inches of mercury exists between the dual sensors, the system will fail safe, and the altimeter setting will be missing from the AWOS weather report. An on-site calibration of the Big Trout Lake AWOS was conducted on 16 March 1995 by an Environment Canada technical service specialist. The dual pressure sensors were found to be well within calibration tolerances.

1.18.4 RAMP Radar Data

The transponder of the occurrence aircraft was transmitting aircraft altitude information to the Big Trout Lake radar site. The last transmission was received at 1248, when the aircraft was approximately 3.1 nm from the radar site, and gave the aircraft's pressure altitude as 800 feet asl. A pressure altitude of 800 feet asl corresponds to an actual altitude of 710 feet asl under the barometric conditions that existed at the time of the occurrence.

1.18.5 Controlled Flight into Terrain

Controlled flight into terrain (CFIT) accidents are those in which an aircraft, capable of being controlled and under the control of the crew, is flown into the ground, water, or obstacles with no prior awareness on the part of the crew of the impending disaster. Previous TSB reports have indicated that meteorological conditions were a significant factor in more than 50 per cent of these type of accidents, and that loss of situational awareness is a fundamental element in the cause of these types of accidents.

1.18.6 Situational Awareness

To make correct decisions when flying an aircraft, the crew must have an adequate knowledge of what is happening around them, that is, situational awareness. Without situational awareness, the
crew has no starting point for correct decision making; appropriate action cannot be taken unless the
information on which the decisions are based is valid.

1.18.7 Information Processing

A considerable body of research has been developed concerning information processing and
decision making. This research has established that stress and high workload may lead to a
narrowing of attention to the primary task at hand and to the most noticeable information source(s) as
perceived by the pilot. The most noticeable information sources may not be the most objective, and
under stressful conditions, important information may be missed or discounted without the awareness
of the decision maker. Hence, the decision maker or pilot unknowingly may become less situationally
aware, even though striving to retain a correct perception of the situation.

1.18.8 Ground Proximity Warning System

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

1.18.9 Approach Chart Holders

Company aircraft are equipped with approach chart holders. These holders are mounted on both
control yokes and are designed to hold approach charts published in the Canada Air Pilot.

1.18.10 Visual Flight Rules

Visual flight rules (VFR) weather minima are specified in ANO Series V, No. 3. When the occurrence
aircraft was manoeuvring southwest of Big Trout Lake, it was operating in uncontrolled airspace
below 700 feet agl. The weather minima specified for these conditions are not less than one mile
visibility and clear of cloud.

2.0 Analysis

2.1 Introduction

The investigation did not reveal any mechanical difficulties with the aircraft's engines nor with the
aircraft's primary and secondary flight controls. This analysis will concentrate on the aircraft's
altimeters, the AWOS altimeter setting, weather, and pilot decision making, all of which could have
contributed to the occurrence. Additionally, survival issues will be discussed.

2.2 Aircraft Altimeters

The last recorded radar transponder information places the aircraft approximately 3.1 nm from the
Big Trout Lake radar site, which corresponds to the approximate distance to the initial impact
location. Consequently, the last blind encoding altimeter transponder transmission received by the
Big Trout Lake radar source likely occurred immediately prior to the aircraft hitting the ice surface of
the lake.

The last recorded transponder transmission received from the aircraft was from 710 feet asl. Because
the known elevation of the surface of the lake is 690 feet asl, the blind encoding altimeter and the
pitot static system it was using were likely functioning correctly. Additionally, because the blind
encoding altimeter uses the first officer's pitot static system as its source, it is likely that the first
officer's pitot static system was also functioning correctly.
The first officer's altimeter performed within limits during post-occurrence testing. Additionally, because its pitot static system was likely functioning correctly, the accuracy of its altitude reading would be solely dependent on the accuracy of its subscale setting. That altimeter setting of 29.96 inches of mercury was obtained from the Big Trout Lake AWOS; consequently, the accuracy of the altitude reading being used by the first officer was solely dependent on the accuracy of the Big Trout Lake AWOS altimeter setting. Additionally, because neither the captain nor the first officer noted any discrepancy between their respective altimeters during their flight, the accuracy of the captain's altimeter was also determined solely by the Big Trout Lake altimeter setting as transmitted to the crew.

2.3 Automated Weather Observation System

Calculations performed by the barometric specialist demonstrated that a setting of 29.96 would have produced an accurate altimeter reading at the time of the occurrence. Additionally, the AWOS fail-safe system did not activate, and the system was found to be functioning within allowable tolerances when tested against the regional standard. Therefore, it can be concluded that the AWOS measured and transmitted a valid altimeter setting of 29.96, which was properly set by the crew. Thus, the voice transmission of the AWOS at the time of the approach into Big Trout Lake was accurate.

The discrepancy reported by other Bearskin crew at Big Trout Lake on the day of the occurrence could not be resolved. However, the discrepancy could have resulted in part from the airport elevation difference of 39 feet between the actual elevation and that found in the Canada Flight Supplement and GPS data base. When this crew set the transmitted Big Trout Lake AWOS altimeter setting on the ground, their altimeters would have read 777 feet, the correct altitude of Big Trout Lake Airport published in the Company Approach Chart, instead of the published 738 feet in the Canada Flight Supplement dated 08 December 1994. Although the discrepancy could not be fully explained, another carrier that had landed at Big Trout Lake at the time of the occurrence did not report any altimeter setting problems while using the AWOS setting.

2.4 Decision Making on Approach

When the captain initially briefed the first officer for the instrument approach into Big Trout Lake, he noted that the only approach chart provided was in a binder and could not be readily removed. The captain accepted this condition, and consequently, to consult the chart during the approach, the captain had to hold the binder in his lap and look down to read the information. In addition, the chart was not readily accessible to the first officer.

The crew descended to 150 feet agl approximately 4.5 miles from the end of the landing runway and maintained 200 to 300 feet agl for some 50 seconds prior to impact. Given the weather conditions of one mile visibility in snow that were reported by the crew, and the monochromatic appearance of the snow-covered surface of the lake, the crew's decision to continue to fly visually at this altitude exposed the crew to the risk of experiencing whiteout conditions. The captain was aware of the danger, and intended to revert to an instrument approach if whiteout were encountered. Although the decision to fly close to the lake surface reduced the margin of safety and the time available to react to any loss of situational awareness in whiteout conditions, the decision did not contravene ANOs or the company SOPs.

This decision also caused an increase in the crew's stress and workload during the final approach phase, in that the crew were faced with maintaining terrain clearance visually at low level in adverse weather conditions. Thus, the crew had increased the likelihood of narrowing their attention to the primary task, that of maintaining visual terrain clearance, and to the most noticeable information source, the surrounding terrain. They had increased the likelihood of missing or discounting critical information provided by the altimeter and vertical speed indicator, without any awareness of doing so. Thus the crew's decision increased the possibility of the loss of situational awareness in whiteout.

Because the radalt was not serviceable, it was not used by the crew as a warning device. The radalt setting of 1,050 feet, as observed by the investigators, is consistent with the crew's statement that they had not used the radalt.

After the aircraft crossed the last chain of islands on track, about 3 1/2 miles from the runway, the Air
Traffic Services radar data indicated that the aircraft was about 300 feet agl and was descending at more than 1,200 feet per minute. The first officer, who was flying the aircraft, did not stop the descent. Both his altimeter and vertical speed indicators were functioning accurately; however, it is unlikely that he was using them for altitude guidance. It is probable that he had unknowingly narrowed his attention to outside references for terrain clearance because of the stress and high workload of the low-level, visual approach. At this distance from the runway, the aircraft was over a wide expanse of lake, with the nearest shoreline in excess of a mile away. Thus, the visual cues required to maintain terrain clearance were beyond the one mile visibility reported by the crew. The absence of visual cues placed the crew in whiteout conditions. Because of a lack of visual altitude references in whiteout, it is unlikely that the first officer realized that he was ignoring instrument indications and that he was allowing the aircraft to descend into the terrain. Consequently, it is likely that the first officer lost situational awareness in whiteout conditions and was unable to take effective action.

The captain had become concerned about the reducing visibility as they flew towards the airport, and decided to conduct an instrument approach. He did not instruct the first officer to begin a missed approach, but instead looked at the company approach chart in order to rebrief the first officer on approach information. After he consulted the chart, he looked up and observed that the altimeter was indicating a descent through 1,000 feet asl. His direction to the first officer was the non-specific command, "Watch your altitude." Because of the low altitude of the aircraft and the high rate of descent, the first officer did not have time to assimilate and respond to the instruction. Consequently, the lack of timely action by the crew, when the first officer lost situational awareness in whiteout conditions, resulted in the aircraft descending into the terrain under controlled flight.

As noted, the radar altimeter was not serviceable and consequently was not used by the crew as a warning device. A GPWS, if installed and operable, would have provided constant warnings and cues to the crew of their proximity to the terrain.

2.5 Survival Issues

2.5.1 ELT

Although the posted instructions for the ELT met the regulatory requirement, they were difficult for passengers to understand in a stressful situation under harsh environmental conditions. In particular, the passengers could not see that they had indeed activated the switch, and they did not understand that the ELT would not emit an audible sound and only be transmitted on a radio frequency.

2.5.2 First Aid Kit

Although the first aid kit met the regulatory requirement, its contents were inadequate to deal with the type of injuries sustained in this accident. Under the harsh environmental conditions to which the passengers were exposed, their chances of surviving for an extended period were greatly reduced.

2.5.3 Survival Kit

The company was exempted from the need to carry sleeping bags in accordance with the Transport Canada approved Company Operations Manual. The company, however, had included foil-type survival blankets in a small kit in the aircraft. These foil blankets were critical in the reduction of hypothermia in the two most critically injured survivors. The lack of sleeping bags made it impossible to prevent hypothermia and might have resulted in more serious injury or death if rescue had been delayed.

2.5.4 Seat-Belt Attachment Fittings

The four seat-belt attachment fittings were tested and found to meet the required standard. Therefore, it is probable that the three that failed during the impact broke because the force of the impact exceeded the design limit of 1,500 pounds. Consequently, the failure of seat-belt attachment fittings in this survivable accident may indicate that the limit is set too low.
3.0 Conclusions

3.1 Findings

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

- The airport elevation listed in the *Canada Flight Supplement* dated 08 December 1994 was incorrect and was 39 feet lower than the correct airport elevation of 777 feet shown on the Company Approach chart.

- The aircraft altimeters were serviceable and set to the correct altimeter setting as reported on the AWOS.

- The AWOS was transmitting the correct visibility at the airport and an erroneous sky condition report. However, operation into Big Trout Lake was based on the ceiling and flight visibility as reported by the occurrence crew. The occurrence crew reported the visibility as one mile.

- The decision to fly visually at low level over the lake surface in one mile visibility increased the crew’s stress and workload and exposed the crew to the risk of experiencing whiteout conditions; however, the decision did not contravene ANOs or company SOPs.

- The first officer unknowingly missed critical altitude information when he lost situational awareness in whiteout conditions.

- The crew did not react in a timely manner when whiteout conditions were encountered.

- The instructions for operating the ELT were confusing to the passengers.

- The lack of sleeping bags on board the aircraft, as permitted by the operating certificate, exposed the most critically injured survivors to hypothermia.

- The foil blankets provided in the aircraft reduced the effects of hypothermia in the most critically injured survivors.

- Three seat-belt attachment fittings failed in overload; the attachments met design specifications for strength.

- The first aid kit met the standard required by regulations but was inadequate for the type of injuries sustained by the survivors.

- The aircraft’s radar altimeter was not serviceable.

- The aircraft was not equipped with a GPWS, nor was one required by regulation.

- The captain accepted an approach chart location that resulted in the only available approach chart not being readily accessible by either crew member.

- The company SOPs for the Beech A100 provided minimal guidance with regard to approach procedures.
3.2 Causes

While the crew were manoeuvring the aircraft to land and attempting to maintain visual flying conditions in reduced visibility, their workload was such that they missed, or unknowingly discounted, critical information provided by the altimeters and vertical speed indicators. Contributing factors were the whiteout conditions and the crew's decision to fly a visual approach at low altitude over an area where visual cues were minimal and visibility was reduced.

4.0 Safety Action

4.1 Action Taken

4.1.1 Airport Elevation

Subsequent to this occurrence, the Canada Flight Supplement was amended to indicate the airport elevation of Big Trout Lake as 777 feet asl.

4.1.2 Visibility Requirement in Uncontrolled Airspace

In the proposed Canadian Aviation Regulations (CARs), the visibility requirement for aircraft operating under visual flight rules in uncontrolled airspace below 1,000 feet agl will be increased to two miles from the current one mile requirement. However, there will be provisions for Transport Canada (TC) to allow commercial operators to operate aircraft at lower visibilities provided that certain pilot training and aircraft equipment criteria are met.

4.1.3 Operating Instruction for ELTs

In this occurrence, the passengers had difficulty operating the ELT. A TSB Aviation Safety Advisory was forwarded to Transport Canada regarding the need for the placarding of clear instructions for the use of ELTs, with the suggestion that this requirement be considered in the new regulations.

4.1.4 Ground Proximity Warning System (GPWS)

Canadian regulations require only commercially operated, large turbo-jet powered aircraft (capable of carrying 10 or more passengers and with 15,000 kg or greater maximum certified take-off weight) to have GPWS installed. In the United States, all turbine powered (turbo-jet and turbo-prop) aeroplanes with 10 or more seats, notwithstanding their weight, require an operating GPWS. The aircraft in this occurrence, the Beechcraft A100, is certified for more than 10 seats; however, the Canadian regulation for GPWS is limited to turbo-jet powered aircraft only.

The Board believes that the increased level of safety provided by GPWS should not be related to an aircraft's type of propulsion; rather the requirement for GPWS installation should be based on the role of the aircraft and its passenger-carrying capacity. Therefore, the Board previously recommended that:

The Department of Transport require the installation of GPWS on all turbine-powered IFR-approved commuter and airline aircraft capable of carrying 10 or more passengers.

(A95-10, issued 21 March 1995)

Transport Canada replied that it would submit the GPWS issue to the Canadian Aviation Regulation Advisory Council (CARAC). The CARAC is establishing a sub-working group to look into safety systems, such as GPWS, traffic collision avoidance systems, and windshear avoiding systems.

4.2 Action Required

4.2.1 Post-Accident Survivability
As evidenced in this occurrence, accident survival can depend to a large extent on post-crash conditions. Notwithstanding that this operator had complied with all regulations, the first aid kit on board the aircraft was not adequate to deal with the injuries to the passengers, some survivors suffered from hypothermia as a result of insufficient protection from the elements, and the passengers had difficulty following the instructions for post-crash use of the ELT.

The issue of post-accident survivability has been an ongoing concern in commercial aviation. In 1986, following a PA-31 accident, the predecessor to the TSB, the Canadian Aviation Safety Board (CASB), expressed concern about the lack of survival equipment on small commercial passenger-carrying aircraft during winter operations, and recommended that:

The Department of Transport, having due regard to space and weight limitations while benefitting from advances in available lightweight materials:

a) prescribe a minimum list of survival equipment suitable for post-accident winter conditions; and

b) require the carriage of prescribed survival equipment on aircraft operating during the winter on passenger-carrying flights under the provisions of Air Navigation Order Series VII, Numbers 3 and 6.

(CASB 86-20, issued in 1986)

TC agreed with the recommendation. However, no significant revisions were made to the ANOs, and the provisions for waivers against the carriage of all or some of the survival equipment specified in the ANOs were retained. Thus, the company in this occurrence was not required to carry sleeping bags in the survival kits.

Following another accident near Bonaventure, Quebec, in 1989, in which three of the five surviving passengers on a small commercial aircraft suffered serious injuries and the contents of the aircraft first aid kit were inadequate, the TSB recommended that:

The Department of Transport reconsider the feasibility and practicality of including a first aid kit specifically equipped for post-accident survival in the aircraft survival kit required by Air Navigation Order (ANO) Series V, No. 12.

(TSB A91-23, issued in 1991)

In response, TC acknowledged that the requirements for first aid supplies might be insufficient for post-accident use. TC was, however, of the opinion that it was not practical to include additional first aid supplies in the survival kit, since some operators were able to waive the requirements for survival kits. An alternative was to improve the contents of the existing first aid kits. As such, the new CARs will require that the contents of the first aid kit(s) on aircraft be equal to those specified in the Aviation Occupational Safety and Health (OSH) regulation. OSH guidelines are used for the safety of employees at their work place, and, in this sense, the first aid kits will be an improvement. However, in the Board's view, the first aid kits will not fulfil on-site medical needs immediately following an aircraft crash and during the wait for rescue.

While data indicate that only a few aircraft accident survivors have had to spend considerable time awaiting rescue, the often harsh Canadian climate can very quickly put the lives of survivors in jeopardy. While the SARSAT<4> system greatly improves rescue response times over those of just a few years ago, the success of this system depends on a functioning ELT in the accident aircraft. Department of National Defence Search and Rescue statistics indicate that, including those instances where the ELT has not been armed, ELTs have not activated in 40 to 50 per cent of all aircraft accidents<5>. In 1991, TC commenced a two-year trial on a new generation of ELTs; however, ELTs designed to the standard of the improved TSOs are still not required in Canada.

As previously stated, the new CARs contain some revisions to the orders affecting post-crash considerations. CAR 602.61 states that sufficient survival equipment, given the season of the year, the geographical area, and anticipated seasonal climatic variations, must be carried for each person on board the aircraft. As with the previous ANOs, however, the CARs also provide for exceptions to
the basic requirements. The Board recognizes the need for waivers given the wide differences in aviation operating conditions that can be encountered across Canada; it would not be practical to expect every air carrier to outfit its aircraft with all the equipment specified in the CARs under all conditions. However, the Board is concerned about the potential misapplication of any exemptions. For example, the CARs state that the carriage of survival equipment is waived on all multi-engine aircraft flying on designated air routes south of the Arctic Circle. Apparently, many air taxi and commuter operators--generally flying smaller, older multi-engine aircraft, operating between remote locations on self dispatch systems with minimal flight following, and comprising a segment of the commercial passenger industry having a higher accident rate than the industry as a whole--would not be required to carry survival equipment on their aircraft.

Aviation accident data indicate that there is a higher risk to safety in commercial aviation from factors related to human performance, such as those found in this occurrence, than from engine failures in single-engine aircraft (a factor on which the cited exemption seems to be based). The Board believes that an approach for the granting of exemptions using risk indicators could better determine the survival equipment requirements on a carrier-by-carrier basis, thus ensuring that sufficient survival equipment is carried on board those aircraft where the potential need is greater.

This CFIT accident was typical, in that it occurred about 2 1/2 miles from the airport on approach. In Canada, 44 per cent of CFIT accidents occur during the approach phase. Fortunately, this accident occurred during the hours of daylight, and the ELT worked, facilitating the ground search. Night or bad visibility might have compromised the outcome, given the severe winter conditions.

Notwithstanding previous recommendations made by the Board and by regulatory and industry working groups, and the improved TSOs for ELTs, safety deficiencies affecting post-crash survivability continue to exist, as exemplified by this accident. Without appropriate guidelines for the carriage of enhanced first aid kits for post-crash use, and for the granting of waivers regarding the carriage of survival equipment, and without the immediate upgrading of ELT requirements for all commercial passenger-carrying aircraft, accident survivors will continue to be put at risk as a result of delayed rescue, lack of preparedness for harsh climatic conditions, and/or inadequate first aid treatment. Therefore, the Board recommends that:

The Department of Transport, using accepted risk management methodologies, create carrier-specific requirements for the carriage of first aid kits, survival equipment, and upgraded ELTs on all commercial aircraft.

A96-08

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 21 May 1996.

Appendix A - Approach Profile
Appendix B - List of Supporting Reports

The following TSB Engineering Branch Report was completed:

LP 060/95 - Seat-belt Attachment Tests - Beech.

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

Appendix C - Glossary

AES - Atmospheric Environment Service
agl - above ground level
AIP - Aeronautical Information Publication
ANO - Air Navigation Order
asl - above sea level
ATC - air traffic control
ATF - aerodrome traffic frequency
ATPL - Airline Transport Pilot Licence
AWOS - automated weather observation system
BLS - Bearskin Lake Air Services Ltd.
CARAC - Canadian Aviation Regulation Advisory Council
CARs - Canadian Aviation Regulations
CASB - Canadian Aviation Safety Board
CFIT - controlled flight into terrain
CPL - Commercial Pilot Licence
CRM - crew resource management
CST - central standard time
ELT - emergency locator transmitter
ERS - emergency response services
FAA - Federal Aviation Administration
GPS - global positioning system
GPWS - ground proximity warning system
hr - hour(s)
IFR - instrument flight rules
kg - kilogram(s)
lb - pound(s)
NDB - non-directional beacon
nm - nautical mile(s)
NOTAM - Notice to Airmen
OSH - Occupational Safety and Health
RAMP - Radar Modernization Project
SOP - standard operating procedure
TC - Transport Canada
TSB - Transportation Safety Board of Canada
UTC - Coordinated Universal Time
VFR - visual flight rules
‘ minute(s)
” second(s)

- degree(s)

- M degrees of the magnetic compass

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<1> See Glossary for all abbreviations and acronyms.

<2> All times are CST (Coordinated Universal Time [UTC] minus six hours) unless otherwise stated.

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

<4> Search and Rescue Satellite system capable of detecting signal transmissions from activated ELTs.

<5> In 1990, as a result of a Cessna 402 occurrence at Charlo, New Brunswick, in which the ELT did not function as intended (A88A0047 refers), the TSB identified a safety concern regarding the fact that such equipment, intended for emergency use, had such a high rate of failure.
Air 1995

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.

Landing Gear Failure  
Capsizing Enterlake Air Services Ltd. (Selkirk Air)  
Beech Aircraft Corporation 3T Beech 18 C-FSFH  
Bradburn Lake, Manitoba  
05 June 1995

Report Number A95C0110

Synopsis

During the float-equipped aircraft's take-off run, the pilot noticed a yaw to the left. The pilot corrected the yaw, but it recurred and worsened. The left float separated from the aircraft, the left wing struck the water, and the aircraft capsized, coming to rest on its left wing tip in about 15 feet of water. The pilot and the six passengers were not injured; they exited the aircraft and swam to shore. The aircraft sustained substantial damage.

The Board determined that the left front swivel fitting attachment bolt probably moved out of position because the securing nut was either not installed or came off in service. A series of failures ensued, culminating in the separation of the left float from the aircraft.

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5.0 Appendices

Appendix A - Float Strut Detail
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1.0 Factual Information

1.1 History of the Flight

The Beech 18 seaplane was departing a fishing camp at Bradburn Lake, Manitoba, for its third flight of the day en route to the operator's base at Selkirk. After boarding the passengers and loading the baggage for the flight, the pilot taxied the aircraft to a position near the southwest shore of the lake and started the take-off run on an approximate heading of 015 degrees true. During the take-off run, after the aircraft was "on the step," the pilot noticed a yaw to the left. He corrected the yaw with the aircraft's rudders and with differential engine power. Shortly thereafter, at about 60 miles per hour<1> (mph)<2>, the yaw recurred and worsened. The left float separated from the aircraft and the left wing struck the water. The aircraft turned sharply to the left, stopped in the water, and came to rest on its left wing tip in about 15 feet of water. The pilot and the six passengers were not injured; they exited the sinking aircraft and swam to shore. The accident occurred at 1040 central daylight saving time (CDT)<3> during daylight hours at latitude 51\textdegree 55'N and longitude 95\textdegree 35'W.

1.2 Injuries to Persons

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1.3 Damage to Aircraft

The aircraft sustained substantial damage when the left float separated and the aircraft stopped in the water and capsized.

1.4 Other Damage

The pilot's and the passengers' baggage was damaged by water when the aircraft capsized.

1.5 Personnel Information

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The pilot had about 6,000 hours of seaplane flying experience. He was working his seventh season with this operator and was certified and qualified for the flight in accordance with existing regulations.

1.6 Aircraft Information

<table>
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</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td>Type and Model</td>
<td>3T (Beech 18)</td>
</tr>
<tr>
<td>Year of Manufacture</td>
<td>1943</td>
</tr>
<tr>
<td>Serial Number</td>
<td>43-35481</td>
</tr>
<tr>
<td>Certificate of Airworthiness (Flight Permit)</td>
<td>Issued 15 June 1984</td>
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<td>Total Airframe Time</td>
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</tr>
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<td>Engine Type (number of)</td>
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<tr>
<td>Propeller/Rotor Type (number of)</td>
<td>Hamilton Standard 22D30 (2)</td>
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<td>Maximum Allowable Take-off Weight</td>
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</tr>
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<td>Recommended Fuel Type(s)</td>
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</tr>
<tr>
<td>Fuel Type Used</td>
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</tr>
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The weight of the aircraft at take-off was about 300 pounds under the certified gross weight of the aircraft, and the centre of gravity was within the prescribed limits. The aircraft was equipped with EDO 56-7850A floats, each of which was attached independently to the aircraft fuselage with five struts; the design does not incorporate a spreader bar<4>. The aircraft is a low-wing design, and the wing and engine cowlings limit the view of the floats from inside the aircraft in flight, and
from some positions on the water during a walkaround. The main entry/exit door is located in the left rear area of the fuselage. The pilot reportedly checked the float struts before departing on the first flight of the day. Neither the aircraft's flight manual nor its operating manual states the maximum amount of down wind component that is acceptable for take-off with the aircraft.

1.7 Meteorological Information

The weather observed at 1100 CDT at Little Grand Rapids, Manitoba, 16 miles southwest of the site, was as follows: 4,500 feet scattered clouds, visibility 15 miles, winds 240 degrees true at 13 knots. Witnesses reported that the winds at the time of the occurrence were out of the south at less than 10 knots and not gusty, and the surface of the water had light rippled waves.

1.8 Wreckage and Impact Information

Examination of the aircraft after the occurrence revealed that the left float's front and rear vertical struts were still attached to the float, but their top fittings (at the aircraft nacelle) were twisted and showed signs of overload failure. The eyebolt fitting of the diagonal side strut failed at the swivel fitting where it attaches to the float. The rear side strut upper attachment bolt at the fuselage was twisted, and the rear swivel fitting bolt, by which the swivel and the diagonal strut are attached to the rear float mount pad, was broken. The mounting pad on the float showed signs of metal smearing. The front side strut was still attached to the fuselage; the attaching bolt was in place and the fitting showed little damage. The float end of the front side strut incorporates a swivel fitting, which attaches to a mounting pad on the float. Neither the front left swivel fitting nor the corresponding mounting pad showed evidence of damage or distortion; the mounting bolt and nut were not recovered.

1.9 Float Installation

The Bristol Float Service Manual specifies that castellated nuts secured with cotter pins are required for the strut mounting bolts. The operator reported that castellated nuts and cotter pins were used in the float installation. The float installation manual specifies 14 bolts with castellated nuts for each float; 10 bolts and nuts for the left float were recovered. Nine of these bolts were installed with fibre self-locking nuts. In order for a self-locking nut to lock securely, the thread of the bolt must pass fully through the end of the nut. It was noted that several of the bolts securing the struts and fittings did not pass fully through the end of the securing nut.

Experience has shown that float fitting bolts left in service for longer than two years tend to deteriorate from the effects of wear and corrosion.

1.10 Tests and Research

The front side strut swivel fitting and the corresponding float mounting pad, and the rear swivel fitting with the attached end of the diagonal
strut eyebolt were submitted to the TSB Engineering Branch for examination. After examination of the front swivel fitting and mounting pad, the Engineering Branch concluded that the attaching bolt probably did not break, but moved out of position, either because the nut was not installed or because it came off during service. The bore of the front float mounting pad showed circumferential markings in a narrow band centred approximately one-half inch from the aft end. These marks appeared to have been made recently, and their form was consistent with the threads of an AN7 bolt, which was the type specified for the missing attachment bolt. The Engineering Branch concluded that the marks were probably made by side loads on the assembly while the bolt was partially withdrawn. The bolt that attaches the rear swivel fitting to the rear mounting pad was found bent and broken by a combination of shear and tensile loading, with no evidence of progressive failure. The swivel fitting was twisted but not broken. The eyebolt attaching the swivel fitting to the diagonal strut was found to be bent and broken and the fracture surfaces were typically 45-degree slant fractures characteristic of tensile overload. Moderate surface corrosion was found on the inner wall of the bolt and on its fracture surfaces. Some of the internal corrosion may have been present before the fracture, but it had not significantly reduced the thickness of the bolt wall or contributed to the fracture. There was no evidence of pre-cracking or progressive failure.

1.11 Inspection Schedule

The Beech Maintenance Manual does not have a seaplane section. The Bristol Service Manual for the EDO 56-7850 floats for the Beech 18 provides that the floats are to be removed for inspection every 500 hours or every end of season, whichever comes first.

The operator is a Transport Canada Approved Maintenance Organization (AMO). The AMO’s Beech 18 inspection program approval specifies that the float struts and attachment are to be checked for cracks and general condition, and attaching bolts for security, every 100 hours. There is no specific requirement in the inspection approval for the struts to be removed for inspection every 500 hours or end of season. Among the conditions attached to the approval are the following:

a) the operator is not absolved from responsibility for ensuring that the aircraft is maintained in an airworthy condition;

b) the operator shall ensure that the aircraft is in compliance with all component life limits and other applicable mandatory requirements;

c) the operator shall evaluate for applicability to the program, all recommendations made by the manufacturer of the aircraft and their installed engines, propellers and appliances, as published in maintenance manuals, recommended schedules service bulletins and other technical documents. Where appropriate, the operator shall initiate amendment action. All amendments shall be approved by the Minister.
According to Transport Canada records, the operator's inspection approval was not amended to incorporate the Bristol inspection provisions.

Some Transport Canada inspectors recommend that operators of the accident aircraft type remove the floats every two years to inspect the struts.

According to the maintenance records for the aircraft, the floats and attachment struts were last removed for inspection in April 1988. Since that time, the aircraft's float attachment fittings have reportedly been inspected annually and attachment bolts replaced on condition. All of the float attachment bolts recovered and examined showed little evidence of wear or corrosion. The aircraft had flown about 1,160 hours between April 1988 and the time of the accident.

1.12 Survival Aspects

Before commencing the take-off, the pilot completed a passenger briefing, in which he mentioned, among other items, the location of the life-jackets mounted on the fuselage of the aircraft above the passenger seats and the locations of the aircraft exits. The passengers were not required to don the life jackets before take-off. After the float separated from the aircraft and while the aircraft was settling in the water, the pilot exited via the overhead hatch and attempted unsuccessfully to open the main cabin door at the rear of the fuselage. The passengers exited the cabin through the overhead hatch and stood on the wing of the sinking aircraft as the pilot re-entered the aircraft, transmitted a distress call from the aircraft's very high frequency (VHF) radio, and retrieved five life-jackets from their positions on the fuselage adjacent to the passenger seats. The pilot and four of the passengers donned the life-jackets and swam to the nearest shore, a distance of about 500 feet. Two of the passengers swam to shore without life-jackets. The pilot and one of the passengers walked and swam back to the fishing camp, returned with a boat, and took the party back to the camp.

2.0 Analysis

2.1 Take-off Direction

The combination of wind direction and take-off direction produced a tail-wind component of 5 to 10 knots during the take-off run. However, the aircraft does not have any published downwind take-off limits, and the wind and water conditions at take-off imposed no unusual stresses on the aircraft. Therefore, the pilot's choice of take-off direction did not contribute materially to the occurrence.

2.2 Aircraft Loading

Because the weight of the aircraft was under the maximum gross weight and the centre of gravity of the aircraft was within the prescribed limits, the loading of the aircraft did not impose any unusual stresses on the aircraft, or contribute materially to the occurrence.
2.3 Float Separation

Because the eyebolt fitting connecting the diagonal strut to the rear swivel fitting was found bent and broken in overload, with no pre-existing damage, it is likely that the fitting failed during the float separation sequence, but did not initiate the failure.

After examination of the front swivel fitting and mounting pad, the Engineering Branch concluded that the attaching bolt probably did not break, but moved out of position, either because the nut was not installed or because it came off during service. Given that the pilot reportedly checked the float fittings before departing the first flight of the day, it is likely that the bolt moved out of the fitting during the two flights completed on the day of the occurrence. Because of the low-wing design of the aircraft, the location of the main entry/exit door, and the seaplane landing gear configuration, a defect in the area of the forward float fittings would be less noticeable than in other aircraft designs. In light of the lack of damage to the front diagonal strut fittings and the overload failure damage found in the other float fittings, it is likely that the departure of the bolt from the front swivel fitting initiated the sequence of failures that resulted in the separation of the float from the aircraft during the occurrence.

2.4 Fasteners

Because the bolt and nut connecting the front swivel fitting to the float mounting pad were not recovered, no definitive statement can be made about the type of nut that was installed. However, 9 of the 10 float fitting bolts for which castellated nuts were specified were recovered with fibre locking nuts, and it is possible that this bolt was also secured with a fibre locking nut. Several of the left float fittings that were recovered had less than one thread of bolt extension past their fibre-locking nuts, and it is possible that the missing bolt lost its nut because the nut did not lock securely, and departed from the bolt in service.

All of the float attachment bolts and nuts that were recovered were in good condition, with little evidence of wear or corrosion. It is likely that the missing bolt and nut were inspected and replaced at the same intervals as the other attachment bolts, and were probably not worn or corroded to the extent that they contributed to this occurrence.

2.5 Inspection Schedule

The Bristol float service manual specifies an inspection schedule which is more rigorous than the one called for in the Transport Canada approved inspection schedule. Although the operator's inspection approval conditions require it to incorporate "other applicable mandatory requirements" of components installed in its aircraft and amend its inspection schedule accordingly, there is no record of changes to the inspection schedule to reflect the Bristol inspection provisions. Transport Canada did not insist on these provisions and reportedly encouraged some operators to incorporate an inspection schedule which differed from the Bristol inspection requirements.
2.6 Survival Aspects

Although the passengers did not wear their life-jackets during the take-off, the pilot's pre-take-off briefing and his actions in retrieving five of the life-jackets as the aircraft was sinking contributed to the survival of the passengers.

3.0 Conclusions

3.1 Findings

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

- The pilot's choice of take-off direction did not contribute materially to the occurrence.

- Although the left front swivel fitting attachment bolt was not recovered after the occurrence, it was probably not worn or corroded to an extent that contributed to the occurrence.

- It is likely that the left front swivel fitting attachment bolt moved out of position, during or before the take-off run, because the securing nut was either not installed or came off in service.

- The departure of the left front swivel fitting attachment bolt initiated a series of failures that resulted in the separation of the float from the aircraft during the take-off run.

- The aircraft's low-wing design and landing gear configuration made it less likely that defects in the area of the forward float fittings would be noted during service and operation.

- The operator's Beech 18 inspection schedule did not incorporate the Bristol inspection requirements for EDO 56-7850 floats.

- Transport Canada did not insist that the component manufacturer's inspection requirements be included in the operator's Beech 18 inspection schedule.

- Nine of the 10 float fitting bolts for which castellated nuts were specified were recovered with fibre locking nuts.

3.2 Causes

The left front swivel fitting attachment bolt probably moved out of position because the securing nut was either not installed or came off in service. A series of failures ensued, culminating in the separation of the left float from the aircraft.
4.0 Safety Action

4.1 Action Taken

The Bristol inspection requirement for EDO floats calls for removal and inspection of the floats every 500 hours, or at the end of each float-flying season. Transport Canada (TC) did not require that the component manufacturer's inspection criteria be incorporated into the approved inspection schedule. A TSB Aviation Safety Advisory was forwarded to TC indicating that TC may wish to review the direction it provides to Approved Maintenance Organizations (AMOs) with regards to following the manufacturer's inspection requirements.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 28 February 1996.

Appendix A - Float Strut Detail

Appendix B - List of Supporting Reports

The following TSB Engineering Branch Report was completed:

LP 96/95 Float Attachment Fittings.

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

Appendix C - Glossary

AMO - approved maintenance organization
CDT - central daylight saving time
CPL - Commercial Pilot Licence
hr - hour(s)
lb - pound(s)
LL - low lead
mph - miles per hour
N - north
TC - Transport Canada
TSB - Transportation Safety Board of Canada
UTC - Coordinated Universal Time
VHF - very high frequency
W - west
¹ - minute(s)
° - degrees

<1> Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.
<2> See Glossary at Appendix C for all abbreviations and acronyms.
<3> All times are CDT (Coordinated Universal Time [UTC] minus five hours) unless otherwise noted.
<4> Appendix A contains a diagram of the aircraft and its float, strut,
and strut fitting arrangement.

Updated: 2002-10-06

Important Notices
Air 1995

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 Air Canada Airbus Industrie A320 -FNNA and Canadian Airlines International Boeing 737 C-GFCP Broadview, Saskatchewan 18 June 1995

Report Number A95C0127

Summary

Air Canada Flight 139 (ACA139), an Airbus A320, was en route from Ottawa to Vancouver at flight level (FL) 350 near Broadview, Saskatchewan when the pilots received a Traffic Alert and Collision Avoidance System (TCAS) warning of conflicting traffic and a resolution advisory (RA) to "descend now" which advice was followed. Canadian Airlines International Flight 636 (CDN636), a Boeing 737, was also in the vicinity, flying in the opposite direction en route from Calgary to Winnipeg at FL350. The pilots of CDN636 also received a TCAS RA and climbed their aircraft. The aircraft passed within approximately one mile of each other and a loss of separation occurred. There were no injuries or damage, and both aircraft continued on to their respective destinations without further incident.

The extent of the aircraft traffic in the area being controlled by the Broadview sector controller of the Winnipeg Area Control Centre (ACC) at the time of the occurrence was considered to be moderate to heavy with added complexities. There was thunderstorm activity in the area and a number of aircraft were deviating off course around weather buildups or travelling at non-standard altitudes to avoid turbulence. The air traffic control radar displays functioned normally throughout the occurrence and all control information was correctly displayed. Unit staffing levels were considered normal and all equipment was functioning normally.

Ce rapport est également disponible en français.

Other Factual Information

The Broadview Sector controller was qualified for the position and had worked the Saskatchewan specialty in the Winnipeg ACC since 1986. He had been on duty for approximately two and one-half hours prior to the occurrence and was carrying out the combined duties of the radar and data controller positions. Shortly before the occurrence, traffic levels began to increase and a number of estimates had been passed to the Broadview Sector controller. The supervisor noted this activity increase and approximately 10 minutes prior to the occurrence an additional controller was assigned and began to assist
by assuming the data position duties.

Air traffic controllers assign flight levels appropriate to the aircraft track as set out in the *Cruising Altitudes Order* of the Air Navigation Orders. A flight level not appropriate to the aircraft track may be assigned by the controller if an aircraft crew requests the flight level because of turbulence. CDN636 was travelling at the same altitude (FL350, wrong way for direction of flight) as ACA139 because of excessive turbulence at the standard altitude and the flight progress strip indicated the non-standard altitude. CDN636 was travelling on Jet route(high level airway) 504 (J504) (see Appendix A) until approximately 50 miles west of Regina, Saskatchewan when the flight was placed on radar vectors for separation from a north-west bound aircraft that was also at FL350. CDN636 carried out a small turn and then was given a vector to Broadview, resulting in little change to the original route (J504).

ACA139 had been given an air traffic control (ATC) clearance along a route that, in the Winnipeg, Manitoba area, resulted in the aircraft travelling along fixed RNAV route T467 (see Appendix A). ACA139 was to proceed along T467 until reaching a waypoint known as KEDGE (near Brandon, Manitoba) and then turn left to proceed along T475 until Medicine Hat, Alberta. However, prior to reaching KEDGE on T467, the pilot of ACA139 contacted the Winnipeg ACC Winnipeg West sector controller and requested clearance to deviate north of track because of en route weather. The request was approved and subsequently coordinated with the Broadview sector controller. Warning indicators (red W) were marked on the flight progress strips for both CDN636 and ACA139, indicating a possible conflict. The Broadview sector controller noted ACA139 to be moving north of T467 and confirmed there were no conflicts. A few minutes later, while handing off ACA139 to the Broadview sector controller, the Winnipeg radar controller again advised of ACA139’s deviation to the north. The Broadview sector controller assumed control of ACA139, believing that it would be continuing on T467, and continued to monitor the aircraft as it continued to deviate to the north.

The pilot of ACA139 carried out a deviation approximately 25 miles north of track, about 85 miles beyond KEDGE, before turning southwesterly back towards track (T475) again, approximately seven minutes prior to the occurrence. ACA139's original track, T475, was south of both T467 and J504 and ACA139 had to cross both routes to regain the originally cleared track. There was no instruction issued to the pilot in his deviation clearance, that required him to request clearance back to his original track nor is there any regulatory requirement for him to do so.

Traffic Alert and Collision Avoidance System (TCAS) is an aircraft-installed device that functions independently from the ground-based air traffic control radar system. TCAS uses the radar beacon transponders installed in other aircraft to provide collision avoidance information to the flight crew in the form of recommended vertical escape manoeuvres known as resolution advisories (RA). The required separation between ACA139 and CDN 636 was 2,000 feet vertically and five miles horizontally. ACA139 continued southwest-bound converging on the eastbound CDN636 until both flight crews received TCAS RAs and advised ATC that they were descending and climbing respectively. Both crews reacted promptly to the RAs and 20 seconds later the aircraft passed each other with 900 feet vertical and 1.3 miles horizontal spacing (see Appendix B).

The Radar Modernization Project (RAMP) was designed to completely replace Canada's existing national ATC radar network with a system utilizing advanced computer technology and was designed with a traffic conflict warning system; however, that warning capability is not yet functional. The Canadian Automated Air Traffic System (CAATS) system, which is currently scheduled to upgrade the RAMP system in 1998, originally incorporated a conflict resolution system, as well as a traffic conflict warning system. The conflict resolution features of the anticipated system have recently been deleted from the project; however, it is
anticipated that the traffic conflict warning capability will be retained. The United States Federal Aviation Administration (FAA) has successfully used a traffic conflict alert system as part of their air traffic control system for approximately fifteen years.

Air traffic controllers use data provided by radar displays and radio communications to form a mental picture of air traffic that assists with the conceptualization and prediction of aircraft movement. Studies suggest that an air traffic controller's mental picture consists of two definable elements: A mental model, and situation awareness (Gilson et al, 1994)\(^1\). The mental model is the underlying knowledge that is the basis for situation awareness and consists of knowledge of airspace, aircraft, and ATC procedures as well as an understanding of the associated electronic systems. The term 'situation awareness' refers to "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988)\(^2\). Data from auditory or visual displays are momentarily perceived, held in situation awareness (if they will be needed), and may update the mental model if there are long term implications. Information in the mental model influences and structures the data held in situation awareness and directs an individual's attention. A controller relies on his mental picture to provide a basis for analyzing new information and making decisions.

**Analysis**

Research into human decision making has shown that in the process of making decisions people develop hypotheses (Wickens, 1992)\(^3\). The contents of the mental model and situation awareness will set the framework for these hypotheses. However, when people select a particular hypothesis, they tend to give inordinate diagnostic weight to any information that supports the chosen hypothesis. Much less weight is then given to data that may support a competing hypothesis. Once a person becomes locked onto a particular hypothesis, it becomes very difficult for them to discard it, even when faced with compelling evidence to the contrary.

The Broadview Sector controller believed that ACA139 was going to continue on T467. On two occasions the controller was prompted about ACA139, and being aware of a possible conflict, he analyzed the available information, and concluded that ACA139 would not conflict with any other aircraft. After determining that ACA139 was no longer a problem, the dynamics of the air traffic situation at the time required the controller to dedicate his time to other aircraft, and their potential conflicts. With his attention now diverted to other aircraft, the change in direction in the radar target representing ACA139 was not sufficient stimulus to cause the controller to discard his previous conclusion that there was no conflict, and to generate a re-evaluation of the available information. The traffic density, the complexity of the coordinations required, the limited time available, and the characteristics of human information processing combined to allow the change in the status of the previously de-conflicted aircraft to go undetected, and the loss of separation occurred.

**Findings**

- The controller was qualified for the position.

- Staffing levels were considered normal.

- The controller had been carrying out the combined duties of the radar and data controller until approximately 10 minutes prior to the occurrence.

- The control radar was serviceable, and the displays functioned normally throughout
the occurrence.

- Traffic density was moderate to heavy with added complexities.

- There was thunderstorm activity in the area and a number of aircraft were deviating off course around weather build-ups or travelling at non-standard altitudes to avoid turbulence.

- There was no instruction issued to the pilot in his deviation clearance that required him to request clearance back to his original track nor is there any regulatory requirement for him to do so.

- After ACA139 turned back towards track (T475), the controller did not recognize the developing traffic conflict between Air Canada 139 and Canadian 636.

- The TCAS systems were activated in both aircraft and provided the flight crews with the information necessary for collision avoidance.

- The aircraft passed within 1.3 miles and 900 feet of each other.

- The traffic conflict warning system incorporated in the radar system is not yet operational.

**Causes and Contributing Factors**

The controller did not recognize the developing traffic conflict between Air Canada 139 and Canadian 636 and did not maintain the required separation criteria for the two aircraft. The combined effect of the traffic density, the complexity of the coordinations required, the limited time available, and the characteristics of human information processing combined to allow the change in the status of the previously de-conflicted aircraft to go undetected. Contributing to the occurrence was that the traffic conflict warning system was not operational.

*This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 24 April 1996.*

**APPENDIX A**

Aircraft Tracks and Routings
## APPENDIX B

### RAMP Radar Data Table

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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 Water
Northern Mountain Helicopters
Bell 205A-1 (Helicopter) C-GNMR
Leaf Rapids, Manitoba
28 June 1995

Report Number A95C0139

Synopsis

The helicopter was being operated on contract to the provincial Ministry of Natural Resources in support of forest fire suppression activities. The pilot departed Leaf Rapids, Manitoba, with seven passengers and their equipment on board, for a local flight to drop off a fire-fighting crew. The reported visibility was three-quarters of a mile in smoke as the flight began and the helicopter flew northward from the town. While crossing the Churchill River, the pilot encountered significantly reduced visibility and turned to the right to return for landing. The helicopter descended while in the turn, the main rotor blades struck the water, and the aircraft crashed into the river. The pilot and four of the passengers exited the aircraft and were rescued; however, three passengers were incapacitated by head injuries and drowned. The aircraft was destroyed.

The Board determined that, while turning the helicopter to avoid an area of reduced visibility, the pilot lost the visual cues required for flight. The helicopter descended while in the turn and struck the water before the pilot was able to regain adequate visual reference.

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1.0 Factual Information

1.1 History of the Flight

The Bell 205 A-1 helicopter was under contract to the provincial Ministry of Natural Resources (MNR)<1> in support of fire-fighting operations. The occurrence helicopter was one of six helicopters that were being operated out of a temporary heliport at a fire base that had been established on the golf course adjacent to the town of Leaf Rapids, Manitoba. The occurrence flight was the first flight of the day for the pilot, and the first flight to depart from the heliport that morning. The purpose of the flight was to transport six fire-fighters and their associated equipment to a location approximately seven and one-half miles<2> northeast of the town. In addition to the six fire-team members seated in the rear of the helicopter, a Natural Resources Officer (NRO), who was the Division Boss in charge of forest fire-fighting operations in the area, occupied the left front cockpit seat.

The visibility in the area of the heliport was reported to be three-quarters of a mile in smoke when the aircraft departed. The plan established between the pilot and the NRO prior to departure was to take off and try to reach their destination, but to turn around and return for landing should visibility be insufficient.

The pilot completed the take-off and initially headed north from the town,
following a highway at an altitude of 75 to 100 feet above ground level (agl) and an airspeed of approximately 40 knots. A few minutes later, the helicopter began to cross a river valley where a road bridge spanned the wide river. Immediately after crossing the river's north shore, and while in the vicinity of the bridge, the pilot noted that the visibility was deteriorating and initiated a right turn to return to better conditions. The pilot lost visual reference while in the turn over the river. The pilot immediately checked the flight instruments and noted that the vertical speed indicator showed that the helicopter was descending at 200 feet per minute. The pilot attempted to stabilize and maintain control of the aircraft while trying to regain visual references; however, the main rotor struck the surface of the water. The helicopter crashed into the Churchill River (elevation 850 feet above sea level), at position 56º29.5'N, 099º58.5'W, at approximately 0935 central daylight saving time (CDT)<3>, during the hours of daylight.

1.2 Injuries to Persons

<table>
<thead>
<tr>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>-</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Serious</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Minor/None</td>
<td>-</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

1.3 Damage to Aircraft

The helicopter was destroyed by the impact with the water.

1.4 Other Damage

Approximately 156 gallons of Jet B fuel was released from the helicopter into the Churchill River.

1.5 Personnel Information

Pilot

<table>
<thead>
<tr>
<th>Age</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot Licence</td>
<td>CPL</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
<td>01 Sep 95</td>
</tr>
<tr>
<td>Total Flying Hours</td>
<td>4,250</td>
</tr>
<tr>
<td>Hours on Type</td>
<td>3,400</td>
</tr>
<tr>
<td>Hours Last 90 Days</td>
<td>130</td>
</tr>
<tr>
<td>Hours on Type Last 90 Days</td>
<td>130</td>
</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
<td>2.5</td>
</tr>
<tr>
<td>Hours Off Duty Prior to Work Period</td>
<td>9.5</td>
</tr>
</tbody>
</table>

The pilot completed his initial helicopter pilot training with the United States military, and received his pilot qualification in 1972. He received instrument flight training and had a limited amount of instrument flight experience during his subsequent military career with the Vietnamese Army. The pilot was issued a Canadian commercial pilot licence in 1980, having accumulated approximately 1,970 hours of flying experience. He did not have an instrument rating and did
not maintain currency in instrument flight. The pilot was certified and qualified for the occurrence flight, in visual flight conditions, in accordance with existing regulations.

1.6 Aircraft Information

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Bell Helicopter Textron Inc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and Model</td>
<td>205A-1</td>
</tr>
<tr>
<td>Year of Manufacture</td>
<td>1968</td>
</tr>
<tr>
<td>Serial Number</td>
<td>30015</td>
</tr>
<tr>
<td>Certificate of Airworthiness (Flight Permit) Valid</td>
<td></td>
</tr>
<tr>
<td>Total Airframe Time</td>
<td>6,341.6 hours</td>
</tr>
<tr>
<td>Engine Type (number of)</td>
<td>Textron Lycoming T53-13B(1)</td>
</tr>
<tr>
<td>Propeller/Rotor Type (number of)</td>
<td>Bell Helicopter Textron 204-011-250-001 (1)</td>
</tr>
<tr>
<td>Maximum Allowable Take-off Weight</td>
<td>9,500 pounds</td>
</tr>
<tr>
<td>Recommended Fuel Type(s)</td>
<td>Jet B</td>
</tr>
<tr>
<td>Fuel Type Used</td>
<td>Jet B</td>
</tr>
</tbody>
</table>

Records indicate that, at the time of the occurrence, the helicopter was equipped with basic instrumentation for flight in visual meteorological conditions (VMC) and was certified for flight in VMC in accordance with existing regulations. The helicopter was not certified or equipped for single-pilot flight in instrument meteorological conditions (IMC).

Post-occurrence calculations indicate that the aircraft weighed about 9,350 pounds when it departed on the occurrence flight. The maximum take-off weight for the aircraft is listed as 9,500 pounds. Both the lateral and longitudinal centres of gravity were determined to be within the acceptable limits.

1.7 Meteorological Information

The MNR fire team obtained public weather information from Environment Canada every morning and sought weather updates during the day. The information was passed along to fire management personnel, who then made it available to the pilots. Pilots could also access weather information directly by telephone through Transport Canada's 1-800-INFO-FSS service; however, it was not determined whether any pilots had done so. There were no aviation weather briefing facilities available locally, neither are there any Environment Canada weather observation personnel at Leaf Rapids.

The smoke from forest fires in the region created a wide area of partially obscured conditions with no clearly defined ceiling. At the time that the occurrence aircraft commenced its flight, the wind was reported to be light, and smoke reduced the visibility in the area of the heliport to approximately three-quarters of a mile. Witnesses reported that, immediately after the occurrence, visibility in the river valley near the occurrence site was approximately 200 yards. The sky was totally obscured by the smoke, and the water surface was observed to be flat and calm.
1.8 Aids to Navigation

A private, unmonitored non-directional beacon (NDB) is located approximately one mile east of the town, and the aircraft was equipped with a global positioning system. The occurrence flight was operated under visual flight rules (VFR) using visual ground references for navigation.

1.9 Communications

There was a trailer adjacent to the heliport set up with a radio communications system manned by a radio operator. Helicopter pilots were required to make departure and arrival advisories by radio to the radio operator, who recorded these aircraft movements in a written log. Shortly after take-off, the pilot made a routine departure advisory to the radio operator, who made an entry in the radio log.

1.10 Heliport Information

Six helicopters under contract to MNR were being operated out of a temporary heliport established at the fire base on the golf course adjacent to the town. One of the golf course fairways had been laid out with ground markings for landing pads. Each landing pad was equipped with portable refuelling and fire extinguishing equipment.

1.11 Flight Recorders

The helicopter was not equipped with a cockpit voice recorder or a flight data recorder, nor was either required by regulation.

1.12 Wreckage and Impact Information

The helicopter was in a descending right turn when the main rotor blades struck the surface of the water and severed the tail boom. The main rotor mast sheared, and the main rotor separated from the aircraft. The forward section of the tail boom was torn from its fuselage mounts.

The fuselage initially contacted the water on the left side in a nose-down attitude. The fuselage tumbled after the initial impact, and struck the water again on the right rear of the fuselage. The fuselage broke behind the front landing gear attachment point and to the rear of the cockpit. The wreckage separated into four major sections: the rear tail boom and tail rotor, the forward tail boom, the main rotor assembly, and the fuselage. The helicopter wreckage came to rest in about 35 feet of water, approximately 100 feet from shore.

All damage to the aircraft was attributable to the contact with the water and the subsequent breakup. The engine was closely examined at a commercial overhaul facility and no evidence of any malfunction was found. There was no evidence found of any aircraft failure or system malfunction either prior to or during the flight.

1.13 Medical Information

There was no evidence to indicate that the pilot's performance was affected by physiological factors.
1.14 Fire

There was no evidence of aircraft fire either before or after the crash. 1.15 Survival Aspects

The helicopter was equipped with personal restraint systems and these restraint systems were being used in accordance with existing regulations. Both of the seats in the cockpit of the helicopter were equipped with four-point safety harnesses. The pilot used the available shoulder harness and lap belt. The NRO in the other cockpit seat used the lap belt only, although a shoulder harness was available. The seats in the passenger cabin were equipped with lap belts only. All the passengers used the lap belts. The pilot was wearing a protective helmet; however, none of the other occupants was wearing a helmet.

When the aircraft struck the water, the damage to the aircraft caused the doors and emergency exits to open. As the aircraft sank, occupants who were not incapacitated by the impact forces were able to release their safety harnesses and float to the surface. The passenger in the left front cockpit seat, and two of the passengers who were seated in the centre rear and right rear portions of the cabin, did not survive. These three passengers were found in their seats with their lap belt safety harnesses still done up. Post-mortem examinations indicated that each of them had suffered head injuries during the impact sequence, which resulted in their incapacitation; unable to release their safety harnesses, they subsequently drowned. There were no other life-threatening injuries found.

Studies have shown that approximately 70 per cent of all serious and fatal injuries in helicopter accidents occur primarily to the head, spine, torso, and neck. An analysis of helicopter crash dynamics by Coltman (1985)<4> showed that, of the personnel who experienced a helicopter crash, only 9 per cent of those who were wearing a shoulder harness had severe injuries, compared with 34.3 per cent of those who wore only a lap belt.

Existing Canadian regulations require that helicopters engaged in specific or special purpose operations conform with more stringent provisions concerning the fitment and use of shoulder harnesses. For example, Air Navigation Order (ANO) Series II, No. 2, requires that all persons aboard a special purpose operation flight keep their lap belt and shoulder harness fastened at all times, except when a person is performing duties that relate to the special purpose operation or the operation of the aircraft and that require the person to remove the shoulder harness or lap belt or both. These "special purpose operations" generally involve greater risk to the passengers and crew and include such operations as helicopter external load operations. Passenger-carrying helicopter flights in support of forest fire-fighting operations, such as in this occurrence, are not considered a "special purpose operation".

1.16 Loss of Visual Reference

The flight was being conducted under visual flight rules (VFR), which demand that flights be conducted with continuous visual reference to the ground or water. ANO Series V, No. 3, specifies that, for a helicopter operating in uncontrolled airspace below 700 feet agl, the visibility must not be less than one-half mile, and the helicopter must be clear of cloud. Also, the helicopter must be operated at such a reduced airspeed as to give the pilot-in-command adequate opportunity to see other air traffic or obstructions in time to avoid a collision.
During VFR flying, pilots rely on cues from the natural horizon and the earth's surface to maintain the desired attitude of the aircraft. When these external visual cues become obscured by environmental conditions, such as smoke, a pilot can quickly become disoriented with respect to the position and attitude of the aircraft relative to the ground or water. Just after the occurrence, the water surface was observed to be flat and calm, creating a mirror-like effect that would have resulted in a virtually monochromatic visual environment devoid of an identifiable horizon.

On entry into IMC, a pilot must revert to flight instruments to determine and maintain proper aircraft attitude. For pilots who are not current in conducting instrument flight, success in overcoming the effects of spatial disorientation is rare<5>. Spatial disorientation can be so overpowering that, even for pilots who are "instrument rated, current, and proficient in helicopters, success at coping with inadvertent instrument flight is not guaranteed."<6> Part of the reason is that, once visual reference is lost, it can take as much as 35 seconds to re-establish full control of the aircraft by reference to instruments<7>; of that 35 seconds, at least 5 seconds are spent recognizing that a hazard exists, determining the necessary corrective action, and initiating a response.

1.17 Organizational and Management Information

1.17.1 Fire Team Structure

Under normal conditions, smaller forest fires are brought under control using the local resources available within each Natural Resources specified district. When a forest fire expands to the extent that the fire-fighting is beyond the capability of the local resources, a project fire team is established and sent to the fire location. The project fire team, under the command of a Fire Boss, is tasked with setting up an organization to combat that fire. A six-member project fire team had been established and was operating on the forest fire when the accident occurred.

The two major components of the fire team are: 1) the suppression group, which is responsible for putting out the fire; and 2) the service group, which is responsible for providing the supplies and services required to support the fire-fighting effort (see Figure 1).

The suppression portion of the organization is headed by a Suppression Boss, who designates Division Bosses to manage subsections of the fire. The Division Bosses direct allocated people and resources (including helicopters) to put out the fire within their assigned area.
At the time of the occurrence, the suppression portion of the fire team was divided into two divisions, each responsible for areas of the fire either east or west of the main highway running north and south through the town. The NRO seated in the left front seat of the occurrence helicopter was the Division Boss for the eastern portion of the fire. To effectively monitor the successful execution of the suppression plan, Division Bosses reportedly spend approximately 50% of their time flying on helicopters in and around the fire.

1.17.2 Fire Team Safety-Related Positions

The MNR Fire Program office has published a Fireline Notebook<8> for use as a guideline by personnel appointed to work on fire teams. The notebook outlines an example of a large fire organization that includes several positions that are assigned duties relating to the safe and effective employment of aircraft used in the fire-fighting effort. Specifically, a Fire Safety Boss reporting directly to the Fire Boss is designated. The Fire Safety Boss is required to "inspect and make recommendations on all safety aspects of the fire operations." The duties of the Fire Safety Boss include several items listed under "Air Transportation Safety"; the book also states that "it [air transportation] has the potential to be the most hazardous part of the operation."

In the example, a Helicopter Officer position is also designated to report through the Transport Officer to the Service Boss. Pages 99 to 107 of the Fireline Notebook list the 80 items that make up the Helicopter Officer's Checklist. Thirty-four of the items are listed under the heading "Safety," and include requirements such as the need to check that tailgate safety sessions between the helicopter officer, ground crew, and pilots are conducted each shift (safety item no. 9), as
well as the need to monitor whether seat-belts and shoulder harnesses are always being worn by pilots and passengers (safety item no. 27).

The Fireline Notebook notes that duties of various job positions may be combined when warranted. The criteria governing when these positions may or may not be filled are not defined. The fire team involved in this occurrence was described as a relatively small organization consisting of about 225 personnel and six helicopters. The positions of Fire Safety Boss and Helicopter Officer were not staffed on the fire team involved in the occurrence.

1.17.3 Management Structures

The Helicopter Flying Offer contract between Northern Mountain Helicopters and the Province of Manitoba indicates that the helicopter operator is to perform "Class 4 charter commercial air services." In outlining the standards for operation of charter flights, the document states that the helicopter operator "shall have exclusive control over its chartered helicopter, its contents and crew and ensure that each flight is conducted in a safe and efficient manner and in accordance with the Aeronautics Act, all applicable air regulations and air navigation orders."

The United States National Transportation Safety Board (NTSB), in a safety study (see footnote 5), acknowledged that, when two management structures are involved in an operation, they can have objectives that conflict and adversely affect safety. To ensure that the objectives of the two management structures do not conflict and become detrimental to safety, the NTSB believes that "effective and regular communication on safety issues between separate managements and the employees is mandatory."

An important step in developing a safety philosophy within an organization is the implementation of risk management principles that allow for the identification of hazards, the evaluation of risk associated with those hazards, and the implementation of controls in the form of clearly defined managerial policies and enforced procedures. The NTSB study also recognizes that, in an operation involving two management structures, it is important for the contracting organization to become knowledgeable about safety issues in helicopter operations because personnel from the contracting organization often become the de facto management for the pilot.

In its discussion of minimum safety standards, the TSB safety study on VFR flight into adverse weather<9> noted the following:

While examining commercial VFR-into-IMC accidents, it became clear that a number of major users of Canadian aviation charter services stipulate additional safety criteria when they contract air charter services. Major clients of Canadian charter services are demanding a higher standard of safety than the existing regulations and industry practices can provide. Oil companies, many air ambulance services, and a number of agencies and departments from various levels of government have adopted such practices.

2.0 Analysis

2.1 Introduction

The examination of the helicopter revealed no evidence of any aircraft failure or
system malfunction either prior to or during the flight. The pilot was certified and qualified for the flight in accordance with existing regulations, and there was no evidence that the pilot's performance was affected by physiological factors. This analysis will focus on the pilot's loss of visual reference, and, although not directly related to the cause of the accident, the chances of survival of the helicopter occupants, and the on-site safety monitoring system.

2.2 Loss of Visual Reference

The flight was being conducted under visual flight rules, which require that the pilot maintain continuous visual reference with the ground or water. Because there were no aviation weather briefing facilities or weather observation personnel available at Leaf Rapids, pilots were required to assess local weather conditions themselves. At the commencement of the flight, the visibility of approximately three-quarters of a mile exceeded the minima required for VFR flight; however, as the helicopter was crossing the Churchill River, the smoke became more dense and the visibility deteriorated rapidly.

The helicopter was equipped with basic instrumentation for VFR flight and was not certified or equipped for single-pilot flight in IMC. The pilot had received instrument flight training early in his flying career, but he did not have an instrument rating, nor had he maintained instrument flying currency during the 15 years preceding the occurrence. As a result, neither the pilot nor the aircraft was certified or equipped to continue the flight in IMC; the only option available to the pilot was to attempt to maintain VFR.

When the pilot decided that visibility conditions were no longer suitable to continue the flight, he elected to carry out a right turn over the river. During the turn, the pilot lost visual reference with the surface. After the accident, the visibility at the occurrence site was reportedly about 200 yards in smoke, the sky was obscured, and the water surface was observed to be flat and calm. This combination of conditions was conducive to spatial disorientation in VFR flight.

The pilot had to rely solely on his manual control of the helicopter and on his interpretation of the aircraft's basic flight instruments to maintain control of the helicopter until he regained external visual cues.

Upon losing visual reference, the pilot checked the flight instruments and noted that the vertical speed indicator showed that the helicopter was descending at 200 feet per minute. Descending at this rate from a height of about 75 feet, the helicopter would have taken only about 23 seconds to hit the water's surface. Since the pilot was not current in instrument flying, and the helicopter was not equipped for IFR flight, and there was a lack of identifiable outside visual references, the pilot had little chance of making a successful recovery.

2.3 Survivability

The analysis of helicopter crash dynamics by Coltman documented the significant reduction in severe injuries incurred in helicopter crashes when people wore shoulder harnesses. The MNR Fireline Notebook also recognizes the benefit of using shoulder harnesses, and assigns the Helicopter Officer to monitor their use by pilots and passengers as a safety-related checklist item. The fact that the pilot, who was wearing both a shoulder harness and a protective helmet, survived the crash, while the other cockpit occupant did not, further
highlights the increased level of protection provided by the additional safety gear.

Forest-fire operations involve risk levels higher than those encountered on routine transportation flights. While it could not be proven that the wearing of shoulder harnesses or helmets would have changed the outcome for those passengers who did not survive this occurrence, there is sufficient evidence to indicate that the use of shoulder harnesses and protective headgear improves chances of survival. Use of shoulder harnesses and protective headgear might have prevented the incapacitation of the casualties in this occurrence.

2.4 Safety Management

Transport Canada’s regulations have been developed primarily to establish minimum safety standards for commercial and private air transport operations, and they do not specifically address the unique nature of forest-fire operations. Oil companies, many air ambulance services, and a number of agencies and departments from various levels of government have examined their flight operations requirements and determined the need to specify particular standards for the safety of their personnel, beyond the minimum standards required by Transport Canada regulation. These higher standards can be specified in the contract signed with the helicopter operator. The contract in effect at the time of the occurrence placed exclusive responsibility for safety standards with the helicopter operator, and only specified compliance with applicable regulations.

The NTSB study advocates the establishment of compatible management policies and procedures in situations where two management structures (in this occurrence, MNR and Northern Mountain Helicopters) are involved together in operations of an urgent nature. The intent is for all operational personnel from both organizations to be operating to the same standards and limits. The NTSB study highlights the de facto management role that on-scene personnel have with helicopter pilots. This role places an onus on fire management organizations to establish a safety philosophy that includes flight operations. To a great extent, a similar philosophy and policies were already embodied in the MNR Fireline Notebook; however, personnel were not assigned to safety-related positions on the fire team.

3.0 Conclusions

3.1 Findings

- There was no evidence found of any aircraft failure or system malfunction either prior to or during the flight.

- Records indicate that the aircraft was certified and equipped for flight in VMC conditions in accordance with existing regulations.

- There was no evidence to indicate that the pilot’s performance was affected by physiological factors.

- The pilot was certified and qualified for the occurrence flight in accordance with existing regulations.
Although the pilot had instrument flight training early in his flying career, he did not have an instrument rating, nor had he maintained instrument flying currency during the 15 years preceding the occurrence, nor was he required to do so under existing regulations.

There were no aviation weather briefing facilities or weather observation personnel available at Leaf Rapids, and pilots were required to assess local weather conditions themselves.

The pilot lost the visual cues required for flight in visual meteorological conditions, and the helicopter struck the water before the pilot was able to regain adequate visual reference.

Three of the eight persons on board were incapacitated by head injuries caused by the crash. They were unable to release their safety harnesses, and drowned.

Studies indicate that the use of shoulder harnesses and protective headgear improves occupants’ chances of survival in helicopter accidents; their use might have prevented the incapacitation of the casualties in this occurrence.

MNR fire-team management guidelines provided for the establishment of safety-related positions on the fire team, but these positions were not staffed.

3.2 Causes

While turning the helicopter to avoid an area of reduced visibility, the pilot lost the visual cues required for flight. The helicopter descended while in the turn and struck the water before the pilot was able to regain adequate visual reference.

4.0 Safety Action

4.1 Action Taken

4.1.1 Passenger Safety Equipment

The Manitoba Ministry of Natural Resources has issued an internal operational guideline, effective as of the 1996 fire season, pertaining to all fire-fighting-related flights. The guideline requires persons on board such flights to wear seat-belts, shoulder harnesses (where available), and helmets or hard hats secured with a chin strap, except when performing duties that require the removal of any or all of these items. In addition, in its future long term contracts with helicopter operators, the Ministry will require that approved shoulder harnesses be supplied at all normally occupied seat locations; this specification will be a preferred item for all casual hire rentals of helicopters.

4.1.2 Fire Team Safety-Related Positions
The Manitoba Ministry of Natural Resources has amended its operational guidelines to ensure that, on any overhead fire team mobilized to manage large fire outbreaks, the role of Fire Safety Officer is assigned to a specific and suitably trained individual. The Fire Safety Officer's responsibilities include complying with the items outlined in the Helicopter Officer Check List and ensuring that both pilots and other fire staff operate under the same standards and limits while on site.

4.1.3 Dissemination of Information

The Board believes that others involved in managing the safety of forest fire operations should be made aware of the safety issues identified during this investigation and of the subsequent action taken by Manitoba's Ministry of Natural Resources. As such, the final report of this occurrence investigation is being distributed to the authorities responsible for forest fire management in each of the provinces and territories.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 25 June 1996.

Appendix A - List of Supporting Reports

The following TSB Engineering Branch Report was completed:

LP 105/95 - Instruments Examination.

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

The following supporting report was completed by Standard Aero Engine Limited:


Appendix B - Glossary

agl - above ground level
ANO - Air Navigation Order
CDT - central daylight saving time
CPL - commercial pilot licence
FAA - Federal Aviation Administration
FSS - Flight Service Station
hr - hour(s)
IFR - instrument flight rules
IMC - instrument meteorological conditions
lb - pound(s)
MNR - Ministry of Natural Resources
NDB - non-directional beacon
NRO - Natural Resources Officer
NTSB - National Transportation Safety Board
TSB - Transportation Safety Board of Canada
UTC - coordinated universal time
VFR - visual flight rules
VMC - visual meteorological conditions

' minute(s)
" second(s)
° degree(s)

<1>See Glossary for all abbreviations and acronyms.
<2>Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.
<3>All times are CDT (Coordinated Universal Time [UTC] minus five hours) unless otherwise stated.
<6>Ibid.
<7>Federal Aviation Administration, Spatial Disorientation, FAA Advisory Circular 60-4A, 2/9/83.
<8>Manitoba Natural Resources Fire Program, Fireline Notebook, Manitoba Government Publication MG-12027.

Updated: 2002-10-06
Air 1995

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.

Engine power loss
mechanical malfunction Skyteck Aviation Ltd.
BELL 206B JETRANGER
(HELICOPTER) C-GXNM
Drydec, Ontario 4 mi NW
07 July 1995

Report Number A95C0149

Synopsis

The pilot and sole occupant of a Bell 206B helicopter, C-GXNM (serial number 1111), was conducting a visual flight rules (VFR) flight from Dryden to Red Lake, Ontario. This was the first leg of a journey that would transport the pilot and equipment to a contract in the Northwest Territories. The start-up and climb-out were normal, and the pilot had established the helicopter on course at 2,500 feet above dense trees and a river. There was a loud but muffled bang near the rear of the helicopter. The aircraft lurched, and the engine-out warning sounded. The pilot commenced an autorotation to a clearing approximately one-half mile to his left. As he approached the clearing, he realized that the rate and angle of descent would result in the helicopter landing in a flooded area, unsuitable for landing, so he extended the glide to reach the field. The helicopter touched down with a forward speed of 10 to 12 miles per hour and pitched tail-up as it slid to a stop in an upright attitude on the high skid gear. The tail boom and tail rotor assembly were severed from the helicopter by the main rotor blades. The pilot was not injured.

Other Factual Information

The engine failure occurred approximately seven minutes into the first flight after the completion of the 300-hour inspection. The engine had exhibited normal temperatures and pressures during the initial phases of the flight, and there were no warning indications prior to the engine failure. When the engine failed, the helicopter yawed and the engine-out warning sounded.

The engine was removed from the helicopter, and a preliminary teardown determined that the effects of oil starvation of the number 6
and 7 bearings resulted in heat damage to adjacent components and a decoupling of the turbine and compressor sections of the engine. The power turbine scavenge sump was dry, and no ferrous material had transferred to the chip detectors to warn of the impending engine failure. The partially disassembled turbine and oil samples from the engine were forwarded to the

TSB Engineering Branch for detailed analysis.

The oil samples were analyzed by the TSB and by the engine manufacturer. The oil was determined to be the correct type and did not appear to have been contaminated; however, there was evidence that the oil had been exposed to high temperatures. It was not possible to determine if anti-foaming additives were present.

A connector assembly (part number 6848194C), commonly referred to as the tee-fitting, supplies pressure oil to the number 6/7 bearing pressure oil nozzle and to the pressure oil supply line for the number 8 bearing. The inlet to the tee-fitting is protected by a filter screen. At installation, the upper portion of the 6/7 bearing pressure oil nozzle is inserted into the base of the tee-fitting, producing a standpipe inside the tee-fitting. As a result, a recess is formed between the standpipe and the inner walls of the fitting. (See Figure 1.)

The TSB Engineering Branch determined that the 6/7 bearing pressure oil nozzle was blocked by a particle of hard carbon. A piece of hard carbon was also found in the oil supply line for the number 8 bearing. Both carbon particles were too large to have passed through the inlet screen of the tee-fitting. Inspection of the tee-fitting revealed a build-up of hard carbon in the area between the standpipe and the inner wall at the base of the tee-fitting. The degree of carbon build-up was excessive for the time-in-service since the DIL 155 inspection. Using the electron scanning microscope (SEM), a sample of the carbon taken from the base of the tee-fitting was compared with the carbon particles. It could not be conclusively determined that the two particles had come from the base of the tee fitting; however, the carbon particle from the pressure nozzle displayed a uniform curvature with a radius that matched the radius of curvature of the interior passageway of the base of the tee-fitting. Energy dispersive X-ray analysis of the three carbon particles showed that they were probably derived from the same combusted material and/or combustion reaction. The carbon particle that blocked the 6/7 bearing pressure oil nozzle most probably originated in the base of the tee-fitting.
TSB Reports - Air 1995 - A95C0149

Allison Gas Turbine/General Motors Corporation publishes the procedures by which the engine is to be maintained and overhauled. The 100-hour inspection specified in the

C20 Operations & Maintenance Manual requires accomplishment of a scavenge flow check from the external sump. If the oil flow from the external sump does not meet 90cc minimum flow, the 6 and 7 bearing pressure oil nozzle, the tee-fitting and filter screen, the scavenge oil strut, and the external scavenge sump must all be cleaned. Additionally, these components must be cleaned at each 300-hour inspection. The procedure for cleaning the pressure oil tee-fitting (O&M Manual, Para 3-184 d.) requires insertion of a number 12, 0.189-inch drill bit into the pressure oil outflow port at the base of the tee-fitting.

The Allison 250-C20 Overhaul Manual calls for the pressure oil nozzle and tee-fitting to be cleaned in an alkaline bath at each overhaul. In distributor information letter (DIL 155) revision 7, dated 28 February 1990, Allison Gas Turbine Division provides the prescribed procedures for accomplishment of a recommended 1,750-hour scheduled turbine heavy maintenance inspection. One of the items of this procedure requires the inspection of all oil nozzle passages and bearing sumps for excessive carbon formation and/or obstructions. The overhauler is directed to clean as necessary.

Essential Turbines Ltd. completed a 1,750-hour heavy maintenance inspection of a turbine (part number 6898735, serial number 33272), in accordance with the DIL 155 procedures. As part of that inspection process, the inlet screens and the pressure tee-fittings for the number 6, 7, and 8 bearings were cleaned using prescribed procedures. The turbine had been received from, and was returned to, Skytech Aviation Ltd., without an external sump installed. The turbine was then installed in the Allison 250-C20B engine (serial number 37173) on Skytech’s Bell 206B helicopter, C-GXNM, at an airframe time of 8,585.8 hours. A used but serviceable sump can was inspected, cleaned, and installed by the operator. At 12.8 flight hours after the turbine installation, the engine exhibited smoke from the exhaust.

At the request of the operator, the overhaul agent completed an in-the-field change of the number 5 carbon seal. When the turbine section was removed and inspected, the power turbine support scavenge strut
was almost completely blocked with carbon, and carbon had also accumulated in the sump can. The engine oil reportedly was dark but did not smell burned. The overhaul agent changed the number 5 carbon seal and cleaned out the external sump can, and the operator's apprentice engineer cleaned out the scavenge strut. The overhauler visually inspected the scavenge strut to confirm it was clean, and re-installed the turbine. The engine oil filter was cleaned, and the engine oil system was replenished with new oil. The 6/7 bearing pressure oil nozzle and tee-fitting assembly was not removed during the scavenge strut cleaning. The engine was motored over to ensure a positive oil flow. During an extended ground run, the engine started normally, did not smoke or leak, and spooled down normally. The next day the operator flew the helicopter to Dryden, a flight duration of 0.9 hours.

At Dryden, while conducting a 300-hour inspection, the operator found evidence of an oil leak in the engine compartment. While assessing the leak source, he pulled and re-installed the turbine, and conducted several extended ground runs. The leak was eventually rectified by replacement of a free-wheeling unit. The helicopter had flown less than 14 hours since the turbine inspection, and approximately one hour since the scavenge strut had been cleaned and the engine oil replaced. Therefore, the operator did not conduct a scavenge flow test and did not accomplish the 300-hour inspection items involving the cleaning of the 6/7 bearing pressure-oil and scavenge-oil components.

A review of the inspection and cleaning procedures for the tee-fitting indicated that existing published procedures for inspection and overhaul may not ensure adequate cleaning of carbon build-up in the area of the recess inside the base of the pressure oil tee-fitting. Immersion in an alkaline bath during overhaul and reaming the outflow passage with a drill bit during field cleaning may not ensure that all carbon is removed. Carbon build-up in the base of the tee-fitting is difficult to inspect because it faces away from the inspection access -- the outflow port at the bottom of the tee fitting -- and current inspection procedures do not outline how to access the hidden area to confirm that the area is clear of carbon.

The engine manufacturer indicates that, even if coke/carbon does form in the tee-fitting passage, the design of the standpipe, with its laterally drilled inlet holes, and the proper accomplishment of the inspection procedures as outlined in the maintenance and overhaul manuals should prevent carbon build-up and subsequent inlet blockage. The manufacturer states that a review of the failure history for the 250-C20 series engines does not indicate an inherent design problem. The manufacturer attributes no failures to clogged inlet holes of the pressure oil nozzle on the existing 14,400 engines that have accumulated a total flight time of 60,200,000 hours. The manufacturer estimates that an engine would fail within five minutes or less if its 6/7 bearing pressure oil nozzle became blocked.

TSB investigators inspected a sample of four turbines in "as-received" condition at an independent overhaul facility. In three of the four turbines, carbon build-up was confirmed inside the base of the tee-fittings. The three turbines that displayed carbon build-up in the tee-
fitting had been in service for 1,000 hours or more since their last overhaul. The fourth turbine had been in service less than 500 hours since overhaul. The 6/7 bearing pressure oil nozzles in all four sampled turbines were clear of obstruction.

**Analysis**

There was substantial heat damage in the engine that indicated there was no oil flow beyond the 6/7 bearing pressure oil nozzle. The bearings had run dry, and there was slight carbon residue in the scavenge strut and sump; however, no ferrous material had been transported downstream to the magnetic chip detectors. This indicates that the engine failure occurred as a result of restricted oil flow from a complete blockage, rather than a partial blockage of the 6/7 bearing pressure oil nozzle.

The design of the tee-fitting and standpipe assembly is conducive to the formation of carbon between the inner wall of the tee-fitting and the standpipe of the 6/7 bearing pressure oil nozzle, where oil becomes trapped. A hard carbon deposit had built up in this area of the tee-fitting. The carbon build-up was considered excessive for the hours of operation since the completion of the heavy maintenance inspection.

The carbon particle which blocked the 6/7 bearing pressure oil nozzle displayed characteristics similar to the composition of the carbon that had formed inside the base of the tee-fitting, and the particle had a uniform curved surface that compared with the inside diameter of the tee-fitting wall. Therefore, it is likely that the carbon originated in the tee-fitting, then broke loose and moved to block the nozzle. Although the manufacturer's data indicate that build-up of carbon in this area has not previously resulted in engine failure, it is concluded that it likely did in this case.

An inspection of pressure oil connector tee-fittings from four independent turbines revealed that carbon deposits had formed in the base of three of the four tee-fittings. The three tee-fittings had been in service for 1,000 hours or more; therefore, they would have been subjected to the drill-cleaning procedures outlined in the manufacturer's 300-hour inspection three or more times.

The current inspection and cleaning instructions may not ensure complete removal of carbon from the recessed area inside the base of the tee-fitting. Solvents may not dissolve all carbon, and reaming of the outflow port with a hand-held drill bit will not reach the area that needs to be cleaned. Considering the degree of carbon build-up in the base of the tee-fitting and the short operating time since accomplishment of the DIL 155 inspection, it is probable that the carbon was not fully removed during the overhaul process.

The following Engineering Branch reports were completed:

LP 103/95 - Engine Examination; and
LP 106/95 - Oil Sample Analysis.
Findings

1. The engine began making smoke 12.8 flight hours after the overhauler completed a turbine heavy maintenance (DIL 155) inspection/overhaul.

2. The overhauler and the operator's apprentice replaced the number 5 carbon seal, removed carbon from the scavenge strut and from the scavenge sump, and motored the engine to ensure that adequate oil flow was provided to the sump, but did not remove and clean the 6/7 oil pressure nozzle and tee-fitting as specified in the manufacturer’s Operating and Maintenance Manual.

3. The turbine had been overhauled less than 14 flight-hours earlier, and the scavenge strut had been cleaned within the last flight-hour. The operator did not complete a power turbine scavenge flow test and did not remove and clean the pressure oil and scavenge components, as outlined in the 300-hour inspection procedures.

4. A build-up of hard carbon in the tee-fitting of this engine was considered excessive for the hours of operation since the completion of the heavy maintenance inspection. It is probable that the carbon was not fully removed during the overhaul process.

5. A particle of carbon blocked the 6/7 bearing pressure oil nozzle, and the engine failed as a result of the lack of lubrication and the excessive heat damage in the vicinity of the number 6 and number 7 bearings.

6. It is likely that the hard carbon that blocked the oil flow originated in the tee-fitting.

7. The design of the tee-fitting and standpipe assembly is conducive to the formation of carbon in an area between the inner wall of the tee-fitting and the 6/7 bearing pressure oil nozzle.

8. The manufacturer's procedures do not specifically identify the area within the base of the tee-fitting in which carbon builds, nor do the procedures identify how to inspect this area that is hidden from view.

9. Tee-fittings from three of four independent turbines that were inspected had developed carbon deposits in the base of the tee-fittings, although they would have been subject to cleaning three or more times during 300-hour inspections.

Causes and Contributing Factors

The engine failed in flight because of a lack of lubrication to the number 6 and 7 bearings when a carbon particle blocked the 6/7 bearing pressure oil nozzle. Contributing to the presence of the carbon build-up were the following: a tee-fitting and standpipe design that is conducive to carbon accumulation; a manufacturer's cleaning procedure that does not completely describe the carbon inspection and removal process; inadequate cleaning of the tee fitting during component overhaul; and incomplete cleaning during two subsequent field inspections.
Safety Action

An Aviation Safety Information letter was sent to TC outlining the particulars of the carbon build-up inside the base of the pressure oil tee-fitting as identified during this investigation.

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.

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 Frozen Lake
Eagle Air Services
Piper PA-31-325 Navajo C-GOLM
Wollaston Lake, Saskatchewan 1 nm NE
25 November 1995

Report Number A95C0250

Synopsis

The medical evacuation (MEDEVAC) flight departed Wollaston Lake, Saskatchewan, at 2325 central standard time en route to La Ronge. After take-off, the aircraft turned about 70 degrees to the left, descended, and struck the frozen surface of Wollaston Lake. The pilot and the patient suffered serious injuries; the other two occupants suffered minor injuries. The aircraft was destroyed.

The Board determined that, after take-off, the left propeller was likely on its start locks, which, as the airspeed increased, allowed the propeller to overspeed. The pilot was unable to resolve the situation in time to prevent the aircraft from striking the surface of Wollaston Lake. Contributing to the severity of the patient’s injuries were the inadequate restraint provided by the stretcher and its restraining strap, the lack of standards regarding stretchers used in aircraft, and the lack of standards as to the operation of MEDEVAC flights.

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1.0 Factual Information

1.1 History of the Flight

The Eagle Air Services Piper PA-31-325 Navajo, C-GOLM, departed runway 34 at Wollaston Lake, Saskatchewan, at 2325 central standard time (CST)\(^1\), on a medical evacuation (MEDEVAC)\(^2\) flight to La Ronge. The flight was arranged by the Wollaston nursing station to transport a patient to a hospital in La Ronge. The patient was accompanied on the flight by her mother and a nurse from the nursing station.

The aircraft was observed to climb at an unusually shallow angle after take-off, and, when efforts by company personnel to reach the pilot by radio were unsuccessful, a ground search was commenced. The aircraft was found about five minutes after the accident, located on the ice- and snow-covered surface of Wollaston Lake, about 0.75 nautical miles (nm) from the departure end of the runway, and about 1.3 nm from the point of commencement of the take-off roll\(^3\).

The pilot and the patient suffered serious injuries. The other two occupants sustained minor injuries. The accident occurred during the hours of darkness at latitude 58°6.98'N, longitude 103°10.79'W, at an elevation of 1,300 feet above sea level (asl). The temperature was about -25°C.
1.2 Injuries to Persons

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<td>3</td>
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</table>

1.3 Damage to Aircraft

The aircraft was destroyed by the impact with the snow and ice, but the main cabin section maintained its structural integrity.

1.4 Other Damage

There was no other collateral damage.

1.5 Personnel Information

Pilot

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<th>Age</th>
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1.6 Aircraft Information

Manufacturer: Piper Aircraft Corporation

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<tr>
<td>Year of Manufacture</td>
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<tr>
<td>Serial Number</td>
<td>317712050</td>
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<tr>
<td>Certificate of Airworthiness</td>
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(Flight Permit)

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<th>Total Airframe Time</th>
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<tr>
<td>Engine Type (number of)</td>
<td>Left - Lycoming TIO-540 F2BD (1) Right - Lycoming LTIO-540 F2BD (1)</td>
</tr>
<tr>
<td>Propeller Type (number of)</td>
<td>Left - Hartzell HC-E3YR-2ATF (1)</td>
</tr>
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</table>
The aircraft's maintenance records indicate that the aircraft was certified and maintained in accordance with existing regulations and approved procedures.

1.7 Meteorological Information

There is no Atmospheric Environment Service (AES) weather reporting station at Wollaston Lake. The nearest such station is at Lynn Lake, Manitoba, 103 nm southeast of Wollaston Lake. The 2300 weather report for Lynn Lake indicated high thin scattered cloud, visibility 15 miles, temperature -22°C, and winds 300° at nine knots. Witnesses indicate that the weather at Wollaston Lake at the time of the accident was sky clear, visibility unrestricted, temperature about -25°C, and winds northwest at about 10 knots.

1.8 Witness Reports

The aircraft was stored outdoors for about 23 hours before the flight. Between flights, an automotive-type electric heater was placed in the cabin. The heater was removed by the pilot when he arrived at the airport, about 20 minutes before the time of departure. After completing his pre-flight inspection, the pilot started and completed the aircraft run-up checks; he noted no abnormalities in the engines or propellers. He shut down the aircraft to refuel, then restarted the engines to position the aircraft in front of the operator's office in preparation for passenger loading. No heat was supplied to the aircraft's cabin from the time the interior heater was removed until the pilot selected the aircraft's combustion heaters on after take-off. There was no evidence of a fuel leak from any part of the aircraft before its departure. The pilot reported that, as a matter of personal preference, he set the aircraft's elevator trim so that the control column required a slight amount of back pressure to maintain level flight.

The pilot reported that the aircraft's handling and performance was normal during the take-off roll and that he switched on the two combustion heaters immediately after lift-off. Immediately after switching on the heaters, the pilot perceived that the aircraft's engines were no longer running in synchronization, and he believed that there was an engine problem and a possible loss of engine power. There was insufficient yaw effect to indicate which engine was affected, or to indicate the nature of the problem. The pilot reportedly confirmed by reference to the aircraft's instruments that the aircraft was maintaining the runway heading of 340°, a pitch attitude of 9° nose-up, and an airspeed of 115 knots. He then confirmed that the engine and propeller controls were fully forward, re-checked the aircraft attitude, and then felt the aircraft's impact with the surface of Wollaston Lake. The pilot estimated that the aircraft was airborne for about four seconds.

Witnesses on the ground observed that the aircraft lifted off the runway after a ground run somewhat longer than previous ground runs of that aircraft. No abnormal sounds were noted during the ground roll. After lift-off, the aircraft's angle of climb was observed to be shallower than normal. The aircraft reportedly attained an altitude of about 100 feet above ground level (agl), turned to the left, and disappeared from the view of observers.

One of the passengers in the aircraft reported that, just before the impact with the lake, sparks, an arcing sound, and an electrical smell came from the cockpit area in front of
the pilot.

1.9 Wreckage and Impact Information

The wreckage trail was about 450 feet long. The impact marks indicate that the aircraft struck the lake surface on a heading of about 270°, in a left bank, and slightly nose down. The aircraft came to rest in an inverted position.

The left wing, complete with engine, was found in front of the main wreckage and had been completely severed from the fuselage. The main spar of this wing broke at the fuselage, and both forward and rear wing-to-fuselage attachment points failed in overload. The wing was also severed at the mid-point between the engine and the wing tip, with only the aileron cable connecting the two sections. Damage to the left nacelle indicated that the engine assembly had been pushed upward and rearward at impact.

The rear attachment point of the right wing had also failed in overload, and the outer portion of this wing was bent downward approximately 20 degrees, thereby rupturing the fuel tanks.

Both propellers had become detached from their respective engines; however, the left propeller had sustained more severe damage. In addition to having more severely bent and twisted blades, the left propeller broke apart in the spider area, thereby allowing one blade to become completely detached from the hub.

The nose cone, radome, and main battery were torn from the forward fuselage as the nose structure was forced upward and to the right, thereby crushing the cockpit area, predominantly on the right side. All occupied seats remained in their respective seat rails. Several electrical panels and buses were broken and detached from their mounts. Electrical sparks and arcing sounds and smells may emanate from electrical equipment if it is damaged while under electrical load.

The nose baggage door was found about 150 feet from the point of initial impact, and along the centre line of the wreckage trail. The overall damage patterns, the latch status, and the position of the door along the wreckage trail indicate that the door was closed and locked at impact.

At impact, the aircraft was configured with the gear up, flaps up, and all throttle, mixture, and propeller controls fully forward. The fuel selectors were found in the main tank positions while the fuel shut-offs were in the open position.

All flight control surfaces were accounted for and control continuity was established. A detailed examination of the airframe revealed no evidence of pre-impact structural failure.

1.10 Fire

After the aircraft struck the ice, a small fuel-fed fire started in the turbocharger area of the right engine. The fire was extinguished by persons from the community who arrived at the scene after the occurrence.

Both forward and rear combustion heaters were examined and no evidence of fire or pre-impact failure was found.

1.11 Tests and Examination

The engines were removed from the accident site and transported to the TSB regional
wreckage examination facility in Winnipeg, Manitoba. During the preparation of the left engine for a test run, the engine-driven fuel pump was found to have a significant fuel leak at the rear cover of the pump body. This leak occurred under gravity fuel pressure before the engine was run, and was attributed to a hardened O-ring and a slight warping of the cover plate. The extent of the fuel leak and the evidence found at the accident site indicates that the unserviceability of the fuel pump occurred after the accident. The engine was test run and was found to operate within normal parameters with the exception of a slightly rich fuel mixture.

The right engine was not test run, because of the damage it had sustained. The engine was torn down, and all damage found was attributable to overload, impact forces, or heat from the post-crash fire. No pre-existing mechanical faults were revealed which would have contributed to a loss in engine power.

The propeller governors were tested, disassembled, and inspected, and both units were found to be functional and operating within accepted parameters.

Both propellers were sent to the manufacturer for further investigation. Examination of the left propeller revealed that both start lock stop pins were broken, and that the related area of the high pitch stop sleeve was damaged. The damage signatures and captured blade angles indicate that the engine was rotating and producing high power on impact. The nature of the damage indicated that the start locks were probably engaged and that the left propeller pitch was at its start lock position at the time of impact. This is not normal, and it was not determined why the start lock could have been engaged at the time of impact.

The right propeller did not sustain damage to the start locks. The blades showed a distinct power-on twist, although not to such an extent as the left propeller blades. Early separation of the propeller from the engine may have limited the power-on twist signatures of the right propeller blades.

On the ground, when the engine is idling, the propeller is on the low pitch stop of 13.2°. During shutdown, as the propeller rpm decreases below 800, spring pressure overcomes centrifugal force and the start locks engage. The propeller blades then are free to coarsen by the action of the propeller feathering springs, from the low pitch stop of 13.2° to a point of between 17.2 and 20.2°, at which point the start locks prevent further movement. After start up, the blades are driven towards the low pitch stop as oil pressure in the cylinder increases, thereby releasing pressure on the start locks. When the propeller rotation rises above 800 rpm, centrifugal force overcomes the spring pressure, extends the start lock pins, and moves them to an outward or retracted position. When the pins are retracted, the propeller blades are free to move throughout their full range of travel. The purpose of the start locks is to prevent the propeller from moving to the feather position after the engine is shut down, so as to reduce drag on the starter during engine start. An engaged start lock pin or pins would allow for blade angle travel between the low pitch stop position of 13.2° and the start lock position (17.2° to 20.2°). A propeller with a blade angle at the start lock position will overspeed at certain combinations of engine power and aircraft speed.

The cockpit section of the aircraft, complete with the intact instrument panels, was shipped to the TSB Engineering Branch for further examination. Examination did not reveal any evidence of failure that might have resulted in electrical arcing prior to the impact. The engine and flight instruments were examined in an attempt to determine their indications at the time of impact; however, no useful information was found.

The vacuum-driven attitude indicator was refrigerated for two days at a temperature of -
25°C; it was then placed on a test bench and vacuum was applied to it. After a three-minute run-up, the indicator stabilized and performed to normal specifications. The background reference horizon and the white "lubber line" mark on the surrounding material and the adjustable aircraft symbol (which had not been adjusted after the occurrence) all coincided to indicate zero degrees of pitch.

1.12 Performance Issues

The maximum allowable take-off weight of the aircraft was 6,500 pounds. The take-off weight of the aircraft was determined to be about 5,800 pounds, and the centre of gravity was within the prescribed limits.

According to the aircraft's Pilot's Operating Handbook (POH), the aircraft's maximum rate of climb under the ambient conditions, with both engines operating, would have been 1,370 feet per minute (fpm). With one engine operating and the propeller of the other engine feathered, the maximum rate of climb would be about 410 fpm. According to the aircraft manufacturer, with one engine operating and the propeller of the other engine windmilling, the maximum rate of climb would be under 200 fpm, and if the aircraft were allowed to turn in the direction of the failed engine, the rate of climb would be nil.

Maximum climb performance is available only at the aircraft's best rate of climb airspeed. The performance section of the POH lists the best single-engine rate of climb airspeed under the occurrence conditions as 94 knots. The emergency procedures section of the POH indicates that in the event of an engine failure during climb, the pilot should maintain 97 knots. Deviation from the aircraft's best rate of climb airspeed will reduce climb performance.

According to the aircraft manufacturer's flight test data, at the accident aircraft's take-off weight, and at a pitch angle of 2.53°, a constant airspeed of 115 knots will result in level flight, regardless of engine power. At pitch angles of more than 2.53°, at 115 knots, the aircraft will climb, and at pitch angles of less than 2.53°, at 115 knots, the aircraft will descend.

Calculations show that the length of the aircraft's flight path was about 6,000 feet, and at an average speed of 115 knots, the flight would have taken about 30 seconds. If the aircraft began turning as it passed over the departure end of the runway, then the average angle of bank required for the aircraft to reach the crash site would have been about 19°.

An overspeeding propeller may produce reduced thrust, even though the engine may be producing power, if the blade angle is so fine that the propeller blade is not operating at a positive angle of attack. In that condition, the engine power would drive the propeller to a high rotational speed where the propeller tips exceed the speed of sound, and sonic drag absorbs some of the engine's power. The overspeeding propeller produces less drag than a windmilling propeller, and may produce thrust or drag, depending on propeller rpm and the aircraft's airspeed. The propeller manufacturer estimates that, in this case, if the propeller was on its start locks, it would have produced net thrust at all airspeeds up to and including 180 knots.

1.13 Aerodrome Information

The aerodrome elevation is 1,360 feet, about 60 feet above the elevation of the crash site on Wollaston Lake. The aerodrome is situated on the western edge of the settlement; therefore, after a night take-off on runway 34, there would be few lights visible to the pilot to use for visual reference.
1.14 Flight Recorders

The aircraft was not equipped with either a flight data recorder or a cockpit voice recorder, nor was either required by regulation.

1.15 Aircraft Equipment

The aircraft was normally equipped with seats for ambulatory passengers. For the occurrence flight, the seat backs were folded down and a stretcher from the Wollaston Lake nursing station, on which the patient was carried, was strapped on top of the seats, using the aircraft's seat-belts. The stretcher was an ABCO AF604 model, constructed of aluminum tubing and nylon cloth, incorporating two lateral restraint straps with an automotive-type buckle. There were no straps or other methods of restraint attached to the stretcher to prevent the forward movement of a stretcher occupant during deceleration. The aircraft's seat-belts restrained only the stretcher, and did not extend to the patient. The patient was positioned on her back with her head toward the front of the aircraft.

Air Navigation Order Series II, No. 2, provides that a passenger may be carried in a stretcher on an aircraft, provided the stretcher installation system is approved by Transport Canada.

An aircraft's stretcher installation system usually comprises a rack or other structure which attaches to hard points in the aircraft cabin and whose upper surface accommodates and secures a stretcher. An approved stretcher installation system may incorporate passenger restraint belts, but they are not mandatory. Transport Canada guidelines indicate that stretchers, aside from their installation systems, are not considered part of the aircraft and do not require approval prior to use in aircraft. Road stretchers are considered acceptable. The operator did not have approval to use the aircraft seats as a stretcher rack or stretcher installation system.

1.16 Training

The operator's Transport Canada approved syllabus requires the following training:

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<tr>
<th>Training</th>
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<th>Recurrent</th>
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<tr>
<td>Aircraft ground training</td>
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<td>Surface contamination</td>
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<td>Emergency procedures</td>
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<tr>
<td>Aircraft flight training</td>
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</table>

Amendment No. 7 to the syllabus provides that: "Captains with more than 50 hours on ME [multi-engine] aircraft with a current PPC need only complete the Recurrent Training."
The operator's records indicate that the pilot completed the initial training as required by the training syllabus.

The pilot's previous employer operated the Piper PA-31 and PA-34 aircraft types and had authority from Transport Canada to group those two aircraft types for the purpose of pilot proficiency checks (PPC). The effect of such grouping is that a pilot may complete a PPC on each aircraft type in alternate years and retain PPC certification on both types, provided that the required recurrent ground training is completed. The pilot completed a PPC on the PA-31 type in July 1994. He completed a PPC on the PA-34 type in August 1995, and flew the PA-31 type at Eagle Air Services. A pilot's PPC remains current for one year from the end of the month in which the check is completed. When the pilot took up his employment
with Eagle Air Services, he completed the required ground training and in each area of study completed the training to initial training standards, but he did not complete another PPC. Transport Canada’s policy is that, after a change of the pilot’s employment, a PPC which is renewed by an operator’s grouping authority is only considered current if the new employer has an equivalent grouping authority. At the time of the occurrence, Eagle Air Services operated the PA-31 and not the PA-34, and did not have authority to group them. The operator reported that the regional Transport Canada, Air Carrier section was consulted at the time the pilot was hired, and that the operator was verbally advised that the pilot’s existing PPC would remain valid despite his change of employment, provided the required company training was completed. Grouping authority is reportedly issued on request for most multi-engine aircraft types with maximum allowable take-off weights under 7,000 pounds.

The pilot’s instrument rating was renewed in August 1995 and was valid until 01 September 1997.

Aircraft systems do not allow a propeller overspeed at take-off power to be readily demonstrated or simulated during training. Training on a flight simulator is the only effective way to train for a propeller overspeed emergency at take-off. A simulator is not available for the PA-31 aircraft type. The cockpit indication of a propeller overspeed is a higher-than-normal propeller rpm. The engine manifold pressure and the other engine indications may match those of a normal engine. The differential rudder pressure required to maintain directional control will probably be less than that required in the event of an engine failure, a condition which is commonly simulated during training. There is no direct cockpit warning of a propeller with start locks engaged.

Normal pre-take-off procedures require that a propeller check be performed to ensure that the propeller blades will move towards the feather position. The pilot reportedly completed this check during his aircraft run-up checks. The check can be accomplished within the range of propeller blade angle movement which is allowed by a stuck start lock.

1.17 Pilot Workload

Pilot workload and stress is at a peak during and shortly after take-off, particularly during single-pilot operations in instrument meteorological conditions. The pilot must adjust rapidly from visual to instrument conditions, and manage the aircraft systems to establish an angle and rate of climb to ensure a safe departure. Pilot workload and stress can be compounded by aircraft emergencies, adverse environmental conditions, and by concerns about passenger condition and comfort. Persons operating under conditions of high workload and stress can become task-saturated or overloaded, and may channelize their attention, concentrating on some tasks at the expense of others.

1.18 Survival Aspects

Nurses from the Wollaston nursing station are required to accompany patients on MEDEVAC flights, and the flight crews expect the nurses to secure patients to the stretchers on MEDEVAC flights. The nurses receive no specific training as to patient care techniques or passenger restraint on board a MEDEVAC aircraft, nor is such training required by regulation.

No pre-flight passenger briefing was provided by the pilot. The pilot believed that the passengers and nurse had flown with the operator before, that the nurse was well-versed on patient restraint issues, and that she would handle patient restraint tasks. In fact, the nurse had only arrived at Wollaston the previous day. When the pilot asked if passengers
were restrained, he was told that they were. Air Navigation Order VII, No. 3 requires air operators to provide pre-flight passenger briefings to passengers. The captain of an aircraft has the ultimate authority and responsibility for passenger security.

The MEDEVAC was being conducted because of the patient's problems with her pregnancy. The pilot and the nurse were reluctant to restrain the patient over the abdomen, fearing that injury to the fetus might result from doing so. The nurse placed one restraining strap over the patient's lower torso. On impact, the patient's stretcher remained attached to the aircraft's seats, but the patient was thrown from the stretcher and struck the aircraft's interior and interior furnishings. She suffered a serious spinal injury. There was no injury to the fetus.

1.19 MEDEVAC Standards

Several provinces set standards as to the medical evacuation of patients by air. The provinces of Ontario and Manitoba, for example, have legislation and regulations which require operators to meet certain, but differing, standards involving aircraft, passenger restraint, aero-medical equipment, ground facilities, and personnel training before conducting MEDEVAC flights. Operators who wish to organize flights for the provincial governments are required to meet the provincial standards. However, the standards are not imposed by the provinces on all operators who offer MEDEVAC flights. The standards are reportedly difficult to enforce in situations where the MEDEVAC flight is arranged or paid for by an organization other than an agency of the respective provincial government.

The occurrence flight was arranged by the Wollaston nursing station, an agency of Health Canada. Most Canadian aviation operation is regulated by the Government of Canada. There are no federal regulations requiring specific training for flight nurses accompanying patients on MEDEVAC flights.

2.0 Analysis

2.1 Flight Path

The pilot estimated the total flight time to have been about four seconds, and reported that he maintained the runway heading of 340° during the flight. However, the location of the wreckage indicates that, at the reported airspeed of 115 knots, the flight time was about 30 seconds, and the orientation of the wreckage trail indicates that the aircraft turned left through about 70° during that time.

2.2 Accident Sequence

Extensive examination revealed no evidence of cockpit electrical malfunctions or short circuits preceding the aircraft's impact with Wollaston Lake. Given the damage to the aircraft's electrical equipment and the tendency of electrical equipment to emit sparks and arcing sounds and smells during such damage, it is likely that the sparks and arcing sounds and smells reported by a passenger occurred during, rather than before, the impact sequence.

2.3 Engine and Propeller Status

Both propellers were rotating and both engines were producing power at the time of impact. However, it is likely that the left propeller start lock was engaged at the time of impact, and that the left propeller was restricted to the start lock position during the take-off sequence. There is no warning of the improper operation of the start locks that is evident to the pilot before the take-off roll. Because the propeller with the start locks
engaged can absorb the engine's power at the beginning of the take-off roll, no abnormal engine or propeller indication would have been evident to the pilot until lift-off. At that time, increasing airspeed and the propeller's restricted range of pitch probably allowed the engine to go into an overspeed condition, where some of the engine's power was absorbed by propeller drag instead of being converted into thrust.

Because of the range of propeller pitch change possible with the start lock engaged, the pilot's pre-flight check might not reveal the left engine's stuck start lock condition.

2.4 Aircraft Performance

The aircraft manufacturer's data indicates that, with the right engine at take-off power, the aircraft was marginally capable of flight in the worst-case scenario: that is, with the left engine inoperative and the propeller windmilling. Although it is likely that the left engine was in an overspeed condition and producing little or no thrust, its engine and propeller were probably producing less drag than a windmilling propeller, and the aircraft should, therefore, have been capable of maintaining its altitude with right engine power after the left engine went into overspeed. However, the aircraft was allowed to turn, and, therefore, may not have been able to maintain its altitude. Because the runway was higher in elevation than the lake, no immediate climb was required.

The airspeed which the pilot reportedly maintained after take-off, 115 knots, was 18 knots higher than the emergency single-engine climb speed listed in the POH. Because maximum climb performance is available only at the best single-engine rate of climb airspeed (94 knots under the occurrence conditions), flying at an airspeed above 94 knots reduces the aircraft's available climb performance. Both engines were producing power, but, because the aircraft's climb angle was shallow, much of the engine power was initially converted to airspeed. Because the left engine was likely on its start locks, the increasing airspeed probably allowed the left engine rpm to increase to the point where some of its power was absorbed by propeller drag and not converted to thrust. The increasing rpm presented the pilot with an indication of a malfunction in one of the aircraft's powerplants. Because the cockpit indications of the malfunction were subtle, and propeller overspeed on take-off is difficult to simulate in training, the pilot probably became task saturated and was unable to readily resolve the situation.

2.5 Crew Issues

The pilot ground and flight training completed after the pilot's arrival at Eagle Air Services was done to "initial training" standards, but no PPC ride was done. Therefore, although the pilot's PPC on the accident aircraft type was current for both the PA-31 and PA-34 aircraft types while he was with his previous employer, and would have remained current there until 31 August 1996, it was not, according to Transport Canada policy, current at Eagle Air Services. However, the operator reportedly received verbal advice that the grouped PPC would remain in effect, and relying on that advice, did not schedule a new PPC for the pilot. Because he flew the PA-31 type at Eagle Air Services, the pilot maintained the continuity of his PA-31 flying from the time of his change of employment to the time of the occurrence.

The engine overspeed emergency faced by the pilot just after take-off was subtle and difficult to analyze, because the engine sounds and cockpit and engine indications would not have been as dramatic as those of an engine failure. Because of the limited thrust still being produced by the left engine, the rudder pressure required to maintain directional control would not have been as great as the pilot would have experienced during engine failure demonstrations during his training. As well, the pilot's elevator trim setting procedure required that he apply a slight amount of back pressure to the controls to
maintain level flight. This may have added to the pilot's workload during the occurrence.

Manufacturer's flight test data indicate that if the pilot had maintained his reported airspeed of 115 knots and wings-level, 9° nose-up attitude, the aircraft should have climbed. However, the aircraft turned, and descended and struck the lake's surface in a different attitude. The pilot's reported perceptions, therefore, differ significantly from the physical evidence. Shortly after take-off, the pilot was confronted with a confusing aircraft emergency under adverse operational and environmental conditions. In this situation, the difference between the pilot's perceptions of the flight and reality indicate that the pilot probably became overloaded and his attention became channelized, and he was unable to prevent the aircraft from striking the surface.

2.6 Patient Restraint

Though the operator did not have Transport Canada approval to use the aircraft's seat-belts to secure the stretcher, the stretcher remained secured during the occurrence, and the method of stretcher installation, therefore, did not contribute to the patient's injuries.

The patient's one restraining strap, which was part of the stretcher accompanying her from the nursing station, was insufficient to secure her to the stretcher during the impact sequence. Because Transport Canada does not consider patient stretchers to be part of the aircraft in which they are used, they are not regulated, and neither their materials nor their construction are required to conform to aircraft standards.

2.7 MEDEVAC Standards

Although the nurses from the Wollaston nursing station were required to attend to patients' medical needs on MEDEVAC flights and ensure that patients were secured to their stretchers in flight, they had no training in MEDEVAC operations, nor is any such training required by federal aviation regulation.

A number of provinces have standards for the operation of MEDEVAC flights, but the standards are only selectively enforced. Because most aviation is federally regulated, provinces have difficulty enforcing their regulations when the MEDEVAC flight is not arranged by a provincial agency. Because many MEDEVAC flights from remote areas are arranged by a federal agency, provincial regulations governing MEDEVAC flights are often not observed.

3.0 Conclusions

3.1 Findings

1. The aircraft was airborne for about 30 seconds after departure from runway 34 at Wollaston Lake airport and, during that time, completed a left turn of about 70°.

2. It is likely that the sparks and electrical arcing sounds and smells reported by a passenger in the aircraft occurred during, rather than before, the impact sequence.

3. The pilot did not complete a PPC on the accident aircraft type within the 12 months before the occurrence, but Transport Canada reportedly advised the operator verbally that the pilot's PPC would continue in effect.

4. The left propeller probably became fixed at the start lock position during the take-off acceleration phase, and went into an overspeed condition as the airspeed increased after lift-off.
5. In the overspeed condition, some of the left engine's power was absorbed by propeller drag and was not converted to thrust.

6. The cockpit indications of a propeller overspeed at take-off cannot readily be simulated in training, and are more subtle than those of an engine failure.

7. The pilot probably became task saturated while attempting to determine the cause of the propeller overspeed, and his attention became channelized.

8. The pilot did not provide a pre-flight briefing to the passengers before take-off.

9. The operator's method of securing the stretcher to the aircraft, though unapproved, did not contribute to the patient's injuries.

10. The restraining strap on the stretcher provided for the patient was insufficient to secure her to the stretcher during the impact sequence.

11. The design and security of stretchers used in aircraft are not regulated by Transport Canada, and are not required to conform to aircraft standards.

12. The company operations manual and company training programs contained no direction as to air ambulance operational procedures.

13. There are no federal aviation standards as to aircraft, equipment, or personnel training specifically for the operation of MEDEVAC flights.

14. Provincial regulations covering MEDEVAC operations are difficult to enforce where a MEDEVAC flight is not arranged by a provincial agency.

3.2 Causes

After take-off, the left propeller was likely on its start locks, which, as the airspeed increased, allowed the propeller to overspeed. The pilot was unable to resolve the situation in time to prevent the aircraft from striking the surface of Wollaston Lake. Contributing to the severity of the patient's injuries were the inadequate restraint provided by the stretcher and its restraining strap, the lack of standards regarding stretchers used in aircraft, and the lack of standards as to the operation of MEDEVAC flights.

4.0 Safety Action

4.1 Action Taken

4.1.1 Stretcher Installations and Patient Restraints

During this investigation, it became evident that the Air Navigation Order (ANO) concerning the installation of a stretcher, incubator, or similar device in an aircraft (ANO Series II, No. 2, subsection 4(2)) was open to different interpretations. The ambiguity could have resulted in the approval of an installation which negated the airworthiness of both the device (e.g., stretcher) and patient restraint. This shortfall has been redressed by Canadian Aviation Regulations (CAR) subsection 605.23, which states that each person carried on a stretcher, in an incubator, or other similar device must be provided with a "restraint system." Such a "restraint system," under the provisions of CAR 605.06, Aircraft Equipment Standards and Serviceability, must meet applicable standards of airworthiness (i.e., the equipment and its installation must be approved by Transport Canada).

Additionally, Transport Canada (TC) has taken action to update its air ambulance-related
publications (Guide to Air Ambulance Operations, TP 10839E and Stretcher Installation in Aircraft, ASI 32) to reflect the changes brought about by the introduction of the CARs.

4.1.2 Dissemination of Information

The Board believes that those agencies involved in contracting for air ambulance services should be made aware of the safety issues identified during this investigation. As such, the final report on this occurrence investigation is being distributed to the appropriate authorities in the federal government as well as all provincial and territorial governments.

4.2 Action Required

4.2.1 Regulatory Overview of Air Ambulance Operations

The term "air ambulance operations" refers to the transport of medical patients by air. The missions can range from a straightforward patient transfer to an emergency medical evacuation (MEDEVAC). At present, air ambulance operations are considered by TC to be a commercial air service and as such are governed by Part VII of the CARs. The granting of an Air Operator Certificate, which allows for the transport of fare-paying passengers, also permits the operator to adapt the operation for an air ambulance service. The CARs contain no specific reference to or standards with respect to the conduct of air ambulance operations, and conducting such a service does not require an amendment to the Operations Specification. As such, TC might not be aware that an operator is conducting an air ambulance service and, therefore, might not include aspects specific to air ambulance operations in any TC audit and surveillance of the operator.

TC currently relies on operators to voluntarily make the necessary changes to aircrew training and operational procedures, and to seek TC airworthiness approval of equipment installations before offering air ambulance service to the public. However, in this occurrence, the operator was conducting an air ambulance service without a TC-approved stretcher installation, additional aircrew training, and amended manuals to reflect specific air ambulance procedures.

As noted earlier, several provinces have set standards for aircraft, passenger restraints, aero-medical equipment, ground facilities, and personnel training. However, these standards are reportedly difficult to enforce in situations where the flight is arranged or paid for by an organization other than an agency of the respective provincial government.

As recognized in Transport Canada's air ambulance guidance documents and in the efforts by some provincial governments to regulate the air ambulance services in their respective provinces, the provision of consistently safe air ambulance service requires equipment, training, and procedures considerably different from those required for regular passenger-carrying operations. The Board understands that in other occurrences (e.g., TSB A8900280), patient safety has been compromised by inadequate protective measures (vis-à-vis those afforded a normal passenger). Notwithstanding measures taken by some provinces to enhance patient safety in air ambulance operations, the Board believes that a consistent level of safety across Canada will not be attained through voluntary measures. Crews and patients will remain at risk to the extent that patients are transported with inappropriate equipment or by crews that have not been adequately trained in meeting the special needs of non-ambulatory medical patients. Therefore, the Board recommends that:

The Department of Transport require all air carriers operating air ambulance services in the course of their business to provide the equipment, procedures, and crew training.
necessary to ensure a level of safety for patients consistent with that provided by commercial air services to fare-paying passengers.

A97-01

4.3 Safety Concern

The Board is concerned that the continuing involvement of MEDEVAC and air ambulance flights in accidents is disproportionate to the activity rate. Too often, patients become victims of air accidents, as in this accident.

In a previous occurrence report involving a MEDEVAC, the Board wrote:

Between 1976 and 1994, there were 38 occurrences involving aircraft engaged in air ambulance or medical evacuation flights. Fifteen of these accidents took place in Canada’s designated North.... Twenty-one of the MEDEVAC accidents occurred during VFR flights, and 18 occurred on dark nights (i.e. notwithstanding reported flight visibility conditions, the absence of ambient lighting, either from surrounding built-up areas or from the moon, created extra problems for conducting flight by visual outside reference). Twelve of the 38 MEDEVAC accidents were CFIT [controlled flight into terrain] accidents, which occurred at night.

This accident at Kuujjuaq underlines the Board’s earlier concern in that MEDEVAC flights may be conducted on an ad hoc basis without operators having met any particular standards for conducting such flights in the harsh physical environment of the Arctic. (TSB A94Q0182)

This accident at Wollaston Lake also raises questions as to the adequacy of the regulatory oversight for the maintenance of safety standards for air ambulance operations.

Although this accident involved a commercial air service, approximately 12% of air ambulance occurrences involve "State-owned" aircraft, usually on behalf of a provincial government. The Board has previously made observations on the different level of safety that is required for such state-owned operations, vis à vis that required for commercial air services. For example, a recent Board report (TSB A93Q0245) stated:

...when passengers are regularly carried on state aircraft, it is reasonable for these passengers to expect that the aircraft and the aircrew involved in state operations are subject to the same regulatory requirements as commercial carriers.... Therefore the Board recommends that:

The Department of Transport require that the operators of state aircraft be subject to regulatory overview, as practicable, equivalent to that of similar commercial operations.

(A96-03, issued April 1996)

In essence, Transport Canada rejected this recommendation.

Although the Board finds no particular fault with state-owned air ambulance services at this time, it remains concerned about continuing disparities between state and commercial operations in the levels of safety offered. The Board is not making a further recommendation in this regard as a result of this accident involving a commercial aircraft. Nevertheless, it is for consideration that any differences in safety standards between state and commercial air services with respect to the conduct of air ambulance operations should be eliminated.
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 May 1997.

Appendix A - Flight Path

Appendix B - List of Supporting Reports

The following TSB Engineering Branch Reports were completed:

LP 194/95 - Electrical System Examination; and

LP 29/97 - Examination of Propeller Start Lock Pins.

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

Appendix C - Glossary

AES - Atmospheric Environment Service
agl - above ground level
ANO - Air Navigation Order
asl - above sea level
ATPL - Airline Transport Pilot Licence
CAR - Canadian Aviation Regulation
CFIT - controlled flight into terrain
CST - central standard time
1. All times are central standard time (Coordinated Universal Time [UTC] minus six hours) unless otherwise stated.

2. See Glossary at Appendix C for all abbreviations and acronyms.

3. See flight path diagram in Appendix A.

Air 1995

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
Altitude Related Event -
Uncontrolled Deviation
TAROM - Romanian Air Transport
Airbus Industrie A310-325 YR-LCA
Near Rivière-du-Loup, Quebec
01 March 1995

Report Number A95H0004

Synopsis

The flight was in cruise, en route from Chicago, Illinois, USA, to Amsterdam, the Netherlands, at FL330 at a speed of Mach 0.83, with autopilot 2 engaged. Shortly after the crew received a clearance to proceed to the ocean-boundary fix, the autopilot disengaged. The aircraft climbed rapidly with a maximum vertical g of 1.94 recorded within five seconds of the autopilot disconnect. At times during the rapid ascent, the rate of climb exceeded 12,000 feet per minute and the maximum pitch angle was nearly 30 degrees. The aircraft reached a maximum altitude of FL385, at a minimum indicated speed of 155 knots. Four stall warning events occurred, commencing at the peak altitude of the manoeuvre and continuing as the aircraft began a rapid descent. The descent continued at rates sometimes greater than 12,000 feet per minute, to FL315 where the aircraft began a rapid climb again. Autopilot 1 was successfully engaged (several engagement attempts were made during the descent) and the climb moderated. The aircraft levelled at FL350 and was then cleared by Moncton Centre (New Brunswick) to maintain that altitude. The flight continued to its destination with no further reported problems. There was no traffic conflict during the flight upset, and no injuries or aircraft damage were reported.

The Board determined that the flight upset manoeuvre was caused by a misrigged autopilot elevator servo control, which led to an initial pitch-up, and by the crew's ineffective or inappropriate pitch control inputs which led to aircraft stall. Contributing factors in the flight upset were the aft centre of gravity position and the aircraft's high speed.

*Ce rapport est également disponible en français.*

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1.0 Factual Information

1.1 History of the Flight

The scheduled international passenger flight (TAROM - ROT 006), with a crew of 14 and 80 passengers on board, was en route from Chicago, Illinois, USA, to Amsterdam, the Netherlands. The aircraft was in cruise at flight level (FL)\(^{(1)}\) 330, at a speed of Mach 0.83, near Rivière-du-Loup, Quebec. The captain was the pilot at the controls. The autopilot was engaged (CMD2) in altitude hold (ALT) and navigation (NAV) modes, and the flight management system (FMS) was providing navigation guidance. Autothrottle was engaged in the Speed/Mach mode.

Shortly after checking in with Moncton Centre (New Brunswick), at 0252:40 UTC\(^{(2)}\), the flight was cleared direct to SCROD, the flight's North Atlantic Track (NAT) ocean boundary point. The controller asked for an estimate for SCROD. The captain had just completed a direct to (DIR) input for SCROD in the FMS and was in the process of providing a SCROD estimate to Moncton Centre from the FMS Flight Plan page of the control display unit (CDU), when he sensed a "whooshing" noise which he associated with turbulence. The autopilot disengaged, and the aircraft pitched up with a maximum normal acceleration of 1.94 g within five seconds of the disengagement.

The aircraft commenced a climb with peak rates of climb greater than 12,000 feet per minute\(^{(3)}\) (fpm) and a maximum pitch angle of nearly 30 degrees. The flight climbed about 5,500 feet above its cleared altitude, peaking at FL385, and reached a minimum indicated airspeed (KIAS) of 155 knots. Stall warning events occurred, commencing at the peak
altitude of the manoeuvre, and continued as the aircraft began a rapid descent. When the stall warning system activated, the pilot commenced recovery procedures; a total of four stall warning activations were recorded on the flight recorder.

A descent from the minimum speed point was commenced with high levels of thrust on the engines. At about FL350, an unsuccessful attempt was made to engage autopilot 2. About five seconds later, as the aircraft was descending through FL340, autopilot 1 was engaged. Maximum descent rates exceeding 12,000 fpm down were recorded during the descent. As the flight was descending through FL320, the captain reported on the radio to Moncton centre "...sorry, we have a very big problem." The flight descended 7,000 feet to about FL315, whereupon autopilot 1 disconnected, and the aircraft then commenced a rapid climb again. The captain indicated that, at times, both pilots were likely operating the flight controls, perhaps at cross-purposes.

As the aircraft was climbing through FL320, autopilot 1 (CMD1) was engaged, and the ascent rate was moderated. The aircraft climbed to FL350 and the flight commenced cruising at that level at about 0256:30, approximately three minutes after the start of the flight upset. At this time, the flight called Moncton Centre and provided the estimate for SCROD. The Moncton Centre controller, who was observing the flight's altitude deviations, asked the flight "what was your problem?" The flight crew indicated that there was a problem with their autopilot, but that they had "recovered the plane" and that "everything was okay." Approximately a minute later, the flight was asked by the controller if they wished to continue maintaining FL350; the crew indicated that they would "like to maintain this level." ROT 006 was then cleared to maintain FL350. There was no indication that the crew wished to divert the flight. No traffic conflict occurred. The flight continued to Amsterdam with no further problems reported.

The incident occurred on 01 March at 2253 Atlantic standard time (02 March 0253 UTC), during conditions of darkness at latitude 48°22'N, longitude 070°08'W.

1.2 Injuries to Persons

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1.3 Damage to Aircraft

The operator indicated that there was no damage to the aircraft.

1.4 Other Damage

No other damage was incurred.

1.5 Personnel Information

1.5.1 General
1.5.2 Captain

The captain commenced his flying career following graduation from Aurel Vlaicu Military Aviation School, Civil Section, in 1969. The captain received his Commercial Licence in 1970, and he was issued an Airline Transport Licence in 1980. The captain flew a variety of aircraft for TAROM, including the LI-2, IL-14, AN-24, BAC 1-11, IAR 818, and Boeing 707. Following training at the Aeroformation facility in Toulouse, France, he completed his A310 captain's checkout on 23 February 1993. Training and authorization for NAT-MNPS-ETOPS were completed on 23 April 1993. No training problems were noted.

The captain was the pilot at the controls. This was planned to be the co-pilot’s sector, and the co-pilot had been the pilot at the controls for the first portion of the flight. However, prior to the upset, the co-pilot indicated that he wanted to relax for a few minutes, and the captain assumed control. Normally, in accordance with TAROM procedures, autopilot 1 (CMD1) would be selected if the captain is flying the sector, but the autopilot selection remains for the appropriate pilot for the sector. As the co-pilot was the appropriate pilot, the autopilot was in CMD2 at the time of the occurrence.

1.5.3 Co-pilot

The co-pilot graduated from the Aurel Vlaicu Military Aviation School, Civil Section, in 1975 and received his Commercial Licence in the same year. He was issued his Airline Transport Licence in 1981. While employed by TAROM, he flew as a co-pilot in a variety of aircraft, including the AN-2, AN-24, and BAC 1-11. In 1992, the co-pilot was upgraded to captain on the BAC 1-11. He qualified on the A310 as a co-pilot on 03 May 1993 following training at the Aeroformation facility in Toulouse, France; he completed NAT-MNPS-ETOPS training on 11 February 1994. No training problems were noted.

1.6 Aircraft Information

1.6.1 General

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<th>Manufacturer</th>
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http://www.tsb.gc.ca/en/reports/air/1995/a95h0004/a95h0004.asp
1.6.2 Hydraulic Systems

1.6.3 Flight Controls

1.6.3.1 General

All control surfaces are actuated by three irreversible servo controls, each supplied by one of the three independent hydraulic systems (B,G,Y). The trimmable horizontal stabilizer (THS) is powered by the green and yellow systems. Pitch trim control is achieved by the horizontal stabilizer hinged on the aircraft structure. Maximum allowable vertical acceleration (g) with the flaps up is +2.5 g and -1.0 g.

1.6.3.2 Elevators

The A310 pitch control is achieved by two elevators hinged on the horizontal stabilizer. Each elevator is actuated by three servo motors controlled by a dual mechanical linkage through dynamometric rods, cable runs, an artificial feel system linked to the cable run of the left-hand control column, and load limiting rods. An autopilot-servo actuator is connected to the left elevator, which is mechanically linked to the right elevator. In cruise, if the crew applies a force greater than 150 newtons on the control column, the autopilot will disconnect.

In normal operation, the two elevators are controlled together. The maximum mechanical deflection ranges from -30 degrees (nose-up) to +15 degrees (nose-down) with the autopilot disengaged. When the autopilot is engaged, the maximum mechanical deflection range is from 18 degrees nose-up to 9 degrees nose-down. A pitch uncoupling unit is designed to prevent accidental asymmetric deflection of the elevators during flight and allows uncoupling of the left and right elevator systems during take-off (speed below 195 KIAS).

1.6.3.3 Pitch Trim

There are two pitch trim computers, each comprising two independent computing channels for command and monitoring. Each pitch trim system provides pitch commands to the horizontal stabilizer. The range of travel is from +3 degrees (aircraft nose-down) to -14 degrees (aircraft nose-up). Trim rotation is inhibited when the horizontal stabilizer reaches +2.5 degrees (nose-down) and -13 degrees (nose-up) to prevent it from reaching the mechanical stops. Horizontal stabilizer travel rate and trim authority depend on the mode and aircraft configuration. Normally both pitch trim systems are engaged, with system 1 automatically active and system 2 synchronized in standby. In normal operation, pitch trim 1 has priority over pitch trim 2.

For the aircraft configuration during the flight upset incident, there are four pitch trim functions: electric trim, auto trim, Mach/Vc trim, and angle of attack (alpha) trim.
The electric trim functions by moving the horizontal stabilizer to provide full elevator authority on either side of the flight-neutral position. Trim action is initiated by two trim rocking levers on each control wheel. If the rocking levers are operated simultaneously in opposition, trimming stops. The control wheel trim rocking levers on the control wheels are deactivated when an autopilot is engaged. Horizontal stabilizer movement rate depends on the aircraft speed. At speeds above 240 KIAS, the horizontal stabilizer moves at 0.17 degrees/second; the rate increases linearly to a maximum rate of 0.9 degrees/second at (and below) 200 KIAS.

Auto trim functions with an autopilot engaged and is designed to perform an integration of the autopilot elevator order in order to keep the elevators neutral. The elevator neutral position at a speed of Mach 0.83 is about 0.4 degrees nose-up due to aerodynamic force which deforms the elevators slightly. With the flaps retracted, the auto trim system moves the horizontal stabilizer at a rate which depends on the autopilot elevator order; 0.066 degrees/second is the maximum rate. Auto trim is designed to prevent bumping when the autopilot is disengaged.

The Mach/Vc trim function is used to improve the aircraft's longitudinal stability by varying the horizontal stabilizer position for Mach number or Vc (computed airspeed) changes. As speed increases, the Mach/Vc trim system causes a nose-up pitch moment to create normal increasing speed stability characteristics. As speed decreases, a nose-down pitch moment is developed. The maximum horizontal stabilizer authority is 0.7 degrees due to Mach trim and 0.82 degrees due to Vc trim.

The angle of attack (alpha) trim system functions by countering pitch-up which occurs at high Mach and at excessive angle of attack at low speed. The alpha trim function is active in manual mode (autopilot not engaged) with the flaps, slats, and airbrakes retracted, regardless of landing gear position. The maximum horizontal stabilizer authority is 1.0 degrees pitch-down.

### 1.6.4 Autoflight Systems

The autopilot can be engaged in CMD to provide three-axis aircraft control. Many conditions exist that allow for autopilot engagement and continued engagement. Some of the conditions for continuous autopilot (CMD) operation are as follows:

- Correct electrical power;
- Hydraulic pressure available from appropriate system(s);
- No failure detection in pitch (and roll) servo motors;
- Appropriate flight control computer (FCC) operative (AP2 uses FCC2);
- Pitch trim lever 1 or 2 engaged;
- Yaw damper 1 or 2 engaged; IRS (inertial reference system) 1 (CMD1) or 2 (CMD2) and one other IRS;
- Air data computer 1 (ADC1) operative for CMD1 or ADC2 operative for CMD2; and flight control unit (FCU) operative.

In cruise, the autopilot disconnects if a force greater than 150 newtons is applied to the control column (pitch axis).

The electrical autopilot commands are transmitted to the mechanical linkage by means of...
autopilot-servo actuators. Autopilot 1 (CMD1) receives its hydraulic power from the green system. When autopilot 2 (CMD2) is in use, the autopilot receives its hydraulic power from the yellow system. Some operators tend to favour the use of autopilot 1 (CMD1) because of the greater number of hydraulic pumps for the green system.

The autothrottle system, when armed, responds by modulating the thrust through the movement of the throttles. The normal rate of throttle movement is approximately one degree per second; go-around (GA) mode and thrust latch (alpha floor) command a throttle speed of about eight degrees per second.

1.6.5 Flight Envelope Protection

There are several systems in the aircraft which are designed to prevent excursions from the normal flight envelope. These systems include the stick shaker, Vmax (maximum selectable speed), and alpha floor.

The aircraft's stick shaker system provides a warning of impending stall condition to the pilots through vibrating motors on the control columns. The stick-shaker speed (Vss) in the clean configuration is equal to 1.138 of the stall speed (Vs), and is g-load dependent.

Maximum selectable speed (Vmax) protection does not allow a Mach number greater than 0.84 to be selected. If excessive speed is selected, the thrust computers or flight control computers limit the speed.

The alpha floor function is active if the autothrottle system is armed when an angle of attack of more than 8.5 degrees is detected with a clean aircraft configuration. When a too-high angle of attack is detected, thrust latch is engaged, producing thrust corresponding to the mode selected on the thrust rating panel.

1.6.6 Fuel System

The aircraft fuel system consists of four wing tanks, a centre tank, an auxiliary tank, and a trim tank located in the horizontal stabilizer. The fuel feed sequence is automatic and is designed to maintain an aft centre of gravity (C of G) for lower aircraft drag and hence reduced fuel consumption. The centre tank fuel is normally burned first, and fuel is transferred between the trim tank and the centre tank, as required, to maintain a C of G between approximately 37% MAC (high weight) and 35% MAC (low weight). The aft C of G limit is 40% MAC (for flight above 20,000 feet). An ECAM pre-warning (amber) is activated when the C of G reaches 41% MAC, and an ECAM warning (red) is triggered when a value of 43% MAC is reached.

The automatic fuel transfer between the trim tank and the centre tank is controlled by the centre of gravity control computer (CGCC). TAROM and other operators have reported problems with the CGCC serviceability rates leading to problems in the automatic fuel transfer for the maintenance of C of G.

During the flight of ROT 006, the automatic fuel transfer had failed ("TRIM TK SYS FAULT") and the crew was maintaining the centre of gravity through the manual manipulation of the fuel valves and pump selections. The checklist action for this fault requires that as much fuel as will fit in the centre tank be transferred forward to the centre tank from the trim tank. The captain indicated that he commenced a fast forward transfer of fuel from the trim tank during the incident sequence.

The aircraft manufacturer indicated that positive longitudinal stability was demonstrated up to 43% MAC, but that longitudinal stability would be less at aft C of G values than at mid-range
values.

### 1.6.7 Maintenance History

TAROM has a maintenance facility at their main base at Bucharest, Romania, and line maintenance progressive checks are performed by TAROM personnel. Heavy checks and major overhauls are conducted by Swissair, normally at Zurich, Switzerland.

Aircraft maintenance logs were reviewed for time periods before and after the flight-upset incident. Technical items of possible relevance were found.

#### 1.6.7.1 Flight Control Maintenance

It appears that the TAROM maintenance organization was not immediately aware of the altitude excursion incident because the captain had not made a log-book entry regarding the flight upset and flight control problems.

After the completion of the trip from Amsterdam to Bucharest following the incident flight, the aircraft flew about 31 more hours and then was flown from Bucharest to Zurich for a routinely scheduled "C" check on 05 March 1995. During the "C" check, both flight control computers were removed in order to perform the modifications outlined in AD 94-185-165. The memory information from the units, which would have revealed the reason for the autopilot disengagement that started the incident, could not be retrieved because the units were not available when the need for the memory information had been identified.

During the "C" check, both elevators were changed. The reason for the elevator change was related to inspection for the possible infiltration of water in its structure. A check of autopilot elevator servo rigging was not part of the reinstallation process of the elevators.

Airbus Industrie issued All Operator Telex (AOT) 27-20, dated 19 December 1994, to notify the operators of the A310 of maintenance action to deal with possible autopilot servo rigging problems. AOT 27-20 was received by TAROM, and the incident aircraft was scheduled for a check of autopilot servo rigging. The aircraft log shows that the work, along with other maintenance items, was completed on 06 January 1995 by TAROM maintenance personnel. The maintenance entry read "A/P actuators rigging." This was the first time rigging checks had ever been performed on the A310 by TAROM personnel.

Following the incident, TAROM requested maintenance assistance from the manufacturer to verify the operation of the pitch control system. Personnel from Airbus travelled to Bucharest and performed a check of the autopilot elevator servo rigging on 16 March 1995. During the check by the Airbus team, it was found that the autopilot elevator servo was misrigged; "one turn" of adjustment was required during the check. Some maintenance personnel suggested the possibility that the incorrectly fitting pin, specified in the Maintenance Manual, might have been used in the 06 January rigging checks. TAROM, during their review of the maintenance carried out during the 06 January check of the rigging, indicated that the correct rigging pin may have been used but that the pin may not have been inserted fully, because of personnel inexperience in conducting rigging procedures.

After the 16 March maintenance action, TAROM pilots were asked to check the aircraft pitch control characteristics upon autopilot disengagement. They found relatively benign pitch "bumps" when the autopilot was disconnected. The maintenance entry stated "tendency to climb with 100-200 ft/min."

#### 1.6.7.2 Fuel System
The incident aircraft had a recurring problem with the fuel-system C of G trimming. From 23 January to 10 March 1995, there were at least 11 log entries related to the fuel trim tank system. The usual rectification was the resetting of the CGCC system. The maintenance entry following the incident was "trim tank syst fault"; the rectification was "reset CGCC."

TAROM and Swissair maintenance personnel indicated that A310 aircraft have had recurring problems with the CGCC system; other A310 operators have reported similar problems. It has been suggested that water condensation in the horizontal stabilizer trim tank or fuel density might be a factor leading to fuel trim problems.

1.6.7.3 Hydraulic System

Several maintenance entries were made concerning the yellow hydraulic system as follows:

- 05 February - "yellow hyd pump lo press"
- 13 March - "After 4 hr FL350 AP2 and yaw damper trips to off, and on ECAM wd, 'yellow pump lo press' for 2 sec."
- 09 April - "lo pressure"

Maintenance action included checks and replacement of pumps, and the cleaning of cannon plugs. Ultimately, it was determined by maintenance, in April 1995, that the fluid low quantity was giving an intermittent false warning, which was causing the shut-off valve to close.

1.6.7.4 Autopilot Disconnects

There were maintenance entries made in the weeks after the incident regarding autopilot 2 disconnects. In addition to the 13 March event noted above with yellow system low pressure, another disconnect occurred on 04 April with a report "FMS2 and A/P 2 u/s for 1 min."

No disconnects were noted for autopilot 1 during the two months prior to, or two months after, the incident.

1.7 Meteorological Information

Weather information was obtained from the Atmospheric Environment Branch Weather Centre for the time of the incident. No SIGMETs were reported in the area of the flight, turbulence was not forecast in the area of the incident, and there were no pilot reports (PIREP) of turbulence in the area.

The forecast wind at FL340 for Rivière-du-Loup was 240 degrees true with a speed of 107 knots. The vertical wind speed change (vertical shear) was, on average, about 2.2 knots per 1,000 feet above FL340, and less than 1 knot per 1,000 feet below FL340. Clear air turbulence is considered to be improbable with such vertical wind shear values. The wind direction and speed at the nearby stations of Sept-Îles, Quebec, and Mont-Joli, Quebec, had forecast wind direction and speed, as well as temperature, nearly identical to that of Rivière-du-Loup, indicating a low probability of horizontal wind shear.

1.8 Aids to Navigation

There is no indication of problems with the available aids to navigation.

1.9 Communications
Transcripts were prepared of the radio conversations between the flight and Moncton Centre, as well as of land-line dialogue between the controllers from Montreal and Moncton. No difficulties were noted in the quality of the radio transmissions.

The flight was in contact with Moncton Centre using very high frequency (VHF) radio. Although the flight was still in Montreal airspace, it had been directed to contact Moncton, which was a normal handoff procedure in the area. Shortly after contacting Moncton Centre, at 0252:40, the flight was cleared to SCROD; the controller requested an estimate for SCROD. ROT 006 acknowledged the clearance and gave an estimate for SCROD as 0402 UTC. The controller asked the flight crew to confirm the estimate; the crew replied that they would check the estimate again. The flight crew did not contact Moncton Centre again for nearly two minutes.

The crew of ROT 006 transmitted at 0255:02 UTC that the flight had "a very big problem"; the Moncton controller replied "go ahead." ROT 006 replied with "standby." About 30 seconds later, there was a land-line conversation initiated by the Montreal Centre controller concerning ROT 006. The Moncton controller indicated that he did not want to "bother" the crew by calling the flight.

At 0257:17, the captain indicated to the Moncton controller that the autopilot had disconnected unexpectedly and he had "... finally ... recovered the plane." The possibility of turbulence problems was suggested by the controller. In further radio conversation, ROT 006 indicated that "...everything is fine now."

1.10 Aerodrome Information

Not relevant to the incident.

1.11 Flight Recorders

1.11.1 Available Recordings

The TAROM A310 aircraft is fitted with a flight data recorder (FDR), a cockpit voice recorder (CVR), and a digital aircraft integrated monitoring system recorder (DAR). Because the CVR had a recording time of only 30 minutes, the applicable voice data had been overwritten and was, therefore, not available for analysis. On 03 March 1995, the TSB requested that the FDR be provided for analysis. The operator, through the Romanian Civil Aviation Authority (CAA), indicated that the FDR was not available. The FDR had been overwritten because the aircraft had already flown more than 25 hours since the incident. The operator did provide a 3.5-inch copy disc of the DAR data for the time of the occurrence. Duplicate discs were also provided to the Bureau Enquêtes-Accidents (BEA) of France and the aircraft manufacturer, Airbus Industrie of Toulouse. Detailed plots of the DAR data are contained in Appendix A.

Radar data analysis (RDA) information was available from the Transport Canada Radar Data Processing System from Moncton Centre using the Sept-Îles radar site. Plots of the radar data were produced by the TSB Engineering Branch using the RADEX software program. The radar data and DAR data are consistent. The radar data plots are found in Appendix A.

1.11.2 Description of DAR

The Penny and Giles DAR is used by TAROM as a flight monitoring tool, and TAROM has a facility in Bucharest equipped to analyze DAR data. The DAR uses the same parameter transducers as the FDR, but the recording medium is not impact protected. The data
recordings are quickly retrieved without the removal of any aircraft components.

The DAR, as operated at the time of the flight-upset incident, did not record data continuously. A data drop-out occurred until just before the autopilot disconnect, and another drop-out occurred before the aircraft regained level flight at FL350. All the parameters appeared to record correctly.

The DAR data disc was analyzed by the TSB Engineering Branch Laboratory. Calibration data were provided to the TSB by Airbus Industrie and TAROM.

1.11.3 Recorded Parameters

The DAR records more than 230 parameters. The sampling rates for the parameters vary from once per four seconds (control wheel force and column force) to eight per second (normal acceleration, or g). The parameters of primary interest used for this investigation were as follows:

- elevator (RH) position;
- trimmable horizontal stabilizer position;
- engines - EPR, N1, N2;
- throttle angle;
- control column force (pitch);
- control wheel force (roll);
- roll angle;
- magnetic heading;
- pitch angle;
- angle of attack;
- airspeed and Mach number;
- vertical g;
- centre of gravity - % MAC;
- yellow hydraulic system pressure (once/4 sec);
- autoflight features (discretes);
- spoilers;
- stall warning (discrete);
- static air temperature (SAT); and
- VHF keying (for time correlation with ATC).

1.11.4 Initial Conditions

At the start of the available DAR data (0253:20 UTC), the aircraft was in cruise at FL330 with a computed airspeed of 296 knots or 0.83 Mach. This speed was higher than the
normal fuel-efficient cruise speed of about Mach 0.80. The aircraft was in a slight left turn with a roll angle (bank) of 7 degrees, and the heading was decreasing from 073 degrees magnetic. The discrete autopilot parameters show that AP2 was engaged and AP1 was not engaged. The autothrottle system was engaged in the Speed/Mach mode. AP2 shows a disconnect at 0253:28.

![Figure 1 - DAR - Autoflight Systems](image)

1.11.5 Manoeuvre Characteristics

Following the AP2 disengagement, the aircraft pitched up. A maximum vertical acceleration (load factor) of 1.94 g was developed within five seconds; the aircraft pitch angle increased to a peak value of 29.5 degrees nose-up within 25 seconds. At the point of maximum pitch, the vertical g decreased to less than 1 g (minimum 0.5 g) and remained at less than 1 g values until the aircraft was descending through FL362. The maximum nose-down pitch was 15 degrees at time 0254:35, as the aircraft was descending through FL365. At 0254:42, AP2 was re-engaged and then was quickly disengaged when AP1 was selected at 0254:45. The minimum recorded pressure altitude was 31,580 feet (at time 0255:10); the airspeed had increased to 292 knots (calibrated air speed). At this minimum-altitude point, AP1 disengaged again. A rapid climb developed again, but was moderated at 0255:20 when AP1 was successfully engaged.

At the time of the AP2 disengagement that started the event, the aircraft was in a left bank of 8 degrees. The aircraft rolled to the right at a low rate until the bank angle reached 10 degrees right. The bank angle varied left and right with a maximum angle of 12 degrees left roll, and then stabilized in level flight with the final successful engagement of AP1 at time 0255:20.
1.11.6 Elevator Travel

The elevator position was at 1.05 degrees nose-down prior to AP2 disengagement. As soon as the autopilot disengaged, the elevator moved quickly toward 1.76 degrees nose-up. The first counter movement of the elevator was recorded at 0253:33, as the elevator moved to 0.3 degrees nose-down. This counter motion occurred as a nose-down column force was recorded. The elevator angle then varied with an amplitude of one degree, centred about 1.5 degrees nose-up. The maximum nose-up elevator was 4.5 degrees at time 0254:14. At 0254:45, AP1 was engaged; the elevator angle then moved to 1.0 degree nose-down and was centred about the 1.0 degree nose-down angle.

![Figure 2 - DAR - Flight Controls](image)

**Figure 2 - DAR - Flight Controls**

1.11.7 Horizontal Stabilizer

Prior to the AP2 disengagement, the horizontal stabilizer angle was maintained at 1.4 degrees nose-up, and just after the disengagement, the horizontal stabilizer angle moved to about 0.4 degrees nose-up. The horizontal stabilizer initially made only small movements centred about the approximate zero-degree-angle position. At the point of maximum pitch (0253:53), the THS was at a 0.5 degree nose-down position. The horizontal stabilizer then moved toward 1.0 degree nose-down at 0254:07 and returned to 0.4 degrees nose-up at 0254:47. The horizontal stabilizer moved toward the pre-disengagement value of about 1.4 degrees nose-up as the aircraft resumed level flight at FL350.

1.11.8 Airspeed/Angle of Attack
Airspeed began to decrease steadily from the FL330-cruise value of 296 knots just after AP2 disengaged. Coincident with the airspeed decrease was an increase in pitch angle and angle of attack. At a time of 0253:32 (about 4 seconds after the autopilot 2 disengagement), the angle of attack increased rapidly from its cruise value (approximately +1 degree) to 9.5 degrees. Just after this time, the highest total (left and right) nose-up column force of at least 110 newtons (about 24 pounds force) was recorded.

The airspeed decreased to a minimum recorded value of 154.5 knots as the aircraft reached a peak pressure altitude of 38,470 feet (FL385). At the apogee of the manoeuvre, the angle of attack increased to about +11.2 degrees. At the same time (0254:10), the stall warning discrete was recorded. The angle of attack then decreased quickly to approximately +7 degrees. About 10 seconds later, the angle of attack again increased and reached a value of +12.1 degrees as the pitch angle was reducing through 3 degrees; again, the stall warning was activated and the angle of attack reduced. Two more +11 degree angle-of-attack values were recorded, each accompanied by stall warnings. The last stall warning occurred at 0254:40, as the airspeed was increasing through 205 knots and while the aircraft was descending through FL358.

1.11.9 Throttles and EPR

The recorded engine pressure ratios (EPR) of the left and right engines, as the aircraft was in cruise at FL330, were at the same value of 1.21. The recorded EPR of the two engines remained at even levels throughout the occurrence. The throttle angles increased within one second of the autopilot 2 disengagement; EPR increases followed to a peak of approximately 1.42 within five seconds. The throttle angle then reduced rapidly at a rate greater than 19 degrees per second. The throttle angle then increased again at about 7 degrees per second; EPR followed and stabilized at an average value of about 1.58. As the aircraft was climbing through FL375 at an airspeed of 172 knots, the throttle angle again increased rapidly; the EPR peaked at 1.65. A throttle angle reduction was recorded and the EPR again stabilized at 1.58 at 0254:04. After passing the maximum aircraft altitude, a small increase of EPR was noted at 0254:27 (peak EPR 1.60), coincident with a rapid throttle angle increase. After 1.5 seconds, the throttle angle decreased and then began increasing five seconds later, at a rate of about 2 degrees per second, as the aircraft was descending through FL365; the throttle angle peaked at 81 degrees. The EPR then peaked at 1.67 and reduced slowly to the previous average value of about 1.58 while the throttle remained at about 81 degrees.

The Airbus review of the throttle movement indicated that the throttle movements at 0253:34, 0254:04, and 0254:27 were the result of pilot movement of the throttle levers.

The Flight Manual charts indicated that the maximum continuous thrust level at FL360 for a total air temperature (TAT) range from -20 to -40 degrees Celsius is 1.675 EPR.
1.11.10 Control Forces

For some portions of the flight-upset manoeuvre there were diverging column forces. At 0253:45, as the aircraft was climbing through FL350 with a pitch angle of 22 degrees, the left column force was nose-up and the right column force was nose-down. Because of the geometry of the control system, the forces should be summed and this resulted in a net nose-up force.

At 0254:42, the co-pilot wheel force increased to about 80 newtons and remained at that value for about 15 seconds; the aircraft rolled to the left and stabilized at a left-bank angle of 8 to 12 degrees during the same time period.

1.11.11 Performance and Systems Parameters

The DAR shows the aircraft mass to be 131,000 kg at the time of the upset. The wind at the time of the upset shows a fairly steady speed of 112 to 114 knots from a direction of 233 degrees true.

The C of G prior to the event was steady at 38.6% MAC. During the upset, the C of G moved aft and reached a maximum value of 39.6% MAC at the apogee of the manoeuvre. At 0254:23 the C of G started to move forward and reached approximately 33% MAC as the flight was approaching stabilized cruise flight at FL350.

There were no recorded pressure drops below minimum values in the yellow hydraulic system; the "pressure" parameter and the "servo control no low pressure" parameter are
each sampled every four seconds. The maximum time difference between sampling of each of the two parameters is approximately 2.2 seconds.

1.12 Wreckage and Impact Information

Not relevant to the incident.

1.13 Medical Information

There are no known medical problems that would have affected the crew's performance.

1.14 Fire

There was no fire.

1.15 Survival Aspects

Reports from the cabin crew did not indicate any significant problems for the crew or passengers as a result of the flight manoeuvres during the incident. The flight forces were more noticeable in the aft portion of the aircraft. No injuries were reported.

1.16 Tests and Research

1.16.1 Research

TAROM, in addition to providing DAR data to the TSB, supplied the manufacturer with a copy of the DAR data on disc. Airbus Industrie reviewed that data and provided information as to the actions of various systems during the incident manoeuvre. Also, the manufacturer provided some performance information related to the incident.

1.16.2 Autothrottles

Only one thrust control computer (TCC 1) operation is recorded by the flight recorder. However, the aircraft manufacturer indicated that its research showed that the autothrottle system was engaged throughout the manoeuvre. This conclusion was based on the throttle motion rates and system redundancy features.

1.16.3 Trimmable Horizontal Stabilizer Motion

Airbus Industrie's study of the horizontal stabilizer movement during the flight upset indicated that the crew did not make trim inputs during the manoeuvre. The nose-down movement of the horizontal stabilizer from 0253:28 to 0254:45 followed by nose-up travel appeared to assist the crew in the recovery from the manoeuvre. This horizontal stabilizer motion was assessed to be the result of Alpha/Mach/Vc trim features, and the manufacturer indicated that horizontal stabilizer operation was normal.

1.16.4 Centre of Gravity Warning

The manufacturer reviewed the aft C of G situation of the incident flight. Their research showed that the crew likely received an "Aft CG" warning which caused the action to commence the forward transfer of fuel. The "Aft CG" warning is based on the flight warning computer (FWC) computation of an "aerodynamic" centre of gravity, which is derived in part from the horizontal stabilizer position. During the flight upset event, the elevator moved upward and the horizontal stabilizer moved downward, which led the FWC to compute a C of G further aft than it actually was. The manufacturer assessed that it was highly probable
that the "Aft CG" amber warning (normally activated at 41% MAC) was triggered at a lower value.

1.16.5 A310 Stall Characteristics

The manufacturer was asked to provide FL370 data for the speeds and angle of attack of stall onset indications and the stall itself. Airbus Industrie stated that buffet onset occurs at Mach 0.63 for an angle of attack of 6.5 degrees. The stall warning is triggered at an angle of attack of 10 degrees, with aerodynamic stall occurring at angles of attack greater than 10.6 degrees. It was further stated that, at altitudes greater than 30,000 feet, "buffet onset appears before the stall warning giving a warning through the inherent aerodynamic qualities of the airplane as requested by FAR 25.207."

1.16.6 Control Forces

Review of the control forces measured by the FDR indicated to Airbus Industrie that there were nose-up control inputs that were inappropriate, very early in the pitch-up. Because its research and tests had shown that the elevator motion to neutral would move the elevator to a maximum value of 0.4 degrees nose-up, the manufacturer also attributed some of the initial elevator movement, following autopilot disconnect, to pilot control input. The manufacturer's review also indicated that considerably more nose-down control authority was available to the crew than was used during the climbing phase of the flight upset.

1.17 Organizational and Management Information

TAROM is a state-owned airline. The maintenance activity at TAROM is led by the airline's Technical Director. Swissair provides contract maintenance support to TAROM, and to many airlines in countries throughout the world, including Canada. The Swissair Technical Advisor stationed in Bucharest monitors the line maintenance activity of TAROM. Scheduling of heavy checks and special maintenance to be performed by Swissair is coordinated through the Swissair representative in consultation with the maintenance organization of TAROM.

Airbus Industrie has a Resident Customer Support Manager in Bucharest to provide assistance to TAROM regarding the A310 and to conduct liaison between the manufacturer and the airline.

1.18 Additional Information

1.18.1 Navigation Track

Just prior to the autopilot disconnect that initiated the flight-upset event, the flight had been cleared from its position (approximately 48°22'N, 070°08'W), directly to SCROD (54°37.0'N, 055°52.0'W). Prior to that time, the flight had been proceeding to reporting point ANCER (48°33.5'N, 06°25.3'W).

An 18-degree ground track change to the left would have been required to change course from the aircraft's position to SCROD vice ANCER.

1.18.2 Orly Incident

On 24 September 1994, while on final approach at Paris Orly Airport, the incident aircraft, YR-LCA, had a 60-degree pitch-up excursion, followed by a pitch-down of more than 30 degrees. The BEA released a preliminary report which indicates that the event was initiated
by the selection of 20/20 slat/flap at a speed slightly above the limiting speed of 195 KIAS. During this incident, the autopilot was not in use. The horizontal stabilizer moved more than 10 degrees from its stable position, just prior to the event, while the aircraft was on final approach.

1.18.3 Other A310 Pitch Incidents

On 25 November 1994, an A310 operated by an Asian airline had an upset manoeuvre following a disconnect of the autopilot at a speed of 0.83 Mach. Following the disengagement, the elevator moved from 0.7 degrees nose-down to 1.05 degrees nose-up, resulting in a load factor of 1.78 g. The elevator was moved to 3.52 degrees nose-down, leading to a slightly negative load factor. The elevator then moved in the opposite direction to produce a load factor of 2.15 g. Some passengers were injured during the manoeuvre as a result of negative and positive g forces.

A test flight following the upset demonstrated that pitch-up occurred on autopilot disengagement. Ground tests confirmed that the elevator movement occurred each time that the autopilot was disengaged. The airline replaced various components, including the autopilot pitch-servo motor, and carried out a complete re-rigging of the autopilot and elevator control linkage, yet the elevator movement continued with autopilot disengagement. Ultimately, with the assistance of Airbus Industrie, it was determined that the Maintenance Manual specified a rigging pin that was not satisfactory. As a result of the Asian flight upset, an All Operator Telex (AOT 27-20) was issued. At least three other unexpected pitch problems, on autopilot disconnect, were reported by other airlines.

1.18.4 All Operator Telex 27-20

AOT 27-20, which applied to all A300, A300-600, and A310 aircraft, was issued by Airbus Industrie on 19 December 1994. The AOT (attached as Appendix B) indicated that mechanical zero rigging of the autopilot could not be achieved when using the rigging pin specified (part number OU131388) in the Aircraft Maintenance Manual (AMM) 27-31-00 page block 501, para 1.a. The pin is not long enough to go through the torque limiter lever and to internally rig the autopilot actuator. AOT 27-20, under "consequences", further stated:

In case of autopilot incorrect rigging, sudden A/C pitch up or pitch down could be experienced at the time of unforeseen A/P disconnection. The amplitude of elevator deflection and associated load factor will depend on the rigging offset. In addition as the rigging pin and principle is similar on the yaw autopilot actuator, the same incorrect rigging could be introduced during adjustment of this actuator, such an incorrect rigging could generate yaw jerk at A/P disconnection.

AOT 27-20 requested a rigging check of both the pitch and yaw autopilot actuator using a standard 8 mm diameter by 200-mm long pin (P/N 98A27307541000). Figure 4 shows the two rigging pins for comparison.
The rigging check was requested at the "next convenient opportunity but not exceeding 500 flight hours after receipt of this AOT." The estimated elapsed time for the check was one man-hour per aircraft. The AOT indicated that a temporary revision to the Aircraft Maintenance Manual chapters specifying the unsuitable rigging pin would be issued by early January 1995. In addition, the manufacturer requested that the results of the AOT 27-20 rigging checks be sent to them. A 25 January 1995 message sent from the Airbus Resident Customer Support Manager, following inspection by TAROM, reported "AOT performed on A/C MSN 450-636-644 check results are correct."

2.0 Analysis

2.1 Introduction

The flight was in cruise at FL330 and was proceeding normally; the captain was the pilot at the controls and was performing routine navigation tasks. The analysis will deal with the autopilot event that triggered the flight-upset event, the subsequent reaction of the aircraft and the crew, as well as the recovery and post-recovery portions of the flight and the return to cruise flight. Maintenance events prior to, and after, the flight upset will also be discussed.

2.2 Autopilot Disconnect

Autopilot 2 (CMD2) was in use at the time of the start of the upset event. The captain was using the FMS in the NAV mode and had just entered the oceanic boundary point SCROD in the FMS and was in the process of looking at the CDU to note the new estimate, as requested by the air traffic controller. At that point, the captain heard a "whooshing" sound
which seemed like the noise created by turbulence; at the same time, the autopilot disengaged and the aircraft began to pitch up.

The noise heard by the pilot suggested turbulence as a possible reason for the initiation of the upset. A review of the weather in the area of the incident did not indicate the likely presence of turbulence. The wind, although strong (greater than 100 knots), had low values of vertical and horizontal shear. The temperature gradients forecast for adjacent areas were very low. There were no other reports of clear air turbulence (CAT) in the area of the incident. The incident flight did not report any more flight disturbances when level cruise was reattained. Noises of the type heard by the captain can be the result of rapid changes in flight path angle, angle of attack, or yaw. The rapid change of pitch and angle of attack experienced at the start of the incident could account for the noise heard by the captain. The noise likely occurred as the autopilot disengaged and was a consequence of the reaction of the aircraft, not an external force such as clear air turbulence.

Because the flight control computers were removed from the aircraft after the incident and were not available for examination, the disconnect reasons could not be determined. A factor which prevented the timely maintenance analysis of the units was the absence of a report of autopilot problems in the aircraft log following the incident flight. Clearly, the event required some type of entry in the aircraft log.

Some of the conditions required to have the autopilot remain engaged were reviewed in an attempt to narrow down the possible reason for the disengagement. There were no reports of problems with several systems under review. For example, no problems were indicated with the pitch and roll servo motors. The flight control computers, the pitch and roll servo motors, and the pitch trim systems did not exhibit any failures in the weeks before or after the incident. There was no indication of problems with the yaw damper systems; IRS 1,2, and 3 functioned normally on the incident flight. ADCs 1 and 2, as well as the FCUs, were apparently operative for the entire incident flight. Neither crew member was manually operating the controls at the time of the disengagement; the possibility of crew nose-up control inputs, shortly after autopilot disconnect, cannot be eliminated.

Because the aircraft was in a left turn as the autopilot disengaged, followed by aircraft pitch-up, the possibility of asymmetric elevator travel was considered. The two elevators are designed to not allow independent movement at the aircraft's airspeed regime at the time of the upset. There were no reports or indications of asymmetric elevator movement, and roll control response appeared normal. The left turn was a normal reaction to the input of the new waypoint SCROD, and does not indicate any abnormal or asymmetric elevator behaviour to be a factor in starting the upset.

Two possible autopilot engagement requirements, correct electrical power and hydraulic system pressure, could not be eliminated as possibilities leading to the disengagement of autopilot 2. Crew-induced column force or the crew's use of the instinctive disconnect button seem to be unlikely causes of the autopilot disconnect.

There is no specific maintenance entry that would indicate that incorrect electrical power was applied to the autopilot 2 system, which led to the disengagement. However, the possibility of a rapid, undetected, transient-type interruption of electrical power to the autopilot cannot be eliminated.

Study of the maintenance history of the incident aircraft showed several entries related to yellow hydraulic system pressure. Many weeks after the incident, the recurring pressure problem was determined to be related to erroneous sensing of the reservoir fluid low-level (LOLVL) warning, leading to closing of a shutoff valve, a design feature to maintain yellow system fluid for the RAT. The intermittent failures of the yellow system, and in some cases
the short-term loss of autopilot 2, were noted in the aircraft log before and after the flight upset incident. Autopilot 2 receives hydraulic power from only the yellow system.

The DAR data did not reveal a loss of yellow system hydraulic pressure at the time of the autopilot disengagement. However, the yellow system pressure is only sampled a maximum of 2.2 seconds apart and it is possible that a momentary pressure loss could have gone undetected by the DAR. The 13 March 1995 maintenance entry indicated that a loss of yellow system pressure lasted only two seconds.

Review of the systems affecting the autopilot's ability to remain engaged leads to a conclusion that a possible reason for the spontaneous disengagement of autopilot 2 was the momentary loss of yellow hydraulic system pressure. This pressure loss may have been due to slight fluid motion resulting from the left turn to SCROD, leading to a false low-level warning.

2.3 Aircraft Reaction

2.3.1 Introduction

A maximum vertical acceleration (load factor) of 1.94 g was developed within four seconds of the autopilot disengagement. Review of the elevator and horizontal stabilizer system movement reveals that the aircraft reacted as a result of a sudden nose-up movement of the elevator from +1.05 degrees nose-down to 1.76 degrees nose-up when the autopilot disconnected. The consequence of the elevator action was a rapid pitch-up moment. The horizontal stabilizer had only minor motion as compared to the 24 September 1994 incident at Orly, involving the same aircraft. The characteristics and genesis of the two incidents are different and appear to be technically unrelated.

The g load on the aircraft during the Canadian event was less than the maximum permissible of 2.5 g, but was a large amount for this category of aircraft. Discussion follows on the reasons for the elevator motion.

2.3.2 Elevator Motion

Operators of the A310 had noted incidents of uncommanded climb or descent when autopilots disconnected in cruise. During an incident in Asia in November 1994, an A310 commenced a rapid climb following an autopilot disengagement; several passengers were injured when aggressive control inputs were used to stop the climb, and negative g forces ensued. The autopilot disconnect, as well as the severity of the event, were attributed to crew pitch inputs. Another European A310 operator reported similar, but less serious, occurrences. A common element in these events was autopilot elevator servo misrigging. The misrigging was attributed to the use of a rigging pin of an incorrect size. The incorrect rigging pin was specified by the approved Maintenance Manual. As a result of the 1994 Asian incident, the manufacturer sent AOT 27-20 to all A310 operators advising that the suspect rigging be checked. TAROM received AOT 27-20, and the aircraft log showed that the work was conducted in efforts to comply with the AOT. Fifteen days after the TAROM occurrence near Rivière-du-Loup, technicians from the manufacturer assisted TAROM in checking the rigging of the autopilot elevator-servo. The Airbus team found problems with rigging and adjusted the rigging to conform to AOT 27-20. Incorrect autopilot elevator-servo rigging existed at the time of the incident.

The incorrect rigging skews the neutral position of the elevator when the autopilot is engaged. With correct servo rigging, the elevator remains in the neutral position and on automatic autopilot disengagement does not move, avoiding a "bump" or pitching moment. For level-flight situations with an engaged autopilot and incorrect elevator servo rigging, the
horizontal stabilizer compensates for the off-neutral position of the elevators by producing opposing trim. If the elevator is out of position down (+), the horizontal stabilizer compensates by trimming nose-up. This was the situation at the time of the upset incident.

The DAR shows that the elevator moved from 1.05 degrees nose-down to 1.76 degrees nose-up, a nose-up change of about 2.8 degrees. The manufacturer indicated that possible misrigging of the autopilot elevator servo would not account for the total amount of elevator motion. The manufacturer indicated that the elevator would have moved to a maximum of 0.4 degrees nose-up and the rest of the travel could be explained by pilot input. The activity of the captain in using the FMS, and the non-activity of the co-pilot, appears to counter the suggestion of crew pitch control input at the exact time of the autopilot disengagement. However, the possibility of an inappropriate reactive pitch control input by a pilot, causing some of the initial nose-up elevator travel, cannot be discounted.

It is concluded that the initial pitch-up reaction of the aircraft was a direct consequence of the misrigged autopilot elevator servo.

2.3.3 Aircraft Speed

The aircraft's speed of 0.83 Mach at the start of the flight upset, although 0.01 Mach less than the limiting speed, was faster than the normal fuel-efficient cruise speed of 0.8 Mach. Higher dynamic pressure augmented the pitch response of the aircraft because of the elevator motion. The Mach/Vc trim system would have had little or no effect on the pitch-up at the moment of autopilot disconnect because there was no increase of airspeed. As the airspeed decreased in the climb, Mach/Vc trim would have provided nose-down trim changes; during the descent, nose-up trim changes would have been developed.

2.3.4 Centre of Gravity

The C of G was aft of the normal maximum of about 37% MAC because of apparent problems with the CGCC system and fuel transfer sequencing. The contribution to the initial pitch-up moment would have been minimal, in that the horizontal stabilizer would have trimmed most of the effect of the aft C of G. However, during the ascent, the C of G moved further aft of the cruise value of 38.5% MAC to 39.3% MAC. As the aircraft reached the minimum speed in the flight-upset manoeuvre, the captain opened fuel valve switches to move the C of G forward.

The aft C of G reduced the stall speed of the aircraft slightly. The manufacturer indicated that aircraft longitudinal stability would have been positive with the C of G near the aft limit of 40%, but the aircraft would have been more stable with a forward C of G. The action of the captain in transferring the fuel forward during the descending portion of the manoeuvre produced a nose-down effect and would not have aided the recovery as the aircraft reached FL315. It appears that the crew's management of the CGCC failure did not comply with the checklist procedure.

2.3.5 Throttles

At several portions of the upset manoeuvre, the throttles moved, resulting in thrust (EPR) changes. During the initial portions of the upset, the throttles were moved by the autothrottle system because the airspeed was reducing below the target speed. As evidenced by the rate of throttle movement, the crew manually reduced the throttle lever angle from 72 degrees as the EPRs reached 1.4. As a consequence, the EPRs reduced to approximately cruise values. The autothrottle system then dutifully moved the throttles forward again to an angle of 72 degrees, and the EPRs stabilized at about 1.6. The thrust of the engines was
maintained at high levels as the autothrottle attempted to achieve the target speed, which was not possible because of the high rate of climb. Thrust latch occurred as part of the flight envelope protection as the aircraft reached high angles of attack.

2.4 Crew Reaction

The workload of the crew was not high at the start of the flight upset. The captain was performing all the flight tasks because the co-pilot was taking a short rest. The captain was carrying out normal navigation tasks that required him to have his head down as he looked at the CDU. The captain’s focus was on the CDU when the autopilot disengaged.

The captain sensed a noise that he associated with turbulence, and he reacted to the pitch up by pushing opposite elevator about five seconds later. The amount of opposite elevator succeeded in temporarily arresting the g forces back to less than 1 g. There is no doubt that the forces experienced by the crew would have seemed extreme for the A310. Several oscillations of pitch rate, elevator travel, and vertical g were noted. The vertical g remained less than 1 g after the maximum pitch angle was reached. It was physically possible for the pilots to exert more pitch-control force to prevent the high pitch angle or to use pitch trim inputs to reduce the control forces. In not using all the pitch-control authority and trim available, the crew avoided negative g forces and consequential passenger and crew injuries, but they allowed the aircraft to enter the stall regime. At some points in the flight upset, commencing just after the autopilot disconnected initially, aircraft control was not effective and the control inputs were inappropriate for recovery of the aircraft. Recovery at the start of the second climb after the descent to FL315 was effected by the engagement of the autopilot.

There was obvious concern that the flight had a serious problem and the captain’s radio transmission reflected this. The crew were very busy in their attempts to recover the aircraft; the co-pilot had also joined in to input some control forces. Their activity was not necessarily coordinated, which had the potential to lead to problems. The decision by the Moncton controller not to bother the crew when he observed the altitude deviation reduced that pilot’s workload. Such a conscious decision would have been difficult if conflicting air traffic had existed. The crew’s recovery to cruise 2,000 feet above their cleared altitude shows that they were distracted by the flight upset. However, there was no indication that the crew was concerned enough to divert the flight for maintenance action, or to enter the incident in the aircraft log.

2.5 Maintenance

The incident was precipitated by a maintenance problem, the misrigging of the autopilot elevator servo. The problem had been identified by the manufacturer, and operators of the A310 had been notified by AOT 27-20 of both the problem and the interim fix.

Despite a rigging check of the autopilot elevator servo nearly two months prior, the incident aircraft was misrigged. There are two possibilities as to why the incorrect rigging existed. Either the incorrect rigging pin was used or the correct rigging pin was not inserted fully, due to the inexperience of the airline maintenance personnel performing the rigging check.

3.0 Conclusions

3.1 Findings

- The aircraft rigging procedure in the maintenance manual allowed incorrect autopilot elevator servo rigging because the procedure specified an inappropriate rigging pin.
- The specified rigging pin was an incorrect size to use for rigging the autopilot servo.
The manufacturer had advised the operators of the A310, including TAROM, of the necessity to recheck the rigging of the autopilot servos with a different rigging pin, specified in AOT 27-20.

The operator carried out an autopilot-servo rigging check, but the aircraft autopilot elevator servo remained incorrectly rigged, either because the incorrect rigging pin was used or because the correct rigging pin was not inserted fully.

When the autopilot disconnected, the elevator was offset from neutral and the horizontal stabilizer was mistrimmed because of automatic horizontal stabilizer adjustments made to compensate for the incorrect rigging.

Autopilot number two (CMD2), which is hydraulically powered by the yellow system, was in use at the time of the incident.

The yellow hydraulic system had a quantity transmitter problem that occasionally caused a temporary shutoff of yellow hydraulic pressure on other flights.

Autopilot number two disconnected, possibly as a result of a momentary indication of low yellow hydraulic system quantity or pressure; other momentary interruptions of autopilot engagement conditions cannot be ruled out as the cause of the autopilot disengagement.

Nose-up elevator motion and the mistrimmed horizontal stabilizer position produced a pitch-up moment when the autopilot disengaged.

The high Mach number of the aircraft added to the pitch-up moment.

At some points in the flight upset, commencing just after the autopilot disconnected initially, aircraft control was not effective and some control inputs were inappropriate for recovery of the aircraft.

The A310 fuel system has recurring CGCC problems.

The centre of gravity was further aft than normal because of a fault in the CGCC system and the procedures used by the crew in dealing with the fault.

The aircraft flight envelope protection system assisted the crew in the recovery from the low speed portion of the upset manoeuvre and attempted to provide beneficial pitch trim changes during the ascent and descent.

The crew did not make a required entry in the aircraft log regarding the flight upset.

The decision by the Moncton air traffic controller not to "bother" the crew at a critical time removed possible distractions from the crew as they attempted to deal with the flight upset.

3.2 Causes

The flight upset manoeuvre was caused by a misrigged autopilot elevator servo control, which led to an initial pitch-up, and by the crew's ineffective or inappropriate pitch control inputs which led to aircraft stall. Contributing factors in the flight upset were the aft centre of gravity position and the aircraft's high speed.

4.0 Safety Action

4.1 Action Taken

There are two operators of the A310 in Canada: Air Club International and the Department of National Defence (DND). (Canadian Airlines International provides maintenance support
to DND.) Each operator was contacted in May 1995 to determine if AOT 27-20 had been carried out. All Canadian aircraft had undergone the autopilot-servo rigging checks specified in AOT 27-20.

As planned and indicated in AOT 27-20, an A310 (and A300-600) Aircraft Maintenance Manual amendment indicating the use of rigging pin 98A27307541000 was published on 01 June 1995.

Consigne de Navigabilité (CN, or Airworthiness Directive) 95-164-183 (B) was released by the Direction Générale de l'Aviation Civile of France on 30 August 1995, with an effective date of 09 September 1995. Airworthiness Directives issued by the country of manufacture are mandatory in Canada. The Airworthiness Directive specified that, within 500 flight hours, operators action AOT 27-20 and check that specific chapters of the Aircraft Maintenance Manual documentation had been correctly updated.

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 November 1996.

Appendix A - Radar Data and Additional Digital Aircraft Integrated Monitoring System Recorder (DAR) Information
Appendix B - Transcription of AOT 27-20

ALL OPERATORS TELEX - ALL OPERATORS TELEX SUBJECT: A300/A300-600/A310/AUTOPILOT ACTUATORS RIGGING CHECK.
OUR REF: A300/A300-600/A310/AOT 27-20/19 DEC 1994
1. AIRCRAFT AFFECTED
ALL DELIVERED A300, A300-600, AND A310 AIRCRAFT.
2. REFERENCED DOCUMENTATION
AMM 22-13-23 AUTOPILOT PITCH ACTUATOR REMOVAL/INSTALLATION (A300-600 AND A310)
AMM 22-13-24 PITCH TORQUE LIMITER LEVER REMOVAL/INSTALLATION (A300-600 AND A310)
AMM 22-13-27 AUTOPILOT YAW ACTUATOR REMOVAL/INSTALLATION (A300-600 AND A310)
AMM 22-13-28 YAW TORQUE LIMITER LEVER REMOVAL/INSTALLATION (A300-600 AND A310)
AMM 22-11-28 AUTOPILOT YAW SERVOMOTOR REMOVAL/INSTALLATION (A300)
AMM 22-11-29 YAW TORQUE LIMITER LEVER REMOVAL INSTALLATION (A300)
AMM 22-12-28 AUTOPILOT PITCH ACTUATOR REMOVAL/INSTALLATION (A300)
AMM 22-12-29 PITCH TORQUE LIMITER LEVER REMOVAL/INSTALLATION (A300)
AMM 27-31-00 PAGE BLOCK 501 PITCH MECHANICAL CONTROL ADJUSTMENT/ TEST (A300, A300-600 AND A310).
3. REASON
3.1. FACTS
DURING A TEST FLIGHT, ONE OPERATOR HAS REPORTED A/C PITCH UP AT AUTOPILOT 1/2 DISENGAGEMENT DURING CRUISE. AFTER REPLACEMENT OF THE PITCH AUTOPILOT ACTUATOR, ANOTHER FLIGHT TEST WAS CARRIED OUT AND SIMILAR PHENOMENON WAS REPORTED. THE ASSOCIATED UPWARD DEFLECTION OF THE ELEVATOR SURFACE AT THE TIME OF A/P DISCONNECTION WAS AROUND 1.5 DEG. DURING TROUBLE SHOOTING AND RIGGING CHECK, IT WAS FOUND THAT THE MECHANICAL ZERO RIGGING OF THE A/P ACTUATOR COULD NOT BE ACHIEVED WHEN USING THE PIN P/N OU131388 AS RECOMMENDED IN A300-600 AND A310 AMM 27-31-00 PAGE BLOCK 501 PARA 1.A (4). FURTHER INVESTIGATIONS REVEALED THAT THIS PIN IS NOT LONG ENOUGH TO GO THROUGH THE TORQUE LIMITER LEVER AND TO INTERNALLY RIG THE A/P ACTUATOR.

AFTER ADJUSTMENT OF THE MECHANICAL ZERO RIGGING USING A LONGER PIN, AN UNEVENTFUL FLIGHT TEST WAS PERFORMED.

3.2. CONSEQUENCES

IN CASE OF AUTOPILOT INCORRECT RIGGING, SUDDEN A/C PITCH UP OR PITCH DOWN COULD BE EXPERIENCED AT THE TIME OF UNFORESEEN A/P DISCONNECTION. THE AMPLITUDE OF ELEVATOR DEFLECTION AND ASSOCIATED LOAD FACTOR WILL DEPEND ON THE RIGGING OFFSET.

IN ADDITION AS THE RIGGING PIN AND PRINCIPLE IS SIMILAR ON THE YAW AUTOPILOT ACTUATOR, THE SAME INCORRECT RIGGING COULD BE INTRODUCED DURING ADJUSTMENT OF THIS ACTUATOR, SUCH AN INCORRECT RIGGING COULD GENERATE YAW JERK AT A/P DISCONNECTION.

3.3. AIM

AIM OF THIS AOT IS TO REQUEST THE RIGGING CHECK OF BOTH PITCH AND YAW AUTOPILOT ACTUATOR USING A STANDARD 8 MM DIA AND 200 MM LONG PIN P/N 98A27307541000 WHICH IS EASIER TO USE THAN THE PIN P/N OU131388 AND PROVIDES A MORE POSITIVE INDICATION CONCERNING THE RIGGING CONDITION.

4. SHORT TERM ACTION

4.1. PLANNING

IT IS REQUESTED TO CHECK THE RIGGING OF THE PITCH AND YAW AUTOPILOT ACTUATOR AT THE NEXT CONVENIENT OPPORTUNITY BUT NOT EXCEEDING 500 FLIGHT HOURS AFTER RECEIPT OF THIS AOT.

THE CORRESPONDING ELAPSED TIME IS ONE MAN HOUR PER A/C FOR BOTH CHECKS (HALF AN HOUR PER ACTUATOR).

4.2. DESCRIPTION

FOR A300-600 AND A310:

- CHECK THE PITCH AUTOPILOT ACTUATOR RIGGING AS DESCRIBED IN AMM 27-31-00 PAGE BLOCK 501 PARA 1.D (4). AT STEP (B) DO NOT RIG THE AUTOPILOT SERVO MOTOR WITH PIN P/N OU131388 BUT WITH PIN P/N 98A27307541000, FULLY INSERT RIGGING PIN TO ASCERTAIN CORRECT RIGGING.

- CHECK THE YAW AUTOPILOT ACTUATOR RIGGING AS DESCRIBED BELOW:

  MAKE SURE THAT RUDDER TRIM IS SET AT ZERO AND THAT RUDDER PEDAL ARE SET AT NEUTRAL.

  INSTALL RIGGING PIN P/N 98A27307546000 IN THE RUDDER CONTROL MAIN BELLCRANK.


  FOR A300:


  - CHECK THE YAW AUTOPILOT ACTUATOR RIGGING AS DESCRIBED BELOW:

    MAKE SURE THAT RUDDER TRIM CONTROL WHEEL IS SET AT ZERO AND THAT RUDDER PEDALS ARE SET AT NEUTRAL.
INSTALL RIGGING PIN P/N 98A27307546000 IN RUDDER CONTROL MAIN BELLCRANK.
INSTALL RIGGING PIN P/N 98A27003001000 IN THE YAW AUTOPILOT ACTUATOR AND CHECK RIGGING. IN CASE THE PIN CANNOT FULLY ENGAGE, THEN ADJUST THE LENGTH OF THE PUSHROD (10) AS DESCRIBED IN ABOVE AMM 22-11-28 PAGE BLOCK 401 PARA 1.B (4) (C) 3.

4.3. MATERIAL TOOLING.
FOR A300-600 AND A310
FOR A300

5. FURTHER ACTION
A TEMPORARY REVISION WILL BE ISSUED BY EARLY JAN 95 TO AMEND ALL AMM CHAPTERS LISTED IN PARA.2 (EXCEPT AMM 27-31-00 PAGE BLOCK 501 FOR A300 WHICH IS CORRECT) IN ORDER TO DELETE THE RIGGING PIN P/N OU131388 AND REPLACE IT BY PIN P/N 98A277003001000 FOR A300 A/C AND BY PIN P/N 98A27307541000 FOR A300-600 AND A310 A/C.

6. REPORTING/ACKNOWLEDGEMENT
OPERATORS ARE REQUESTED TO ACKNOWLEDGE RECEIPT OF THIS AOT TO AI/SE-EQ R. LASCOURS WITHIN 48 HOURS AFTER RECEIPT. THIS ACKNOWLEDGEMENT CAN BE MADE THROUGH THE AIRBUS CUSTOMER SUPPORT OFFICE WHEN AVAILABLE.
RIGGING CHECK RESULTS (CORRECT OR INCORRECT) AND PERFORMED RE-ADJUSTMENT (MODIFICATION OF PUSHROD LENGTH, SHORTENED OR LENGTHENED) ARE TO BE SENT TO AIRBUS ENGINEERING SERVICES ATTENTION AI/SE-E42, AS SOON AS POSSIBLE, AFTER THE AOT APPLICATION.
BEST REGARDS
D. THERIAL
DIRECTOR OF ENGINEERING SERVICES
CUSTOMER SERVICE DIRECTORATE.

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

   LP 046/95 - Flight Recorder Analysis.

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

Appendix D - Glossary

<p>| AD     | Airworthiness Directive |
| ADC    | air data computer       |
| ALT    | altitude hold           |
| AOT    | All Operator Telex      |
| AP     | autopilot               |
| A/P    | autopilot               |
| ATC    | air traffic control     |
| ATPL   | Airline Transport Pilot Licence |
| B      | blue (hydraulic system) |
| BEA    | Bureau Enquêtes-Accidents |
| CAA    | Civil Aviation Authority |</p>
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>CGCC</td>
<td>centre of gravity control computer</td>
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<tr>
<td>C of G</td>
<td>centre of gravity</td>
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<tr>
<td>CDU</td>
<td>control display unit</td>
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<tr>
<td>CMD (1,2)</td>
<td>Command, an autopilot engaged indication</td>
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<tr>
<td>CVR</td>
<td>cockpit voice recorder</td>
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<tr>
<td>DAR</td>
<td>digital aircraft integrated monitoring system recorder</td>
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<tr>
<td>DIR</td>
<td>direct to</td>
</tr>
<tr>
<td>DND</td>
<td>Department of National Defence</td>
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<tr>
<td>EPR</td>
<td>engine pressure ratio</td>
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<tr>
<td>ETOPS</td>
<td>extended twin (engine) operations</td>
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<tr>
<td>FAR</td>
<td>Federal Aviation Regulation</td>
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<tr>
<td>FCC</td>
<td>flight control computer</td>
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<tr>
<td>FCU</td>
<td>flight control unit</td>
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<tr>
<td>FDR</td>
<td>flight data recorder</td>
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<tr>
<td>FL</td>
<td>flight level</td>
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<tr>
<td>fpm</td>
<td>feet per minute</td>
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<tr>
<td>FMS</td>
<td>flight management system</td>
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<tr>
<td>FWC</td>
<td>flight warning computer</td>
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<tr>
<td>G</td>
<td>green (hydraulic system)</td>
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<tr>
<td>g</td>
<td>G load factor</td>
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<tr>
<td>hr</td>
<td>hour(s)</td>
</tr>
<tr>
<td>KIAS</td>
<td>knots, indicated airspeed(s)</td>
</tr>
<tr>
<td>kg</td>
<td>kilogram(s)</td>
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<tr>
<td>LOLVL</td>
<td>low level</td>
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<tr>
<td>MAC</td>
<td>mean aerodynamic chord</td>
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<tr>
<td>mm</td>
<td>millimetre(s)</td>
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<tr>
<td>MNPS</td>
<td>minimum navigation performance specification</td>
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<tr>
<td>N</td>
<td>north</td>
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<tr>
<td>NAT</td>
<td>North Atlantic track</td>
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<tr>
<td>NAV</td>
<td>navigation FMS mode</td>
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<tr>
<td>PIREP</td>
<td>pilot report of weather conditions in flight</td>
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<tr>
<td>psi</td>
<td>pounds per square inch</td>
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<tr>
<td>RAT</td>
<td>ram air turbine</td>
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<td>RDA</td>
<td>radar data analysis</td>
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<td>Romania Air Transport - flight plan assignment</td>
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<td>SAT</td>
<td>static air temperature</td>
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<tr>
<td>SIGMET</td>
<td>significant meteorological (forecast)</td>
</tr>
<tr>
<td>TAT</td>
<td>total air temperature</td>
</tr>
<tr>
<td>THS</td>
<td>trimmable horizontal stabilizer</td>
</tr>
<tr>
<td>TSB</td>
<td>Transportation Safety Board of Canada</td>
</tr>
<tr>
<td>UTC</td>
<td>Coordinated Universal Time</td>
</tr>
<tr>
<td>Vc</td>
<td>computed airspeed</td>
</tr>
<tr>
<td>Vmax</td>
<td>maximum selectable speed</td>
</tr>
<tr>
<td>Vs</td>
<td>stall speed</td>
</tr>
</tbody>
</table>
Vss  stick-shaker speed
W  west
Y  yellow (hydraulic system)
VHF  very high frequency
'  minute(s)
"  second(s)
°  degree(s)

1. See Glossary at Appendix D for all abbreviations and acronyms.

2. All times are Coordinated Universal Time (UTC) unless otherwise stated.

3. Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.
Air 1995

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.

Mid-Air Collision Between
Bearskin Airlines Fairchild Metro 23 C-GYYB and
Air Sandy Inc. Registration PA-31 Navajo C-GYPZ
Sioux Lookout, Ontario 12 nm NW
01 May 1995

Report Number A95H0008

Synopsis

Air Sandy flight 3101, a Piper PA-31 Navajo with one pilot and four passengers on board, had departed Sioux Lookout on a flight to Red Lake, Ontario. Bearskin Airlines flight 362, a Fairchild Swearingen Metro 23 with a crew of two and one passenger on board, was inbound to Sioux Lookout on a flight from Red Lake. The two aircraft collided at 4,500 feet above sea level, approximately 12 nautical miles northwest of Sioux Lookout. All eight occupants were fatally injured.

The Board determined that neither flight crew saw the other aircraft in time to avoid the collision. Contributing to the occurrence were the inherent limitations of the see-and-avoid concept which preclude the effective separation of aircraft with high closure rates, the fact that neither crew was directly alerted to the presence of the other aircraft by the Flight Service specialist or by onboard electronic equipment, and an apparent lack of pilot understanding of how to optimize avoidance manoeuvring.

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1.0 Factual Information

1.1 History of the Flight

Bearskin flight 362, a Fairchild Swearingen Metro 23, departed Red Lake, Ontario, at 1300 central daylight saving time (CDT) <1>, with two pilots and one passenger on board, en route to Sioux Lookout on an instrument flight rules (IFR)<2> flight plan. At approximately 30 nautical miles (nm)<3> north of Sioux Lookout, the flight was cleared by the Winnipeg area control centre (ACC) for an approach to the Sioux Lookout airport.

Air Sandy flight 3101, a Piper Navajo PA-31, departed Sioux Lookout at 1323 with one pilot and four passengers on board en route to Red Lake on a visual flight rules (VFR) flight. The pilot of Air Sandy 3101 reported clear of the Sioux Lookout control zone at 1326. No other communication was heard from the Air Sandy flight.

At 1315 the Winnipeg ACC controller advised the Sioux Lookout Flight Service specialist that Bearskin 362 was inbound from Red Lake, estimating Sioux Lookout at 1332. At 1327, Bearskin 362 called Sioux Lookout Flight Service Station (FSS) and advised them they had been cleared for an approach and that they were cancelling IFR at 14 nm from the airport. At 1328, as Sioux Lookout FSS was giving an airport advisory to Bearskin 362, the specialist heard an emergency locator transmitter (ELT) emit a signal on the emergency frequencies.

Moments later, the pilot of Bearskin 305, a Beechcraft B-99 in the vicinity of Sioux Lookout, advised the specialist that he had just seen a bright flare in the sky and that he was going to investigate. The pilot of Bearskin 305 stated that the flare had fallen to the ground and a fire was burning in a wooded area. A communications search was initiated to locate Bearskin 362, but the aircraft did not respond. A Search and Rescue aircraft from Trenton, Ontario, and an Ontario Ministry of Natural Resources (MNR) helicopter were dispatched to the site. The source of the fire was confirmed to be the Air Sandy aircraft. The MNR helicopter noticed debris and a fuel slick on a nearby lake, Lac Seul. It was later confirmed that Bearskin 362 had crashed into the lake. (See Appendix A.)
The two aircraft collided in mid-air at 1328 during the hours of daylight at latitude 50°14'N and longitude 92°07'W, in visual meteorological conditions (VMC). All three persons on board the Bearskin aircraft and all five persons on board the Air Sandy aircraft were fatally injured.

1.2 Injuries to Persons

1.2.1 Bearskin Swearingen Metro 23 C-GYYB

<table>
<thead>
<tr>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Serious</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Minor/None</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

1.2.2 Air Sandy Piper Navajo PA-31 C-GYPZ

<table>
<thead>
<tr>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Serious</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Minor/None</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

1.3 Damage to Aircraft

Both aircraft were destroyed.

1.4 Other Damage

There was localized environmental damage. The trees surrounding the Navajo were damaged or burnt, and the water surrounding the Metro 23 was contaminated by fuel and oil from the aircraft.

1.5 Personnel Information

1.5.1 Bearskin Swearingen Metro 23 C-GYYB

<table>
<thead>
<tr>
<th>Captain</th>
<th>First Officer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>27</td>
</tr>
<tr>
<td>Pilot Licence</td>
<td>ATPL</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
<td>01 Oct 95</td>
</tr>
<tr>
<td>Total Flying Hours</td>
<td>7,330</td>
</tr>
<tr>
<td>Hours on Type</td>
<td>580</td>
</tr>
<tr>
<td>Hours Last 90 Days</td>
<td>170</td>
</tr>
<tr>
<td>Hours on Type Last 90 Days</td>
<td>170</td>
</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
<td>7</td>
</tr>
<tr>
<td>Hours Off Duty Prior to Work Period</td>
<td>10</td>
</tr>
</tbody>
</table>

The captain and first officer were certified and qualified for the flight in accordance with existing regulations. Both crew members were trained in accordance with Transport Canada requirements.

1.5.2 Air Sandy Piper Navajo PA-31 C-GYPZ

<table>
<thead>
<tr>
<th>Captain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Pilot Licence</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
</tr>
<tr>
<td>Total Flying Hours</td>
</tr>
<tr>
<td>Hours on Type</td>
</tr>
</tbody>
</table>
The captain was certified and qualified for the flight in accordance with existing regulations. The captain was trained in accordance with Transport Canada requirements.

### 1.5.3 Flight Service Specialist

- **Specialist Position**: Air/Ground
- **Age**: 32
- **Licence**: Not Required
- **Medical Expiry Date**: 14 June 1997
- **Experience**:
  - as a Specialist
  - in Present Unit: 7 years
    - 21 months
- **Hours on Duty Prior to Occurrence**: 5.5
- **Hours Off Duty Prior to Work Period**: 12

The FSS was being staffed by two specialists; one was assigned to weather functions and the other to handling the air/ground communication duties. When the accident occurred, the specialist assigned to the air/ground duties was half-way through his final 12-hour shift of a three-day-on/three-day-off schedule. He was qualified, and there were no indications of any medical or physiological problems that would have had any bearing on his ability to perform the assigned functions. Flight Service specialists do not receive any formal training on the limitations of the see-and-avoid concept, nor are they required to by regulation.

### 1.6 Aircraft Information

#### 1.6.1 Bearskin Metro 23 C-GYYB

- **Manufacturer**: Fairchild Aircraft Incorporated
- **Type and Model**: SA227-CC Metro 23
- **Year of Manufacture**: 1993
- **Serial Number**: CC-827B
- **Certificate of Airworthiness**
- **Valid**
- **Total Airframe Time**: 3,200.8 hours
- **Engine Type (number of)**: Garrett TPE331-11U-612G (2)
- **Propeller/Rotor Type (number of)**: McCauley 4HFR34C652-F (2)
- **Maximum Allowable Take-off Weight**: 16,500 pounds
- **Recommended Fuel Type(s)**: Jet A, Jet A1, Jet B
- **Fuel Type Used**: Jet B

The aircraft was configured to carry 19 passengers. The aircraft's weight and centre of gravity on the occurrence flight were within the prescribed limits.

The aircraft was being maintained on a progressive phase inspection program and had undergone a No. 4 phase and service check on 27 April 1995, 15 flight hours prior to the occurrence. There were no recorded deferred unserviceabilities, and documentation indicates that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

#### 1.6.2 Air Sandy Piper Navajo PA-31 C-GYPZ
Manufacturer: Piper Aircraft Corporation
Type and Model: PA-31-350 Navajo
Year of Manufacture: 1976
Serial Number: 31-7652168
Certificate of Airworthiness: Valid

(Flight Permit)
Total Airframe Time: 6,784.4 hours
Engine Type (number of): Lycoming TIO-540-J2BD (2)
Propeller/Rotor Type (number of): Hartzell HC-E3YR-2ATF (2)
Maximum Allowable Take-off Weight: 7,250 pounds
Recommended Fuel Type(s): 100 Low Lead
Fuel Type Used: 100 Low Lead

The aircraft had been modified with a Boundary Layer Research vortex generator kit which increased the aircraft's maximum allowable take-off weight from 7,000 pounds to 7,250 pounds. The aircraft's weight and centre of gravity on the occurrence flight were within the prescribed limits.

On 26 April 1995, 17 flight hours prior to the occurrence, the aircraft's autopilot was repaired, both altimeters were recertified, and the aircraft's transponder was repaired and recertified. The work report indicated that the transponder unit still had a low power output and that a tube replacement was recommended in the near future. A check of the aircraft's pitot static system was carried out. The pilot's horizontal situation indicator (HSI) was removed on 21 September 1994 because of sluggishness and replaced with a directional gyro (DG).

The aircraft underwent a 100-hour inspection on 28 April 1995, 12 flight hours prior to the occurrence. Documentation indicates that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

1.7 Meteorological Information

The area forecast for Sioux Lookout issued at 1230 on 01 May 1995 indicated a broken and locally scattered cumulus cloud layer based at 4,000 to 5,000 feet above sea level (asl) and topped at 8,000 feet asl. Other broken, variable scattered, cloud layers were forecast between 10,000 and 14,000 feet asl. Visibility was forecast greater than six miles. Isolated towering cumulus clouds, producing light rain showers, were anticipated with the tops of the cumulus cloud reaching up to 14,000 feet asl. The freezing level was forecast to be at 2,000 to 3,000 feet asl, and turbulence was predicted to be light to nil.

The terminal forecast for Sioux Lookout for the time of the occurrence indicated a scattered layer at 4,000 feet above ground level (agl) with a broken ceiling of 10,000 feet agl and visibilities in excess of six miles. The terminal forecast predicted occasional ceilings of 4,000 feet agl with visibilities greater than six miles in light rain showers.

The 1800Z weather reported at Sioux Lookout, about 28 minutes prior to the occurrence, was as follows: clouds 3,500 feet agl scattered, estimated 8,000 feet agl overcast; visibility, 15 miles; temperature, 9 degrees Celsius; dew point, -1 degree Celsius; wind, 210 degrees true at 6 knots. The 1851Z weather reported at Sioux Lookout, about 23 minutes after the collision, was as follows: clouds 4,000 feet agl scattered, estimated 8,000 feet agl overcast; visibility 15 miles.

The flight crew of the Bearskin Airlines Beech 99 that was flying in the area at the time of the occurrence indicated that they were in VMC at the time of the occurrence; they saw a brilliant flash, then saw debris and a fireball-type object fall to the ground. They stated that they were at an altitude of approximately 4,000 feet asl, 5 to 6 nm east of the explosion. The flight crew indicated that the visibility was unlimited beneath a solid overcast of approximately 6,500 feet asl, and that there was no direct sunlight breaking through the solid overcast.

1.8 Aids to Navigation

Each aircraft was equipped with a global positioning system (GPS) receiver. Bearskin aircraft have the GPS receiver connected directly to the HSI, and company procedures require the pilots to use GPS as an aid to primary navigation systems. Air Sandy company procedures also require the pilots to use GPS as an aid to navigation. The Canadian air navigation system is rapidly moving towards increased reliance on GPS as an inexpensive and accurate navigation system.

Airways are designed to be 8 nm wide (8.6 for non-directional beacon [NDB]) at their narrowest point. This width takes into account the inaccuracies of the ground transmitter and those of the aircraft receivers. GPS receivers, however, are considered accurate to within ± 300 feet and will show course deviations of 0.1 nm—in effect, the airway has become 600 feet wide. A large portion of the ± 300-foot accuracy error is deliberately introduced by the United States (U.S.) military on a random basis and is designed to deny high precision signals to unfriendly military aircraft.

When two aircraft using GPS are flying the same route and are in the same location, they could receive the same signal. Although they can be as much as 300 feet from their intended position relative to the ground, the distance between the two aircraft could be much less (see LP 95/95). Thus, GPS has greatly reduced the lateral displacement of aircraft flying along identical intended tracks.

Since the introduction of GPS, there have been no changes to procedures to take into account the increased risk of mid-air collisions for aircraft navigating by GPS. Transport Canada has acknowledged the problem and has promulgated a leaflet that discusses the use of GPS offset procedures to ensure separation en route. Although the information suggests using an offset track while navigating by GPS, there are no established procedures that would ensure that all pilots using GPS offset their tracks. If procedures for separating aircraft are not used, the probability of collision between aircraft using GPS is significantly higher than between aircraft using conventional navigation aids.

1.9 Characteristics of the See-and-Avoid Concept

1.9.1 General

Safe VFR flight is predicated on the see-and-avoid concept. The effectiveness of the see-and-avoid concept for collision avoidance is dependent on flight crew detecting other aircraft on collision courses in time to take evasive action. A pilot's ability to visually detect another aircraft is affected by many factors, including physiological limitations of the human visual and motor-response systems, the pilot's awareness of the presence of another aircraft, the pilot's available field of view, obstructions to that field of view, aircraft conspicuity, pilot scanning techniques, and pilot workload.

1.9.2 Physiological Factors

Physiological limitations in both the human visual and motor-response systems reduce the effectiveness of see-and-avoid as the relative closing speed of the aircraft increases.

The main physiological limiters are as follows:

a. when the threat is distant and sufficient time is available to react, the ability of the human optical system to perceive the required information is limited; however,

b. when the threat is close enough to allow the eye to perceive the required information, then the time available to allow for information processing and motor response may be insufficient.

1.9.3 Traffic Advisories

It is generally recognized that traffic advisories will improve a pilot's ability to visually acquire another aircraft. First, the advisory provides advance warning of a potential conflict and will tend to increase the time that the crew will devote to the visual search for the traffic. Second, the advisory will aid the pilot in concentrating the visual search in the proper direction.

Research conducted by the Lincoln Laboratory<4> during traffic alert and collision avoidance system (TCAS) flight testing showed that a pilot alerted to the presence of other aircraft visually acquired the other aircraft in 57 of 66 cases; the median range of visual acquisition was 1.4 nm. However, in cases where the pilot was not alerted to the presence of the other aircraft, visual acquisition of the other aircraft was achieved in only 36 of 64 encounters; in the successful encounters, the median acquisition range dropped to 0.99 nm.

These studies showed that verbal guidance as to where to look increased the acquisition probability for the pilots, and found that a pilot who had been alerted to the presence of another aircraft was eight times more likely to see the aircraft than was a pilot who had not been alerted.

1.9.4 Visibility from the Cockpit

Cockpit design affects the available view. In particular, obstructions such as window posts mask certain areas
around the aircraft. Pilots are required to consciously alter their head position in order to look around these obstructions.

1.9.5 Conspicuity Of Aircraft On Collision Course

The human visual system has physical limitations which reduce effective visual performance. For example, people are particularly attuned to detecting movement, but are less effective at detecting stationary objects. Unfortunately, because of the geometry of collision flight paths, an aircraft on a collision course will appear to be a stationary object in the pilot's visual field.

The contrast between an aircraft and its background, and the apparent size of an aircraft are two of the factors that affect an aircraft's detectability. At the time of the occurrence, according to a report from pilots in another aircraft operating in the immediate area, the sky was overcast with a layer of cloud at about 6,500 feet asl. The pilots also indicated that there were no obstructions to flight visibility. The aircraft involved in this occurrence were white and light beige, and would have been relatively indistinguishable from their background or the clouds.

Most of the snow in the area had melted, including some of the snow in the woods. However, some of the lakes in the area of the occurrence were still ice covered and appeared white in colour from the air. The frozen surface of the lakes, as well as the snow and the topography of the area, made the detection of either aircraft more difficult.

1.9.6 Pilot Scanning Technique

A pilot's visual scanning technique is affected by the level and complexity of other pilot tasks and the pilot's level of concern about the threat of a collision.

The company procedure for the Navajo was to have the pilot climb the aircraft at a rate lower than the best-rate-of-climb in order to provide adequate airflow over the engine for cooling purposes. Assuming this rate-of-climb, the aircraft would have reached cruise altitude prior to the impact. The level-off checks for the Navajo require that the pilot momentarily look inside the cockpit at the flight and engine instruments in order to set cruise power.

The Metro pilots were preparing for a landing and talking to the Flight Service specialist. Analysis of the cockpit voice recorder (CVR) indicated that the crew also discussed the approach and landing, completed checks, and talked to company personnel on the radio.

1.9.7 Factors Affecting Visual Acquisition

For the see-and-avoid principle to be effective, it is necessary that a pilot be able to detect aircraft by visual means, recognize collision geometry based on visual cues, and react correctly, and in sufficient time, to avoid a mid-air collision.

In a potential mid-air collision situation, physiological limitations of the eye, pilot visual-scanning techniques, target characteristics, pilot reaction time, aircraft speed and design, and numerous other factors will influence a pilot's ability to acquire a target visually and avoid it. In general terms, assuming that a pilot is looking in the correct direction, the visual detection of a target is largely a function of target size. A pilot will only see an aircraft when the size of the target becomes large enough to meet the minimum resolution capability of the eye. Commercial or charter aircraft similar to the ones involved in this occurrence should, under good conditions, be detectable at an approximate range of 1 to 1.5 nm. Contrast with the background, aircraft attitude, and relative flight path of an aircraft can affect this detection range, often reducing it significantly.

1.9.8 Human Response Limitations

Simple detection of another aircraft in flight is not the only problem with the see-and-avoid concept. Studies indicate that minimum times required for a human to process information and then react will range from six to nine seconds. Additionally, in a flying situation, there will be a further delay due to the inertia of the aircraft. As a result, the total reaction time necessary for a pilot to recognize and analyze visual information and then effect a change to an aircraft's flight path could be as high as 12 seconds, assuming that the pilot is alert, attentive, and doing visual scanning.

With closing speeds in the range of 410 knots, a pilot would have to see the approaching target at a minimum range of approximately 1.4 nm (12 seconds) in order to have sufficient time to take effective evasive action. Using data from a study conducted at the Massachusetts Institute of Technology (MIT) (see LP 86/95), it was determined that the probability of the Air Sandy pilot detecting the Bearskin flight 12 seconds before impact was about 13%. The probability of his detecting the Bearskin aircraft 20 seconds (2.3 nm) prior to impact was only
As the two aircraft approach each other, the probability of detection increases. Using the same MIT study data, it was determined that, at 20 seconds prior to impact, the Bearskin pilots had a 7% chance of detecting the Air Sandy aircraft. At 12 seconds (1.4 nm) to impact, they had a 16% chance of detecting the Air Sandy aircraft. At a time of 4.4 seconds (0.5 nm) prior to impact, the Bearskin pilots would have had a 53% chance of detecting the Air Sandy aircraft. At a time of 3.5 seconds (0.4 nm) prior to impact, the Air Sandy pilot would have had a 52% chance of detecting the Bearskin aircraft. These probabilities were determined using optimum flight conditions with no restriction to the visibility field of the pilots. Restrictions to a pilot's visibility field could come from the aircraft's attitude, the aircraft airframe, a windshield post, windshield size, or from dirt, scratches, or bugs on the windshield.

1.9.9 Pilot Avoidance Techniques

Assuming that a pilot will be capable of visually detecting another aircraft in flight and determining that the closing geometry represents a mid-air threat, then the final stage in the see-and-avoid sequence is to initiate an effective avoidance response. The aim of that response will be to increase the miss distance between the aircraft. The effectiveness of that response is dependent on a number of factors; in general, either pilot can alter the geometry of a collision by changing some combination of aircraft speed, altitude, and heading. Because each of these actions will affect the geometry differently, it is essential that the pilot choose an appropriate combination of actions that will merge to achieve a corresponding effect.<7>

The optimum avoidance response will differ depending on the time to impact. There is research evidence<8> to indicate that, outside 10 seconds to the point of closest approach, the pilot should use compatible manoeuvres combining speed, altitude, and heading change. However, once the aircraft are inside the range of approximately 10 seconds to impact, the pilot should employ an altitude change only. This conclusion is based on an argument that, when two aircraft are confined in close quarters, the essential action is to minimize the relative cross-sectional areas of each aircraft. Under these circumstances, it has been generally found that any application of bank will increase the relative cross-sectional area and thereby increase the probability of impact.<9>

As an example, a Piper Navajo aircraft similar to the one involved in this occurrence will have a vertical cross-section of approximately 13 feet when in level flight. At bank angles in the range of 45 to 60 degrees, the vertical cross-section will be in the range of 28 to 34 feet. The final value of the vertical cross-section will be dependent on the aircraft's wing span and on the applied bank angle.

Formal training on how to recognize in-flight collision geometry and on how to optimize avoidance manoeuvring is not part of the required syllabus for any level of civilian pilot licence in Canada.

1.10 Aerodrome Information

1.10.1 General

Sioux Lookout airport, located at 50°06'N and 91°54'W, is a certified aerodrome operated by the town of Sioux Lookout. The field point elevation is 1,280 feet asl. The main runway, which is oriented 160/340 degrees magnetic, is paved and measures 4,500 feet by 100 feet. An NDB and a distance measuring equipment (DME) transmitter are located at the airport. The control zone extends around the airport for a 5 nm radius from the surface of the earth to an altitude of 4,300 feet asl. A pie-shaped corridor in the western section of the control zone is exempted from the mandatory frequency (MF) at an altitude below 700 feet agl. This corridor is designed to permit float-equipped aircraft access to the lake and townsites without having to enter the control zone. A flight service station is located at the airport and provides traffic advisories, among other things, to aircraft flying in the area. IFR traffic operating in and out of Sioux Lookout is controlled by Winnipeg ACC.

1.10.2 FSS Facilities/Operation

The Sioux Lookout FSS is normally busy, in that the airport supports scheduled flights for Bearskin Airlines, Air Sandy, charter flights for a number of commercial carriers, and local traffic. Additionally, the Sioux Lookout area encompasses float bases and an MNR base, both of which are within several miles of the airfield.

FSS duties and functions are governed by a Flight Service Manual of Operations (MANOPS) which stipulates the priority of duties and establishes specific procedures to govern how the FSS support functions will be accomplished.

1.10.3 Flight Service Specialist Equipment

The specialist is responsible for providing airport advisory information to aircraft operating to or from a location within the MF area. In accordance with MANOPS, when giving the advisory, the specialist must provide a summary of known pertinent aircraft traffic that may affect the aircraft's flight safety. While operating in visual meteorological conditions, pilots have the sole responsibility for seeing and avoiding other aircraft. The specialist did not directly advise Air Sandy of the Bearskin 362 flight inbound from Red Lake; however, he did advise two other aircraft on the MF of the approaching Bearskin 362 flight while Air Sandy 3101 was on the same frequency. Pilots are also responsible for maintaining a listening watch on the MF.

The Flight Service specialist can contact Winnipeg ACC via landline for IFR traffic information; however, the tools available to the specialist to facilitate traffic recognition and determine the traffic location are limited. The Sioux Lookout specialist had a plotting board on which he would make a strip that would identify the traffic in his area. He would also be able to rely on position reports provided on 122.0 (the MF) and 126.7 megahertz (MHz) frequency. Taking this type of traffic information and processing a mental picture of the various aircraft and their positions in relation to one another is more difficult without adequate visual references.

Most air traffic controllers in area control centres are able to view a radar screen for traffic information. The information on the radar screen allows the controller to identify traffic and have a pictorial display of the traffic in his or her area of control. Some air traffic control towers that are located near radar sites have personal-computer-based radar displays of the traffic in their area. Although the tower controllers do not use the radar information for traffic separation, they do use this information to provide traffic information with respect to their location. The Sioux Lookout FSS is equipped with very high frequency (VHF) direction finding (VDF) equipment. Information is displayed by a numerical readout which gives an indication of the bearing of an aircraft from the VDF site. This is based on a radio signal from the aircraft; however, no distance information is provided.

1.10.4 Air Carrier Radio Frequency Procedures

On a VFR departure from Sioux Lookout, the Air Sandy company procedure is for the pilot to communicate on the MF until clear of the control zone and then change to an en route frequency of 122.8 MHz. The second radio in the aircraft would be tuned to either 126.7 MHz or 122.0 MHz. The switch to 122.8 MHz would be made prior to reaching a distance of 10 nm from the airport.

Bearskin 362 was on the Winnipeg ACC frequency en route to Sioux Lookout. Once cleared for the approach by Winnipeg ACC and instructed to contact the Sioux Lookout FSS, the Bearskin crew delayed contacting the FSS for about 70 seconds. This delay was intentional because the crew wanted to wait until they were clear of cloud so that they could cancel their IFR clearance and proceed VFR. Had they contacted Sioux Lookout FSS immediately after being instructed, they still would not have heard the Air Sandy flight clearing the zone; however, the specialist would have had more time to relay vital traffic information to the Bearskin crew.

1.11 Flight Recorders

The Metro 23 wreckage was in about 30 feet of water; a tuneable hydrophone receiver was used to locate the underwater locating beacons of the flight data recorder (FDR) and the cockpit voice recorder (CVR). Investigators experienced difficulty locating the underwater beacons of the recorders because impact damage to the transducer ring on both beacons degraded the signal output beyond the manufacturer's specification.

Information from the FDR and CVR of the Metro 23 proved invaluable to the investigation. A review of the FDR information shows that the Bearskin aircraft took no evasive manoeuvres prior to impact, and that the mid-air collision occurred at 4,500 feet asl. There was no indication of mechanical problems that would have contributed to the occurrence. The airspeed of the Bearskin aircraft during the descent was about 250 knots, slowing to about 230 knots prior to the collision. There were no indications on the CVR that the Bearskin crew saw the Air Sandy aircraft. The CVR also indicated that the Bearskin crew turned on the aircraft's recognition lights during the descent into Sioux Lookout, in accordance with company procedures.

The Air Sandy aircraft was not equipped with an FDR or CVR, nor was either required by regulation.

1.12 Wreckage and Impact Information

The wreckage from both aircraft was scattered over an area measuring approximately 1 1/2 by 1/2 miles. The major portions of the Bearskin Metro were located in water (designated Site 1). The high-speed impact with the water resulted in the destruction of the aircraft. Evidence showed that the aircraft was on fire prior to impact with the water. The major portions of the Air Sandy Navajo wreckage were located on land (designated Site 2), where the majority of the aircraft was burned in a post-crash fire.

1.12.1 Site 1 - Metro Wreckage and Impact Information
The major portion of the Bearskin Metro wreckage was located in about 30 feet of water, approximately 200 feet south of an island directly west of Devil's Elbow in Lac Seul. The tight wreckage pattern at the bottom of the lake indicates that the aircraft struck the water in a near vertical attitude. Numerous pieces of aircraft debris were discovered floating downstream into the channels on either side of the Devil's Elbow point. Bubbles and a noticeable oil/fuel slick were noted emanating from the underwater location.

The left engine, left landing gear assembly, and wheel well structure were recovered from the water in one section. The landing gear was extended upon recovery; however, damage to the uplock roller casting on the main gear housing and damage to the gear door uplock roller bearing indicates that the landing gear was retracted prior to impact and forced out of the wheel well during the crash sequence. Portions of the left propeller hub were attached to the engine flange—the remaining pieces of the propeller hub and propeller blades were not located. The right engine and propeller were not located.

The right landing gear assembly and wheel well structure were recovered from the water as one section. The landing gear was retracted and both tires were deflated and driven off the rims. The landing gear housing was split open vertically along its length from being driven rearwards at an angle, and a piece of Navajo wing skin was found jammed between the wheel brake assemblies. The wing structure, outboard of the nacelle, was cut through at an approximately 45-degree angle.

The cockpit floor section through to the tail section was pulled out of the water in one crumpled section approximately 1/5 of its original length. The roof and side wall structures were blown open, crumpled, and fragmented. Fire sooting was evident on pieces of the right fuselage structure and on the upper and lower surfaces of the right horizontal stabilizer and elevator. The cockpit instrument and radio panel section was broken apart and scattered in small pieces along the bottom of the lake; only one altimeter was recovered.

The right wing of the Bearskin Metro, outboard of the right engine nacelle, and pieces of one of the Metro's propeller spinner and engine exhaust duct housing wrap were located on land in an area approximately midway between the two wreckage sites. The wing was cut through at about a 45-degree angle, consistent with the damage to the wing located at the Metro site. In this same area were numerous pieces of the Navajo's right wing and right aileron.

### 1.12.2 Site 2 - Navajo Wreckage and Impact Information

The major portion of the Navajo was located on land approximately 1.2 nm northwest of Site 1. The aircraft came through the trees on a heading of approximately 320 degrees magnetic and in an approximately 65 degrees nose-down left-wing-low attitude. The nose of the aircraft struck the ground and deflected forward while the remainder of the aircraft buried itself into the partially frozen ground. A post-crash fire consumed most of the cabin structure. Both engines were located in the crater.

The tail section and left wing structure through to the right engine nacelle were removed from the crater and partially reconstructed. The reconstruction showed that most of the right wing structure outboard of the engine nacelle was missing. The remainder of the aircraft appeared to be present. All three landing gear were located, and it was noted that the right landing gear was retracted in the wheel well.

### 1.12.3 System Examination

Due to the near complete destruction of both aircraft, a complete physical examination of all the aircraft systems was not possible. The aircraft flight profiles, however, coupled with CVR and FDR information from the Bearskin Metro 23, indicate that the aircraft were likely not experiencing any mechanical or flight system control difficulties prior to the collision.

### 1.12.4 Wreckage Reconstruction

The partial wreckage reconstruction of both aircraft indicates that the aircraft collided nearly head on, at a sharp bank angle. Because the Metro FDR and CVR information does not show a sudden roll input, it is likely that the Air Sandy Navajo was in a sharp left turn at the point of initial contact. Examination of the wreckage indicates that the right wing of the Navajo struck the nose of the Metro before contacting the Metro's right propeller. The Metro's right propeller was fragmented at this point and the engine sheared outboard off its mount. Portions of the Navajo's right wing continued on to drive the Metro's right main landing gear rearwards and outboard and slice off the Metro's right wing at a 45-degree angle, outboard of the engine nacelle. The Navajo's right wing, outboard of the engine nacelle, was completely fragmented at this point and both aircraft, minus one wing, descended nearly vertically into the ground.

### 1.13 Fire
Witnesses observed a brilliant flash in the sky, followed by an arcing streak leading to an explosion, which was thought to be fireworks. Following the explosion, an object was observed falling to the ground, and smoke was later observed emanating from the area of ground impact. This area of impact was later determined to be the Air Sandy Navajo site.

Both aircraft lost their right wings during the mid-air collision, and both wings contained fuel cells which ruptured upon impact. Sooting on the tail of the Bearskin Metro indicates that the aircraft was on fire prior to striking the water. The Air Sandy Navajo was burned by a post-crash fire after impact with the ground.

1.14 Survival Aspects

The in-flight collision took place at an approximate closing speed of more than 400 knots and at an altitude of approximately 3,200 feet agl. Both aircraft were damaged structurally by that collision. In each case, portions of one wing were destroyed by the in-flight collision and both aircraft commenced an immediate and uncontrolled descent. The collision and the impact with the ground or water would have resulted in "g" forces beyond the range of human tolerance.

1.15 Communications

The inbound Bearskin (IFR) changed from Winnipeg ACC to the MF frequency, and the outbound Air Sandy (VFR) normally changes from the MF frequency to 122.8 MHz. The only common frequency for the two aircraft would have been the MF, and, when the collision occurred, both aircraft were well outside the 5 nm MF zone.

Many aircraft operating in northwestern Ontario use the 122.8 MHz frequency for en route communication instead of 126.7 MHz. The 122.8 MHz frequency is not published in the Canada Flight Supplement for the Sioux Lookout area. Any pilot using the published frequency of 126.7 MHz or the MF will not be able to hear local traffic that is on 122.8 MHz and may be deprived of relevant traffic information. Similarly, the traffic operating on 122.8 MHz will not receive traffic information provided by aircraft on 126.7 MHz or on the MF.

1.16 Traffic Alert and Collision Avoidance System (TCAS)

TCAS is designed to operate independently of air traffic control and is designed to provide pilots with traffic information to assist them in the visual acquisition of other aircraft. TCAS I is a less sophisticated system which will provide a warning of proximate traffic (traffic advisories, or TAs) without providing guidance to avoid potential collisions. TCAS II is capable of providing TAs and resolution advisories (RAs) in the form of recommended vertical escape manoeuvres to avoid conflicting traffic. TCAS makes use of the radar beacon transponders installed on other aircraft; specifically, basic transponder returns are used to provide azimuth and range information; Mode C information, the aircraft altitude to the nearest 100-foot level, and Mode S intent-to-maneuvre information are used to interpret the vertical geometry required for the generation of RAs. Once a target is tracked and displayed, the TCAS processor will update the associated displays and advisories as long as transponder signals are received and until the target no longer constitutes a threat or goes beyond the display parameters. Aircraft without transponders are invisible to TCAS.

TCAS was developed in the U.S. by the Federal Aviation Administration (FAA). The U.S. is the only state in the world which mandates the use of TCAS. As of 31 December 1995, it is mandatory that all aircraft flying in U.S. airspace with 10 to 30 passenger seats be equipped with TCAS I. All aircraft with more than 30 passenger seats have been required to be equipped with TCAS II since 30 December 1993. There is no requirement for aircraft in Canada to be TCAS equipped, and neither of the two accident aircraft was so equipped.

2.0 Analysis

2.1 General

The pilots of both aircraft were certified and qualified, and there was no evidence that any physiological factors affected their ability to conduct the flights safely. There were no mechanical discrepancies found with either aircraft that would have contributed to the occurrence. The only apparent evasive action to avoid the collision was taken by the Air Sandy pilot; however, it was taken in insufficient time to avoid the collision.

Although this was a typical VFR situation in that two aircraft were flying under visual conditions, a number of factors combined to create a high risk of collision. Therefore, this analysis will examine the pilots’ ability to see the other aircraft, the limitations of the see-and-avoid concept, the lateral precision of GPS, why the pilots were not alerted, the effects of high closing speeds, the apparent lack of pilot understanding of how to optimize avoidance manoeuvring, and other factors that could have contributed to the occurrence.

2.2 Limitations of the See-and-Avoid Concept
See-and-avoid is used as the primary means of separating aircraft in visual flight conditions; however, due to the physiological limitations on the human visual and motor-response systems, it may be impractical to rely on this system as the primary means of separation. This is particularly true in situations that involve head-on geometry with high closing speeds; the risks involved in relying on see- and-avoid increase as the relative closing speed of the aircraft increases.

In this occurrence, the Bearskin Metro had been descending at approximately 250 knots and was decelerating to approximately 230 knots. The departing Navajo would have just levelled off from an en route climb and would have been accelerating to a flight planned cruise speed of approximately 180 knots. At a closing speed of about 410 knots and with 12 seconds before impact, the Bearskin pilots had less than a 16% probability of detecting the Air Sandy aircraft, and the Air Sandy pilot had less than a 13% chance of detecting the Bearskin aircraft. Not until the Bearskin pilots were within 4.4 seconds of impact and the Air Sandy pilot was within 3.5 seconds of impact did the pilots of either aircraft have at least a 50% chance of detecting the other aircraft. It is likely that the Air Sandy pilot saw the Metro and attempted an evasive manoeuvre.

With 12 seconds required to see and avoid another aircraft, it is doubtful that a pilot could effectively avoid another aircraft on a head-on collision course at a high closure rate.

Advisory communications by Air Traffic Services and flight crew monitoring of frequencies are crucial in helping prevent collisions. It is, therefore, considered important that Flight Service specialists have a level of understanding comparable to that of pilots on the limitations of see-and-avoid.

2.3 Avoidance Manoeuvre

Based on the aircrafts' relative attitudes at impact, it appears that the Air Sandy pilot had detected the approaching Bearskin Metro, and had begun an evasive manoeuvre by initiating a steep left-turn which had reached approximately 45 degrees to 60 degrees of bank. As the bank angle increased, the aircraft's cross-section would have increased correspondingly from a minimum value of approximately 13 feet to some final value in the range of 28 to 34 feet; the net result of the evasive roll would have been to inadvertently increase the Navajo's cross-sectional area and, thus, increase the risk of colliding with the oncoming Metro aircraft.

A vertical manoeuvre, consistent with that demanded by TCAS-equipped aircraft, is normally more effective in close-range, head-on collision scenarios. However, formalized training on how to recognize in-flight collision geometry and on how to optimize avoidance manoeuvring is not part of the required syllabus for any level of civilian pilot licence in Canada. Without appropriate training, it is possible that a pilot who sees a target in sufficient time to react may react by turning, thereby increasing the cross-sectional area of the aircraft and increasing the risk of collision.

2.4 FSS Advisory Communications

In this occurrence, it is unlikely that the involved aircraft were on the same radio frequency at the point where the collision occurred. Since the collision occurred approximately 12 nm from the airport, outside of the MF zone, it is likely that the Air Sandy aircraft would have been on 122.8 MHz and would not have heard any of the radio transmissions between the FSS and the Bearskin aircraft. The inbound Bearskin flight was operating under IFR control and had been directed to change from Winnipeg ACC to the Sioux Lookout MF. It is therefore unlikely that either aircraft would have heard transmissions generated by the conflicting flight. The only common frequency for the two aircraft would have been the MF, but, when the collision occurred, both aircraft were well outside the 5 nm control zone. If the flight crew of either aircraft had been alerted to the presence of the other, the likelihood of seeing the other aircraft would have increased by about a factor of eight. This increased likelihood of detection might have given the crew of either aircraft the opportunity to initiate a collision avoidance manoeuvre in time to prevent the collision.

Unlike air traffic controllers, Flight Service specialists do not have radar equipment. The specialist at Sioux Lookout was provided with VDF equipment, which has some capability to display potential collision information; however, VDF does not provide distance information.

The specialist had to rely on voice reports from aircraft, and, aided by a plotting board, his own ability to keep mental track of traffic in the area to visualize potential conflicts. He did not have additional equipment that would have helped alert him to the presence of the Bearskin flight and the conflict between it and the Air Sandy flight.

2.5 Control Zone

The use of the MF is only required while in the control zone. The edge of the control zone in Sioux Lookout is 5 nm from the airport. High performance, multi-engine aircraft that frequent the airport can have closing speeds of up to 400 knots (one departing, one landing), which is equivalent to more than 6 nm per minute. If the control zone radius is 5 nm, it is likely that these aircraft will have less than one minute before their paths cross within

the control zone. At such a speed, there is little time for the Flight Service specialist to convey traffic information, especially if he is tasked with other duties such as talking to other traffic or to the ACC on the telephone. If the MF area were larger, or if the aircraft were approaching and departing at lower speeds, there would be more time for aircraft to be made aware of each other.

2.6 Lateral Precision of GPS

Although all indications are that the pilots of both aircraft were navigating with the use of GPS, it was not possible to determine this with certainty. However, the use of GPS makes it possible to navigate with great precision. Navigating with an accuracy of ± 300 feet laterally does not leave much space when aircraft are converging at high speeds and are climbing or descending. Transport Canada has recognized this problem and has promulgated leaflets which discuss this issue. The leaflets suggest that pilots use laterally offset navigation tracks. However, there is no established procedure to ensure that all pilots navigating by GPS are using lateral separation. If one aircraft uses an offset track and another does not, the risk of collision will be reduced, but not by as much as it would be if both aircraft used offset tracks.

2.7 TCAS and Transponder Use

Modern TCAS equipment depends on transponder operation. Neither of the aircraft involved in this occurrence was TCAS equipped; however, if one of the aircraft had been equipped with TCAS and both had had operating transponders, the collision would likely not have occurred. TCAS, if installed and operable, would have provided constant warnings and cues to the crew of their proximity to the other aircraft. The warning likely would have provided the crew with adequate time to take appropriate actions to avoid the collision.

3.0 Conclusions

3.1 Findings

- The two aircraft collided at 4,500 feet above sea level, approximately 12 nautical miles northwest of Sioux Lookout.

- The aircraft flight profiles, coupled with CVR and FDR information from the Bearskin Metro 23, indicate that the aircraft were likely not affected by any mechanical or flight system control malfunctions prior to the collision.

- Neither aircraft was equipped with TCAS, nor was either required to be by regulation.

- In the United States, it is mandatory that all aircraft with 10 or more passenger seats be equipped with TCAS. There is no corresponding requirement for aircraft in Canada to be TCAS equipped.

- The Flight Service specialist did not directly advise Air Sandy 3101 of the Bearskin 362 flight inbound from Red Lake; however, he did advise two other aircraft on the MF of the approaching Bearskin 362 flight while Air Sandy 3101 was on the same frequency.

- The specialist had to rely on voice reports from aircraft, VDF equipment, and his own ability to keep mental track of traffic in the area to visualize potential conflicts. He did not have additional equipment that would have helped alert him to the presence of the Bearskin flight and the conflict between it and the Air Sandy flight.

- There was no direct communication, TCAS, or radar information available to alert either aircraft crew to the presence of the other aircraft. A pilot who has been alerted to the presence of another aircraft is eight times more likely to see the aircraft than is a pilot who has not been alerted.

- The probability of a collision between aircraft using GPS on established air routes is significantly higher than between aircraft using conventional navigation aids because of the greater accuracy of navigation using a GPS.

- Various procedures have been established for IFR and VFR aircraft to reduce the risk of mid-air collisions; however, there have been no prescribed changes to procedures as a result of the introduction of GPS.

- Neither flight crew saw the other aircraft in time to avoid the collision.
Physiological limitations in both the human visual and motor-response systems reduce the effectiveness of the see-and-avoid concept as the relative closing speed of the two aircraft increases.

Formal training on how to recognize in-flight collision geometry, and on how to optimize avoidance manoeuvring is not part of the required syllabus for any level of civilian pilot licence in Canada.

Many aircraft operating in northwestern Ontario use the 122.8 MHz frequency for en route communication instead of 126.7 MHz. Consequently, the traffic operating on 122.8 MHz will not receive traffic information provided by aircraft on 126.7 MHz or on the MF.

3.2 Causes

Neither flight crew saw the other aircraft in time to avoid the collision. Contributing to the occurrence were the inherent limitations of the see-and-avoid concept which preclude the effective separation of aircraft with high closure rates, the fact that neither crew was directly alerted to the presence of the other aircraft by the Flight Service specialist or by onboard electronic equipment, and an apparent lack of pilot understanding of how to optimize avoidance manoeuvring.

4.0 Safety Action

4.1 Action Taken

4.1.1 Operator Action

Subsequent to the accident, Bearskin Airlines developed procedures to reduce the risk of mid-air collisions in the busy Sioux Lookout area. These procedures include a requirement that all Bearskin aircraft be flown at a speed of less than 150 knots when operating within 5 nm of the Sioux Lookout airport. This reduction in airspeed should decrease the probability of mid-air collision by increasing both the likelihood of detecting conflicting traffic and the time available to take evasive action once conflicting traffic has been detected.

4.1.2 Transport Canada Action

Transport Canada has taken action to increase pilot awareness of procedures to reduce the likelihood of mid-air collisions. An Aviation Notice entitled "Mid-Air Collision Alert Bulletin" was issued in July 1995. The notice informs pilots of the increased potential for collision when using GPS and stresses the benefits of using arrival, departure, and position reports in order to be alerted to potential conflicting traffic. The notice also included an enhanced version of the Mid-Air Collision Avoidance Guidelines.

Two posters have been produced: the first, entitled "MF/ATF Communications Requirements," reviews applicable pilot reporting/communication requirements; the second, entitled "GPS-Traffic Separation," suggests flying one or two miles right of the centre line of the track when navigating with GPS in order to avoid conflict with opposite direction traffic.

In addition, Transport Canada has published four articles about collision avoidance in issue 2/96 of the Aviation Safety Newsletter.

Furthermore, Transport Canada (Central Region) has established a Mandatory Frequency Working Group. In July 1995, the group solicited input from the aviation community concerning the adequacy of procedures associated with mandatory frequency areas. Various procedural and structural solutions to problems related to MF areas are being evaluated in light of the responses received.

4.1.3 MF Area Procedures

The new Canadian Aviation Regulations, which are expected to come into force in 1996, change the reporting procedures for aircraft approaching an MF area. The pilot-in-command of a VFR aircraft will now be required, where circumstances permit, to call at least five minutes before entering the MF area. This change will give both arriving and departing aircraft more warning of conflicting traffic, and will effectively expand the radius of the MF area in accordance with an aircraft's speed; under these procedures, given the radius of the MF area and the ground speed of the Metro, the Bearskin flight would have been required to contact Sioux Lookout FSS at least 25 nm back from the airport.
4.1.4 FSS Traffic Awareness

Flight Service specialists are required to provide airport advisory information to aircraft operating to or from locations within an MF area. A summary of known pertinent aircraft traffic that may affect the aircraft's safety must be provided, and must be updated if the specialist becomes aware of potential conflicts. Pilots use traffic advisories to assist in seeing and avoiding conflicting traffic. The resources available to specialists to provide these advisories, however, are scant.

The quality of traffic advisories can be adversely affected by inaccurate aircraft position reports, communication errors, and frequency congestion. Further inaccuracies can be introduced when specialists rely primarily on radio to determine the position and intentions of aircraft in their area, then attempt to recognize potential conflicts by extrapolating from their mental picture of the current traffic situation. As traffic densities and aircraft speeds increase, a specialist's ability to integrate available information and provide credible and timely traffic advisories is adversely affected, thereby increasing the risk of collision.

The Board understands that relatively low cost equipment is now available which can provide a pictorial display of aircraft traffic. If used by specialists, such systems could reduce the potential for cognitive errors, reduce frequency congestion, and facilitate remote monitoring. In light of the reduced risk of collision which might accrue through the use of such systems, the TSB forwarded a Safety Advisory to Transport Canada (TC) suggesting that TC evaluate the use of systems which provide pictorial displays of aircraft position (such as ground-based TCAS systems and Personal Computer systems displaying radar data via land line) to assist Flight Service specialists in identifying potential conflicts and in providing accurate and timely traffic advisories.

Although the specialist at Sioux Lookout advised two aircraft on the MF of the approaching Bearskin 362 flight while Air Sandy 3101 was on the same frequency, it is not known if the Air Sandy pilot heard the traffic advisory concerning the Bearskin flight. The TSB is not aware of the extent to which specialists are ensuring that aircraft are aware of conflicting traffic and has suggested in a Safety Advisory that Transport Canada consider placing increased emphasis in this area during quality assurance reviews.

4.2 Action Required

4.2.1 Separation Procedures for Aircraft Navigating with GPS

GPS has been approved for use under VFR and as a backup aid to navigation under IFR; approval as a primary IFR navigation aid is imminent. The Canadian Air Navigation System is rapidly moving toward increased reliance on this inexpensive and accurate navigation system.

In 1995, the Board made two recommendations to TC aimed at reducing the potential for GPS-related occurrences resulting from the use of unapproved equipment, inadequate understanding of the system, or lack of approved approaches. Transport Canada agreed with the recommendations and outlined several initiatives to expedite the implementation of GPS standards and raise the aviation community's awareness of the limitations and safe use of GPS.

The correct use of GPS decreases the average displacement of an aircraft from the centre line of its desired track; consequently, if separation procedures fail, the probability of a mid-air collision will increase (see LP 95/95). This increased risk of collision applies to both IFR and VFR aircraft in all types of operations.

The probability of collision for aircraft using GPS could be reduced if pilots used the area navigation (RNAV) capabilities of GPS to avoid high traffic routes, either by flying at an off-set distance from the centre line of these routes or by creating their own routes. Although TC has taken some action in this regard (see 4.1.2), the action is limited in scope and short term in nature. Given the increasing use of GPS, and the increased potential for mid-air collision associated with its use, the TSB recommends that:

The Department of Transport expedite the development and implementation of safe separation procedures for the use of GPS in navigation.

A96-04

4.2.2 Collision Avoidance

Procedures to separate aircraft are not always followed (as evidenced by IFR loss-of-separation incidents) and are not always effective (for example, during VFR climb/descent). There have been eight mid-air collisions in Canada since 1991, and 142 reported occurrences where aircraft safety was compromised due to a loss of separation. Where procedures to separate aircraft fail, pilots may have to rely on the see-and-avoid method to
avoid a mid-air collision. This method, however, becomes less effective as aircraft airspeeds increase.

The estimated closing speed of the accident aircraft was 410 knots. At this speed, the probability of the pilots of one aircraft acquiring the other aircraft in time to take effective evasive action was only about 20 per cent (LP 086/95 and LP 001/96 refer). This probability would have been doubled if the closing speed had been reduced to about 300 knots. In light of the increased probability of acquiring conflicting traffic at reduced airspeeds, the TSB recommends that:

The Department of Transport ensure that aircraft are flown at reduced airspeeds, consistent with safe manoeuvring, in the vicinity of aerodromes where separation relies primarily on the see-and-avoid concept.

A96-05

Even if aircraft are flown at reduced airspeeds, pilots must be able to recognize a collision threat and take appropriate action if a collision is to be avoided. Transport Canada's Flight Instructor's Guide advocates the use of a steep turn to avoid collisions; however, this manoeuvre may actually increase the probability of impact if it is initiated when the aircraft are inside the range of approximately 10 seconds to impact<10> (evidence indicates that the Navajo was steeply banked at the time of the collision).

Since inappropriate responses to a risk of collision situation may increase the risk of a mid-air collision, the TSB recommends that:

The Department of Transport take both long- and short-term action to increase the ability of pilots to recognize in-flight collision geometry and optimize avoidance manoeuvring.

A96-06

4.2.3 TCAS

The see-and-avoid method of traffic separation can be much more effective if pilots are alerted to the existence and relative location of conflicting traffic. TCAS I provides such proximate traffic alerts (TAs).

Although United States Federal Aviation Regulations would have required the Metro to be TCAS equipped, and many other countries are instituting TCAS requirements, no such requirements exist or are planned in Canada.

In view of the demonstrated capabilities of TCAS, and the increasing risk of collision due to improved navigational accuracy, increasing aircraft speeds, and mixed VFR/IFR traffic at uncontrolled airports such as Sioux Lookout, the Board recommends that:

The Department of Transport conduct an analysis of the benefits of requiring commercial passenger-carrying aircraft to be equipped with TCAS versus the risks associated with operating aircraft without TCAS.

A96-07

*This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 04 April 1996.*

Appendix A - Wreckage Distribution
Appendix B - List of Supporting Reports

The following TSB Engineering Branch reports were completed:

LP 71/95 - Preservation of Documents;
LP 72/95 - Underwater Acoustic Beacons Analyses;
LP 73/95 - Instruments Examination;
LP 74/95 - Structures Examination;
LP 75/95 - Site Survey;
LP 86/95 - Visibility Study; and
LP 95/95 - Probability of Mid-Air Collision, Effects of Navigation System, GPS vs VOR and NDB/ADF.

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

Appendix C - Glossary

ACC - Area Control Centre
ADF - automatic direction finder
agl - above ground level
AIP - Aeronautical Information Publication
asl - above sea level
ATC - air traffic control
ATF - aerodrome traffic frequency
ATPL - Airline Transport Pilot Licence
ATS - Air Traffic Services
CDT - central daylight saving time
CPL - Commercial Pilot Licence
CVR - cockpit voice recorder
DG - directional gyro
Updated: 2002-10-06

Important Notices

<1>All times are CDT (Coordinated Universal Time [UTC] minus 5 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 the crew.
<5>See Glossary for all abbreviations and acronyms.
<7>J.L. Harris, Sr., "Avoid", *The Unanalyzed Partner of "See"*. ISASI Forum #2, 1983 pp 12-17.
<8>J.L. Harris, Sr., p 16.
<9>J.L. Harris, Sr., p 16.
<10>J.L. Harris, Sr., "Avoid", *The Unanalyzed Partner of "See"*. ISASI Forum #2, 1983 p 16.
Air 1995

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.

VFR into IMC
Controlled Flight into Terrain
Western Straits Air
de Havilland DHC-3 (Turbine) Otter C-FEBX
Campbell River, British Columbia 7 nm NW
27 September 1995

Report Number A95H0012

Synopsis

The aircraft was en route from Triumph Bay (40 nm south of Kitimat), British Columbia, to the Campbell River Airport. Approaching Campbell River, the pilot requested and received a special visual flight rules (SVFR) clearance to enter the Campbell River control zone. While on an intercept heading for the final approach and in straight-and-level flight, the aircraft crashed into the side of a mountain. The pilot and seven of the passengers received fatal injuries; the other two passengers received serious injuries.

The Board determined that the pilot progressively lost situational awareness while attempting to navigate in conditions of low visibility or in cloud and was unaware of the rapidly rising terrain in his flight path. Contributing to this accident were the existing visual flight regulations and the prevailing industry attitudes and practices which did not provide adequate safety margins. Contributing to the severity of the injuries was the detachment of the passenger seats at impact.

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1.0 Factual Information

1.1 History of the Flight

The single-engine turbine Otter on amphibious floats departed Triumph Bay, British Columbia, at 1634 Pacific daylight saving time (PDT <1>) with one pilot and nine passengers on board for a visual flight rules (VFR<2>) flight to Campbell River. At 19:01:59 the pilot called Campbell River Flight Service Station (FSS) and reported that he was seven nautical miles (nm) northwest of the airport, inbound for Campbell River. Radar data from Comox indicate that, when this call was made, the aircraft was actually 11 nm northwest of Campbell River, just south of the Narrows (see map, Appendix A). At 19:02:40, the pilot was given the 1900 PDT Campbell River weather observation, which was as follows: ceiling 300 feet overcast and visibility two miles in light rain and fog.

The pilot requested a special VFR (SVFR) clearance to enter the Campbell River control zone. Clearance for SVFR was delayed by Comox air traffic control (ATC) until an instrument flight rules (IFR) aircraft on approach to Campbell River had landed. At 19:03:54, the IFR aircraft reported breaking clouds at 900 feet above sea level (asl), which would be approximately 550 feet above ground level, on the ILS approach to runway 11 at Campbell River (airport elevation is 346 feet). This information was acknowledged by the turbine Otter pilot. The IFR aircraft landed at 1904, and the turbine Otter was issued an SVFR clearance at 19:04:45. Radar data indicate that, at that time, the aircraft was about one mile northwest of Tyee Spit, a frequently used, alternate landing site (water)
for company aircraft when weather conditions preclude landing at Campbell River airport.

Radar data indicate that, at 1906, after passing by Tyee Spit, the aircraft turned southbound and flew directly toward the airport. At about 2 1/2 miles from the airport, at 19:07:40, the aircraft turned right to a heading of approximately 310° magnetic and flew in that general direction for about two minutes. The aircraft was on a track that was approximately parallel to the extended runway centre line, tracking outbound from the airport with the localizer and the Campbell River (YBL) non-directional beacon (NDB) to the left. The aircraft passed abeam the YBL NDB, which serves as the final approach fix (FAF) for the ILS approach to runway 11, and continued outbound.

At 19:09:40, at about three miles outside the beacon, the aircraft turned left to a southerly heading toward the localizer and the YBL NDB. At 19:10:08, the pilot radioed that he was seven miles northwest; this was the last transmission received from the aircraft. At 19:10:25, radar contact was lost.

The aircraft crashed into the northwest side of a 1,047-foot mountain at about the 860-foot level, in straight-and-level flight on a heading of 183° magnetic. The pilot and seven of the passengers received fatal injuries. The two remaining passengers received serious injuries. The accident occurred at 1910 PDT during the hours of official daylight, at latitude 50°01'N, longitude 125°22'W. Official sunset in Campbell River was at 1908, and night was at 1940 PDT.

1.2 Injuries to Persons

<table>
<thead>
<tr>
<th></th>
<th>Crew</th>
<th>Passengers</th>
<th>Others</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Fatal</td>
<td>1</td>
<td>7</td>
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<td>8</td>
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<tr>
<td>Serious</td>
<td>-</td>
<td>2</td>
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</tr>
<tr>
<td>Minor/None</td>
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<tr>
<td>Total</td>
<td>1</td>
<td>9</td>
<td>-</td>
<td>10</td>
</tr>
</tbody>
</table>

1.3 Damage to Aircraft

The aircraft struck the mountain in an area of heavily forested upslope. It shed the right wing and tail section while passing through the trees, then struck an embankment beside an access road that leads to the top of the mountain. The aircraft was destroyed during the impact sequence.

1.4 Other Damage

Several trees were broken. There was no other environmental damage.

1.5 Personnel Information

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Captain</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>37</td>
</tr>
<tr>
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<td>ATPL</td>
</tr>
<tr>
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</tr>
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<tr>
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<tr>
<td>Hours on Type Last 90 Days</td>
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<tr>
<td>Hours Off Duty Prior to Work Period</td>
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</tr>
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</table>

The pilot was certified and qualified for the flight in accordance with existing regulations. He was flying the aircraft from the left seat. The right front seat was occupied by a passenger. The pilot had a valid Category 1 medical at the time of the accident, and records indicate that he had renewed his
aviation medical regularly since his first aviation medical in 1976. His only restriction was that "glasses must be worn."

The pilot had flown in the Campbell River area for most of his career. He had been employed by Western Straits Air since 1988, and had flown several types of light, single- and twin-engine aircraft for the company. He began flying the turbine Otter in 1989 and was considered to be experienced on the aircraft.

He held a valid instrument rating. Most recently, his primary job was to fly as captain on the company Beechcraft King Air 200 on scheduled IFR flights between Campbell River and Vancouver. He was also the company's chief pilot, and had previously held the positions of company safety officer and operations manager.

The pilot had previously discussed with the company's current operations manager the option of doing an IFR approach into Campbell River with the turbine Otter if weather conditions would not allow VFR or SVFR flight. Although IFR flight was not authorized under the company's operating certificate for this type of passenger-carrying operation, the pilot felt that the aircraft was adequately equipped to climb to a safe altitude and follow radar vectors provided by the Comox ATC unit, to conduct an IFR approach. There are indications that the pilot had previously conducted such IFR arrivals in the turbine Otter.

The pilot's training records indicate a history of satisfactory performance on proficiency checks. All required currency training had been completed. He was considered a safe, careful, and competent pilot by both his employer and his colleagues.

### 1.6 Aircraft Information

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>de Havilland Aircraft of Canada Limited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and Model</td>
<td>de Havilland DHC-3 Otter</td>
</tr>
<tr>
<td>Year of Manufacture</td>
<td>19 February 1954</td>
</tr>
<tr>
<td>Serial Number</td>
<td>38</td>
</tr>
<tr>
<td>Certificate of Airworthiness</td>
<td>12 June 1989</td>
</tr>
</tbody>
</table>

(Flight Permit)

| Total Airframe Time       | 16,428.5 hours                      |
| Engine Type (number of)   | P&W PT6A-135A (1)                   |
| Propeller/Rotor Type (number of) | Hartzell HC-B3TN-3DY (1)          |
| Maximum Allowable Take-off Weight | 8,000 lb                              |
| Recommended Fuel Type(s)  | Jet A/Jet A-1                       |
| Fuel Type Used            | Jet A-1                               |

#### 1.6.1 General

The original DHC-3 Otter aircraft is an all-metal, high-wing monoplane designed to carry passengers and/or cargo and powered by a Pratt & Whitney, 9-cylinder, radial, air-cooled engine fitted with a Hamilton Standard propeller. The occurrence aircraft was equipped with a Pratt & Whitney PT6 turbine engine and a Hartzell propeller, which were installed in 1989 as a modification. At the time of the accident, the aircraft was equipped with Bristol-Edo amphibious floats.

#### 1.6.2 Flight Instruments and Radios

The aircraft was equipped with standard flight instruments and the following communication and navigation equipment: dual very-high-frequency (VHF) communication radios; dual VHF omnidirectional range (VOR)/instrument-landing-system (ILS) receivers; a single automatic direction finder (ADF) receiver; dual transponders; and a Loran C receiver. The aircraft was not equipped with distance measuring equipment (DME). It was not equipped with a radar altimeter or a ground...
proximity warning system, nor was either required by regulation. The aircraft maintenance records and post-accident testing both indicate that the flight instruments, communication radios, and navigation equipment were serviceable at the time of the occurrence. Details are available in TSB Engineering Branch Report LP 143/95.

1.6.3 Weight and Balance

The aircraft load-control/manifest form was retrieved from the aircraft wreckage. The form recorded a take-off weight from Triumph Bay of 7,999 pounds, one pound below the maximum gross take-off weight of 8,000 pounds. There was no indication that a centre of gravity (C of G) position was calculated for the flight.

Post-accident calculations using actual passenger and baggage weights (see Appendix B) indicate that the weight of the aircraft exceeded the maximum allowable gross weight by approximately 900 pounds at take-off from Triumph Bay, and by approximately 50 pounds at impact. Also, the actual C of G exceeded the aft limit by 3.29 inches at take-off from Triumph Bay, and by 2.71 inches at impact.

Errors in the load-control calculations were the result of the following: using lower than standard weights for male occupants (using 172 pounds instead of 182 pounds); not including baggage in the calculations (395 pounds of baggage was recovered from the wreckage); and underestimating the fuel weight by 323 pounds.

A review of the aircraft journey log entries indicates there were other flights for which the duration and the passenger and fuel loads were similar to those of the accident flight. Since the company load control practices were the same, it is likely that the aircraft weight and balance on those flights were also in excess of the approved limits for the aircraft.

There was no indication that company management and operational personnel were aware of the extent to which the turbine Otter aircraft was operated above its maximum approved gross weight; however, there is also no indication that the appropriate steps were taken to determine the actual aircraft weights.

1.6.4 Aircraft Engine

The engine in the accident aircraft had accumulated 1,342.8 hours since undergoing a hot section inspection (HSI). During the accumulation of these hours, the company had stopped a previously used Engine Condition Trend Monitoring Program (ECTM) designed to lengthen operating times between HSIs; therefore, the engine should have undergone an HSI at 1,250 hours. At the time of the accident, the aircraft's engine was 92.8 hours over the 1,250 hours of operating time allowed between hot section inspections. This was not found to be contributory to the accident. Details are available in Engineering Branch Report LP 164/95.

1.6.5 Maintenance Records

There were no recorded current or deferred defects on the occurrence aircraft at the time of the accident. Company maintenance records indicate that, at the time of the occurrence, along with the overdue HSI, required inspections on the altimeters, pitot-static system, and the transponders were overdue. These overdue inspections were not a factor in this accident. Details are available in Engineering Report LP 164/95.

1.7 Meteorological Information

The pilot was known to review the available weather information before each flight. The forecast for Campbell River, issued at 0803 PDT, and valid from 27/1500Z (0800 PDT) to 28/0300Z (2000 PDT), was included in the weather package faxed to the company on the morning of the accident. The forecast was as follows:

500 feet scattered, ceiling 1,500 feet broken, 4,000 feet overcast, visibility more than 6 miles,
occasional ceiling 500 feet broken, 1,200 feet overcast, visibility 5 miles in light rainshowers and fog. By 2100Z (1400 PDT) 1,500 feet scattered, ceiling 5,000 feet broken, visibility more than 6 miles, occasional ceiling 1,500 feet overcast, visibility more than 6 miles in light rainshowers. Next forecast by 2100Z (1400 PDT).

Light rime icing was forecast to occur in cloud above the freezing level, which was located at 8,000 feet.

No other weather forecast was requested by, or issued to, either the pilot or the company prior to the occurrence.

At 1405 PDT, one hour and ten minutes after the turbine Otter departed Campbell River for the round-trip flight to Triumph Bay, a new weather forecast was issued, valid from 27/2100Z (1400 PDT) to 28/0500Z (2200 PDT). The forecast was as follows:

500 feet scattered, ceiling 1,500 feet broken, 4,000 feet overcast, visibility more than 6 miles, occasional ceiling 500 feet broken, 1,200 feet overcast, visibility 3 miles in light rainshowers and fog. By 0000Z (1700 PDT) 1,500 feet scattered, ceiling 5,000 feet broken, visibility more than 6 miles, occasional ceiling 1,500 feet overcast, 5,000 feet overcast, visibility more than 6 miles in moderate rainshowers. Next forecast by 0300Z (2000 PDT).

An amended forecast was issued at 1614 PDT, valid from 27/2300Z (1600 PDT) to 28/0500Z (2200 PDT), as follows:

500 feet scattered, ceiling 1,500 feet broken, 4,000 feet overcast, visibility more than 6 miles, occasional ceiling 500 feet broken, 1,200 feet overcast, visibility 3 miles in light rainshowers and fog. By 0400Z (2100 PDT) 1,500 feet scattered, ceiling 5,000 feet broken, visibility more than 6 miles, occasional ceiling 1,500 feet overcast, 5,000 feet overcast, visibility more than 6 miles in light rainshowers.

An amended forecast was issued at 1724 PDT, valid from 28/0000Z (1700 PDT) to 0500Z (2200 PDT), as follows:

500 feet scattered, 1,500 feet broken, 4,000 feet overcast, visibility more than 6 miles, occasional ceiling 300 feet broken, 1,200 feet overcast, visibility 2 miles in light rainshowers and fog. By 0400Z (2100 PDT) 1,500 feet scattered, 5,000 feet broken, visibility more than 6 miles, occasional ceiling 1,500 feet broken, 5,000 feet overcast, visibility more than 6 miles in light rainshowers. Next forecast by 0300Z (2000 PDT).

Ceilometer readings and observed weather conditions at the Campbell River airport indicate that, throughout the day of the accident, the ceiling varied between 300 feet and 500 feet above ground level (agl) broken to overcast, and that the visibility varied between 2 and 4 statute miles (sm) in light rain and fog.

The pilot received several weather reports for Campbell River during the flight from Triumph Bay to Campbell River, as described below.

At 1727 PDT, 1 hour 43 minutes before the accident, he received the 1700 PDT actual weather as follows: measured 300 feet broken, 500 feet overcast, visibility 2 1/2 miles in light rain showers and fog.

At 1812 PDT, 58 minutes before the accident, the pilot received the 1800 PDT actual weather as follows: measured 400 feet broken, 600 feet overcast, visibility 2 1/2 miles in light rain showers and fog.

At 1902 PDT, 8 minutes before the accident, he received the 1900 PDT actual weather as follows: measured 300 feet overcast, visibility 2 miles in light rain and fog.

At 1904 PDT, 6 minutes before the accident, he overheard and acknowledged the crew of another aircraft, who reported breaking clouds at 900 feet asl, 550 feet agl, on approach to runway 11 in Campbell River.
One survivor reported that there was heavy fog in the area of the crash site.

About 30 minutes after the accident, the pilot of a fixed-wing, search and rescue (SAR) aircraft noted localized low cloud in the accident area. The pilot reported that, on approach to Campbell River, the aircraft broke out of clouds at 200 to 300 feet agl, and that the visibility was 1/2 mile or less. A SAR helicopter that departed from Comox about one hour after the crash could not get to the Campbell River airport because of low stratus cloud and fog. About one hour after that, as the weather in Campbell River lifted and an aerial search could begin, the weather was observed to be zero/zero in the area of the emergency locator transmitter (ELT) signal.

### 1.8 Aids to Navigation

The Campbell River airport is equipped with an NDB located 4.3 nm from the runway threshold along the final straight-in approach path to runway 11, an ILS that serves runway 11, and a DME (the accident aircraft did not have a DME receiver). There were no reports of any abnormalities with these navigation/approach aids.

### 1.9 Communications

A review of the taped transmissions between the aircraft and ground-based facilities revealed that all communications were routine and normal, with no abnormalities.

### 1.10 Aerodrome Information

The Campbell River airport (CYBL) is located 4.5 miles south of the city and is operated by the District of Campbell River. It is serviced by a single asphalt runway, 5,000 feet long and 150 feet wide. The runway orientation is 11/29 (113 degrees/293 degrees). Airport elevation is 346 feet asl.

The airport is located in controlled airspace and is surrounded by a control zone of 5 nm radius extending upward to 3,300 feet asl. There is no control tower; an FSS provides advisory information on the mandatory frequency (MF). For flights under IFR and SVFR, authorization from the Comox terminal control unit is relayed by the FSS on the MF.

Pilots familiar with the area indicated that they were not aware of the actual height of the mountain that the accident aircraft had collided with. Although the top of the mountain is 1,047 feet, it is not high enough for it to be required to be marked as a spot height on an instrument approach chart. Pilots conducting instrument approaches would not necessarily be aware of the mountain as their attention would be concentrated on navigational instruments and not on outside visual cues. In addition, the two towers at the top of the mountain are not marked on the VFR Navigation Chart (VNC) because they are less than 300 feet agl. Normal VFR flights are not conducted in the area of the mountain. During the investigation, pilots familiar with the area commented that they had not previously placed any significance on the hazard that the mountain might impose on VFR flight. It is possible that the accident pilot also would not have been aware of the height of the mountain and the significance of the hazard.

### 1.11 Flight Recorders

The aircraft was not equipped with a flight data recorder (FDR) or cockpit voice recorder (CVR), nor was either required by regulation.

### 1.12 Wreckage and Impact Information

#### 1.12.1 Site Details

Examination of the accident site indicates that the aircraft was in straight-and-level flight on a heading of 183° magnetic when it flew into a tree-covered, 34-degree upslope at the 860-foot level of a 1,047-foot high mountain.

The length of the wreckage trail was approximately 183 feet. The initial impact was with the top of a
cedar tree, which broke off at a point 60 feet above the ground. This impact tore away the left elevator. As the aircraft continued into the trees, the right wing came off and the aircraft rolled to the right. The horizontal stabilizer struck a tree, and the remainder of the tail section was torn from the fuselage. The drag from the float pieces still attached to the fuselage turned the fuselage to the left and it struck an embankment and a large tree stump on the side of an access road. The main force of the impact was sustained by the right side of the fuselage structure.

At the time of impact, the flaps were retracted, and the wheels in the amphibious floats were in the down-and-locked position.

1.12.2 Wreckage Examination and Testing

After an initial examination at the site, several aircraft components were transported to the TSB Engineering Branch and to other facilities for further inspection and testing. Components inspected included the following: cockpit and panel light bulbs, flight and engine instruments, communication and navigation radios, seats and seat-belts/shoulder harnesses, and the propeller. The engine was shipped to the manufacturer's facility where it was examined under the direction of a TSB investigator. The generator was forwarded to the manufacturer for testing under the direction of the United States of America Federal Aviation Administration (FAA). The aircraft digital fuel-management system was examined at the TSB Engineering Branch and then forwarded to the manufacturer, where the non-volatile memory chips were examined.

There were no pre-impact material failures or component malfunctions found that could have contributed to the cause of the accident.

1.12.3 Communication and Navigation Radio Settings

The communication and navigation radios were set as follows: number 1 radio set to 123.30 Unicom; number 2 radio set to 122.50 Campbell River mandatory frequency; number 1 VOR/ILS receiver to 112.05 (this frequency is not allotted to any radio facility); number 2 VOR/ILS to 109.1, the ILS frequency for runway 11; and Loran C set to navigate direct to the YBL NDB (which is also the final approach fix for the approach to runway 11). The ADF active frequency was 400, the Comox NDB, and the standby frequency was 203, the YBL NDB. Switching between the two frequencies is achieved by depressing a spring-loaded, push-button switch on the front panel of the ADF. The position of this switch made it vulnerable to being moved during the accident sequence.

1.13 Medical Information

An autopsy was conducted on the pilot, and toxicological samples were examined. There was no indication that incapacitation or physiological factors affected the pilot's performance.

1.14 Fire

It was reported that small, post-crash fires were extinguished by rescue personnel; however, there was no other indication of fire at the accident site either before or after the occurrence.

1.15 Survival Aspects

1.15.1 Search and Rescue

When the aircraft failed to arrive at Campbell River airport, the FSS operator immediately informed the company, and, within 10 minutes of the accident, an emergency response had been initiated. A Search and Rescue (SAR) Buffalo aircraft on a training flight in the area was informed of the overdue aircraft by the FSS; the SAR aircraft had already picked up an ELT signal (the ELT functioned and was instrumental in confirming the status of the overdue aircraft and locating its position). Weather conditions precluded a visual aerial search.

About one hour after the crash, a SAR Labrador helicopter took off from Comox. Low ceilings and fog forced the helicopter to land at the Campbell River hospital, where one search and rescue technician
from the helicopter joined local police for a land search. The air search resumed at 2310, and a steady ELT signal was picked up at 2320. Using flood lights, searchers located the aircraft in a wooded area, and at 2355 the site was reached by the ground search team.

One survivor was found wandering outside the aircraft and was evacuated by ambulance. The second survivor was extricated from the wreckage and flown to hospital by the SAR helicopter.

1.15.2 Impact Forces

An estimation of crash impact loads was completed. Details are available in TSB Engineering Branch Report LP 146/95.

It was concluded that the aircraft did not lose much speed as it crashed through the trees, and that most of the crash impact force experienced by the occupants was lateral, to the right, as the aircraft struck the embankment. The total load factor was determined to be over 14 g but under 22 g. The lateral force caused the left-side seats to break free from the aircraft structure, allowing the left-side occupants to be thrown to the right. The right-side occupants were then subjected to impact forces from the aircraft striking the embankment, and the impact by the left-side occupants.

In addition to the pilot and co-pilot seats, the cabin seating consisted of two rows of seats, one on each side of the cabin, separated by a centre aisle. The left-side row consisted of four seats, with a double-width cargo door located between the third and fourth seats. The right-side row consisted of five seats, with a single main cabin entry door located between the fourth and fifth seats. One survivor, a female, was seated in the most rearward seat on the right side, immediately aft of the main cabin door. She was apparently thrown free of the aircraft during the impact sequence. The second survivor, a male, was seated on the left side, immediately behind the bulkhead separating the cockpit from the cabin. He was found in the wreckage lying prone next to the bulkhead. Neither of the survivors was subjected to crushing injuries. All other occupants died from crushing injuries and multiple trauma.

1.15.3 Certification Requirements for Seats

The basis of approval for this aircraft, according to Transport Canada Type Approval Data Sheet A-27, is the United States Civil Air Regulation (CAR) Part 3 as amended to 01 November 1949. That regulation requires that aircraft seats be able to withstand the following crash inertia load factors: forward 9.0 g, upward 3.0 g, sideward 1.5 g. In this standard, the structural requirement is met by either structural analysis alone, a combination of structural analysis and static load tests, or static load tests alone.

Although the standard for inertia load factors has not changed, current occupant protection standards are significantly more effective because the static load testing formerly used to verify compliance has been replaced by dynamic testing. Aircraft are required to meet the design standards in force at the time of the conception of the aircraft design. Subsequent revisions to standards are not made retroactive.

1.15.4 Seats/Seat-belts/Shoulder Harnesses

Both of the cockpit seats remained attached to the fuselage, and neither of the lap belts had failed. The pilot was not wearing the available shoulder harness. The front-seat passenger was wearing the available shoulder harness; however, the harness webbing had failed in overload. The overload failure of the front-seat passenger's shoulder harness is attributed to a combination of the occupant's crash inertia and the force from the pilot as he was thrown to the right by impact forces.

All passenger seats were equipped with lap belts that were attached to the seats, and all the passengers' lap belts were fastened. None of the belts failed because of overload of the webbing. All of the left-side passenger seats that were occupied were detached from the fuselage as a result of the impact. The left-side passenger seats were torn from their side-fuselage attach points, the seat backs were torn free, and the floor attachments were popped out of place. On the right side, several side-fuselage attach points were still in place; however, the seat backs were torn free, the floor attach
points were popped out of place, and the seats were badly deformed.

1.16 Organizational and Management Information

1.16.1 Description of the Company

Western Straits Air was operating under a valid Transport Canada operating certificate, first issued in March 1986 and last amended in September 1994. The company is approved for domestic and non-scheduled international commercial air services and operates five aircraft, including two turbine Otters, from its main base in Campbell River. The company management structure is designed to comply with Transport Canada requirements and is typical of other such operators who, under the president of the company, employ an operations manager, director of maintenance, chief pilot, chief engineer, and quality manager.

Company management is required by Transport Canada to put in place procedures to ensure compliance with the conditions of the company's operating certificate, and to ensure that company aircraft are operated and maintained in accordance with all approved manuals.

The degree of company supervision of the operations and maintenance functions at Western Straits Air was found to be typical of other such companies offering similar services.

1.16.2 Transport Canada Audits

The company had been audited by Transport Canada on a regular basis since the initial certification audit in 1986. The most recent operational audits, conducted in July 1993 and January 1995, were deemed to be satisfactory.

The latest Transport Canada maintenance audit, conducted in August 1994, and three base inspections did not discover that the company had stopped using its approved Engine Condition Trend Monitoring Program (ECTM). Transport Canada does not have in place a training program to ensure that all inspectors who are tasked with conducting such inspections are formally trained in ECTM.

1.17 Additional Information

1.17.1 Weather and Minimum Altitude Regulations

For the flight from Triumph Bay to Campbell River, while the aircraft was outside the Campbell River control zone and in uncontrolled airspace, the ceiling and visibility requirements to maintain VFR would have been clear of cloud with a minimum of two miles visibility. Given that the flight could be conducted over non-populous areas or over open water, there would be no altitude restriction mandated by the minimum altitude regulations; however, a distance of 500 feet would still have to be maintained from any person, vessel, vehicle, or structure. In summary, the flight would have been operating in accordance with regulations if operated clear of cloud with a minimum of two miles visibility.

VFR weather limits in the Campbell River control zone were a minimum ceiling of 1,000 feet agl (in order for the aircraft to be able to maintain a distance of 500 feet vertically from both the cloud base and the surface), and a minimum visibility of three miles. The weather at Campbell River was reported as ceiling 300 feet overcast, visibility two miles. The pilot requested, and was granted, SVFR to enter the control zone for landing.

SVFR restrictions applicable for flight within the Campbell River control zone would have been as follows: weather - flight and ground visibility of not less than one mile and clear of cloud; and minimum altitude - not less than 1,000 feet if over (within 2,000 feet of) a "built up area of any city, town or other settlement or over any open air assembly," or not less than 500 feet unless over a non-populous area or over open water. Prevailing weather conditions were above the minimum permissible to conduct flight in accordance with SVFR authorization; however, the weather conditions would have precluded the pilot from complying with the minimum altitude restrictions applicable to the
track flown.

1.17.2 TSB Safety Study

The TSB released Report of a Safety Study on VFR Flight Into Adverse Weather (No. 90-SP002) in 1990. In this safety study, 333 accidents involving VFR flight into instrument meteorological conditions (IMC) in Canada were studied. Approximately 35% of the accidents involved aircraft engaged in commercial operations.

The safety study raised many concerns with respect to VFR commercial operations, with particular emphasis on VFR weather minima, SVFR, industry practices, and pilot decision making. The safety study concluded that accidents involving continued VFR into IMC account for a disproportionate number of fatalities each year, and that the causes and contributing factors to these accidents have recurring themes.

The recommendations in the safety study included the following:

The Department of Transport revise the safety standards for commercial operations to include requirements designed to reduce the probability and seriousness of VFR-into-IMC accidents.

(TSB A90-82)

The Department of Transport increase the minimum flight visibility for VFR flight in all designated Mountainous Regions to two miles.

(TSB A90-67)

The Department of Transport increase the VFR weather minima for fixed-wing commercial operations in uncontrolled airspace.

(TSB A90-66)

The Department of Transport reconsider the decision to reduce SVFR weather minima to visibilities of one mile.

(TSB A90-68)

The Department of Transport's response to recommendation TSB A90-82 indicated that no action would be taken and stated that the Department was continually reviewing and taking action to improve safety.

Recommendation TSB A90-67 was adopted and the limits were changed to two miles.

The Department of Transport passed recommendations TSB A90-66 and TSB A90-68 to a VFR Working Group for consideration. Weather limits in uncontrolled airspace were increased; however, operators may request waivers which would effectively return the VFR limits to those which were in effect at the time of this accident. There were no changes to the SVFR weather limits. It is important to note that, on the sliding scale of ceiling and visibility limits for SVFR in effect before 1990, SVFR would not have been approved for the accident flight.

1.17.3 Influence on Pilot Actions

Pilots tend to be greatly influenced by their perception of the prevailing attitudes and practices of other pilots and companies in the area where they work. These attitudes and practices can be strong determinants in the choices that they make. Discussions with people in the Campbell River aviation community indicate that it is common practice for pilots to attempt to find their way to the airport in bad weather by descending to low altitudes to "take a look" and see if there is a way to get to the airport. This practice is not unique to the Campbell River area, but is common within the aviation community. The accident pilot was experienced in the area, and reportedly performed such manoeuvres successfully on many occasions. There was no indication that company management
exerted pressure on pilots to complete flights into Campbell River airport in marginal weather.

The more times people do something successfully, the more they tend to discount the risks involved, and the more likely they are to believe that, although the practice may have inherent risks in a general sense, nothing bad will happen to them. This can lead to a level of comfort where they are likely to further reduce the margin of safety.

1.17.4 Situational Awareness and Information Processing

Situational awareness consists of "all the knowledge that is accessible and can be integrated into a coherent picture, when required, to assess and cope with a situation"<3>. Pilots must maintain situational awareness in order to make sound judgements and decisions. Situational awareness develops as the pilot perceives the situational elements such as weather, clearances, aircraft instrumentation, etc., integrates the information by using experience and knowledge, and projects the information into the future to make or modify plans. The development and maintenance of accurate situational awareness is progressively impaired by inadequate information, or inaccurate interpretation of the available information, or both.

1.17.5 Canadian Accident Information

A controlled flight into terrain (CFIT) accident can be defined as an accident in which an aircraft, under the control of the crew, is flown into terrain (or water) with no prior awareness on the part of the crew of the impending disaster. The TSB accident database shows that, between 01 January 1984 and 31 December 1994, 70 commercially operated aircraft not conducting low-level specialty operations had a CFIT accident. For 95% of CFIT accidents where VFR flight was intended, weather conditions were below those required for VFR. The data also indicate that in 97% of CFIT accidents, the crew(s) either continued descending below a known safe altitude, or were not considering a safe altitude at which to fly. Also, none of the aircraft involved were equipped with a ground proximity warning system (GPWS), and 91% were not equipped with a serviceable radio altimeter.

This occurrence is typical of a CFIT accident, the most common element of which is that the pilot has lost situational awareness, and is unaware of the imminent danger. Information from TSB data, including the 1990 safety study of VFR flight into adverse weather, shows that this accident fits the profile of a typical weather-related accident for a VFR commercial operator.

2.0 Analysis

2.1 Introduction

The accident aircraft was adequately equipped and maintained for VFR flight, and there were no pre-impact mechanical failures. There is nothing to suggest that the aircraft load was a contributing factor, and there was nothing to indicate loss of control before the aircraft struck the trees in straight-and-level flight.

2.2 Seats/Seat-belts (Survivability)

No conclusion could be made as to whether there might have been additional survivors had the seats been more securely attached to the airframe. However, there is no doubt that additional injuries occurred as a result of the seats breaking free.

Injuries to the pilot and the front-seat passenger would have been lessened had the pilot been wearing the available shoulder harness.

2.3 Regulations for VFR/SVFR

The 1990 TSB safety study found that CFIT accidents involving VFR aircraft were linked to flight in marginal weather conditions, and that regulations provided inadequate safety margins. At that time, the Board was concerned that the amendment to Air Navigation Order (ANO) Series V, No. 1 (June 1990) that eliminated the sliding scale authorizing SVFR would lead to greater use of SVFR in weather conditions "worse than those which permitted the studied accident flights to occur."
Accordingly, the Board recommended that:

The Department of Transport reconsider the decision to reduce SVFR weather minima to visibilities of one mile.

(TSB A90-68)

Transport Canada responded that this recommendation would be addressed by the VFR working group. To date, the SVFR weather minima remain unchanged. It was apparent during the investigation of this accident that, in fact, the use of SVFR in such weather conditions had become an accepted norm in the Campbell River control zone. It is important to note that, prior to June 1990, an SVFR clearance would not have been approved for the accident flight because of the reported weather conditions and the pilot would not have been able to continue with his plan to land at the Campbell River airport.

2.4 Decision to Fly to the Airport

As the aircraft approached Campbell River, the pilot had two options to continue visual flight: to attempt to land at the airport, or to land at Tyee Spit. When he overflew Tyee Spit, the pilot was aware of the official weather reports from the airport; however, he was also aware of the fact that another aircraft on approach to runway 11 had reported a better ceiling than the official report.

The pilot's decision to fly to the airport is consistent with the accepted industry and local practice of taking a look at the conditions, and with the pilot's own history of operating in such conditions. Once he obtained SVFR, he could attempt the airport landing without violating any weather limits. Given the flight route and altitude flown, it appears that he either ignored, or was not aware of, the minimum altitude order which would have required him to maintain a minimum of 500 feet agl over populous areas.

After the pilot turned back from his initial attempt to fly directly to the airport, the track of the aircraft, as recorded by radar, is consistent with an attempt to proceed outbound parallel to the ILS for runway 11, and then turn onto a heading to intercept the localizer inbound in the area of the Campbell River NDB. This hypothesis is supported by the settings on the navigation equipment.

Although the pilot may have considered the option of conducting an instrument approach at that point, there is no indication that he had attempted to do so. The pilot may have been influenced by either his assessment of the weather conditions as being still suitable for SVFR flight, or a possible reluctance to violate the company's operating certificate which restricted operation of the aircraft to VFR.

The aircraft was in straight-and-level flight at impact. This suggests either that flight visibility was such that the mountain was totally obscured, or that the aircraft had entered cloud; this also suggests that the pilot had lost situational awareness and did not see the rising terrain until it was too late to avoid a collision.

2.5 Summary

Had the flight been completed successfully, it would have been viewed as just another normal flight. The pilot's decision to try to get to the airport in marginal weather conditions is consistent with both his past practice and the industry-accepted norms for this type of operation, and led to the progressive erosion of his situational awareness. It is apparent that he was attempting to use visual flight, supplemented by IFR navigational methods. In such marginal weather conditions, this combination does not provide the level of protection normally associated with either flight regime, in that pilots are restricted in their ability to navigate visually, and are not protected by the minimum obstruction clearance altitude restrictions imposed by IFR navigation. Accident statistics consistently show that VFR flight in marginal weather imposes a significant risk. More stringent regulations, as previously recommended by the Board, might have led the pilot to alter his plan to fly to the airport.

3.0 Conclusions
3.1 Findings

- The pilot was certified and qualified in accordance with existing regulations, and there was no indication that incapacitation or physiological or psychological factors affected his performance.

- There were no indications of any pre-impact failures or aircraft malfunctions that could have contributed to the occurrence.

- For the entire flight, the aircraft was operating outside its certified weight and balance envelope. This was not found to be contributory to the accident.

- Review of the aircraft journey log entries indicates there were other flights where the aircraft weight and balance were also in excess of the approved limits for the aircraft.

- At the time of the accident, the aircraft's engine was 92.8 hours over the 1,250 hours of operating time allowed between hot section inspections. This was not found to be contributory to the accident.

- Although the weight and balance and engine discrepancies were not found to be contributory, they indicate inadequate management supervision in these areas.

- The degree of company supervision of the operations and maintenance functions at Western Straits Air was found to be typical of other such companies offering similar services.

- DHC-3 Otter passenger seats do not meet current design standards, nor is this required by regulation.

- The pilot was not wearing the available shoulder harness and was thrown into the front-seat passenger on impact. This contributed to the injuries suffered by both the pilot and the passenger.

- Failure of the passenger seats to remain attached to the airframe contributed to the extent of the injuries suffered by the occupants.

- The continued flight into marginal weather conditions resulted in the progressive loss of the pilot's situational awareness and the collision with the terrain.

- The pilot's decision to continue the flight into marginal weather conditions was probably influenced by the prevailing industry attitudes and practices regarding VFR and SVFR operations.

- In the marginal weather of this occurrence, the pilot's use of visual flight procedures supplemented by IFR navigational methods did not provide the level of safety normally associated with either regime.

- The regulations governing VFR and SVFR commercial operations at the time of this accident were the same as the regulations assessed in the 1990 TSB safety study as providing inadequate safety margins.

3.2 Causes

The pilot progressively lost situational awareness while attempting to navigate in conditions of low
visibility or in cloud and was unaware of the rapidly rising terrain in his flight path. Contributing to this accident were the existing visual flight regulations and the prevailing industry attitudes and practices which did not provide adequate safety margins. Contributing to the severity of the injuries was the detachment of the passenger seats at impact.

4.0 Safety Action

4.1 Action Taken

4.1.1 Seating and Restraint System

Subsequent to this accident, the TSB issued a safety advisory to Transport Canada (TC) identifying a concern that seating and restraint systems of some aging aircraft do not provide adequate protection to passengers in the event of a crash or forced landing. Aircraft systems are being modernized to extend their useful lives for commercial passenger-carrying operations, but these upgrades seldom include the improved passenger safety provisions consistent with contemporary standards. Thus, the TSB suggested that TC take a more systems-oriented approach in approving such life-extension programs.

4.1.2 Engine Condition Trend Monitoring

During the investigation, it was established that the ECTM program, which formed part of the approved maintenance program for the turbine engine installation on C-FEBX, had not been used as per Transport Canada's approval. It was also determined that some of the TC airworthiness inspectors responsible for the Western Straits Air maintenance system were not trained in trend monitoring programs. The TSB subsequently advised TC of this issue and suggested that TC consider adding ECTM to the airworthiness inspectors' training curriculum.

4.2 Action Required

Air Regulations and Air Navigation Orders established under the Aeronautics Act, such as those governing VFR and SVFR flights, prescribe operating limits. Such limits are designed to provide operational flexibility, while ensuring minimum acceptable safety margins. Such regulations are influential elements in determining industry operational practices and in establishing the level of safety of the transportation system.

The Campbell River accident raises questions regarding the feasibility of VFR and SVFR flights in marginal weather conditions, considering pilots' limited capability to recognize deteriorating visibility, the adequacy of the margin of safety afforded by VFR and SVFR regulations, and the level of operators' awareness of the risks associated with commercial operations in marginal weather conditions.

4.2.1 Visual Flight - Margin of Safety

In its 1990 Report of a Safety Study on VFR Flight into Adverse Weather (90-SP002), the Board made several recommendations to the Department of Transport concerning visual flight rules. In recognition of the problems of safely maintaining visual references in mountainous terrain, the Department of Transport subsequently increased VFR visibility minima in designated mountainous areas from one mile to two miles.

At the time of this occurrence, the aircraft was operating under VFR in uncontrolled airspace within a designated mountainous area. To be in compliance with VFR, the aircraft was required to be flown with reference to the ground or water and remain clear of cloud; the pilot was required to stay within sight of the surface of the earth at all times, and was required to ensure a minimum flight visibility of two miles. Under SVFR in the Campbell River control zone, the same restrictions would apply except that the minimum flight visibility would be one mile. There are no minimum ceiling requirements for either SVFR flight or VFR flight in uncontrolled airspace below 1,000 feet agl.

The accident record continues to show that VFR CFIT accidents occur primarily when operations are
being conducted in marginal weather and/or dark night conditions. Interviews with flight crew and operators obtained during this investigation indicate that it is common practice in the industry to continue flight operations at the minimum visibility requirements for VFR and SVFR. When operating in conditions that include low ceilings and visibilities, pilots often pick their way through the weather while trying to stay visual. Flight in marginal weather presents a high risk of inadvertent entry into conditions where visual reference is insufficient for the maintenance of aircraft control, terrain and traffic avoidance, and accurate navigation. There are substantial grounds for questioning a pilot's ability to safely complete flights under such conditions.

Visual Depth Perception. In perceiving both depth and distance, humans interpret several visual cues in such a way as to generate a three-dimensional image in the visual cortex of the brain:

a. Linear Perspective The distances between distant images appear to be less than those separating near images. For instance, railway tracks appear to converge in the distance. Knowing that the tracks remain a fixed distance apart, the convergence is interpreted as a distance cue.

b. Clearest in general, the more distant an object, the less clearly it is seen. Further, a mountain on a hazy day appears more distant than it would on a clear day.

c. Interposition When an object partially obstructs the view of another object, the first object appears nearer.

d. Shadows Humans are used to perceiving objects with light sources situated above them; this information is used to give objects a spatial orientation.

e. Gradients of Texture Generally, the texture of a scene appears finer and there is less detail as distance increases; conversely, foreground appears coarser and there is more perceptible detail.

f. Movement When the head moves, objects move in relation to oneself and to each other. Objects beyond the eyes' visual fixation point move in the same direction as the head. Objects nearer than the point of visual fixation appear to move in the direction opposite to the movement of the head. The amount of movement is less for distant objects than for near objects.

Assessing Distance in Marginal VFR. When visibility is poor, the cues to perceive distances of objects are diminished. Without these cues, consistent, accurate judgement of distance is improbable, even in a relative sense.

Humans tend to be poor judges of distance in absolute terms; they can best judge distance in relation to some fixed marker. Thus, trained weather observers use known distances from ground features to establish ground visibility. In the mountainous area of Vancouver Island, distance cues or markers are much less likely to be available. Reliably judging one mile of visibility from a moving aircraft is arguably a task beyond human capability.

Another factor that could detract from a pilot's ability to judge whether the one-mile visibility requirement is being met relates to the angle of flight visibility being considered. The primary requirement of visual flight is that the aircraft shall be flown with reference to the ground or water. When an obscuring phenomenon like fog is present, the reduction in visibility at low altitude can be much less looking downward than looking forward. The survivors of the Campbell River crash reported that they were able to see the ground in the Campbell River area; however, obstacle avoidance requires forward visibility, which was not available. A reasonably clear view of the ground in marginal conditions could lead a pilot to believe that the one-mile forward flight visibility requirement was being met. Clear downward visibility would likely be an influential cue to the pilot, even though not necessarily a reliable or accurate cue.

Aircraft flight control and navigation may be conducted exclusively by visual reference to cues outside the cockpit, by reference to aircraft instrumentation, or by varying combinations of external and internal references. In this accident, the pilot was apparently attempting to avoid terrain and navigate by using a combination of external references and aircraft instrumentation.

In Canada, air-taxi operations are often conducted fully or in part under visual flight rules. Over an
eleven-year period (01 January 1984 to 31 December 1994), there were 70 accidents involving commercially operated aircraft not conducting low-level special operations, where the aircraft were flown into terrain, water, or obstacles, under control, while the crew had no awareness of the impending disaster. In over half of the occurrences, the crew was attempting to see the ground in order to fly visually, although the conditions apparently precluded visual flight. These 70 CFIT accidents involved pilots with the full range of experience, indicating that experience does not appear to be a factor in reliably coping with conditions of marginal visibility. Several recent commercial accidents (A95P0265, A95C0026, A95Q0104) in which VFR flights were attempted in flight conditions which did not allow the pilots to visually navigate and/or avoid collision with terrain illustrate that the same issues continue to be factors in this type of occurrence.

The Board understands that the present VFR and SVFR requirements are the result of years of evolution in committee proceedings; however, these committees seldom include representation from the scientific community, and therefore do not take into account the research available on such aspects as the human visual system and normal human information processing capabilities. Safe operations in VFR and SVFR conditions depend almost entirely on the pilot's ability to assess flight visibility and immediately recognize any deterioration. When flying in the minimum weather conditions allowed by VFR and SVFR, recognition of deteriorating visibility can be virtually impossible, particularly when combined with other factors such as high workload, variable weather conditions, poor light conditions, or limited outside visual cues. Therefore, the Board recommends that:

The Department of Transport sponsor research to establish on a scientific basis the ability of pilots to assess distances, make appropriate decisions, and control aircraft without reference to aircraft instruments in the marginal visibility conditions of VFR and SVFR minima.

A96-09

Adequacy of Current Regulations. Under current regulations, the requirement to fly VFR is that the aircraft shall be flown with visual reference to the ground or water. The new Canadian Aviation Regulations state that the aircraft shall be operated with "visual reference to the surface." Neither regulation defines just what constitutes "visual reference to the surface"; nor is any rationale provided as to what a pilot is expected to do based solely on that visual reference. Nevertheless, it is the Board's understanding that the basic tenet of VFR flying in Canada is that the pilot be able to maintain control of the aircraft, avoid obstacles and other air traffic, and navigate solely through the observation of references external to the aircraft. Given that the 70 CFIT accidents involving commercially operated aircraft referred to above claimed 106 lives and left 23 persons seriously injured, the Board believes that the regulatory requirements for visual flights and the understanding and the application of these requirements by pilots (even experienced and instrument-rated pilots) are inadequate. The severe consequences and high probability of error in assessing flight visibility suggest that these regulations are particularly inappropriate in the context of commercial passenger-carrying operations. Therefore, in the light of the findings of the research recommended above, the Board recommends that:

The Department of Transport evaluate the adequacy of the margin of safety afforded by current VFR and SVFR regulations—particularly for commercial passenger-carrying operations.

A96-10

Application of Regulations. Regardless of the prescribed minima, the variability of flight visibility and the subjectivity in assessing it from a moving aircraft make enforcement of visibility requirements implausible in most circumstances. Apparent differences of opinion among pilots and operators as to the application of the prescribed minima further exacerbate the situation. Education and training seem to offer the most scope for practically implementing the visibility requirements. Yet, commercial aircraft accidents in adverse weather continue, despite frequent emphasis in TC safety newsletters and presentations on the importance of adhering to established VFR limits. In view of the occurrence record involving experienced as well as instrument-rated pilots, the Board believes that there is inadequate understanding throughout the aviation community of the risks and the consequences of operating in marginal weather conditions. A false sense of security develops when pilots and their peers repeatedly succeed in getting through marginal conditions—without incident. The Board believes that many CFIT accidents could be prevented if dangerous situations were recognized as
conditions deteriorate. Therefore, the Board recommends that:

The Department of Transport develop and implement a targeted national promotion campaign aimed at raising commercial operators' awareness of the inherent risks associated with flight operations in marginal VFR flight conditions.

A96-11

4.2.2 Pilot Decision Making

In accordance with standard investigation practice, accident pilots’ decision-making processes are analyzed. The temptation to judge the quality of a pilot's decisions by the outcome, however, must be guarded against. Fairness to the individual and the advancement of transportation safety require that the actions of the pilot be understood within the context in which pilots typically are operating.

Cockpit decisions can be conceived of as having two components: situation assessment and selection of a course of action. Thus, the difficulty involved in decision making depends primarily on "the degree of clarity of the cues signifying the problem and the nature of the response options available in the situation."<4>

Cues, or information about the situation, can vary between clear and ambiguous. In situations such as emergency procedures, the cues are so strong that decision options are prescribed and the response is automatic. Sometimes, once a situation is defined or interpreted, the pilot must choose among options, or schedule tasks in the most appropriate order for the conditions. This represents a higher level of complexity. The most demanding decision making involves those situations where there are no pre-determined options. In these cases, pilots must develop their plans by using both their knowledge of the system and their assessment of the situation. The more complex and difficult a decision is, regardless of whether the difficulties are in the situation assessment component or in the response selection component, the greater the likelihood of a decision that is less than ideal. Consequently, decision tasks in the cockpit differ in the degree to which they are well-structured and thus have an agreed-upon "best" solution.

The accident pilot was familiar with the area and the aircraft. Low ceilings and poor visibility are common occurrences in the area and he had flown many hours in similar meteorological conditions. As he approached Campbell River, the ceiling at the airport was low (about 300 feet), but over the water, the clouds were about 1,000 feet above the surface.

The decision making in this occurrence required that the pilot assess the situation and choose between continuing to the airport or landing on the water at Tyee Spit, which would undoubtedly have entailed some inconvenience for the passengers. He may also have considered climbing and requesting an IFR approach, for which he was qualified and equipped.

As the pilot approached the control zone, the weather in his immediate area was above ceiling and visibility minima. The Campbell River airport reported a ceiling of 300 feet and two miles visibility, but the ceiling had been varying between 300 and 500 feet through the day and an aircraft ahead reported sighting the Campbell River runway from 900 feet asl. The pilot had an SVFR clearance which only required a flight visibility of one mile and the aircraft to remain clear of cloud. The fact that the aircraft was instrument equipped, and that the pilot was qualified for instrument flight and experienced in conducting instrument approaches into Campbell River would likely have further contributed to his confidence in continuing to the airport. The course of action selected by this pilot, based upon the existing regulations and his experience, would have been taken by many pilots with similar experience.

Once the decision to try to land at the airport was made and the aircraft turned inland, the clarity of the visual cues deteriorated. At about 2 1/2 miles from the airport, the pilot apparently changed his plan and attempted to set up an approach from the same direction as the aircraft which had reported sighting the runway from 900 feet. It is doubtful that the pilot would modify his plan as he exited from the control zone; in principle, though, his visibility criteria increased from one mile for SVFR to two miles for VFR in designated mountainous terrain as he crossed an imaginary line at the boundary of the control zone. It is likely that his attention was focused on controlling the aircraft and his workload.
was heavy at this point, so that both the transition to uncontrolled airspace and the significance of it were probably not recognized at a conscious level. It appears as though he did maintain visual reference with the ground during this time.

In the light of the outcome, changing his plan and returning to Tyee Spit would have been more prudent; but the cues available to the pilot were apparently not compelling enough to change his mental model, or assessment of the situation. Once individuals select a particular course of action, it takes very compelling cues to alert them to the advisability of changing their plan. Indeed, there is a tendency to use these cues to confirm the validity of the intended plan of action<5>. This pilot had control of the aircraft, was maintaining visual contact with the ground, and was able to navigate, probably with the aid of instruments. These cues would be sufficient to lead many professional, safety-conscious pilots to continue the approach to the airport.

A recent analysis by the National Transportation Safety Board (NTSB) in the US involving 37 accidents showed that, when faced with Go/No-Go decisions, 66% of the crews continued with their current plan in the face of cues which suggested they should have abandoned it. "However, in many of these cases the cues were ambiguous and it was difficult to assess with great confidence the level of risk inherent in the situation."<6>

Inexperience, lack of knowledge, imprecise guidelines, and ambiguous cues will continue to make some pilot decision-making circumstances difficult. However, strategies to maximize the quality of decisions can be learned, and include such things as situation assessment, risk assessment, planning, resource management, communicating, and the identification of special skill requirements<7>.

Of note, increasing the SVFR minima could change the nature of decisions to be made in occurrences like the Campbell River accident. If there had been a greater minimum visibility requirement, or rules requiring a combination of ceiling and visibility, the pilot would have been faced with an easier decision. Had the previous SVFR rules been in force, the only option would have been to land at Tyee Spit. Thus, the need to re-assess the adequacy of current VFR weather minima (recommended above) should be considered in the light of normal pilot decision-making processes.

The accident pilot was operating in an environment which accepted as "normal operations" flights into marginal weather conditions, when other options, such as landing at Tyee Spit, were available. Typically, pilots involved in VFR CFIT accidents have not had any special training in decision making. At the same time, pilots flying in small air carrier operations are arguably the most exposed to such ambiguous situations with the least decision-making support. They often operate as single-person crew into a variety of unfamiliar locations with minimal infrastructure and are self-dispatched, and the aircraft do not usually possess sophisticated instrumentation or control systems.

The Board has previously recommended that Transport Canada develop and implement a means of regularly evaluating the practical decision-making skills of commercially employed pilots in small air carrier operations (TSB A90-86). TC's response in part stated:

It has been Transport Canada's position that the benefits of this training were intrinsic in the enhanced performance of the pilot and that a properly planned and executed Pilot Proficiency Check would provide a practical and realistic assessment of a pilot's ability to make reasoned and timely decisions when faced with a simulated emergency situation. We will continue to keep abreast of developments in the field of decision-making training and assessment and will not hesitate to introduce improvements in our present system should they become available.

National and regional carriers have broadly embraced the concepts of Cockpit Resource Management (CRM) and Pilot Decision Making (PDM) training, and under the new Canadian Aviation Regulations, airline operators will be required to complete initial and recurrent CRM training. However, for other commercial operators, formal programs are being introduced on a voluntary basis. The Board believes that, given the natural human limitations in interpreting distances in marginal visibility conditions, natural human tendencies in complex decision making in the presence of changing and ambiguous cues, and

the CFIT accident record involving small commercial operators, further counter-measures are
required to facilitate safe crew decision making. Therefore, once again, the Board recommends that:

The Department of Transport require that pilots involved in air-taxi and commuter operations receive specialized training, including skills development, in making prudent decisions under deteriorating operational conditions.

A96-12

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 15 August 1996.

Appendix A - Flight Path
Appendix B - Weight and Balance
Appendix C - List of Supporting Reports

The following TSB Engineering Branch Reports were completed:

LP 164/95 - Technical Group Report DHC-3, C-FEBX;
LP 147/95 - Shoulder Harness Analysis;
LP 146/95 - Estimation of Crash Impact Loads;
LP 143/95 - Instrument Examination; and
LP 149/95 - Exhaust Stack Analysis Temperature Determination.

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

Appendix D - Glossary

ADF - automatic direction finder
agl - above ground level
ANO - Air Navigation Order
asl - above sea level
ATC - air traffic control
ATPL - Airline Transport Pilot Licence
CAR - Civil Air Regulation (United States)
CFIT - Controlled Flight into Terrain
C of G - centre of gravity
CRM - cockpit resource management
CVR - cockpit voice recorder
DME - distance measuring equipment
ECTM - Engine Condition Trend Monitoring Program
ELT - emergency locator transmitter
FAA - Federal Aviation Administration
FAR - flight data recorder
FSS - Flight Service Station
g - G load factor
GPWS - ground proximity warning system
hr - hour(s)
HSI - hot section inspection
IFR - instrument flight rules
ILS - instrument landing system
IMC - instrument meteorological conditions
lb - pound(s)
MF - mandatory frequency
NDB - non-directional beacon
nm - nautical miles
PDM - pilot decision making
PDT - Pacific daylight saving time
SAR - Search and Rescue
sm - statute miles
SVFR - special visual flight rules
TC - Transport Canada
TSB - Transportation Safety Board of Canada
UTC - Coordinated Universal Time
VFR - visual flight rules
VHF - very high frequency
VMC - visual meteorological conditions
VNC - VFR navigation chart
VOR - very high frequency omni-directional range
YBL - Campbell River
' - minute(s)
" - second(s)

- degree(s)
- M degrees of the magnetic compass
- T degrees true

<1> All times are PDT (Coordinated Universal Time [UTC] minus seven hours) unless otherwise stated.
<2> See Glossary at Appendix D for all abbreviations and acronyms.

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.

Rejected Take-off/Runway Overrun
Canadian Airlines International
McDonnell Douglas DC-10-30ER C-GCPF
Vancouver International Airport,
British Columbia
19 October 1995

Report Number A95H0015

Synopsis

Canadian Airlines International Flight 17 was on a scheduled flight from Vancouver International Airport to Taipei, Taiwan. On board were 4 flight crew, 8 cabin crew, 2 interpreters, and 243 passengers. During the take-off on runway 26 and approximately two seconds after the V1 call, the crew heard a loud bang and felt an airframe shudder and considerable vibration, later attributed to an engine stall. The captain called for and initiated a rejected take-off. The aircraft could not be stopped on the runway, and the nose-wheel gear collapsed as the aircraft rolled through the soft ground beyond the end of the runway. The aircraft came to rest in a nose-down attitude approximately 400 feet off the declared end of the runway. Six passengers were slightly injured during the emergency evacuation of the aircraft.

The Board determined that engine number 1 lost power at a critical point in the take-off and that the rejected take-off was initiated at a point and speed where there was insufficient runway remaining to stop the aircraft on the runway. Contributing to this occurrence were the misidentification of the cause of the loud bang and the lack of knowledge regarding the characteristics of engine compressor stalls. Contributing to the engine power loss was a delay between the collection and analysis of the engine monitoring data.

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2.6 Aircraft Load Control Factors
2.7 Evacuation Signal System
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2.9 Wet Runway Considerations

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3.1 Findings
3.2 Causes

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4.1.3 Take-off Performance System Changes
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5.0 Appendices

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Appendix B - List of Supporting Reports
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1.0 Factual Information

1.1 History of the Flight

Canadian Airlines International (CAI) \(<1>\) Flight 17, a DC-10-30ER, with 4 flight crew, 8 cabin crew, 2 interpreters, and 243 passengers on board, was scheduled to depart Vancouver at 1200 Pacific daylight saving time (PDT)<2> on 19 October 1995 for a direct flight to Taipei, Taiwan. The departure was delayed approximately 75 minutes because of a mechanical fault on the number 2 engine thrust reverser. The fault could not be rectified, and the aircraft was dispatched with the thrust reverser disabled.

The captain did a rolling take-off. The aircraft was aligned with the runway centre.
line, and the power levers were positioned to the take-off power range by 80 knots; "Thrust set" was called by the second officer as the aircraft accelerated to 95 knots. The first officer called V1 (critical engine failure recognition speed) at 164 knots, and approximately two seconds later, there was a loud and startling bang, followed by an airframe shudder and considerable vibration. The captain called for a reject and retarded the power levers. The first officer advised the tower that Flight 17 was rejecting the take-off, and the second officer manually deployed the spoilers, which activated the wheel auto-brakes as the aircraft reached a peak speed of 175 knots.

When it became apparent that the aircraft would not stop on the runway, the captain steered the aircraft to the right to avoid hitting the approach lights. The aircraft was travelling at approximately 40 knots as it went off the end of the runway. As the aircraft rolled through the soft ground, the nose-wheel gear collapsed. The aircraft came to rest in a nose-down attitude approximately 400 feet off the declared end of the runway, or 255 feet past the end of the paved area off the end of the runway. Immediately after the aircraft came to a stop, the in-charge flight attendant entered the cockpit and requested instructions. The augmenting first officer told him that there would probably be an evacuation, but to give them a minute. The captain then directed the cockpit crew to initiate the evacuation checklist, and he ordered the evacuation over the public address system. Six passengers were slightly injured during the evacuation. There was major damage to the aircraft in the area of the nose-wheel collapse.

### 1.2 Injuries to Persons

<table>
<thead>
<tr>
<th>Crew Passengers Others Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
</tr>
<tr>
<td>Serious</td>
</tr>
<tr>
<td>Minor/None</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Six of the passengers were transported to a local hospital for examination. All six had incurred minor injuries as a result of descending the emergency slides.

### 1.3 Damage to Aircraft

As soon as the nose wheels ran off the end of the paved surface, they began to dig into the soft ground, placing aft force on the gear support structure. Approximately 100 feet off the end of the runway, there was a buried power cable, and ground above the cable was harder than the surrounding soil. Surveying data and photographs indicate that the wheels were pushed up in the area of this buried cable, which would have placed additional stresses on the gear. The failure of the nose gear occurred at the attachment point for the gear's forward bracing. As the gear was pulled aft, the structure inside the nose wheel well was torn out. The nose gear was pushed into the airframe, aft of the gear well, when the airframe came down on top of the gear. The failure of the nose gear was a result of overload, and no signs of previous fatigue were noted. The cowlings of the wing-mounted engines were damaged when they contacted the ground after the nose gear collapsed.

### 1.4 Other Damage

Two runway-end lights were reportedly broken by the aircraft's wheels. Some
damage to the surrounding ground was caused by the aircraft during the overrun, and later by the heavy equipment used to extricate the aircraft from the overrun area.

1.5 Personnel Information

1.5.1 Flight Crew - General

<table>
<thead>
<tr>
<th></th>
<th>Captain</th>
<th>First Officer</th>
<th>Second Officer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>55</td>
<td>49</td>
<td>44</td>
</tr>
<tr>
<td>Pilot Licence</td>
<td>ATPL</td>
<td>ATPL</td>
<td>S/CPL</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
<td>1 Apr 96</td>
<td>1 Feb 96</td>
<td>1 Feb 96</td>
</tr>
<tr>
<td>Total Flying Hours</td>
<td>16,631</td>
<td>9,013</td>
<td>6,964</td>
</tr>
<tr>
<td>Hours on Type</td>
<td>3,969</td>
<td>5,784</td>
<td>5,430</td>
</tr>
<tr>
<td>Hours Last 90 Days</td>
<td>141</td>
<td>188</td>
<td>128</td>
</tr>
<tr>
<td>Hours on Type Last 90 Days</td>
<td>141</td>
<td>188</td>
<td>128</td>
</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Time Off Duty Prior to Work Period</td>
<td>25 days</td>
<td>5 days</td>
<td>18 days</td>
</tr>
</tbody>
</table>

1.5.1.1 Captain

The captain joined Canadian Pacific Airlines on 05 July 1965 and was initially employed as a first officer on Douglas DC3 aircraft. He subsequently transferred to CAI when it was formed in 1988. He has flown a variety of aircraft, including the B727, DC3, DC8, B747 and DC-10. He attained captain status on the DC-10 in January 1987, and, since that time, he has accumulated 3,816 hours as captain on the DC-10.

At the time of the occurrence, the captain held an Airline Transport Pilot Licence (ATPL), endorsed for the DC-10, and a Group 1 instrument rating. He also held a Category 1 medical. The occurrence flight was his first flight during the month of October. The captain successfully completed his last line check on 19 February 1995, and his last recurrent training on 15 September 1995. Both these flights were assessed as being very well flown and managed.

1.5.1.2 First Officer

The first officer joined Canadian Pacific Airlines on 14 June 1973 as a first officer on DC3 aircraft and subsequently on DC8s. He also transferred to CAI, where he has attained 1,668 and 4,118 hours on the DC-10 as second and first officer respectively.

The first officer held an ATPL, endorsed for the DC-10, and a Group 1 instrument rating. He held a Category 1 medical.

The first officer successfully completed his last line check on 25 February 1995, and his last combined pilot proficiency check and instrument rating renewal flight on 26 June 1995. Both these flights were assessed as being "well flown."

1.5.1.3 Second Officer
The second officer joined Canadian Pacific Airlines on 17 August 1979, and subsequently transferred to CAI; he successfully completed conversion as a second officer on the DC-10 aircraft in 1985. In September 1994, he successfully completed an upgrade to and received an endorsement as first officer on the DC-10. However, due to scheduling changes, his recent flying was as second officer on the DC-10. He has flown 5,430 hours on the DC-10.

At the time of the occurrence, the second officer held a senior commercial pilot licence endorsed for second officer on the DC-10; he also held a Category 1 medical. The second officer completed his most recent recurring training on 29 May 1995; during this session, he was assessed as having done "excellent work" and as performing to "high standard."

1.5.1.4 Augmenting First Officer

For its long-haul flights, CAI augments its DC-10 flight crew with one more qualified first officer to meet the regulatory requirement for exceptions to extend the maximum flight duty time beyond 15 hours<3>. The airline’s contract with its pilots requires that an augmenting first officer be assigned when flight-duty time will be over 14 hours. On these flights, the augmenting first officer is responsible for preparing the take-off data card, and for providing any additional help to the crew as requested by the individual crew members or as directed by the captain.

The augmenting first officer for this flight was a qualified DC-10 first officer, who held a current ATPL and a Group 1 instrument rating. He had a total of 11,736 flying hours, and, at the time of the occurrence, he had accumulated 5,774 hours on type, of which 4,362 were as first officer. The augmenting first officer successfully completed his last line check on 22 September 1995; he was rated as having done "very nice work."

At the time of the occurrence, the augmenting first officer was occupying the observer seat.

1.5.2 Cabin Crew - General

The cabin crew included eight flight attendants, one of whom was the customer service director (CSD), who was in charge of the cabin crew under the operational command of the captain. According to Canadian Air Navigation Orders, a minimum of seven flight attendants was required for this flight.

Company records indicate that all the flight attendants had successfully completed their annual recurrent training within the preceding 12 months, and that they were qualified and certified for the flight. At the time of the occurrence, the flight attendants were each seated in a jump-seat at their assigned aircraft door.

<table>
<thead>
<tr>
<th>Flight Attendant by Door Position</th>
<th>Years of Experience</th>
<th>Hours on Duty Prior to Occurrence</th>
<th>Hours off Duty Prior to Work Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1L</td>
<td>29</td>
<td>3.5</td>
<td>72+</td>
</tr>
<tr>
<td>1R</td>
<td>25</td>
<td>2.5</td>
<td>72+</td>
</tr>
<tr>
<td>2L</td>
<td>29</td>
<td>2.5</td>
<td>72+</td>
</tr>
<tr>
<td>2R</td>
<td>31</td>
<td>2.5</td>
<td>72+</td>
</tr>
<tr>
<td>3L</td>
<td>10</td>
<td>2.5</td>
<td>48</td>
</tr>
</tbody>
</table>
In accordance with CAI policy, a Chinese-language-qualified flight attendant was part of the cabin crew complement. She was seated at Door 3L.

On flights such as this one to Taipei, CAI, although not required to do so by regulation, provides the services of two interpreters, whose sole function is to provide translation services for passengers and cabin crew. The two interpreters were seated facing the flight attendant at Door 3L.

1.6 Aircraft Information

1.6.1 Aircraft Information - General

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>McDonnell Douglas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and Model</td>
<td>DC-10-30ER Airliner</td>
</tr>
<tr>
<td>Year of Manufacture</td>
<td>1980</td>
</tr>
<tr>
<td>Serial Number</td>
<td>46543</td>
</tr>
<tr>
<td>Tail Number</td>
<td>904</td>
</tr>
<tr>
<td>Certificate of Airworthiness</td>
<td>Valid</td>
</tr>
<tr>
<td>Total Airframe Time</td>
<td>61,289 hrs</td>
</tr>
<tr>
<td>Engine Type (number of)</td>
<td>CF6-50C2B (3)</td>
</tr>
<tr>
<td>Maximum Allowable Take-off Weight</td>
<td>590,000 lb</td>
</tr>
<tr>
<td>Maximum Allowable Ramp Weight</td>
<td>593,000 lb</td>
</tr>
<tr>
<td>Recommended Fuel Type(s)</td>
<td>Jet A1</td>
</tr>
<tr>
<td>Fuel Type Used</td>
<td>Jet A1</td>
</tr>
</tbody>
</table>

The aircraft maintenance records indicated that the aircraft had been maintained in accordance with the company's Maintenance Control Manual and applicable airworthiness standards.

For the occurrence flight, the aircraft was being operated with two minimum equipment list (MEL) item limitations:

1.MEL Item 36-04 Pneumatic Pressure Regulator Valve:

Because the pneumatic pressure regulator valve on engine number 3 would not shut off when so selected, the valve had been locked in the "OFF" position; and

2.MEL Item 78-01 Thrust Reverser/Fan Reverser:

Because the thrust reverser on the number 2 engine would not stow properly after landing on the previous flight, the thrust reverser had been locked out.

The dispatch of the aircraft with these two unserviceable items was permitted by CAI's Transport Canada (TC) approved DC-10 MEL. The MEL did not direct any operational limitation conditions for either of these items.
1.6.2 Aircraft Wheels and Brakes

The aircraft was equipped with an auto-brake system (ABS). During a rejected take-off, the ABS is activated when the ground spoilers are deployed manually by the crew, or when the ground spoilers are deployed automatically as the result of the power levers being retarded and the thrust reversers being selected. The ABS system deactivates if the brake pedals are depressed. The aircraft's antiskid system is designed to enable maximum braking effectiveness by allowing approximately five per cent skidding while ensuring that the wheels do not lock.

The flight data recorder (FDR)<4> indicated that the wheel brakes were applied by the ABS, which was activated when the spoilers were selected by the second officer. FDR data further indicated that full brake pressure was maintained by the ABS until the aircraft came to a stop.

All of the brake units were dismantled and examined by representatives of the TSB, the aircraft manufacturer, and the company. Most of the brake wear-pins were missing because the brakes were worn beyond the normal tolerances as a result of the heavy braking during the rejected take-off. Each brake segment did contain remnants of brake material, which indicates that none of the wheel brakes wore out completely during the rejected take-off manoeuvre. There were no signs of hydraulic fluid leakage from the brake pistons or cylinders.

The eight main-gear tires did not have any flat spots. The entire circumference of each tire showed signs of some heat and wear. The eight main wheels on the left and right bogies were found deflated as a result of the fuse plugs being melted. Fire department personnel who were on scene after the accident heard the fuse plugs blowing.

The two centre-gear tires were not worn as much as the rest, which is normal because the centre wheels do not carry as much weight as the main-gear tires. The centre-gear tires remained inflated until the valve cores were removed by recovery personnel at the accident site.

The runway had six clear, continuous lines of rubber from the point that the rejected take-off began to the point where the aircraft left the runway, indicating that each tire was skidding to some degree. The lack of any flat spots worn on the tires indicates that the wheels did not lock up at any time.

1.6.3 Aircraft Engines

1.6.3.1 Aircraft Engines - General

The aircraft was equipped with General Electric CF6-50C2B engines. The engine maintenance records indicated that the three engines installed on the aircraft had been maintained in accordance with the manufacturer's recommendations and as specified in the CAI CF6-50 Engine Specification Manual. All relevant Airworthiness Directives and Service Bulletins had been incorporated into the maintenance schedule, and test records were complete. Engine performance monitoring was conducted in accordance with CAI's TC-approved Maintenance Control Manual and met the manufacturer's recommended program.

Engine data on the FDR indicated the following: engines number 2 (S/N 517762)
and number 3 (S/N 517925) operated normally during the take-off; engine number 1 (S/N 517955) experienced a significant power loss as the aircraft reached 170 knots; and the thrust reversers on engines number 1 and number 3 were selected and deployed<5>. When the thrust reverser levers were retarded, engine number 3 speed increased and normal reverse thrust was produced; however, engine number 1 speed remained low, and no significant reverse thrust was generated by this engine.

### 1.6.3.2 Engine Number 1 - General Condition

FDR data indicated that during the initial portion of the take-off roll, engine number 1 operated normally. As the aircraft reached 129 knots, there was a slight increase in vibration level for about 12 seconds. At approximately 170 knots, there was a spike in the vibration data coincident with the start of a rapid decrease in engine speed from 112 per cent engine fan speed (N1) to below 40 per cent N1. The FDR also indicates that about 2.0 seconds before this power loss, the exhaust gas temperature (EGT) on engine number 1 started increasing. At the time of the power loss, the EGT reached about 960 degrees, subsequently peaking at 1,064 degrees five seconds later, just after the power levers were retarded. Following the occurrence, an external visual inspection of engine number 1 did not reveal any anomalies; however, a borescopic inspection of the engine revealed significant damage to the high-pressure compressor section of the engine. The engine was removed from the aircraft, disassembled, and subjected to a detailed examination.

<table>
<thead>
<tr>
<th>Engine 1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial Number</td>
<td>517955</td>
</tr>
<tr>
<td>Date of Installation</td>
<td>21 Dec 94</td>
</tr>
<tr>
<td>Time Since New</td>
<td>42,731 hrs</td>
</tr>
<tr>
<td>Time Since Last Inspection</td>
<td>3,775 hrs</td>
</tr>
<tr>
<td>Compressor Section Time</td>
<td>6,671 hrs</td>
</tr>
</tbody>
</table>
The fan and booster blades were all intact and showed no signs of damage, except for light streaking attributed to earth ingestion during the overrun. All actuators, lever arms, and unison rings of the high-pressure compressor were intact and showed no signs of distortion. The variable-guide-vane lever arms were found to be intact, undistorted, and properly assembled. The pins and bushing showed no signs of excessive wear. The actuators were removed and found to be free of leaks. The feedback cables were pull tested and were within the manufacturer's limits. The combustor condition was normal with no signs of mechanical damage. All fuel nozzles were intact. There were no liner deformations or disruptions of airflow.

The high-pressure turbine module showed no signs of impact damage. The first-stage nozzle and a sector of about six stage-1 blades were sooted. The stage-1 blades showed thermal distress with missing blade tips. The stage-2 blades were in good condition. The low-pressure turbine module showed no signs of mechanical damage. The turbine midframe liner was intact and not deformed. There were no signs of any flow-path anomalies.

A sniff test was made on the oil, and no fuel in the oil was detected. The filters and master chip detector were inspected and found to be free of notable debris. The gear train was intact, and neither the fuel pump nor the main engine control (MEC) splines showed unusual wear. No anomalies were identified with the compressor-inlet temperature sensor. The MEC unit, which was tested by the manufacturer (Woodward Governor Company), was found to be serviceable.

1.6.3.3 Engine Number 1 - High-Pressure Compressor Damage

A visual inspection confirmed that there was no significant damage to the blades of
stages 1 and 2 of the compressor. The first notable blade damage was in stage 3 blades, mostly on the trailing edges. Stage 4 contained one blade that separated about 30 per cent from the tip. The remaining stages of the compressor rotor showed nicks, tears, and tip damage caused by hard-body impacts. The rotor lands exhibited light rubs through 90 to 180 degrees of the rotor circumference. The degree of damage diminished toward the aft stages of the high pressure compressor, and final stages 12 through 14 showed light to moderate leading-edge and trailing-edge blade damage in the forms of nicks, tears, and missing fragments caused by hard-body impacts. A close visual examination of the set of stage 3 blades revealed that several blades showed streaks from airflow patterns around nicks in the leading edges, indicating a certain degree of engine operation after the nicks had occurred.

The damaged blades from the high-pressure compressor were removed from the engine and underwent a metallurgical examination at the TSB Engineering Branch<6>. It was determined that there was fatigue damage to high-pressure compressor blades from stage 3 on. For all but one of the blades exhibiting fatigue fractures, the fracture origins were at the leading edge or trailing edges, and were associated with mechanical damage to that area of the blade. The origin of the fracture to one stage 3 blade (number 31), however, was at mid-chord. Blade 31 was also found to be bent, which may explain the location of the fracture origin. The material of the fractured blades satisfied the manufacturer's requirements as regards the chemistry and microstructure. Laboratory examination of the physical evidence did not yield sufficient information to pinpoint the cause of the fatigue cracking nor to estimate the crack propagation rates. The fatigue portions of the fractures were tarnished, discoloured or oxidized, especially in the higher stage blades where the air temperature progressively increases. The Engineering Branch Report indicated that some fatigue cracks predated the occurrence event.

1.6.3.4 CF6-50 Engine History

Occurrence data bases were reviewed for incidents involving the CF6-50 engine, concentrating on stalls, power loss, compressor failures, and foreign object damage events. General Electric records indicate that there are over 2,100 CF6-50 engines now in service installed on DC-10s, A300s, and B747s. Stall testing during the development of the CF6-50 engine has shown the engine to be stall tolerant.

Between 1972 and 1995, there were approximately 300 take-off power events involving stalls or power loss. About 30 per cent of the events were related to high pressure compressor blade damage. The remainder of the events were a result of sensor, variable geometry, or downstream components problems. About 10 per cent of the events resulted in rejected take-offs. The number of bird-ingestion events is in excess of 2,400, and non-bird foreign object damage (FOD) events, approximately 500. Records also indicate that there have been about 400 FOD events that resulted in only high-pressure compressor blade damage.

According to the manufacturer, there were no previous events documented involving the fatigue failure characteristics and the mid-chord fatigue-origin location noted on blade 31.

1.6.3.5 General Electric Engine Trend Monitoring Program

An engine condition monitoring program was developed by General Electric to track
engine health, with the aim of providing an opportunity for early fault detection. General Electric promulgates the guidelines for engine parameter trend monitoring in its Operations Engineering Bulletin 15 and Customer Service Rep Tips 373. Adherence to General Electric trend-monitoring guidelines is not mandatory, and General Electric advises each operator to establish its own reporting and analysis procedures, and alert levels for parameter shifts. General Electric does not specify urgency or how much time should be taken to complete the analysis of the trend data.

The following table represents guidelines on parameter trend analysis as specified by General Electric Rep Tips 373:

<table>
<thead>
<tr>
<th>Trend Shift Noted</th>
<th>Action Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGT up-shift more than 10°C, but less than 20°C</td>
<td>Check for indication of bird strike or FOD at Inlet and Exhaust.</td>
</tr>
<tr>
<td></td>
<td>Check Last Stage LPT Blades.</td>
</tr>
<tr>
<td></td>
<td>Place engine On-Watch for next three flights. If average shift is greater than +20°C, perform troubleshooting listed below.</td>
</tr>
</tbody>
</table>

EGT up-shift more than 20°C

1. Perform troubleshooting before next flight

General Electric Rep Tips 373 states that a rise in EGT accompanied by a rise in fuel flow and engine core speed (N2) can be an indication of high-pressure compressor damage.

1.6.3.6 Trend Monitoring of Engine Number 1

CAI adopted General Electric's engine monitoring program and integrated it into the operation of the DC-10 fleet by monitoring cruise data. Generally, readings are taken and entered on an "Instrument Readings DC-10" form by the flight crews every three hours, or once per flight for shorter flights. When the aircraft lands at a base that has access to the CAI/AMR (American Airlines Corporation) mainframe computer in Tulsa, Oklahoma, the data from the completed forms are entered into the computer. Once every 24 hours, the mainframe computer processes the data using the General Electric Aircraft Data Engine Performance Trending (ADEPT) computer program. The output from ADEPT is then sent to CAI's computers in Vancouver, where it is analyzed by the power plant maintenance group. At CAI, it takes somewhere between two and a half to four days from the time the readings are taken in the aircraft until the results are analyzed and can be acted upon.

The number 1 engine monitoring records produced by ADEPT on 19 October 1995, the morning of the occurrence, were based on data up to and including flights on 16 October 1995. This printout indicated that, starting on 14 October 1995, the number 1 engine EGT had drifted upward by 9 degrees toward the baseline over the last three entries. Records indicate that a similar drift was experienced around 25 September 1995; however, on that occasion, the EGT subsequently dropped back to normal. Consequently, the increase in EGT recorded in this 19 October 1995 printout was viewed at CAI as normal variation or scatter.
The data for 17 and 18 October 1995, analyzed after the occurrence, indicated that the upward trend of the EGT on engine number 1 had reached 27 degrees, and that the high EGT was accompanied by increases in fuel flow and engine core speed (N2). For this magnitude of shift in engine parameters, General Electric recommends an immediate borescopic inspection of the high-pressure compressor and low-pressure turbine. In addition, CAI's DC-10 Flyaway Manual specifies a borescopic inspection of the high-pressure compressor in the event of abnormal EGT and engineering performance trend increase.

Discussions with the engineering and maintenance personnel at CAI revealed that engine trend monitoring has been used since the mid 1980s and has been instrumental in identifying engine problems. Prior to this occurrence, CAI had not correlated a trend shift with an impending engine failure.

1.6.3.7 Engine Number 1 Exhaust Gas Temperature Gauge

The engine EGT gauges on the DC-10 incorporate a temperature pointer that records the peak EGT experienced by the engine, and an amber temperature-advisory light, which illuminates to warn the crew when the EGT exceeds 940-960 degrees Celsius.

The EGT indicator for the number 1 engine was removed from the aircraft and tested. The temperature indicator and light were found to function within the tolerances of the test parameters, and the peak EGT pointer was found at an extremely high position, off the temperature scale. The FDR recorded that EGT peaked momentarily at 1,064 degrees about three seconds after the reject call.

It is concluded that the number 1 engine EGT gauge in the cockpit had been functioning properly. During the take-off, the gauge did momentarily indicate a very high reading, and the amber light should have illuminated about the time of the loud bang. None of the flight crew members saw the temperature-advisory light illuminate.

1.6.3.8 Engine Failure Lights

The DC-10 cockpit is equipped with two amber "Engine Fail" lights, one on the glare shield in front of each pilot. The system is armed on the take-off roll once the N1 speeds of all the engines go beyond 85 per cent. The engine-fail lights will illuminate when the system detects an 11 per cent difference between any of the engines' N1 speeds. The ground-sensing relay on the nose gear disables the engine-failure detector system in flight, or at any time the oleo strut is extended enough to deactivate the switch. Detector logic prevents the engine-fail lights from illuminating during reverse thrust operation.

FDR data indicate that, on the take-off roll, at the time that the number 1 engine speed decayed more than 11 per cent below the speed of the other engines, there was an abrupt, backwards movement of the control column, and a momentary, nose-up pitch of 1.4 degrees. At this time, the ground-sensing system changed to the air mode for about two seconds, which would have de-armed the engine-fail light system. The engine-fail lights may have illuminated for up to approximately one second. The crew does not recall seeing an engine-fail light illuminate during the occurrence.
During simulator flights conducted by TSB investigators to examine factors of the occurrence, it was noted that the engine-fail light was not very compelling.

1.6.4 Aircraft Systems

1.6.4.1 Emergency Evacuation Horn

Each of CAI's DC-10 aircraft is equipped with an emergency evacuation warning audio signal, which can be activated from the cockpit or from the flight attendant control panel at door 2L to order an evacuation. When used, the system activates a flashing "EVAC" light on the flight attendant panel and causes a high-pitched beeping sound to be produced from devices at door 1L at the front of the cabin and door 4L at the rear of the cabin.

During this occurrence, the warning system was activated by the first officer just prior to the captain's order over the public address system to evacuate. However, the warning signal was not recognized by some flight attendants, reportedly because of the signal's low volume and its unfamiliar sound.

The evacuation system was examined and the signal devices were found to be functional. Decibel readings were taken on the occurrence aircraft, on another CAI DC-10, and on the company's B767 and A320 evacuation training doors. The volume of the evacuation signal on the occurrence aircraft exceeded the manufacturer's specifications as well as the volume on the company DC-10 and on the training doors.

1.6.4.2 Aircraft Forward Door Operation

One flight attendant indicated that, when the evacuation was ordered, door 1L failed to open on the first attempt, but opened properly on the second attempt.

The door is normally opened by an electric motor activated when a button is pressed. For emergency opening, a handle is moved, which first moves a latch out of the way and then fires a nitrogen bottle that drives a motor to open the door. The door and fittings were examined to the degree possible, and no defects that could impede the proper operation of the door were identified. The door could not be functionally tested by investigators because repairs to the forward nose section of the aircraft precluded the use of electrical power on the aircraft. However, the door was subsequently checked by CAI, and it reportedly operated normally.

Company maintenance practices require that an emergency door opening be carried out on one door and slide on each airplane each year. Door 1R was activated in September 1995 and it operated normally.

1.6.4.3 Evacuation Slide/Raft Cover

The post-occurrence review of the exit doors used during the aircraft evacuation revealed that the Emergency Evacuation Slide/Raft Cover (Part number AWD 7446-245) at the bottom of doors 1L and 1R did not retract properly into the overhead area, but hung down into the exit door openings. The hinge torsion springs on these covers were weak and were unable to close the covers after the evacuation slides deployed. These covers, when closed, are held in position by a magnetic latch.
An inspection by CAI discovered similar problems on its other DC-10 aircraft, and the information regarding the weak springs was forwarded to McDonnell Douglas.

In March 1995, as a result of a similar problem on the MD-11 doors, McDonnell Douglas had issued Service Bulletin 25-148, which mandated the replacement of these hinge springs with more powerful springs. When issued, this service bulletin did not apply to the DC-10 aircraft. The problem with the hinge springs on the DC-10 had not been detected by CAI or McDonnell Douglas prior to this occurrence.

1.7 Meteorological Information

At 1324, when CAI Flight 17 received taxi instructions, the altimeter was reported to be 30.25 inches; two minutes later, the wind was reported to be 240 degrees magnetic at 2 knots. A meteorological observation taken at 2040Z, eight minutes after the accident, reported the following conditions: sky conditions 8,000 feet scattered, 15,000 feet scattered, 25,000 feet thin broken; visibility 30 miles; temperature 12.3 degrees Celsius; dew point 7.4 degrees; and wind 270 degrees True at 3 knots. The altimeter setting was 30.22 inches.

1.8 Communications

The Vancouver Airport Tower Controller cleared CAI Flight 17 for take-off at 1330, and the next communication was the call from the first officer at 1332 advising the tower that Flight 17 was rejecting the take-off. Ten seconds later, the first officer advised the tower that Canadian 17 was going off the end of the runway.

On hearing the call for the reject, the Tower Controller looked up and saw that the aircraft was at about the intersection of the two runways. Because the aircraft appeared to be moving too quickly to be able to stop on the available runway, he activated the crash alarm.

Approximately 13 seconds after the aircraft came to a stop, the first officer advised that the aircraft had suffered major structural damage, and the tower advised that the response vehicles were on the way. Thirty-one seconds after the first officer acknowledged the tower's response, the captain called the tower and asked if there was any sign of fire around the aircraft. The tower responded that there was only smoke and dust visible.

1.9 Aerodrome Information

Field elevation for the Vancouver International Airport is nine feet above sea level. Runway 26, used by the occurrence aircraft, is an asphalt/concrete runway, which is 11,000 feet long and 200 feet wide; runway slope is negligible. There is a 145-foot-long paved area off the end of the runway. The runway's declared distance for take-off run available (TORA) and the accelerate stop distance available (ASDA) is 11,000 feet. The take-off distance available (TODA), which includes a clearway, is 12,000 feet. The runway is not grooved. At the time of the occurrence, runway 26 was bare and dry.

Friction testing, conducted on runway 08/26 on 24 August 1995, recorded a runway-average Grip Tester Friction Number of 63. Rubber removal from the runway was carried out on 22 September 1995. On 30 November, friction testing recorded a runway-average Grip Tester Friction Number of 71. Transport Canada guidelines for runway maintenance indicate that remedial action should be
programmed for a runway when its overall average (unadjusted Grip Numbers) falls below 48.

The aircraft used taxiway "N" to enter the runway; the left edge of the taxiway is approximately coincident with the start of the declared runway.

The aircraft left distinct wheel marks on the runway in the form of rubber deposits as a result of braking during the rejected take-off. The first marks of the main wheel tires started at 7,694 feet from the threshold of runway 26 (3,306 feet from the end of the runway). The centre main gear produced marks commencing about 36 feet further along the runway. The skid marks displayed the alternating nature of antiskid cycling.

The survey showed a maximum aircraft excursion left of the runway centre line of 28 feet when the aircraft was 1,232 feet from the end of the declared runway. Thereafter, the tire marks indicated that the aircraft crossed the centre line of the runway, from left to right, at 600 feet from the end of the runway. The right main wheel went off the right side of the runway asphalt surface when the aircraft was 41 feet from the end of the runway. The aircraft came to rest with the main wheels 315 feet past the end of the declared runway, the nose of the aircraft 420 feet past the end of the runway, and the right bogie 161 feet to the right of the extended runway centre line.

The depths of the wheel ruts in the unpaved surface past the end of the runway varied from 0.2 to 1.1 feet for the left main bogie wheels and 0.1 to 1.2 feet for the right bogie.

1.10 Flight Recorders

1.10.1 Cockpit Voice Recorder

The CVR was a Loral model number 93A100-30, serial number 15659. There was no damage or wear to the CVR. The CVR recorded the pilot, co-pilot, flight engineer, and cockpit area microphone (CAM) audio channels on a 30-minute continuous loop<8>. Hot microphones were not used; therefore, internal communications between the crew were recorded on the CAM channel only. Despite the lack of hot microphones, most of the internal communications were discernible.

The only problem with the CVR playback was that the radio channels contained some residual data from previous flights, which made it difficult to recover the audio from the occurrence flight. Under normal CVR operation, previously recorded audio is erased as new information is recorded. An inspection of the CVR at CAI after the occurrence revealed that there was a fault in the erase circuitry, which had disabled the erase function.

The loud bang heard by the crew and other witnesses was not evident on the CVR. The only unusual sounds recorded occurred two seconds after the V1 call, when the first of a series of 21 "thuds" was heard. A loud bang would certainly contain significant frequency components well within the CVR bandwidth (200-5,000 hertz). The lack of a pronounced loud bang on the CVR was likely the result of the wave transmitted through the aircraft structure causing the automatic gain control on the CVR to squelch the structure-borne signal, thereby masking the slower-travelling airborne sound. The series of thuds was considered similar to the sound of
repeated compressor stalls.

1.10.2 Flight Data Recorder

The FDR was a Sundstrand Universal Digital Flight Data Recorder, model number 980-4100-AXUN, serial number 5314. A visual inspection of the unit revealed no indications of damage or wear. The FDR was read out using the TSB's Recovery, Analysis and Presentation System (RAPS). The FDR tape had been recently installed on the aircraft and contained 19 hours of data. The previous FDR tape was recovered and used to extract engine performance data.

1.10.3 Flight Profile Analysis

An empirical aircraft performance analysis was carried out to develop an accurate time-distance profile of the rejected take-off. Recorded longitudinal acceleration was used as the basis for developing an accurate time-distance history. The profile analysis was validated using the CVR data and runway survey information.

The aircraft's position on the runway at the time of the engine power loss was determined by analyzing the FDR data, which showed a slight loss in longitudinal g acceleration as the aircraft reached 170 knots and had consumed 6,750 feet of runway. The loss in acceleration was coincident with the first "thud" sound on the CVR. At the same time, the N1 for engine number 1 began to decay, and a 15-degree right rudder input was recorded, along with a slight amount of right aileron.

1.11 Medical Information

There was no evidence that incapacitation or physiological factors affected the crew's performance. All aircrew were in possession of valid medical categories.

1.12 Fire

Small grease-type fires occurred around the hot wheels some time after the evacuation and were extinguished by fire-fighters.

1.13 Survival Aspects

1.13.1 Airport Emergency Response

The Emergency Planning Coordinator of the Vancouver International Airport Authority conducts table-top exercises about once every two weeks to ensure that agencies that respond to aircraft occurrences are prepared. In addition, the Vancouver International Airport Authority conducts a major simulation of an aircraft accident on a yearly basis.

1.13.1.1 Emergency Rescue Services

The fire-fighters from the Richmond Fire Rescue unit, stationed at Fire Hall Number 8 at the airport, heard a loud bang from the aircraft as it was taking off. Immediately following the bang, the crash alarm was sounded and the fire hall bay doors were opened. By the time that the dispatch order was given from the Richmond Fire Department, the firemen were aboard their equipment and leaving for the site. A total of nine fire/rescue vehicles responded to the occurrence.
Three foam trucks and a utility vehicle arrived at the site within a minute of dispatch. When these fire-fighters arrived at the aircraft, the doors of the aircraft were still closed. Shortly thereafter, all the doors opened at once, and the passengers evacuated in an orderly fashion. Because there were no immediate signs of fire, the fire-fighters concentrated on assisting passengers and monitoring the aircraft brakes.

The small grease-type fires that ignited around the hot wheels were quickly extinguished with foam. Foam was also applied under the aircraft as a precaution in case of a possible fuel spill. Because the only dry chemical truck was on maintenance and not available, two portable 350-pound dry chemical units were brought to the site from the ramp.

The first ambulance from BC Ambulance Services arrived at the airport's south gate within five minutes of the occurrence and was on scene two minutes later. A triage area was set up, injured passengers were cared for, and blankets were provided to other passengers. A total of 26 ambulances responded to the occurrence. Six passengers with minor injuries were transported to hospital.

1.13.1.2 Passenger Transportation from the Site

The control of the air-side of the airport is the responsibility of the Vancouver International Airport Authority. The air carrier is responsible for arranging the transportation of uninjured passengers and crew back to the terminal area. For this occurrence, CAI requested buses from a local contractor. By 1410, the first of four buses was through the airport south gate, arriving at the accident site at 1417, or 45 minutes after the evacuation. By 1438, all the passengers were on board buses en route to the terminal.

Weather was not a significant factor; however, because the aircraft cabin had been very warm prior to departure, the passengers and crew were lightly clad, and the 45-minute wait for the buses to arrive was uncomfortable.

1.13.2 Aircraft Evacuation Issues

1.13.2.1 Crew Preparedness Issues

According to the Canadian Airlines Flight Attendant Manual, a rejected take-off is an abnormal situation for which flight attendants are advised to maintain a high alert awareness of their surroundings. They are advised to remain seated with their seat-belts and shoulder harnesses securely fastened while the aircraft is still moving. Once the aircraft has stopped or turned off the runway, they are to remain seated and assess conditions, while awaiting the captain's instructions. If they notice an emergency situation developing at that time, they are to assess the situation further, getting out of their seats only if necessary. If, in their estimation, the situation is an emergency, they are to advise the flight deck immediately.

According to the DC-10 Flight Crew Manual procedures for passenger evacuation following a rejected take-off, if time is available, the captain calls the CSD to the flight deck and provides the CSD with pertinent information and instructions to await the evacuation command. The captain then carries out a series of 10 "After Stopping" items, of which the eighth is initiation of the evacuation. To initiate an
evacuation, the captain announces "Evacuate, Evacuate" via the public address system, and the first officer moves the Evacuation Command switch to the ON position when the captain makes the evacuation announcement. The checklist implies that the evacuation signal would begin to sound at the same time as, or slightly after, the captain makes his announcement. The sequencing of the evacuation announcement and activation of the evacuation signal system as specified in the Flight Crew Manual differs from that described in Section 5, "Abnormal and Emergency Procedures," of the Flight Attendant Manual. According to this manual, the flight crew signals the cabin crew to evacuate via the public address announcement "Evacuate, Evacuate," after which the crew activates the evacuation signal system.

In accordance with Section 6 of the Flight Attendant Manual, flight attendants are required "to conduct an evacuation when signalled to do so by the flight crew or by the evacuation signal system." All flight crew members assist with the evacuation as required.

Flight crews and cabin crews train and practise evacuation procedures in simulators annually; some of this evacuation training is done together in a cabin simulator. Practical evacuation training for cabin crews is done using a training door in the generic cabin simulator; this training is supplemented by exit-operation drills on actual doors of aircraft on which they are qualified. When the flight attendants who were on the occurrence flight trained on evacuation procedures, the company's DC-10 door trainer was not equipped with an evacuation signal device. At the time of the occurrence, CAI had already planned to install the signal device on its DC-10 training door; the signal-device installation has since been completed.

The "Evacuate, Evacuate" command is always used during training as the prime cue to initiate the evacuation; the evacuation signal, which is not installed on all training doors, is not always used. As well, the evacuation signal is never used in training as the sole cue to initiate the evacuation.

1.13.2.2 Passenger Preparedness Issues

The pre-flight passenger safety briefing is normally given on CAI flights in both English and French. To accommodate the majority of the passengers on this flight, the CSD directed that the briefing be given first in English, then in Mandarin, followed by French.

1.13.2.3 Aircraft Evacuation Decision Making

The cabin crew all described hearing a very loud bang, followed by a series of bangs, sensing the aircraft shuddering and decelerating, and feeling the collapse of the nose-wheel gear as the aircraft came to a stop. On stopping, the CSD reported to the cockpit for instructions and was told by the augmenting first officer that they would probably be evacuating, but to give them a minute. The captain then called for the evacuation checklist to be initiated by the crew in the cockpit.

Prior to ordering the evacuation, the captain, to determine if it would be safe to use all the slides, asked the first officer to contact the tower to determine if there was any sign of fire. The first officer tried twice, but could not contact the tower using audio panel 2 on his side of the cockpit; so, the captain tried audio panel 1, and successfully made contact with the tower. When the first officer tried to contact the
tower, the emergency power switch had already been turned on. With this electrical power configuration, only audio panel 1, on the captain's side of the cockpit, is powered. A review of the Flight Crew Operating Manual and Training Manual indicates that these manuals do not contain information on the unavailability of audio panel 2 when on emergency power. The company was not aware of this communications limitation.

The captain's "Evacuate, Evacuate" command was made approximately one minute after the aircraft came to a stop.

1.13.2.4 Passenger and Crew Evacuation

The cabin crew reported that during the rejected take-off procedure the passengers quietly remained in their seats, watching the flight attendants and waiting for instructions. Other than a ceiling panel over door 1L dropping down because of an unfastened connector, and some spilled milk in a galley, the cabin area remained secure and intact. Some of the flight attendants gestured to the passengers to remain seated, and the interpreters were used to make announcements for the passengers to remain seated with their seat-belts fastened.

Upon hearing the captain's command, the flight attendants began the evacuation. Other than minor problems with door 1L, all doors opened smoothly and the slides inflated automatically. Because the nose-gear had collapsed, the aircraft was in a considerable nose-down attitude; nevertheless, all slides touched the ground. The slope of the slides at doors 1L/R was shallow, and halfway down the slides, passengers had to get up from their sitting position and walk to the bottom of the slide. There was some slump in the slides at doors 2L/R, but this condition did not impede the evacuation from these exits. At doors 3L/R, the configuration and attitude of the slides were normal. The slides in the rear of the aircraft at doors 4L/R were on a steep angle, and although the slide down these slides was fast, the flight attendants reported that the landing at the end of the slide was fine.

Although the flight attendants shouted out the required evacuation commands in English, they all reported that their tone and hand gestures were more effective than the actual words, given that Mandarin was the language of the majority of the passengers on board the flight. They stated that the evacuation was smooth and that the passengers followed their orders and gestures. One of the flight attendants noted that, at first, passengers in her section rushed to the door; however, after she instructed them to slow down, they proceeded in an orderly manner. The flight attendants reported that the flow at all the doors was fairly continuous and orderly.

The evacuation, which took between one and two minutes, was reported to be orderly. There were only minor anomalies with the evacuation. At door 2R, there was a slight build-up of passengers at the bottom of the slide, which necessitated holding the flow back until it cleared. This may have been because many of the passengers who evacuated from door 2R were elderly people who experienced difficulty getting up from the bottom of the slide. At doors 3L/R, the passengers had to walk out on the wing for about eight feet to slide down the inclined portion of the slide from the edge of the wing, which slightly slowed the flow at these doors. Even though the slides at doors 4L/R were on a steep angle, there was little hesitancy to slide down the slides.

Many of the passengers attempted to take luggage with them. For the most part,
the flight attendants removed luggage from exiting passengers; however, in order to not unnecessarily slow down the evacuation, some passengers were allowed to egress with small hand luggage. There were no indications that the carrying of luggage impeded the evacuation.

Prior to exiting the aircraft, the captain, first officer, and second officer went through the passenger cabin to ensure that all the passengers and cabin crew had evacuated the aircraft.

1.14 Operations and Training Information

1.14.1 Pre-flight Planning Issues

1.14.1.1 Take-off Performance Calculations

Since 05 November 1994, CAI has been using American Airlines Corporation's (AMR) SABRE computer system to support its flight operations. One element of SABRE is the Take-off Performance System (TPS), which is used for calculating take-off performance based on the airport and runway conditions, weather, and aircraft loading. As well, the TPS provides the flight crews with the operational parameters for the take-off, including engine power settings, flap settings, the critical engine failure recognition speed (V1), rotation speed (VR), take-off safety speed (V2), and flap/slat retraction speeds.

The TPS considers three types of engine power settings for a DC-10 take-off: STANDARD power, MAX (C2) power, and BLACK (C2B) power. The TPS always uses the lowest power possible for any given take-off. The TPS will not provide C2B power setting figures if it calculates that a lower power setting is sufficient for a particular take-off.

The TPS calculated that C2 power using improved-performance<9> was required for the take-off, with the following operational parameters: engine speed of 110.4 N1, flap setting of 16 degrees, V1 of 164 knots, VR of 175 knots, V2 of 187 knots, flap-retraction speed of 203 knots, and slat-retraction speed of 255 knots. This information was entered on the take-off data card, and the speeds were set on the airspeed bugs.

The captain, knowing that one of the thrust reversers was not available, and assessing that a take-off using C2B power would provide additional runway for stopping the aircraft in the event of a rejected take-off, requested CAI's flight operations to provide him with the operational parameters for a C2B-power take-off. However, because the TPS had calculated that the lower C2 power setting was sufficient for the take-off conditions, the TPS program could not provide the C2B power parameters. In order to get C2B power performance parameters, the crew referred to the Canadian Airlines DC-10-30 OD43J Performance Manual and calculated that the take-off parameters were the same as for C2 power, except that the C2B-power V1 would be 167 knots, versus the 164 knots calculated by TPS for C2 power. The Take-off Data Card was amended to show the C2B power setting of 112 per cent; however, the C2B-power V1 of 167 knots was not set on the airspeed indicator bugs or the take-off data card.

1.14.1.2 Aircraft Load Control
Attached to the TPS are the preliminary load planning system (LPS) weight and balance calculations and load information. Factors considered by the LPS for weight and balance include the aircraft empty operational weight (EOW)<10> and weights for passengers, baggage, freight, and fuel; additional factors considered for take-off performance and maximum allowable take-off weight limit include the ambient weather conditions and the runway to be used. The final ramp load is planned to be the maximum allowable take-off weight plus the fuel to be used for taxiing from the ramp to the runway. The maximum design ramp weight for the aircraft was 593,000 pounds, and the maximum brake-release take-off weight was 590,000 pounds.

As part of the initial briefing, the crew of Flight 17 was provided with the initial (1112 PDT) TPS information for the planned flight. The passenger weight, on the weight and balance data attached to the TPS, was based on an anticipated load of 250 passengers. A trip sheet produced by the LPS at 1106 indicated a cargo weight of 20,956 pounds broken down as follows: the baggage weight was 11,504 pounds, based on the 328 passenger bags checked at an average bag weight of 35 pounds<11> plus the actual weight of some mail bags; the freight weight was based on actual weights. The ramp fuel weight was the flight planning system (FPS) calculation of the fuel required for the planned flight. The taxi fuel was the planned taxi fuel based on a fuel burn rate of 75 pounds per minute and the planned taxi time of 30 minutes, which was based on the aircraft’s gate position, runway in use, and the traffic flow pattern anticipated at the Vancouver airport for the planned take-off time.

The amount of fuel to be loaded on the aircraft is based on the FPS calculation of the fuel required for the flight minus the fuel on board the aircraft prior to the refuelling. When the crew arrives in the aircraft, a final check of the fuel on board the aircraft is done by the second officer using the fuel gauges in the cockpit. The total of the fuel gauges for the individual tanks, as recorded by the second officer, was 248,400 pounds; the fuel totaliser gauge reading was recorded as 248,800 pounds. When the final fuel load was passed to the Operations Agent at about 1200 for input into the LPS, the FPS-planned fuel figure of 247,300 was provided, instead of the figure of 248,400 pounds, which was the total of the individual fuel tank gauges. The captain was aware that the lower fuel figure had been passed; he did not consider it to be a problem because, at the briefing, he had noticed that the planned aircraft weight was 1,400 pounds below the maximum allowable weight.

The final weight and balance calculation generated by LPS at 1223 indicated that the passenger count was 242, the passenger weight was 39,446 pounds, the passenger baggage (291 bags) weight was 10,189 pounds, and the freight weight was 12,879 pounds. This same information was included in the 1240 Final Load Closeout that was received by the second officer. The aircraft EOW also had been adjusted for variances from the standard DC-10-30 crew complement and the addition of one additional cargo pallet. The passenger weight had been adjusted to reflect the actual recorded passenger count. The increase of the planned take-off
weight was included in the Load Closeout Message and was forwarded to the crew via ACARS at 1240. The captain stated that he was not aware of the increased planned take-off weight.

After the occurrence, the cargo and passenger baggage was weighed by CAI. Company records indicate that there were 314 passenger bags weighing 10,838 pounds<12>. Because of the nose-down attitude of the aircraft following the occurrence, not all the cargo could be off loaded at the time that the weighing took place; the freight that was off loaded and weighed was 11,230 pounds. The remaining freight was off loaded when the aircraft was recovered from the accident site, but inadvertently was not weighed<13>.

There were three notable discrepancies in the Load Closeout: the ramp fuel weight was 1,096 pounds lower than the total fuel weight as recorded from the aircraft's fuel tank gauges by the second officer; company records could not explain the additional 23 passenger bags on the aircraft and the resulting 805-pound weight discrepancy; and there were 243 passengers on board as compared to the 242 recorded in the aircraft load documentation.

Another factor affecting the take-off weight of the aircraft was the difference between the planned taxi time of 30 minutes and the actual taxi time of 14 minutes. This 16-minute difference in time would have resulted in a reduction in taxi fuel-burn of 1,200 pounds. The captain was aware of the implications of the reduced taxi time; however, he assessed that, based on the 1812 TPS planned take-off weight (PTOW) figure of 588,600 pounds, the reduced fuel burn would not put the aircraft over the design maximum take-off weight. Based on the TPS final Load Closeout figures and the discrepancies noted in the ramp fuel weight, passenger baggage weight, the additional passenger, and the reduced taxi fuel burn, the occurrence aircraft could have been up to 951 pounds over maximum ramp weight and 2,901 pounds over the maximum design take-off weight.

**1.14.2 Rejected Take-off Decision Making**

**1.14.2.1 Certification Criteria**

The DC-10-30 was type-certified in accordance with United States Federal Aviation Regulations (FARs). Part of this certification is the requirement for the manufacturer to demonstrate to the Federal Aviation Administration (FAA) the performance data that are included in the FAA-approved Airplane Flight Manual (AFM).

One element of this performance data is the engine-out accelerate-stop distance, which is based on the engine-failure recognition speed (V1). In the context of a field-length-limited take-off, V1 is the maximum speed at which the rejected take-off manoeuvre can be initiated and the airplane stopped within the remaining field length. Specifically, the definition of V1 in the FARs considers that the engine-failure must be recognized<14> and the pilot's initial stopping action to reject the take-off must be taken by V1. If this pilot stopping action is initiated at a speed
higher than the field-length-limited V1, insufficient runway will remain to stop the aircraft on the runway.

Another aspect of this certification performance is the engine-out accelerate-go criteria, which also references V1 speed. In this scenario, V1 is the earliest point from which an engine-out take-off can be continued safely.

The Canadian Airlines DC-10 Flight Crew Operating Manual (FCOM) defines V1 as follows:

Decision Speed, V1 - The speed at which, after an engine failure has been recognized during the takeoff, the pilot decides whether to abort or continue the takeoff. V1 is actually the engine fail speed plus a recognition increment which corresponds to a time delay of one second. A further 3 seconds is allowed until full braking with spoiler actuation is attained.

1.14.2.2 Rejected Take-off Training Issues

In 1989, in reaction to a number of take-off accidents resulting from improper rejected take-off decisions and procedures, a joint FAA/industry team studied what actions might be taken to increase take-off safety. The team studied approximately 3,000 rejected take-offs that occurred between 1959 and 1990. The findings of this team were published by the FAA in April 1993 in a publication entitled Takeoff Safety Training Aid and in a flight crew briefing video entitled Rejected Takeoff and the Go/No Go Decision. In June 1993, CAI's Director of Flight Training and Development provided all company pilots with a publication entitled Pilot Guide to Takeoff Safety, which contained Chapter 2 of the FAA training aid. The training video was also shown during some pilot recurrent training sessions. These training aids emphasize the need to adhere to the V1 decision-making concept and highlight the inevitability of an overrun if a rejected take-off is initiated after V1. In its discussion of rejected take-off situations, the Takeoff Safety Training Aid states that a take-off should not be rejected once the aircraft has passed V1 unless the pilot has reason to conclude that the airplane is unsafe to fly. As well, the study concluded that in most overrun accidents, the pilots, using visual cues, did not accurately assess the amount of runway remaining or the aircraft's ability to stop.

The FAA/industry analysis of the 74 rejected take-off occurrences that resulted in overruns indicates that a number of these rejected take-offs involved crew uncertainty about the ability of the airplane to fly, as well as unidentifiable loud bangs, vibrations, and other characteristics, that later were assessed to be indications of engine stall or engine failure.

Another study into occurrences involving benign engine malfunctions and inappropriate crew responses indicates that the majority of these engine-plus-crew-error events involved engine malfunctions that generated loud noise. Seventy per cent of this type of event occurred near to ground and/or at high engine power during phases of flight such as take-off, go-around, or climb. The study further states that the effect of time compression associated with these phases of flight appears to be a significant factor that affects crew action following the engine problem. The time needed to process and integrate the auditory, tactile, and visual symptoms of engine malfunctions in a time-constrained environment may be so difficult that it leads to inappropriate flight crew response. Another factor cited was the fact that, because of the high reliability of today's turbine engines, many flight
crews will complete their whole career without experiencing an engine failure; consequently, training programs and simulators must provide flight crews with the knowledge to positively recognize an engine-failure condition. The Boeing study concludes that lack of positive recognition of the engine event appeared to be the most significant factor contributing to inappropriate crew actions.

Training on rejected take-off scenarios is conducted by CAI pilots during annual recurrent simulator flying training. The training is designed to provide the crew experience in decision making before and after V1. The training is also designed so that the scenario events will be adequately clear to facilitate an objective evaluation of the crew's performance. The training scenarios ensure that there are adequate cues to clearly portray the nature of the emergency. CAI DC-10 simulator training includes heavy-weight take-offs with aircraft weights between 560,000 and 580,000 pounds.

During simulator sessions, engine failures are normally signalled by one or more of the following symptoms: a pronounced yaw, an engine fail light, engine instrument indications, and an announcement of the nature of the emergency by the first or second officer. Compressor stalls are simulated by a series of muffled thumps.

There is no information regarding the characteristics of engine stalls or surges in either the aircraft manufacturer's or engine manufacturer's manuals, nor is there any information on this issue in CAI's operations manual, standard operating procedures, or training manuals. Although there is no direct reference in operational manuals to the inevitability of an overrun if a rejected take-off is initiated above the V1 speed in a field-length-limited situation, discussions on this issue are covered in a company 1988 Flight Operations Circular contained in the policy section of the DC-10 FCOM, and in the Pilot's Guide to Takeoff Safety provided to DC-10 pilots in 1993.

1.14.2.3 Decision Making on Flight 17

Although the crew, using C2B power charts, had manually calculated 167 knots as the V1, the airspeed bugs and the take-off data card reflected the TPS-calculated V1 speed of 164 knots, and the FDR/CVR data indicated that the first officer did call V1 as the aircraft accelerated through 164 knots. The captain believed correctly that by using the higher C2B power he would have more runway available to conduct a rejected take-off if one became necessary. He also believed that he would have some time after the 164-knot V1 call to make a reject decision.

FDR/CVR analysis indicated that the loud bang occurred 2.2 seconds after the V1 call. The captain called the reject 1.3 seconds later. His first action to reject the take-off, retarding the power levers, occurred at 4.3 seconds after the V1 call and as the aircraft was accelerating through 172 knots. The auto-brake system activated 6.1 seconds after V1 as the result of the second officer manually deploying the spoilers. The thrust reversers were selected 3.5 seconds after the power levers were retarded, and the reverse levers were

<table>
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<th>Event</th>
<th>Speed kts</th>
<th>Time sec</th>
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<tr>
<td>V1 Call</td>
<td>164</td>
<td>0</td>
</tr>
<tr>
<td>Bang</td>
<td>170</td>
<td>+2.2</td>
</tr>
<tr>
<td>Reject Call</td>
<td>171</td>
<td>+1.3</td>
</tr>
<tr>
<td>P/Levers ret</td>
<td>172</td>
<td>+0.8</td>
</tr>
<tr>
<td>ABS Activate</td>
<td>175</td>
<td>+1.8</td>
</tr>
</tbody>
</table>
pulled into reverse 11.1 seconds after the V1 call. The captain's decision to reject was based on the fact that he did not recognize the initial sound and subsequent thumping noises, and that, because he thought the bang could have been a bomb, he had concerns about the integrity of the aircraft and its ability to fly. Also, the captain stated that, based on the rejected take-off provisions in the DC-10 Flight Manual and on a fatal DC8 accident that he had witnessed, he had developed a mental rule to not take an aircraft into the air if he suspected that there was aircraft structural failure.

The captain indicated that the time delay between retarding the power levers and selecting reverse thrust was, in part, due to an expletive expressed by another crew member, which interrupted his thought process.

The FDR data showed that, when the captain made his decision to reject the take-off, the number 1 engine EGT was above 950 degrees and the N1 speed had decayed to below 85 per cent. None of the crew members noticed anything unusual about the engine operation during the take-off roll, including the second officer, whose prime duty is to watch the engine instruments. The crew reported being extremely startled by the suddenness and intensity of the loud bang, and none of the crew members recognized the sound or its origin. Because the number 1 engine was still operating in the idle range when the aircraft came to a stop, the crew were not aware that there had been a power loss on that engine until this fact was discovered on the FDR data.

1.15 Organizational and Management Information

1.15.1 Regulatory Overview - General

The last national audit of CAI was accomplished between 21 September and 23 October 1992. The conclusions of this audit were that the company systems were sufficiently responsive and capable of initiating necessary or desirable program changes to meet regulatory requirements, and that the quality of aircraft condition and on-time performance was directly attributable to CAI's system-wide commitment to program quality.

The audit noted that CAI's maintenance and engineering organization operated in a professional manner and strived to achieve a high quality standard. It was noted that the aircraft were well maintained and MEL deferrals were held to a low level. Although no formal, national audit has taken place since then, CAI has a system in place for internal maintenance audits. These audits are ongoing and TC does send an observer during some of these audits. Although some problems are always uncovered during these audits, regional TC airworthiness officials expressed no concern about CAI's maintenance operation.

1.15.2 Maintenance Management Issues

Because of financial pressures on the airline, all sections of the airline had been examining their operations and finding ways to reduce costs. In the maintenance
department, a 30 per cent decrease in budget has required centralizing many of the maintenance functions and reducing staff and middle-management levels. However, the dispatch reliability and use of the MEL have remained relatively constant. The mechanical scheduled reliability of the DC-10 fleet at CAI was just over 92 per cent in 1989 and had been steadily improving to 96 per cent in 1994. The number of open MEL items per day per aircraft was approximately 0.5 in 1990, 0.3 in 1991, 0.3 in 1992, 0.2 in 1993, and 0.6 in 1994.

1.16 Aircraft Performance Issues

1.16.1 Aircraft Performance Issues - General

A detailed examination of aircraft and systems certification criteria and of documented performance data was carried out to evaluate the performance of the aircraft and its systems during the occurrence. These were then compared with the accident scene evidence, CVR/FDR data, theoretical performance studies by the manufacturer, and simulator flights.

1.16.2 Acceleration to V1 (164 knots)

The DC-10 Flight Study Guide produced by the manufacturer describes the rolling take-off as the most desirable take-off method because it expedites traffic flow, realizes fuel economies, and provides greater comfort. The guide states that both the static and rolling techniques provide essentially the same take-off distance. CAI's DC-10 FCOM recommends that, when conditions permit, crews use a rolling take-off for reasons of passenger comfort, fuel economy, and aircraft performance.

The aircraft was cleared for take-off as it was rolling towards the runway, via a 45-degree-angle taxiway. Based on the FDR data, the aircraft's groundspeed was calculated to be approximately 15-17 knots as the aircraft entered the runway, and the power levers were advanced rapidly to the take-off power setting of 112 per cent N1.
The manufacturer indicated that there is no performance difference between a rolling and static take-off; however, neither the manufacturer's performance program nor the simulator sessions could provide data upon which to evaluate the performance of the occurrence aircraft in this phase of the take-off. Analysis of the FDR data indicated that the aircraft, using a rolling take-off, reached 164 knots at a point 6,200 feet from the button of runway 26. The manufacturer's calculation was that a static take-off should have taken 6,227 feet. In addition, the actual acceleration performance curve, as shown in Figure 2, closely matches that of the predicted performance for an aircraft weighing 590,000 pounds.

1.16.3 Acceleration From V1 to Reject Initiation

Following the V1 call, the aircraft continued to accelerate at 0.16 g until the aircraft reached 170 knots, at which time the acceleration decreased by approximately 30 per cent to 0.11 g. By this time, the aircraft was 6,750 feet from the start of the runway, and was at the point at which the CVR recorded the thudding sounds and the FDR recorded the sudden drop in N1 speed on engine number 1.

The memory checklist items for rejected take-off procedure are described in CAI's DC-10 FCOM as follows:

- Captain commands "REJECT."

- Captain retards throttles to idle, immediately selects full reverse thrust and observes or applies maximum antiskid braking.
- F/O monitors airspeed, applies slight forward pressure on the control column, and maintains wings level. The S/O announces the status of reverse thrust, verifies that auto spoilers have activated, and monitors engine instruments. S/O extends manual ground spoilers if required.

- Captain maintains directional control. Captain moves reverse levers to reverse idle detent, then to forward idle position when safe stop is assured.

- F/O advises tower of rejected take-off and requests assistance, if required.

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**Figure 3 - Take-off Sequence of Events.**

CAI's DC-10 standard operating procedures provide additional guidance on spoiler deployment during a rejected take-off. Specifically, when the captain calls "REJECT," the second officer is to monitor auto spoiler deployment; if the spoilers do not deploy automatically, the second officer is to call "NO SPOILERS" and, without further command, to pull the spoiler handle full aft and up.
On the occurrence flight, the captain called the reject 1.3 seconds after the power loss, and initiated reject action 0.8 seconds later by retarding the power levers to idle as the aircraft was accelerating through 172 knots, 7,300 feet along the runway<17>. The second officer, noting that lights indicating that the thrust reversers were deploying had not come on, called "No reverse" and immediately moved the spoiler handle back. As a result, the spoilers were deployed and the auto-brake system activated. At this point, the aircraft had accelerated to 175 knots and was 7,850 feet from the start of the runway, and 3,150 feet from the end of the runway.

### 1.16.4 Deceleration Performance

Activation of the ABS and spoilers resulted in an initial deceleration rate of 0.46 g. A peak deceleration rate of 0.47 g occurred when reverse thrust power was applied as the aircraft was decelerating through 140 knots, 1,850 feet from the end of the runway.

As the aircraft slowed down, there was a gradual loss of deceleration due to the decreasing aerodynamic drag and the reduced effectiveness of the brakes as they heated up from use. As indicated in Figure 2, the occurrence aircraft's performance was slightly better than the deceleration performance predicted by the manufacturer for a 590,000-pound aircraft.

The aircraft went off the end of the runway at 43 knots. The manufacturer's data indicate that a deceleration from 43 knots to a stop on a paved runway surface would have taken approximately 400 feet.

### 1.16.5 Accelerate/Stop Performance Summary

The following chart summarizes the acceleration performance comparisons:

<table>
<thead>
<tr>
<th>Theoretical Performance for Brake Release Weight of 590,000 pounds</th>
<th>Occurrence Flight</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2 V1 164 kts C2B V1 167 kts C2B Pilot's Initial Action C2B 172 kts</td>
<td>C2B 172 kts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acceleration to Initial Reaction</th>
<th>6,216</th>
<th>6,491</th>
<th>7,024</th>
<th>7,300&lt;18&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Reaction Reaction Plateau&lt;19&gt;</td>
<td>852</td>
<td>867</td>
<td>900</td>
<td>800</td>
</tr>
<tr>
<td>Deceleration from Initial Action Speed</td>
<td>3,300</td>
<td>3,417</td>
<td>3,627&lt;20&gt;</td>
<td>3,300&lt;21&gt;</td>
</tr>
<tr>
<td>Total Accelerate/Stop Distance</td>
<td>10,368</td>
<td>10,775</td>
<td>11,547</td>
<td>11,400</td>
</tr>
</tbody>
</table>
The theoretical performance figures do not take into account the line-up distance. According to the manufacturer, the minimum distance would be 0.8 of one aircraft length for a 90-degree entry to the runway; for the DC-10, this would be 146 feet.

The manufacturer's prediction of the accelerate-stop distance for a DC-10-30ER at 592,000 pounds was 34 feet more than the distance predicted for a 590,000-pound maximum take-off weight.

1.16.6 Accelerate-Go Performance

FDR/CVR data indicated that the engine power loss occurred at a speed of 170 knots, when the aircraft was 6,750 feet from the start of the runway and 4,250 from the end of the runway. This point of power loss was 550 feet beyond the point that V1 was called, and about 275 feet beyond the point that the aircraft accelerated through C2B power V1 speed of 167 knots. When engine number 1 lost power, engines 2 and 3 were still producing take-off thrust. Because there were no other factors that would have adversely affected the aircraft's performance, the DC-10-30ER certification data indicate that, at the time of the engine failure, the aircraft would have been able to continue the take-off and get airborne safely with only two engines operating.

1.16.7 Take-off Performance Below Sea Level Calculations

During the review of the take-off performance calculations for the flight, it was noted that the TPS incorrectly calculated the effect of below sea level pressures on engine performance. The manufacturer confirmed that the engine thrust curves indicated less thrust output for operations at below-sea-level pressure altitudes; whereas the TPS program calculated that performance increased as pressure altitude decreased below sea level.

The CAI DC-10 FCOM and the OD43J Performance Manual also do not incorporate a performance-reduction correction for operations at below-sea-level pressure altitudes.

1.16.8 Auto-brake System Certification and Performance

When the DC-10 was initially certified, it was not equipped with an ABS. However, the DC-10 was later equipped with an ABS following the airline industry's study of overrun occurrences, which indicated that crews did not optimally use the manual brakes. In particular, investigations into many of these occurrences determined that the pilots did not maintain maximum brake pressure or that they released brake pressure before the stop on the runway was assured.

The ABS on the DC-10 provides the means for automatic brake application during take-off or landing. The ABS take-off mode is armed, in part, by selecting "T.O." on the AUTO BRAKE deceleration selector. The ABS take-off mode is activated during a rejected take-off when the spoilers are deployed and the throttle angle is less than 15 degrees. Automatic activation of the spoiler handle occurs when the thrust reversers are deployed; alternatively, the spoilers can be deployed manually by pulling the spoiler handle back. Once automatic brakes are applied, reversion to manual braking will occur when the brake pedals are depressed beyond approximately 40 per cent of pedal travel.
The DC-10 FCOM states that an ABS malfunction will cause the system to automatically disarm and to illuminate the AUTO BRAKE light and the MASTER CAUTION light. The aircraft manufacturer has indicated that it is possible to have failures in the system that will not result in the warning features outlined in the FCOM. Although the manufacturer recognizes that a properly functioning ABS will provide more consistent braking than manual braking, it also acknowledges that there will be a slightly slower brake initiation time with the ABS. Also, there are potential risks associated with crews performing the multiple actions required to automatically deploy the ground spoilers and/or reacting to an ABS failure. Although the manufacturer does not specifically recommend the use of ABS for rejected take-offs for these reasons, a Douglas publication, *Rejected Takeoffs - A Refresh Look*, which is contained in the DC-10 FCOM, states that "Low workload and positive deployment of the ground spoilers with associated immediate application of full anti-skid braking gives the ABS some very significant advantages in successfully accomplishing the RTO [rejected take-off] manoeuvre."

The FAA-approved DC-10 Flight Crew Operating Manual, Volume II, states that, for a rejected take-off, the pilot flying "simultaneously retards the throttles and applies maximum braking." Section IV of the FAA-approved Aircraft Flight Manual states that "throttles should be retarded to idle at engine failure recognition while simultaneously applying maximum braking (full pedal deflection)." Although these sections of the Flight Crew Operating Manual and Aircraft Flight Manual are silent on the use of ABS for rejected take-offs, Appendix XXIII to Section III of the Aircraft Flight Manual does include the cockpit selections to prepare the ABS for take-off, "if automatic braking is desired in the event of a rejected take-off."

In the CAI TC-approved DC-10 FCOM, rejected take-off procedures put priority on the use of auto-brakes. The taxi check requires that the ABS be armed for all take-offs. When a take-off is rejected, the captain is to observe that full automatic braking is applied or apply maximum braking, and, if the automatic braking system malfunctions, the captain is to apply maximum antiskid braking (full pedal deflection) until the aircraft stops. Crews are also trained to use ABS during rejected take-offs.

On the occurrence flight, the ABS began applying pressure 1.8 seconds after the captain pulled the power levers back to idle. This activation of the ABS was the direct result of the second officer manually deploying the spoilers when he noted that the thrust reversers had not been selected. The thrust reversers were not deployed until 3.5 seconds after the power levers were retarded. The brake pedals were not used by the crew during the rejected take-off.

The FDR data indicate that the distance travelled from the point that the captain retarded the power levers at 172 knots to the point that the aircraft was decelerating through 172 knots was about 800 feet. Based on a predicted 3.1-second crew reaction time, as determined during the DC-10 certification process, the crew reaction plateau should have been 900 feet.

**1.16.9 Effect of Thrust Reversers**

The DC-10 FCOM provides information on the amount of reverse thrust generated by each engine. This table indicates the pounds of reverse thrust for engine N1 speeds of 90 per cent. The manufacturer determined that, for the occurrence aircraft and the conditions at

<table>
<thead>
<tr>
<th>Airspeed</th>
<th>Each Wing Engine</th>
<th>Centre Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>132</td>
<td>6,000</td>
<td>10,500</td>
</tr>
</tbody>
</table>
the time of the accident, and from a V1 of 164 knots, the reverser on engine 3 would have shortened the aircraft's stopping distance by 131 feet. Had the thrust reverser on engine number 2 been in use, it would have shortened the stopping distance by an additional 134 feet.

1.17 Wet Runway Rejected Take-off Considerations

1.17.1 Wet Runway Requirement - General

Although a wet runway was not a factor in this occurrence, the investigation into the performance issues noted that weather records indicate that wet runways are the norm at Vancouver on 21 days during the month of October. The take-off performance data charts for the DC-10, however, do not include provisions for the adverse effect of wet runways on the accelerate/stopping distances. Although there are provisions for take-offs on contaminated runways, these standards only apply to snow, slush, and ice covered runways, and runways with standing water or pooling in excess of 0.25 inches. For landings, provisions in the DC-10 operating manual require that dry-runway landing distances be increased by 15 per cent when the runway is wet. However, neither the FAA nor TC certification requirements or regulations appropriate to the DC-10 require that wet runways be taken into account for take-off operations.

Other certification agencies, such as the United Kingdom Civil Aviation Authority (CAA), require that aircraft manufacturers provide performance data for take-offs on wet runways. The CAA also requires that operators certified in the United Kingdom take into account wet runways. To meet these CAA requirements, McDonnell Douglas produced a chart, labelled "Wet Runway RTO Stopping Distance Increment," showing the wet runway adjustments for the DC-10-30. This chart is premised on the use of two engines in thrust reverse<22>.

CAI, in common with most carriers in North America, does not have any procedures to compensate for the reduced braking action that would occur as a result of a rejected take-off on a wet runway surface. To date, the aviation industry and regulatory authorities have not been able to resolve this issue for North American certified aircraft. Calculations using the McDonnell Douglas wet runway chart indicate that, had the runway been wet, Flight 17 would have required an additional 880 feet to stop.

1.17.1.1 Past Occurrences and Safety Action in Canada

As a result of the investigation into the 20 July 1987 B737-200 rejected take-off accident (take-off was rejected below V1) at Wabush, Quebec, the Canadian Aviation Safety Board (CASB), on 28 September 1987, recommended that:

The Department of Transport revise air carrier procedures involving wet runway take-off operations, in order to provide a margin of safety comparable to that for dry runway operations;

(CASB 87-45)

and that

<table>
<thead>
<tr>
<th>Runway Length (ft)</th>
<th>Wet</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>99</td>
<td>4400</td>
<td>7800</td>
</tr>
<tr>
<td>66</td>
<td>2800</td>
<td>3500</td>
</tr>
<tr>
<td>33</td>
<td>1900</td>
<td>200</td>
</tr>
<tr>
<td>0</td>
<td>2700</td>
<td>-2700</td>
</tr>
</tbody>
</table>
The Department of Transport require air carriers to improve flight crew knowledge of the effects of wet runways on take-off performance and the means available to flight crews to provide a margin of safety comparable to that for dry runways.

(CASB 87-46)

Transport Canada responded to the recommendations by indicating that performance data for wet runways are limited and by stating that:

Transport Canada will request the Transport Development Centre to initiate a research project to investigate the effects of wet runways on aircraft performance.

The CASB, in a 15 March 1988 letter to TC, agreed that a research project was a sound long-term measure for the prevention of wet runway RTO accidents, but expressed regrets that the Transport Canada response was limited to a study.

A study entitled Aircraft Take-off Performance and Risks for Wet and Contaminated Runways in Canada was conducted by Sypher Mueller International Inc. for the Transport Development Centre. Among the conclusions of the 1991 report are the following:

The accelerate-stop distance is increased by approximately 15% on wet runways, 50% on snow, 75% on water deeper than 3 mm and 100% on ice covered runways; and

The combination of contaminated runway and critical event such as engine failure near V1 pose threats to safety under current regulations.

The report also recommended that a Phase II of the study be undertaken, which would investigate contaminated runway performance and determine the operational problems and costs of implementing new regulations ("countermeasures"). There is no indication that a Phase II took place.

The Moshansky Commission of Inquiry into the Air Ontario Crash at Dryden, Ontario, made the following recommendations related to wet runway operations:

Transport Canada require that aircraft flight manuals and related aircraft operating manuals contain approved guidance material for supplementary operating procedures, including performance information for operating on wet and contaminated runways;

(MCR 43)

and

Transport Canada, in cooperation with aircraft manufacturers and operators, expedite the search for a technically accurate means of defining runway surface conditions and their effects on runway performance.

(MCR 44)

In July 1995, in its final response to the Moshansky Commission of Inquiry, Transport Canada presented its planned implementation measures. Regarding MCR 43 and MCR 44, the implementation measures include the following:
To participate actively with manufacturers, operators, and other civil aviation authorities in the international fora, with a view to achieving international harmonization of international standards;

To amend Canadian Aviation Regulations to require, for turbo-jet aircraft, that operations manuals contain performance information for operating on wet and contaminated runways;

To form a government industry working group, under the Canadian Aviation Regulation Advisory Council, to develop the associated standards;

To have the Transport Canada Aviation's Standing Committee on Operations Under Icing Conditions carefully review the research and development plan regarding operations on wet and contaminated runways in order to identify research priorities and to make funding recommendations; and

Prior to the full implementation of the above, to use Air Carrier Advisory Circulars to communicate the significant information contained in the Sypher Mueller report.

Section 525.1581 (g) of the Canadian Airworthiness Standards was modified on 30 December 1993 to state, "The Aeroplane Flight Manual shall contain information in the form of approved guidance material for supplementary operating procedures and performance information for operating on wet and contaminated runways." With the introduction of the new Canadian Air Regulations, the operators will be required to use this guidance material. However, the Airworthiness Standards in Section 525.1581 (g) will only apply to newly certified aircraft types and not to aircraft like the DC-10.

1.17.1.2 Past Foreign Occurrences and Safety Action

The United States National Transportation Safety Board (NTSB) has conducted considerable investigative work on contaminated runway issues. In 1982, as a result of several serious overrun accidents, the following recommendations were issued to the FAA:

Amend 14 CFR 25.107, 25.111 and 25.113 to require that manufacturers of transport category airplanes provide sufficient data for operators to determine the lowest decision speed (V1) for airplane take-off weight, ambient conditions, and departure runway length which will comply with existing take-off criteria in the event of an engine power loss at or after reaching V1.

(NTSB A-82-163)

Amend 14 CFR 121.189 and 14 CFR 135.379 to require that operators of turbine engine-powered, large transport category airplanes provide flight crews with data from which the lowest V1 speed complying with specified take-off criteria can be determined.

(NTSB A-82-164)

The NTSB conducted a special study (SIR-90/01) which reviewed accidents and incidents involving runway overruns following high-speed rejected take-offs. As a result of this review, the NTSB, on 04 April 1990, issued a series of recommendations to the FAA, A-90-40 to A-90-48. These recommendations, in
part, addressed such items as the definition of V1, the accuracy of take-off information provided to operators and their crews, factors which adversely affect stopping distance, and policies related to operations from contaminated runways.

Action by the FAA and industry has continued in the nearly six years since the issuance of the NTSB recommendations, the latest of which was a Notice of Proposed Rulemaking (NPRM) 93-8, which would amend current standards (14 CFR Parts 1, 25, 91, 121 and 135) to, in part, take into account the effect of wet runways on take-off performance. According to NPRM 93-8, this action is being taken to improve the current standards, reduce the impact of the standards on the competitiveness of new versus derivative airplanes without adversely affecting safety, and harmonize with the proposed standards for the European Joint Aviation Requirements (JAR).

Nevertheless, NPRM 93-8 also states that the revised standards would not be applied retroactively either to airplanes currently in use or to airplanes of existing approved designs that will be manufactured in the future. JAR requirements will be applied to aircraft currently in use.

2.0 Analysis

2.1 General

The information gathered during the investigation indicates that the aircraft was maintained in accordance with manufacturer's specifications and applicable regulations. Other than the problems with the number 1 engine and the disabled thrust reverser on engine number 2, the aircraft systems operated as designed, and did not contribute to the overrun or adversely affect the evacuation of the aircraft. In particular, the wheels, tires, brakes, spoilers, and antiskid systems performed according to specifications.

The runway surface was dry, and, based on the results of surface friction testing and the tire marks on the runway, the braking action on the day of the occurrence was ideal. As well, the aircraft's performance during the acceleration to the point of engine power loss and the deceleration following this event closely matched the manufacturer's theoretical predictions.

Although the unavailability of audio panel 2 resulted in a short delay in the captain's ordering of the evacuation, and although some cabin crew members did not recognize the evacuation tone, the evacuation of the aircraft went well. The cabin crew reacted to the rejected take-off and subsequent evacuation in accordance with the established procedures. Language differences did not present a problem during the evacuation or thereafter.

The response to the occurrence by emergency response services, airport authorities, and company personnel was well coordinated and timely, largely due to the continued preparation and practice for this type of event by all those involved. There was, however, some delay in transporting the passengers from the occurrence site.

This analysis will concentrate on the technical and management issues affecting the engine power loss, and those operational factors affecting the flight and crew decision making.
2.2 Engine Number 1 Loss of Power

The power loss on the number 1 engine was sudden and occurred without being recognized by the flight crew. The rising internal engine temperature and uncommanded decrease in N1 speed, accompanied by the loud bang and a number of thuds, are indicative of a series of engine stalls. The inability of the number 1 engine to increase in speed in response to the selection of reverse thrust indicates that the stall never cleared itself, or that damage to the compressor was such that proper airflow through the engine could not be re-established.

It was not possible to determine which compressor blade broke first. It was also not possible to determine whether the compressor stall initiated the compressor blade failures, or whether a blade failure initiated the events leading to the stall. The propagation rate of the fatigue fractures on the blades also could not be determined. Nevertheless, the gradual increase in EGT and fuel flow on engine number 1 since 14 October 1995, and the stained and tarnished appearance of some fatigue fracture surfaces of the compressor blades indicate that the damage to the compressor had built up gradually, and that, on the day of the occurrence, the combination of the compressor condition and the demand for power during the take-off created the conditions that resulted in the compressor stall.

There were no signs of foreign object damage to the fan blades or the blades of stage 1 and stage 2 of the high-pressure compressor section. The fatigue fractures of the high-pressure compressor blades originating from the blade edges suggest that the damage to these blades, in stages 3 through 12, was secondary. Although the cause of the measurable deformation of blade 31 and the initiating mechanism to its cracking could not be determined, foreign object damage cannot be ruled out.

2.3 Engine Number 1 Trend Monitoring

CAI's trend monitoring program for its DC-10 engines met the specifications of General Electric's guidelines. These guidelines, in allowing each operator to establish its own procedures, did not specify how much time should be taken to complete the analysis of the trend data. The procedures used by CAI were not fast enough to have the information on the previous day's flight available for analysis by the power plant engineering group before the occurrence aircraft took off.

Had CAI's maintenance personnel known that the trend of the EGT of engine number 1 had reached 27 degrees and that there was a corresponding upward trend on the fuel flow and engine core speed (N2), a borescopic inspection of the engine probably would have been done. An inspection would most likely have discovered the damage to the high-pressure compressor section, so that appropriate maintenance could have been performed prior to the flight.

2.4 Rejected Take-off Decision Making

2.4.1 Influences on the Decision to Reject

The captain's decision to reject the take-off was based on his perception of the circumstances. The influences that could have shaped his understanding of the situation were his training and experience, his perceptions as to flexibility provided by the use of C2B power, and the available visual and aural cues. In addition, the wording contained in the CAI DC-10 FCOM, that a "further 3 seconds is allowed until full braking with spoiler actuation is attained," may be ambiguous in that it
implies that some time beyond V1 is available for the pilot reaction. The limited published information regarding the inevitability of an overrun when a take-off is rejected beyond the V1 speed could also lead to this adverse consequence not being considered in the decision to reject.

The captain's understanding was that an engine failure would not be an adequate reason to initiate a rejected take-off after V1. In this case, however, prior to making his reject decision, he did not see or perceive indications, or hear advice from his crew, that an engine failure had occurred. Also, the loud bang was neither similar to any compressor stall symptom that he knew about, nor similar to sounds that he had heard in training or experienced during actual flying.

All the members of the flight crew reported that the sound was unlike anything they had heard before. Not only was the bang very loud, but it was difficult to specify its point of origin. None of the crew saw the engine fail light illuminate<23>, nor did they notice the drop in N1. The only cue the captain received to indicate that the take-off was no longer normal was the loud bang, followed by a series of thuds and vibrations. Because the situation did not match any of the captain's previous training or actual flying experience, he was required to respond instantly to the situation by drawing on whatever knowledge or other experience he had.

When the captain heard the loud bang, he immediately thought of a bomb. The only procedural guidance available for this circumstance was that a rejected take-off after V1 could be initiated when "the captain believes that the aircraft has suffered catastrophic failure and will not fly." According to the captain, his action was probably also influenced by the fatal DC8 occurrence that he had witnessed and which resulted in his mental rule of thumb that if structural failure were suspected, he would not take the aircraft into the air.

When the captain decided to reject the take-off, it was his correct belief that, because they were using C2B power figures, the aircraft would have reached the 164-knot V1 earlier, and that there would be additional runway available for the reject. Based on this fact and his visual impression of the runway available, he was confident that the aircraft would be able to stop on the runway.

2.4.2 Engine Malfunction Recognition

Although the flight crew members were all very experienced pilots and had taken simulator and ground training throughout their careers, they did not recognize the loud bang produced by the stall on engine number 1 for what it was probably for the following reasons:

- None of the flight crew members had ever experienced such a compressor stall;

- There is no information in operational and training manuals or in other guidance material on the symptoms of large-fan engine stalls; and,

- Current simulator training and ground training do not provide this knowledge.

Additionally, the engine instruments and warning systems were not compelling
enough in this situation for the crews to recognize the initial engine stall or the resulting engine failure.

2.5 Performance Issues

2.5.1 Performance - General

The distance used for the aircraft to accelerate to 164 knots was the same as predicted by the manufacturer's data for a static take-off; consequently, the rolling take-off procedure was not a factor in this occurrence. Also, up to the time of the power loss on engine number 1, the aircraft's overall performance was normal for a 590,000-pound DC-10-30ER. Based on the assessed aircraft position on the runway at the time of the power loss, the reaction time of the crew, and the actual deceleration performance of the aircraft, the aircraft's deceleration performance was also normal. The significant differences in overall accelerate/stop distance from the C2B-power certification data were the following: the additional 533 feet covered from the C2B-power 167-knot V1 point to the point of initial crew action to reject at 172 knots; and the additional 210 feet required to brake the aircraft from 172 knots to 167 knots. Based on the speed at which the aircraft went off the end of the runway, an additional 400 feet would have been required to bring the aircraft to a stop on a hard runway surface. The availability of a number 2 engine thrust reverser could have reduced the stopping distance by 134 feet.

2.5.2 Use of Auto-brakes

The elapsed time from the moment the captain started to retard the power levers to the point that the ABS system applied full brake pressure was 1.8 seconds. Had the crew relied on the ABS being activated by thrust reverser selection, which occurred approximately 3.5 seconds after the power levers were retarded, the aircraft would have run off the end of the runway at a speed in excess of 80 knots, instead of at 40 knots. The captain allowed the ABS to bring the aircraft to a stop with maximum braking being applied and maintained throughout the rejected take-off.

Although the current DC-10 Abnormal Procedures do not call for immediate manual activation of the spoilers, the second officer's actions to do so, in accordance with CAI standard operating procedures, greatly reduced the amount of overrun.

The CAI procedure to use ABS during a rejected take-off, as contained in its TC-approved DC-10 FCOM, may be viewed as being in conflict with the manufacturer's recommendation to use manual brakes, as contained in the FAA-approved Flight Crew Operating Manual.

Although a manual braking procedure could have resulted in braking being applied quicker, evidence from previous occurrences indicates that it is unlikely that maximum, continuous brake pressure would have been maintained until the aircraft stopped.

The FDR data indicate that the crew reaction plateau for this occurrence was somewhat better (shorter) than the theoretical 3.1-second, 900-foot plateau. Also, the FDR data indicate that the use of ABS during the deceleration resulted in deceleration performance that slightly exceeded the manufacturer's predicted performance.
2.6 Aircraft Load Control Factors

The integrity of the overall control of the weight and balance of an aircraft relies on everyone involved in the process adhering to the established procedures. The fuel load, passenger count, and baggage count discrepancies noted on this flight may suggest a lack of appreciation by those persons involved of the critical nature of their role in the overall integrity of the load control system. The cumulative total of the loading discrepancies noted on this flight was approximately 2,000 pounds. Although the captain may have been unaware that the weight of the aircraft on the final load closeout was only 117 pounds short of the maximum brake-release weight, he was aware that there were at least 1,000 more pounds of fuel loaded on the aircraft. Therefore, he should have been aware that the reduced taxi fuel burn would result in the aircraft take-off weight being in excess of the 590,000-pound limit.

Although the performance degradation caused by an additional 3,000 pounds to an aircraft like the DC-10-30 at maximum gross weight can be viewed as negligible, the load-control discrepancies noted for this flight probably resulted in the aircraft being over its maximum design ramp weight and its maximum design take-off weight.

2.7 Evacuation Signal System

The evacuation signal on the occurrence aircraft was examined and found to be functioning in accordance with the manufacturer's specifications and at the volume of the signals on the other company DC-10 aircraft and crew training doors. The Flight Attendant Manual states that “Flight attendants are required to conduct an evacuation when signalled to do so by the flight deck or by the evacuation signal system.” However, training evacuations have not been initiated based solely on the evacuation signal.

There may also be an anomaly between the sequencing of the evacuation command and signal as described in the Flight Attendants’ Manual and the sequence outlined in the DC-10 Flight Crew Manual. Specifically, the Abnormal Standard Operating Procedures of the Flight Crew Manual state that the signal is to be activated when, or at the same time as, the captain gives the command to evacuate; the Flight Attendants' Manual, however, states that the evacuation signal will follow the captain's command.

When the evacuation signal sounded, it was not immediately recognized by some of the flight attendants due to the perceived low volume of the signal. This perception probably was the result of three factors:

- The DC-10 door trainer was not equipped with an evacuation signal; therefore, the flight attendants would have had no experience with the evacuation signal system on the DC-10 or exposure to its sound in training;

- The evacuation signal came before the captain's command to evacuate, which differed from the expectations of the flight attendants; and

- Evacuation training is never done using the evacuation signal system alone.
To optimize individuals' performance, training conditions should be highly similar to actual on-board conditions. In this occurrence, because the flight attendants had not been exposed to the evacuation signal system on the DC-10 in training, and because they had not been trained to evacuate an aircraft in response to the evacuation signal system alone, the sounding of the signal before the announcement from the captain caused momentary indecision and was not recognized as a signal to evacuate.

2.8 Evacuation Slide/Raft Cover

Although not considered a factor in this occurrence, the extension of the evacuation slide/raft covers down into the exit door openings would have obscured the vision and path for taller people, which could have slowed the flow of persons using the exit to evacuate the aircraft. Had these covers been pushed closed, they would been held in the closed position by the magnetic latches.

CAI's detection of similar problems on its other DC-10 aircraft indicates that the problem of weak spring hinges could be a DC-10 fleet problem.

2.9 Wet Runway Considerations

Although a wet runway was not a factor in this occurrence, wet runways are the norm at Vancouver on more than 60 per cent of the days during the month of October. Had the runway been wet, the runway overrun would have been significantly longer and the adverse consequences of the overrun much greater.

Based on the McDonnell Douglas DC-10-30 Wet Runway RTO Stopping Distance Increment, currently in use in the United Kingdom, the aircraft would have required an additional 860 feet to stop on a wet runway. Based on the actual distance used by the aircraft to accelerate to 164 knots (6,200 feet) using C2B power, the theoretical crew reaction and deceleration distance (4,152 feet), and the wet runway factor, the aircraft would not have been able to stop on a wet 11,000-foot runway, even if the rejected take-off were to have been initiated at the 164-knot V1 point.

Past TSB and NTSB recommendations to establish regulations requiring that reduced braking effectiveness on wet runways be taken into consideration when calculating accelerate/stop take-off distances have not resulted in effective safety action. Even if the planned rule-making by the FAA as a result of NPRM 93-8 is implemented, the requirement to take into account wet runway conditions when calculating accelerate/stop distances will not be retroactive and will not apply to CAI's fleet of DC-10s.

3.0 Conclusions

3.1 Findings

- The flight crew were qualified and licensed for the flight.
- The cabin crew were qualified and certified for the flight.
- Records indicate that the aircraft had been maintained in accordance with the company's Maintenance Control Manual and applicable airworthiness standards.
- The TPS incorrectly calculates the effect of below sea level pressure altitude on aircraft climb performance.

- The loud, startling bang occurred 2.2 seconds after the V1 call as the aircraft accelerated through 170 knots.

- The loud bang was a sound unlike anything the flight crew had heard before in training or in flying.

- The captain called for the reject and started to retard the power levers as the aircraft accelerated through 172 knots.

- The captain's decision to reject was based on the fact that he did not recognize the initial sound and subsequent thumping noises, and that, because he thought the loud bang could have been a bomb, he had concerns about the integrity of the aircraft and its ability to fly.

- The wording contained in the CAI DC-10 FCOM, that a "further 3 seconds is allowed until full braking with spoiler actuation is attained," may be ambiguous in that it implies that some time beyond V1 is available for the pilot's initial reaction.

- The rising internal engine temperature, the uncommanded decrease in N1 speed, the loud bang, and the thuds are indicative of a series of engine stalls.

- None of the flight crew noticed an indication of engine failure, or realized that there had been a power loss on engine number 1 until after the FDR data was made available.

- The rolling take-off did not add to the runway distance required for the acceleration to V1.

- The CAI procedure to use ABS during a rejected take-off differs from the manufacturer's recommendation to use manual brakes. The use of ABS did not add to the theoretical distance required for the rejected take-off.

- The acceleration and deceleration performance of the aircraft closely matched the predicted performance of a DC-10-30ER weighing 590,000 pounds.

- According to the manufacturer's data, the use of the thrust reverser on engine number 2, had it been available, could have reduced the distance required to stop by 134 feet.

- The aircraft's auto-brake system, brakes, antiskid system, and tires functioned properly throughout the rejected take-off.
• The runway surface was dry and braking action was ideal.

• A number of blades in the high-pressure compressor of engine number 1, from stage 3 on, exhibited signs of fatigue cracks. Some cracks predated the occurrence engine stall event.

• Engine number 1, stage 3, blade 31 was found to be bent, and the fatigue crack on this blade originated at mid-chord. Although the cause of the deformation of blade 31 and the initiating mechanism to its cracking could not be determined, foreign object damage cannot be ruled out.

• The physical evidence did not yield sufficient information to determine the cause of the fatigue cracking nor to estimate the crack propagation rates.

• CAI's trend monitoring of its DC-10 engines indicated that there was a problem with engine number 1, but the process used to analyze the trend data was not timely enough to result in the required maintenance action being taken before the flight.

• The manufacturer's trend monitoring guidelines do not specify urgency or how much time should be taken to complete the analysis of the trend data.

• The final fuel load that was passed to the Operations Agent for input into the TPS was 1,100 pounds below the total of the readings of the fuel tank gauges.

• Based on the LPS final Load Closeout figures and the discrepancies noted in the ramp fuel weight, passenger baggage weight, and the taxi fuel burn, the occurrence aircraft could have been up to 951 pounds over maximum ramp weight and 2,901 pounds over the maximum design take-off weight.

• The emergency response to the occurrence was well coordinated and timely because of the continued preparation and practice for this type of event by all those involved.

• The Flight Crew Operating Manual and the Training Manual do not contain information on the unavailability of audio panel 2 when the aircraft emergency power switch is ON. The company was not aware of this communications limitation.

• Uncertainty by some flight attendants regarding the evacuation signal can probably be attributed to lack of exposure to the signal on the DC-10, and the fact that the signal and the captain's command were heard in the opposite order in training.

• The weak spring hinges on the evacuation slide/raft covers could be a DC-10 fleet problem.
The first buses to arrive at the accident scene to transport the passengers from the accident site did not arrive until 45 minutes after the evacuation.

CAI, in common with other carriers in North America, does not have any procedures to compensate for the reduced braking action that would occur as a result of a rejected take-off on a wet runway surface, nor is there a regulatory requirement to have such procedures.

Calculations using the McDonnell Douglas Wet Runway RTO Stopping Distance Increment chart for the DC-10 indicate that, had the runway been wet, the aircraft would have required an additional 880 feet to stop.

Based on the actual distance used by the aircraft to accelerate to 164 knots (6,200 feet) using C2B power, the theoretical crew reaction and deceleration distance (4,152 feet), and the wet runway RTO stopping distance increment, the aircraft would not have been able to stop on a wet 11,000-foot runway, even if the rejected take-off were to have been initiated at the 164-knot V1 point.

Past TSB and NTSB recommendations to establish regulations requiring that reduced braking effectiveness on wet runways be taken into consideration when calculating accelerate/stop take-off distances have not resulted in effective safety action.

3.2 Causes

Engine number 1 lost power at a critical point in the take-off and the rejected take-off was initiated at a point and speed where there was insufficient runway remaining to stop the aircraft on the runway. Contributing to this occurrence were the misidentification of the cause of the loud bang and the lack of knowledge regarding the characteristics of engine compressor stalls. Contributing to the engine power loss was a delay between the collection and analysis of the engine monitoring data.

4.0 Safety Action

4.1 Action Taken

4.1.1 Engine Monitoring

Since the occurrence, CAI has taken steps to enhance the timeliness of its processing of engine trend monitoring data. In March 1996, CAI completed a program, begun before the occurrence, of equipping all of its DC-10 aircraft with an Aircraft Communications and Reporting System (ACARS), which can relay the flight data to ground stations. An interface program will be installed to acquire the airborne data and to feed this data through a ground-based personal-computer ADEPT program at CAI. The new procedures will require flight crews, using ACARS, to transmit engine readings to the ground station at the time that they are recorded. This new system will provide a near real-time acquisition, processing, and evaluation of the engine trend monitoring data.

Following the accident, the TSB forwarded a Safety Advisory to Transport Canada (TC) suggesting that other users of engine trend monitoring systems be advised of the safety benefits associated with timely analysis of engine data. TC subsequently
published an article regarding jet engine fault monitoring in its *Maintainer* newsletter and is planning a similar article for the *Feedback* newsletter.

### 4.1.2 Evacuation Slide/Raft Cover Hinge Springs

Following the discovery of the problem with the hinge springs, CAI conducted a special inspection of the slide/raft covers on all its DC-10 aircraft, and found similar problems. As a result, CAI has begun retrofitting its DC-10 aircraft with larger hinge springs as recommended in McDonnell Douglas MD-11 Service Bulletin 25-148.

TC has sent a letter to the Federal Aviation Administration (FAA), requesting that the FAA urge McDonnell Douglas to address the problem of the DC-10 chute/raft cover hinge springs through action similar to that recommended in Service Bulletin 25-148 for the MD-11.

The FAA and McDonnell Douglas agreed with this course of action, and Service Bulletin DC10-25-367, applicable to DC-10 chute/raft cover hinge springs, has been issued by McDonnell Douglas.

### 4.1.3 Take-off Performance System Changes

American Airlines Corporation (AMR) has stated that software changes are being developed to correct the Take-off Performance System (TPS) program errors in calculating engine thrust when pressure altitudes are below sea level. AMR is also amending the TPS program to make it possible for crews to obtain performance data for power settings other than the TPS selected settings.

The TSB is investigating occurrences in which errors in ground-based aviation related software adversely affected safety. The adequacy of current quality assurance methods for such software is being examined.

### 4.1.4 Passenger Recovery

The Vancouver International Airport Authority reports that, in response to the delays in recovering the passengers of Flight 17 from the accident site, the Airport Duty Manager Incident Call Out/Checklist has been revised. The checklist for the Airport Duty Manager in the Emergency Operations Centre now reflects the need to call the Vancouver International Airport Authority Ground Transportation Department to acquire immediate bus transportation. Buses will be requested from the Airport Authority's fleet of shuttle buses normally used for transportation to and from public and employee parking lots. Using the Airport Authority shuttle buses is meant to complement the efforts of the individual air carriers, who remain responsible for transporting the passengers from the accident site to the terminal building.

### 4.1.5 Spoiler Extension During Rejected Take-offs

As a result of CAI's assessment of the potential delay resulting from relying on the selection of thrust reversers to deploy the spoilers to activate the auto-brake system, CAI has redrafted its DC-10 Flight Crew Operating Manual (FCOM) rejected take-off checklist to indicate that the second officer "deploys the spoilers without command." CAI's DC-10 Standard Operating Procedures on rejected take-offs have also been amended to direct the second officer "as soon as the throttles
are closed to pull the spoiler handle full aft and up without command."

4.1.6 MEL Changes

As a result of CAI's assessment of the potential adverse effect of a disabled thrust reverser on a high-weight rejected take-off, CAI redrafted its DC-10 MEL Item 78-01 Thrust Reverser/Fan Reverser. TC has approved CAI's MEL amendment which specifies that the dispatch of DC-10-30 aircraft within 20,000 pounds of its runway-limit weight or above 572,000 pounds with a thrust reverser disabled will require the concurrence of the captain and chief pilot and their favourable assessment of the take-off conditions and environment.

4.1.7 Communications Limitations

CAI amended its DC-10 FCOM and crew training program to include information about the unavailability of audio panel 2 when the aircraft emergency power switch is ON.

The TSB sent a Safety Advisory to TC suggesting that they liaise with McDonnell Douglas and the FAA concerning dissemination of information regarding the communication limitations associated with the use of emergency power on the DC-10.

4.1.8 Definition of V1 in DC-10 FCOM

The wording in the CAI DC-10 FCOM may be ambiguous in that it implies that some time beyond V1 is available before the pilot needs to initiate the rejected take-off. Given the potential for pilots to misconstrue the definition of V1 in the FCOM, and given the potential for adverse consequences as a result of rejecting a take-off after V1 (in a field-length-limited context), the TSB forwarded a Safety Advisory to CAI. The Advisory suggested that CAI might wish to amend the definition of V1 in the DC-10 FCOM and review the V1 definition in other pilot reference materials, including those for other CAI aircraft.

4.2 Action Required

4.2.1 Engine Malfunction Recognition

The captain did not recognize the loud bang as a symptom of a high bypass ratio engine compressor stall and thought that the noise might have been caused by a bomb. Consequently, he decided to reject the take-off even though the speed was above V1. Although the flight crew members were all very experienced pilots and had taken simulator and ground training throughout their careers, they had not been trained to recognize a loud bang as a symptom of a high bypass ratio engine compressor stall, and none of the crew members noticed the cockpit indications of power loss.

Rejecting a take-off at a speed above V1 during a field-length-limited take-off places an aircraft at more risk than continuing the take-off, and should not be attempted unless the pilot has reason to conclude that the airplane is unsafe or unable to fly. The FAA's Takeoff Safety Training Aid states that "in order to eliminate unnecessary RTOs, the crew must differentiate between situations that
are detrimental to a safe take-off, and those that are not." Also, a Boeing report entitled *Engine Plus Crew Error Events* indicates that positive recognition and correct identification of engine malfunctions appear to be significant contributors to the outcome of engine-plus-crew-error events. If pilots do not consider a loud bang as a symptom of a possible compressor stall, they may assume that the noise was caused by a bomb (a much less likely event) and unnecessarily reject the take-off.

Crew errors are often associated with engine failures that create loud noises. The Boeing report indicates that the majority of engine-plus-crew-error events involved engine malfunctions that generated loud noise. The report further indicated that the number of such events involving high bypass powered aircraft had steadily increased over the last five years covered by the study.

Few resources are available to flight crews to aid in the quick identification of engine failure conditions. Neither engine manufacturers nor aircraft manufacturers have specific information available on the characteristics of high bypass ratio engine compressor stalls. The Boeing report observes that there is currently no flight crew training for positive recognition and correct identification of engine failure conditions; the noises, vibration, and other "cues" of real engine failures are not simulated in the vast majority of flight crew training simulators. In light of the risks associated with unnecessary rejected take-offs, the Board recommends that:

The Department of Transport ensure that flight crews operating high bypass ratio engines can correctly identify and respond to compressor stalls or surges.

A96-13

4.3 Safety Concern

4.3.1 Wet Runway Considerations

Despite the various recommendations, studies, and working groups pertaining to wet runway take-offs over the last 10 years, there is still no requirement for manufacturers to provide approved performance data for aircraft taking off on wet runways, other than for newly certified aircraft. Furthermore, there is no requirement for operators to take into account such data when calculating aircraft take-off performance. Although TC is pursuing these issues, corrective action does not appear to be imminent.

In light of previous recommendations on this subject and in recognition of TC's current related activities, the TSB does not plan to make new safety recommendations on this deficiency at this time. Nevertheless, the Board remains concerned that fare-paying passengers continue to be placed at risk when field-length-limited take-offs are conducted without taking into account reduced braking effectiveness on wet 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 09 October 1996.

Appendix A - Number 1 Engine ADEPT Printout

Appendix B - List of Supporting Reports

The following TSB Engineering Branch Reports were completed:

LP 163/95 HP Compressor Failure; and

LP 154/95 Flight Recorder Report.

These reports are available upon request from the Transportation Safety Board of Canada.
Appendix C - Glossary

ABS - auto-brake system
ACARS - Aircraft Communications and Reporting System
ADEPT - Aircraft Data Engine Performance Trending
AFM - Airplane Flight Manual
AMR - American Airlines Corporation
ASDA - accelerate stop distance available
ATPL - Airline Transport Pilot Licence
C2 CF6-50 - maximum take-off power
C2B CF6-50 - improved performance take-off power
CAA - United Kingdom Civil Aviation Authority
CAI - Canadian Airlines International
CAM - cockpit area microphone
CASB - Canadian Aviation Safety Board
CFR - Code of Federal Regulation (US)
CSD - customer service director
CVR - cockpit voice recorder
EGT - exhaust gas temperature
EOW - empty operational weight
FAA - Federal Aviation Administration
FAR - Federal Aviation Regulation
FCOM - Flight Crew Operating Manual
FDR - flight data recorder
F/O - First Officer
FOD - foreign object damage
FPS - flight planning system
g G - load factor
JAR - European Joint Aviation Requirements
kts - knots (nautical miles per hour)
LPS - load planning system
MEC - main engine control
MEL - minimum equipment list
mm - millimetre(s)
N1 - engine fan speed
N2 - engine core speed
NPRM - Notice of Proposed Rulemaking
NTSB - National Transportation Safety Board
PDT - Pacific daylight saving time
PTOW - planned take-off weight
RTO - rejected take-off
SABRE - AMR flight support computer system
S/CPL - Senior Commercial Pilot Licence
S/O - Second Officer
TC - Transport Canada
TODA - take-off distance available
TORA - take-off run available
TPS - Take-off Performance System
TSB - Transportation Safety Board of Canada
VEF - engine-failure speed
V1 - Critical Engine Failure Recognition Speed
V2 - Take-off Safety Speed
VR - Rotation Speed

ZFW - Zero Fuel Weight

See Glossary at Appendix C for all abbreviations and acronyms.

All times are PDT (Coordinated Universal Time minus seven hours) unless otherwise noted.

Air Navigation Order VII, Number 2, Section 41, Flight Time Limitations.

The complete FDR report is contained in TSB Engineering Branch Report LP 154/95.

The number 2 thrust reverser was not used because it had been disabled in accordance with the aircraft MEL.

The report on this metallurgical analysis is contained in TSB Engineering Branch Project Report LP 163/95.

Appendix A contains the ADEPT printout for the period 25 August through to 18 October 1995.

Engineering Branch Project Report LP 154/95 contains the complete FDR/CVR report.

The term "improved performance" is used when the take-off performance is based on the use of a clearway or a stopway.

EOW includes the weights of the crew members, and the pallets and containers used to hold the baggage and cargo.

The average bag weight of 35 pounds and the average passenger weight of 163 pounds were the weights approved by Transport Canada for this type of CAI trans-Pacific flight.

Using the TC-approved figure of 35 pounds per passenger bag, the load documentation should have recorded a weight of 10,990 pounds.

Based on load records, the weight of the freight not weighed should have been 1,549 pounds.

Under the FARs, the time interval between the engine-failure speed (VEF) and V1 is the longer of the flight-test demonstrated time or 1.0 seconds. For the DC-10-30 this interval time is 1.1 seconds.


The term "engine-plus-crew-error event" is used by the Boeing Report in the context wherein the engine failure/malfunction in itself would not have caused an accident, but inappropriate flight-crew response to the engine malfunction has.

The point at which the captain initiated the rejected take-off action was 4.3 seconds after the 164-knots V1 call, and 3.0 seconds after the aircraft accelerated through 167 knots, the V1 speed for C2B power as contained in the OD43J manual.

Includes distance used during the rolling take-off.

The reaction plateau is defined as the distance travelled by the aircraft from the point at which the pilot initiates stopping action to the point at which the aircraft, with the wheel brakes fully applied and the spoilers fully extended, is decelerating through the speed at which the initial action was taken.

Distance includes a 131-foot reduction attributable to the use of engine number 3 thrust reverser.

The 400-foot overrun was based on the 43-knot speed at the end of the runway and the manufacturer's predicted deceleration data.

No data are presented for the case of using only one thrust reverser.

The engine-fail light may not have illuminated due to the ground-sensing system going into the air mode.
Air 1995

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 in adverse weather
CESSNA 310Q C-FAKW
Caledon, Ontario 2 mi W
28 July 1995

Report Number A95O0150

Synopsis

The pilot was on a visual flight rules (VFR) flight from Lindsay, Ontario, to the Kitchener/Waterloo regional airport. At 0725 eastern daylight time (EDT), the pilot requested and obtained radar flight following from the Toronto area control centre. The aircraft was radar identified 30 miles north of Toronto at 4,500 feet above sea level (asl), on a direct track to Kitchener. The pilot then contacted Kitchener/Waterloo control tower and reported being over the Orangeville area. The tower controller told the pilot that the weather was below VFR limits with an estimated broken cloud ceiling of 4,000 feet above ground level, and two and half miles visibility in fog. The controller approved special VFR (SVFR) for the aircraft to land at the airport; however, the approval was subsequently cancelled when the pilot did not respond to further queries from the controller. About 10 minutes after initial radar contact, the area controller observed the radar target descend from a cruising level of 4,500 feet asl to about 1,800 feet where the target went into coast. The target was re-acquired at 1,500 feet, climbed to 1,800 feet, then went into coast again. This time the target remained in coast mode. The pilot did not respond to further radio calls, an emergency locator transmitter (ELT) was heard by an aircraft in flight, and the noise of an aircraft followed by the sound of a crash was heard by persons on the ground. The aircraft had crashed, and the wreckage was found within 20 minutes of the aircraft disappearing from radar.

The aircraft had struck trees in rising terrain, at an elevation of about 1,150 feet asl, and came to rest in a canola field. There were low stratus cloud ceilings and heavy fog in the area of the occurrence. The pilot, who was the sole occupant, was not wearing a shoulder harness and was fatally injured in the accident.

Other Factual Information
Based on the pilot's initiative, the company management had recently agreed that it would be both economical and convenient to have the pilot rent and fly an aircraft, rather than chartering an aircraft for business-related travel. As a result of these discussions, the company had paid for the pilot's recurrent training on the Cessna 310 aircraft. This was the first flight for the company under this arrangement. The plan was to fly from Lindsay to Kitchener, where the pilot would pick up one passenger, proceed to Manitoulin Island to conduct company business, and return to Lindsay.

The pilot had been a licensed pilot since 1971. He obtained his first instrument rating in 1976, and a class III instructor rating in 1978. The pilot was active in aviation as a flight instructor and a charter pilot, and accumulated about 1,542 flying hours from 1976 to 1979. By 1979, the pilot had 11 hours of instrument flying, 53 hours of simulated instrument flying, and 32 hours in a training simulator. In the 15-year period between 1980 and 1995, the pilot had flown an additional 55.2 hours. In the three months preceding the accident, the pilot had flown nine hours, including one hour of instrument flying in a Cessna 310 aircraft, and 2.2 hours in a Link simulator.

In June 1991, the pilot consulted his family physician after experiencing dizziness, visual disturbance, and numbness in his left hand, nose, and upper lip, followed by a headache. An electroencephalogram (EEG) was performed on 19 June 1991, and the results were normal. On 22 October 1991, a consultation was made with a neurologist, who diagnosed the condition as a migraine. On 30 November 1991, the family physician noted that the pilot experienced a further episode of visual disturbance, right hand numbness, and headache. The diagnosis of this episode was also migraine. There is no further evidence of headaches between November 1991 and 28 July 1995. This medical condition could result in a sudden decrement in performance or in complete incapacitation. The pilot did not disclose this medical information on any of his aviation medical examinations. If this information had been reported during his aviation medical examination, it likely would have resulted in his pilot privileges being revoked. Whether the pilot was suffering from a migraine headache or any of the associated symptoms at the time of the accident was not known.

The aircraft was a twin-engine Cessna 310. There was no evidence of any aircraft failure or malfunctions prior to the collision with the trees and ground. Analysis of the recorded radar information shows that the aircraft descended from level flight at 4,500 feet asl to 1,500 feet asl in about 1 minute 45 seconds, about 1,700 feet per minute. The rate of descent was fairly constant throughout.

Recent changes to the Air Navigation Orders (ANO Series II, No. 2/CRCc.-28, Order Respecting Aircraft Seats and Safety Belts) required commercial aircraft to be outfitted with shoulder harnesses for the front-seat occupants. The aircraft owner had applied for, and been given, a temporary exemption to the requirement. When the aircraft was examined, shoulder harnesses were installed in the aircraft. The log-book entries regarding the installation were not certified in an approved manner. The shoulder harness was a fixed type, not an
Inertial reel type. If the fixed type shoulder harness was used and properly adjusted across his chest, the pilot could not lean forward and reach various switches and items in the cockpit without first loosening the shoulder harness.

On the day of the accident, a weak frontal trough was situated between Muskoka and Kingston by 0700 EDT. The air mass over the region was very moist, and after 0600 EDT, fog and low cloud began to form. The moist south to southeasterly upslope flow resulted in low stratus cloud ceilings from the surface to 500 feet above ground level (agl), and visibilities of one half mile or less in the vicinity of the accident site.

Before departing from Lindsay, the pilot phoned the Sault Ste. Marie Flight Service Station and received a weather briefing. The briefing included thunderstorm and turbulence warnings in the Georgian Bay area, and warnings of reduced visibilities in fog for southern Ontario. Clear weather conditions were forecast for the central Ontario regions, including Lindsay. As part of the briefing, the pilot was told that visibility in Kitchener was three miles in fog, and that London had two and a quarter miles in fog. The reported cloud conditions were 9,000 feet scattered in Kitchener and 11,000 feet broken in London.

**Analysis**

The pilot's rationale in electing to continue into deteriorating weather conditions and descend into rising terrain could not be determined with any degree of certainty. However, there are several factors which may have created a stressful environment and contributed to his decision. The pilot, having flown only 55.2 hours in the last 15 years and only 9 hours in the 90 days preceding the accident, although qualified, had very limited recent flight experience. Further, this was the pilot's inaugural business flight, and he had a passenger waiting for him in Kitchener and meetings scheduled later in the day in Manitoulin Island. The better weather conditions at Kitchener as compared to en route may have influenced his decision to descend. Lastly, although there was no evidence of this from the recorded radio transmissions or radar information, the possibility of a migraine adversely affecting the pilot's performance during the flight cannot be eliminated.

When the pilot departed from Lindsay, the sky was clear, but he was aware that he would be encountering low cloud and reduced visibility in the Kitchener area, as well as possible thunderstorms in the vicinity of Manitoulin Island. En route to Kitchener, the pilot encountered weather that was worse than forecast. The constant, seemingly controlled descent from 4,500 feet until very near the ground indicates that the aircraft was under the control of the pilot. This controlled descent, in conjunction with the low ceilings and visibility reported and forecast, would indicate that the pilot was descending with the intention of maintaining visual contact with the ground or, more probably, breaking out of the cloud. Unfortunately, the pilot descended in an area of rising terrain and, prior
to establishing adequate visual contact with the terrain, struck the trees and ground. As the pilot descended, he did contact the Kitchener/Waterloo control tower and was given SVFR to enter the control zone. As it turned out, the weather conditions at the Kitchener/Waterloo airport, although not suitable for VFR, were considerably better than the weather conditions that the pilot encountered en route and during his descent. It was likely that the pilot assumed the weather conditions he was operating in were similar to the reported weather conditions at Kitchener, and that by descending he would be able to maintain or regain visual contact with the ground.

The aircraft had been fitted with a shoulder harness modification to the existing lap belts, but the pilot was not wearing the shoulder harness when the aircraft struck the trees; this may have been related to the inconvenience of the fixed type installation. The use of the shoulder harness likely would have reduced the severity of the upper torso injuries to the pilot.

The following Engineering Branch report was completed:

LP 111/95 - Instrument Examination.

Findings

1. The pilot, in an attempt to maintain or regain visual contact with the ground, descended in low cloud and heavy fog into rising terrain, and the aircraft struck the ground.

2. The aircraft was serviceable, although the pilot shoulder harness installation was not certified.

3. The pilot was not wearing the available shoulder harness.

4. The pilot did not fully disclose his medical condition on his aviation medical assessments.

Causes and Contributing Factors

The pilot encountered weather conditions that were worse than forecast, and, in an attempt to maintain or regain visual contact with the ground in an area of low cloud and dense ground fog, he descended and the aircraft struck the ground. Contributing to the pilot’s decision to continue the flight into known adverse weather conditions may have been his lack of currency, the waiting passenger, and the better weather conditions reported at Kitchener.

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 25 July 1996.

Updated: 2002-10-06

Important Notices
Air 1995

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
Air Canada Airbus A320-211 C-FFWJ
Montreal International (Dorval) Airport,
Quebec 45 nm W
14 November 1995

Report Number A95O0232

Summary

An Airbus A320 aircraft, Air Canada flight 431, was on a scheduled domestic flight from Montreal International (Dorval) Airport, Quebec, to Toronto/Lester B. Pearson International Airport, Ontario. The take-off and departure were normal until a loud bang was heard while the aircraft was climbing through flight level 280. The flight crew immediately observed the rpm of the No. 2 engine (CFM International [CFMI] CFM56-5A, ESN 731-308) decrease as the exhaust gas temperature (EGT) increased. The engine was shut down. After securing the engine, the flight crew notified company maintenance and carried out an uneventful single-engine landing at Toronto with emergency response services standing by.

Ce rapport est également disponible en français.

Other Factual Information

The failed engine was removed from the aircraft and shipped to the Air Canada engine teardown facility in Montreal where it was dismantled and inspected. The inspection revealed extensive internal damage to the high pressure turbine nozzle assembly (HPTN) and the high pressure turbine (HPT) sections, extending back to the low pressure turbine (LPT) sections. The nature and extent of the damage was consistent with an initial failure in the HPTN and HPT sections.
The engine HPTN is a single-stage, air-cooled assembly which directs the gas flow from the combustion chamber to the HPT rotor blades. The assembly is made up of 21 nozzle segments, and each segment has two guide vanes. High pressure compressor discharge air, used for cooling, enters each vane through the nozzle segment inner and outer platforms and exits through holes in the leading and trailing edges of the guide vanes.

The engine manufacturer's part numbers for the nozzle segments in the failed engine were 1668M37G02 and 1668M37G03.
The Serviceable/Maintenance Release tags for the HPTN segments noted that the parts had been "PACH [Partitioned Alloy Component Healing] repaired" for service evaluation. Impact damage, blue heat discoulouration, trailing edge cracking, and trailing edge corner breakout were noted across the trailing edges of all of the HPTN guide vanes. Cracks in the convex side and material distress were also noted on five nozzle guide vanes. One of the nozzle guide vanes had a large section missing from its aft panel (convex side adjacent to the HPT rotor), and an adjacent portion of the trailing edge of this vane had been burned and eroded away with the loss of cooling air.

Examination of the fractured surfaces of the missing section of the assembly nozzle guide vane indicated that the separation was progressive in nature and occurred during normal engine operation.

The failure of the material on the convex face of the guide vane was consistent with low-cycle fatigue related to thermal stress. When the panel was liberated, the loss of cooling air meant the trailing edge of the vane was now subjected to more heat than the material could withstand and it was subsequently burned and eroded away. Examination of both the construction material and the repair material showed that both were in compliance with the manufacturer's specifications.

The HPT rotor assembly is a single-stage turbine with 80 air-cooled, dove-tailed blades. The failed HPT rotor blades and HPTN assembly nozzle segments were sent to the TSB Engineering Branch for metallurgical examination. All 80 turbine airfoils separated within 0.3 inches of their respective platforms. The fracture surfaces on all but one of the separations were characteristic of overload separation. The fracture surface of the remaining blade had a flat planar crack which originated at or near the trailing edge of the blade and propagated forward toward the leading edge of the blade.

The engine manufacturer, CFMI, had experienced cracking problems on the convex face of HPTN guide vanes in the past. These cracks, if
undetected, could propagate and eventually result in the loss of a section of the convex face of the nozzle guide vane. To ensure that the HPTN assemblies were removed from service before the nozzle guide vanes failed, CFMI developed a repetitive inspection process to detect defective HPTN guide vanes. The inspection criteria were detailed in CFMI service bulletin (SB) (CFM56-5) 72-170, which required a borescope inspection of the convex surface of the HPTN guide vanes to identify any cracking and/or material loss. A first inspection was to be performed after 3,200 cycles, and, depending on the nature of the cracks, re-inspections would be carried out after every 800, 400, or 100 cycles. Compliance with the SB was voluntary.

SB 72-170 was an interim control program which was brought into place while CFMI modified the nozzle design. The design improvements increased the nozzle durability and reduced its susceptibility to cracking of the convex face. The redesigned HPTN assemblies were re-identified as P/N 1358M73G30 and 1358M73G32. The installation of the redesigned HPTN assemblies as per CFMI SB (CFM56-5) 72-207 removed the need for the borescope inspection of the convex face of each guide vane as detailed in SB (CFM56-5) 72-170.

CFMI also developed a repair procedure to recondition unserviceable HPTN guide vanes which had cracked and been removed from service. Various size cracks, including thru-cracks had been brazed-fill repaired via Partitioned Alloy Component Healing (PACH). In addition to the repair, the nozzles were modified to meet the latest design and re-identified in SB (CFM56-5) 72-207 as P/N 1668M37G01, 1668M37G02, and 1668M37G03.

CFMI invited three airlines to participate in an "in-service" evaluation of five sets of repaired HPT nozzles. Contingent on Air Canada participating in the evaluation, CFMI, through its on-site representative, offered Air Canada two repaired HPTN assemblies at no charge. These were accepted and introduced into the Air Canada fleet. It was the view of Air Canada's maintenance and engineering staff that this offer was to compensate Air Canada for having to remove HPTNs prematurely because of cracks. The CFMI maintenance release tag stated in the comment section, "Parts have been PACH repaired for service evaluation." Air Canada's past experience with PACH type repair methods performed by the same vendor on CFM56-26 and Rolls Royce HPTN assemblies had been favourable. Neither Air Canada nor either of the engine manufacturers had in the past found it necessary to reduce the inspection interval on HPTN assemblies repaired by this method. Air Canada therefore had no hesitation in accepting these parts for the CFM56-5A engines.

In an internal CFMI document, the CFMI engineering department had requested that the service evaluation include an 800-cycle repetitive borescope inspection of the HPTN assembly, including the convex side of the nozzle guide vanes (as per SB [CFM56-5] 72-170), and that, if possible, a CFMI engineer be present when these inspections were carried out. CFMI's on-site representative at Air Canada rewrote the request and stated only that, "an inspection after 800 hours is
requested", and there was no mention of either inspecting the convex face or CFMI's desire to be present for the inspection.

The Air Canada engineering staff decided that an 800-hour (400-cycle) inspection was not required and did not action the request. Since the part numbers of the new HPTN were identified in SB (CFM56-5) 72-207, which stated "Incorporation of this Service Bulletin eliminates the need for the special on-wing borescope inspection per Service Bulletin (CFM56-5) 72-170R1," Air Canada decided to inspect the repaired HPTNs every 1,600 cycles. This decision was made without consulting the manufacturer.

The CFMI engineer responsible for the service evaluation program sent correspondence to CFMI's on-site representative at Air Canada on two occasions. The purpose of the correspondence was to confirm that the airline had agreed to participate in the evaluation and would inspect the convex surface of the HPTN assembly nozzle guide vanes with a borescope every 800 cycles and document the inspection results. At this time, there was a change of CFMI personnel at Air Canada. The first correspondence arrived immediately prior to the departure of the first representative and the second arrived shortly after the arrival of the second representative. The significance of the request was missed in the hand-over of responsibilities, and there is no indication that the information was passed on to the Air Canada engineering staff. The repaired HPT nozzle guide vanes underwent two 1,600-cycle inspections at Air Canada. Air Canada's inspection did not include a borescope inspection of the convex side of the nozzle guide vanes, and no documentation regarding the inspections or the condition of the guide vanes was provided to CFMI.

Subsequent engineering evaluations and calculations by CFMI revealed that the missing trailing edge section of the nozzle guide vane would cause a disruption in the flow of air through the nozzle. The disrupted airflow would produce a regular pulse wave on each of the turbine blades as the blades rotated past the damaged (missing) nozzle guide vane area. The pulse induced by the disrupted airflow was not, in itself, considered significant enough to cause an HPT blade to fatigue and fail. However, it was considered that, if one of the blades had a stress concentration point, such as a trailing edge crack, the pulse would be of sufficient magnitude to cause the crack to progress to the point of ultimate failure.

Analysis

The engine suffered a catastrophic internal failure when one of the HPT blades failed under normal operating conditions. The HPT blade had a fatigue crack which propagated to a point where the weakened blade could not withstand the normal operating forces imposed on it, and the blade separated from the rotating HPT rotor assembly. The liberated blade air foil interfered with adjacent and downstream moving engine parts, resulting in the overload separation of the remaining HPT blades and secondary low pressure turbine impact and over temperature distress.
The fatigue crack found in the HPT blade originated at or near the blade trailing edge and progressed forward towards the leading edge of the blade. The originating defect in the trailing edge of the blade was not identified. However, the presence of a small defect in an engine HPT blade, although undesirable, is not uncommon. Developmental testing by CFMI has established a crack acceptance limit of 0.10 inch of crack length. Cracks of less than 0.10 inch have been shown by CFMI not to be a threat to blade integrity; therefore, there is no reduction of the inspection interval time for blades cracked within that limit. The Air Canada boroscope inspections did not detect any cracks which exceeded the limit of 0.10 inch. The missing segment of the HPTN assembly nozzle guide vane, while in itself not significant enough to cause a sound HPT blade to fail, was significant enough in combination with the slightly defective HPT blade to result in failure of the HTP blade and, ultimately, internal failure of the engine. The HTP blade failed in fatigue.

The failed engine HPTN assembly was a repaired unit, provided by CFMI for an in-service evaluation of the repair procedures. The evaluation criteria written by the CFMI engineering department included an 800-cycle repetitive inspection of the convex surface of the nozzle guide vanes to monitor the status of the repaired nozzle segments. It could not be demonstrated that this information was communicated directly to the Air Canada engineering and maintenance departments.

The inspection information that was received by the Air Canada engineering and maintenance department, after being passed through several CFMI departments then several Air Canada departments, was incorrect--it detailed that a one-time, 800-hour inspection was required, and made no reference to the borescope inspection criteria for the convex surfaces of the HPTN assembly nozzle guide vanes. In addition, since the part number on the repaired HPTN assembly was identified in SB (CFM56-5) 72-207, the Air Canada engineering and maintenance staff assumed (without consulting with CFMI) that a 1,600-cycle inspection which did not include a borescope inspection of the guide vane convex surfaces was adequate.

Consequently, the repaired HPTN assembly nozzle guide vanes were not being inspected in accordance with the CFMI engineering recommendations for the service evaluation, and the fact that the convex surface of a nozzle guide vane had a substantial amount of material missing went unnoticed until the engine failure.

The following Engineering Branch report was completed:

LP 179/95 - Turbine Blade Failures.

Findings

- CFMI developed a repair scheme for cracked HPTN assembly guide vanes, supplied Air Canada with two repaired assemblies, and requested that Air Canada participate in an in-service evaluation program of the repaired components.
The repetitive inspection criteria to be used during the in-service evaluation of the repaired HPTN assembly nozzle guide vanes were not accurately conveyed to Air Canada.

Air Canada did not follow the inspection criteria they were given, nor did they query CFMI to ensure that the inspection cycle they employed was adequate.

Since SB (CFM56-5) 72-207 did not specify an inspection interval for the redesigned nozzle segments, Air Canada interpreted that the 1,600-cycle inspection procedures were adequate for the HPTN assembly components provided for the in-service evaluation.

The undetected progressive deterioration of an engine HPT nozzle segment guide vane contributed to the propagation of a fatigue crack in one of the engine's high pressure turbine blade airfoils.

The HPT blade failed in fatigue during normal engine operation, and the liberated blade caused the internal failure of the aircraft engine.

Causes and Contributing Factors

A high pressure turbine blade failed in fatigue during normal operation of the aircraft engine, causing catastrophic internal failure of the engine. Contributing to the blade failure was undetected damage to a repaired engine high pressure turbine nozzle assembly. Inspection requirements were not accurately communicated to Air Canada by the engine manufacturer, nor did Air Canada follow the inspection requirements they were given.

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

Controlled Flight into Water
Canada Jet Charters Limited
Learjet 35 C-GPUN
Masset, British Columbia 8 nm NW
11 January 1995

Report Number A95P0004

Synopsis

The Learjet 35 departed Vancouver International Airport, British Columbia, at 0035 Pacific standard time, on a one-hour medical evacuation flight to the Masset aerodrome in the Queen Charlotte Islands. On board the aircraft were two pilots and a medical team of three persons. During the instrument approach to runway 12 at Masset, the aircraft crashed into the ocean, eight nautical miles northwest of the Masset aerodrome. Intense Canadian military search and rescue operations, coupled with extensive civilian underwater searching, resulted in finding the aircraft wreckage and the bodies of two of the occupants; the other three occupants are presumed to have also perished in the accident. The aircraft was destroyed.

The Board determined that the crew most likely conducted the instrument approach with reference to an unintentionally mis-set altimeter of 30.17 in. Hg, and unknowingly flew the aircraft into the water. The circumstances leading to the incorrect altimeter setting could not be determined, nor was it determined why the crew did not detect the mis-set altimeter.

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1.0 Factual Information

1.1 History of the Flight

On 11 January 1995, at 0035 Pacific standard time (PST)<1>, the twin-engine Learjet 35 departed Vancouver International Airport, British Columbia, on a night, instrument flight rules (IFR)<2>, medical evacuation (MEDEVAC) flight to the Masset aerodrome, on the northern end of the Queen Charlotte Islands. On board the Learjet were a flight crew of two pilots, and a medical team consisting of two attendants and a doctor. Their mission was to evacuate a patient from Masset and deliver her to Prince Rupert for treatment; the aircraft was then to return to Vancouver.

The flight-planned route was at flight level (FL) 390, direct to Sandspit then direct to Masset. Following routine communications with Air Traffic Services (ATS), at about 0144, the aircraft reported "outbound" from the Masset non-directional beacon (NDB) on the published NDB "A" instrument approach procedure to runway 12. Air Traffic Control (ATC) radar, situated near Sandspit, tracked the aircraft as it flew the approach. Radar data shows that the aircraft began a descent about 10 seconds after it had completed the procedure turn and was established on the final inbound approach track. Forty-three seconds later, at a point 8.8 nautical miles (nm)<3> from the threshold of runway 12 and on the final, inbound track, the aircraft disappeared from radar.
Department of National Defence (DND) Search and Rescue (SAR) aircraft began searching the area shortly after the aircraft was declared missing, and were later assisted by other private and military aircraft and vessels. On the second day of the search, flotsam from the aircraft was found in the area. Extensive underwater searching using sonar and underwater cameras found the aircraft wreckage on 31 January 1995, in 260 feet of water, near the last known position. The aircraft had been destroyed.

The bodies of two occupants were found several days after the accident, but the other three occupants have not been found and are presumed to have been fatally injured. The accident occurred at latitude 54°08'N and longitude 131°58’W, at about 0149 PST, during the hours of darkness in unknown weather conditions.

1.2 Injuries to Persons

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1.3 Damage to Aircraft

The aircraft was destroyed by impact with the water.

1.4 Other Damage

None.

1.5 Personnel Information

<table>
<thead>
<tr>
<th></th>
<th>Captain</th>
<th>First Officer</th>
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<td>29</td>
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<td>Hours Off Duty Prior to Work Period</td>
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1.5.1 The Captain

The captain held a valid Airline Transport Pilot Licence (ATPL) and a Group 1 instrument rating, valid until 01 November 1996. A category 1 Licence Validation Certificate (LVC) had been issued for this licence, with a limitation that glasses had to be worn during flight, and was valid until 01 October 1995. The captain’s most recent Learjet 35 pilot proficiency check (PPC), which included an upgrade to captain status and an instrument rating test, was successfully completed on 31 October 1994.

The captain was hired by Canada Jet Charters Ltd. (the company) in September 1989 as a first officer for the Learjet aircraft. At that time, he had accumulated about 2,000 hours’ flight experience on several small and medium single- and twin-engine aircraft. Until his upgrade to captain on 31 October 1994, he had flown the company’s Learjet 25, 35, and 55 series aircraft as a first officer and had amassed about 2,450 hours on them. Since his upgrade, he had flown about 65 hours as pilot-in-command on the Learjet.

During his tenure with the company, the captain had flown many IFR operational and MEDEVAC flights, both day and night, and had flown into Masset on several occasions. His last flight before the accident...
was a night MEDEVAC from Prince Rupert on 09 January 1995, and previous to that, on 07 January 1995, he flew a MEDEVAC flight into Masset in C- GPUN.

Before joining the company, the captain had flown as a flight instructor providing basic, instrument, and multi-engine flying instruction. He had also been employed as a pilot with two other air carrier and charter companies in Vancouver operating Cessna 402, 414, and 421 aircraft.

A review of both the Transport Canada (TC) and the company files did not reveal any adverse aspects of the captain's aviation career and experience; the review identified a normal and competent progression of training, experience, development, and advancement.

1.5.2 The First Officer

The first officer held a valid ATPL and Group 1 instrument rating valid until 01 December 1996, and a valid class 1 instructor rating valid until 01 May 1996. A category 1 LVC had been issued for this licence, without limitation, and was valid until 01 July 1995. His first and only Learjet 35 PPC was successfully completed on 14 November 1994, during which he was evaluated as a first officer only. This classification is a common air carrier practice and allows for pilots, inexperienced on type, to accumulate on-the-job experience under the supervision of experienced captains.

The first officer was hired by the company in November 1994 as a first officer for the Learjet aircraft. At that time, he had accumulated about 2,800 hours' flight experience on several small and medium, single- and twin-engine aircraft. In his short time with the company, the first officer had flown about 60 hours as first officer on the Learjet, of which about 7 hours were spent in training. He had flown about 20 IFR operational and MEDEVAC flights, totalling about 55 hours, of which 27 hours were at night. He had not flown into Masset previously. His last flight before the accident was a night MEDEVAC into Cranbrook on 06 January 1995, and previous to that, on 05 January 1995, he flew a night MEDEVAC into Prince George.

Before joining the company, the first officer had flown as a flight instructor providing basic and multi-engine flying instruction, and he had worked for another air carrier in Vancouver as a first officer on Beechcraft 99 series aircraft. None of these aircraft flew above 18,000 feet.

The bulk of his flying with the company had been conducted with either the chief pilot or the company training captains. He had been on the line for nearly eight weeks, and had only begun flying with regular line captains on 22 December 1994.

A review of both the TC and the company files did not reveal any adverse aspects of his aviation career and experience; the review identified a normal and competent progression of training, experience, development, and advancement.

1.5.3 Crew Personality Profiles

Although they had only flown together for 1.2 hours, the captain and first officer were thought by their fellow employees to have interacted well, both as a crew and as fellow aviators.

The captain, a single man, was said to have been a quiet, compassionate, and meticulous individual. He was regarded as a conscientious pilot, respected by his peers and supervisors in the company. He had no significant outside pressures.

The first officer, a happily married man, was said to have been a well-adjusted and dedicated individual who was in the early stages of his aviation career. He was new to the company; nevertheless, he was regarded by his peers as helpful and energetic, and by his supervisors as a cheerful person with a positive, professional attitude. He did not have any significant outside pressures.

1.5.4 Pilot at the Controls

Eyewitnesses confirm that, when the Learjet taxied away from the company terminal at Vancouver, the captain was seated in the left seat. Additionally, the medical examination of the captain revealed injuries consistent with control manipulation during impact, indicating that he was likely flying the aircraft.
ATS audio tape recordings and company interviews indicate that the first officer made most of the radio communications upon departure from Vancouver and en route, although the captain's voice was also identified on the ATS tapes. It is common practice within the company that the pilot not flying make the radio calls; however, based on cockpit workload, either pilot may use the radio. Furthermore, by company convention, the captain normally flies the outbound leg and, at the captain's discretion, the first officer flies the return leg.

For these reasons, and because the captain would have likely preferred to fly the demanding night approach into Masset, it is most likely that the captain was flying the aircraft. However, without cockpit voice recorder (CVR) information from the accident flight, there is not enough evidence to confirm that the captain was flying the aircraft when it struck the water.

### 1.6 Aircraft Information

<table>
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<th>Manufacturer</th>
<th>Bombardier Learjet Inc.</th>
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<tbody>
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</tr>
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<td>Serial Number</td>
<td>35-058</td>
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<td>Certificate of Airworthiness</td>
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<tr>
<td>Engine Type (number of)</td>
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<td>Recommended Fuel Type</td>
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<tr>
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The airframe and engines maintenance records for C-GPUN were reviewed for the period from April 1976 to the accident date. The review showed that the company maintenance practices were in accordance with requirements as specified in Air Regulations and Air Navigation Orders that pertain to their operations.

The aircraft was certified, equipped, and, with the exception of CVR testing, maintained in accordance with existing regulations and approved procedures.

The aircraft was purchased new by the company from Learjet. In October 1988, it was involved in a landing accident which caused substantial damage to the landing gear and wings (TSB occurrence report A88P0252). The aircraft was rebuilt by the manufacturer, returned to the company, and had since been in continuous service without further mechanical incident.

In accordance with company procedures, a copy of the aircraft weight and balance loading form for this flight was left behind at the company dispatch office at the Vancouver airport. The aircraft's weight at the time of the occurrence was estimated to have been 14,150 pounds, which is 3,850 pounds below the maximum certificated all-up weight. The centre of gravity was estimated to have been within the prescribed limits throughout the flight.

C-GPUN was not equipped with a ground proximity warning system (GPWS), but it had been in the past. A GPWS is an electronic system that automatically operates without any pilot input and provides pilots with a timely and distinctive warning, both visible and audible, that their aircraft is in potentially hazardous proximity to the earth's surface. GPWS has prevented many accidents where, until the warning was given, the pilots had been unaware that the aircraft was in danger because of its proximity to the ground or water. Air Navigation Order (ANO) Series II, No. 22 indicates that only turbo-jet aircraft in excess of 33,069 pounds are required to be fitted with GPWS; there was no regulatory requirement that Learjet 35 aircraft be so equipped. The Board is concerned that safety equipment is being removed from aircraft because it is not required by regulation.

### 1.7 Meteorological Information

#### 1.7.1 Weather Reports for Masset

The Masset aerodrome had no provision for reporting weather conditions to an acceptable Atmospheric
Environment Service (AES) standard. There was no calibrated meteorological equipment, nor was there an accredited weather observer. As a result, pressure altimeter settings and weather observations from Masset, if any, were informal and for general information only. The nearest approved weather observation station was the manned lighthouse at Langara Island, located about 35 nm west of Masset, which provided human-observed weather reports during daylight hours. At night, these observations reverted to hourly reports from the Automated Weather Observation System (AWOS) station at Langara Island. An AWOS located at Rose Spit, about 12 nm northeast of Masset, also provided hourly reports. An AWOS located at the Sandspit aerodrome, about 48 nm south of Masset, provided normal and ongoing weather observations. Weather observations were also available from the manned station at Prince Rupert, about 70 miles east of Masset.

In addition to other meteorological information, an AWOS station also measures atmospheric pressure using two separate electronic sensors. Mean sea level pressure is reported to the nearest 0.1 millibar (mb), while the altimeter setting is reported to the nearest 0.01 inches of mercury (in. Hg). The pressure sensors are fail-safe; that is, if one unit is out of tolerance more than 0.04 in. Hg, the altimeter setting information is not reported.

On the night of the accident, the Sandspit AWOS5 station was apparently functioning correctly. The Langara and Rose Spit AWOS1 stations—which do not transmit information concerning ceiling, visibility, or altimeter setting—were also functioning correctly. Both stations continued to report the mean sea level pressure and temperatures.

1.7.2 Sandspit Weather

The 0100 PST weather report at Sandspit was as follows: estimated ceiling 1,600 feet\(^5\) overcast, visibility more than 9 miles, light rain, 987.8 mb sea level pressure, temperature 7 degrees Celsius, dew point 6 degrees Celsius, wind from 120 degrees true at 20 knots, and altimeter setting 29.17 in. Hg.

The 0129 special weather report was as follows: 100 feet scattered, estimated ceiling of 1,200 feet broken, 2,000 feet overcast, visibility 5 miles in rain, temperature 7 degrees Celsius, dew point 6 degrees Celsius, wind from 110 degrees true at 12 knots, and altimeter setting 29.17 in. Hg.

The 0136 special weather report was as follows: 100 feet scattered, estimated ceiling of 1,900 feet overcast, visibility 4 miles in heavy rain, temperature and dew point 6 degrees Celsius, wind from 120 degrees true at 16 knots, and altimeter setting 29.17 in. Hg.

The subsequent weather reports until 0800 PST continued to report the altimeter setting gradually rising from 29.17 to 29.20 in. Hg.

1.7.3 Masset Weather

According to the aerodrome manager at Masset, the weather conditions up to the time the aircraft was declared missing were not adverse. At 2330 on 10 January 1995, he had informed the Learjet pilot by telephone that the wind was from the southeast at about five knots, with light rain, and that the visibility was such that he could clearly see the lights on the NDB tower. The NDB tower is 585 feet high. When the aircraft called over the beacon outbound, the wind and visibility had remained unchanged, and the light rain had reduced in intensity. No local altimeter setting was requested by, or given to, the pilot. The actual inflight weather conditions offshore were not known.

1.7.4 Masset Weather Aftercast

During the early hours of 11 January 1995, a low pressure area (975 mb or 28.80 in. Hg) was centred 200 miles southwest of Masset. This feature was generating a moderate 15- to 25-knot northeasterly wind in the lowest levels along the north coast of Graham Island. Above 2,000 feet, the winds veered to the southeast with speeds of 25 to 35 knots. Vertical windshears of 10 knots per thousand feet of altitude were likely present between 2,000 and 4,000 feet. The air mass was moist and stable. A weak trough in the upper atmosphere was generating broken layers of stratocumulus based at 2,000 feet and additional overcast layers of altocumulus. The cloud shield also produced light and locally moderate rain. Scattered to broken layers of stratus cloud formed in the precipitation and produced local ceilings of 200 to 800 feet. In areas of offshore flow, such as Prince Rupert, the visibility was greater than six miles, but in areas of onshore flow, such as Masset, rain and fog patches would have reduced the visibility to one mile. The
1.7.5 Flight Crew Briefings

An examination of the flight planning document left behind by the crew, and a review of the taped conversations between the crew and various ATS facilities, reveal that the pilots had obtained the most recent and appropriate forecast and actual weather conditions for the area, the destination, and the alternate and surrounding aerodromes, both before and during their flight. Just before descending from FL390, the first officer received and acknowledged a Sandspit altimeter setting of 29.17 in. Hg from Vancouver ATC. It could not be determined if he adjusted his altimeter at that time.

1.8 Aids to Navigation

The navigational aids available at the Sandspit aerodrome were an NDB, a very high frequency omni-directional range (VOR) station, and a distance measuring equipment (DME) system, which were all reported by ATS as serviceable at the time of the accident. The navigational aid available at the Masset aerodrome was an NDB, which was also reported as serviceable at the time of the accident. Although the beacon was owned and operated by the village of Masset, there is a formal arrangement with the DND at Canadian Forces Base (CFB) Masset to continuously monitor the performance of the beacon. The ATC Secondary Surveillance Radar (SSR) situated near the Sandspit aerodrome was fully functional at the time and received track and altitude data of the Learjet down to the point where contact was lost.

No evidence was found to indicate that any of the on-board aircraft navigation systems had malfunctioned, either during the accident flight or in recent service. None of the DND SAR aircraft or other aircraft responding to the scene of the accident reported any difficulty with the Masset NDB.

1.9 Communications

A review of the applicable ATS audio tapes revealed that radio communications between all ATS facilities and C-GPUN had been normal throughout the flight. The review identified the first officer as the flight crew member principally communicating with Vancouver Area Control Centre (ACC), and revealed that all communications characterized an alert and professional flight crew. The last radio transmission from the aircraft was the "outbound" report to the Masset aerodrome manager at the beginning of the approach to Masset on 123.2 MHz, the aerodrome traffic frequency. There had been no distress call, and at no time did the crew indicate they were experiencing any difficulties.

1.10 Aerodrome Information

1.10.1 Masset Aerodrome Information

The Masset aerodrome is located near the northeastern corner of Graham Island, about 1.5 miles north of the village of Masset. The aerodrome geographical reference point is at latitude 54°01.29¢N and longitude 132°07.06¢W, with a reference elevation of 24 feet above sea level (asl). It is registered as a public-use aerodrome and is operated and maintained by the Village of Masset. At the time of the accident, the only runway, runway 12/30, was 4,400 feet long and 75 feet wide. Apart from 200 feet of level gravel surface at each end of the runway, the paved surface was smooth asphalt in unremarkable condition.

A DND communication complex, CFB Masset, is situated about four miles east of the aerodrome, and is surrounded by a 30-foot tall enclosure fence, marked by obstruction lights on the fence support posts. The villages of Masset and Old Masset lie to the west of the aerodrome and have conventional residential and commercial lighting.

1.10.2 Runway Lighting

Canadian Aviation Regulations (CAR) Series III, No. 2, Airport Regulations, is the order respecting minimum lighting at aerodromes. On 19 October 1994, this CAR replaced the former ANO Series III, No. 2, the Aerodrome Minimum Lighting Order. In essence, however, the new CAR embodies the provisions and requirements of the former ANO; the obligation to ensure that appropriate lighting is available for an aircraft to land and take off at an aerodrome at night continues to rest with the pilot-in-command.

In part, CAR Series III, No. 2, section 3(1), requires that an aerodrome, where it is to be used at night,
display lights "... to mark take-off and landing areas, [with] two parallel lines of fixed white lights visible in all directions for at least two miles." Section 3(2) of the CAR establishes the arrangement of the lights forming the parallel lines.

The runway lights used at Masset are individual, portable, battery-operated lights that are set up by the airport staff when required. At the time of the accident, the runway was lighted for an aircraft arrival on runway 12. The Village of Masset had issued written instructions to be followed with respect to the arrangement of this lighting. These instructions were in accordance with the applicable CAR, and the lighting on the night of the accident exceeded the CAR requirements. The only variation from the requirements was that the parallel lines of lights consisted of amber and white lights, placed alternately in line, instead of all white lights.

1.10.3 The NDB "A" Approach to Runway 12

In accordance with the instrument approach procedures published in the Canada Air Pilot (CAP) - West dated 08 December 1994, an aircraft conducting the Sandspit transition to the NDB "A", non-precision approach to runway 12 at Masset would initially cross the Masset NDB at an altitude of 3,600 feet asl and proceed outbound on a track of 300 degrees magnetic. It would then enter the procedure turn and maintain 1,600 feet asl, before descending on the final inbound track to the minimum descent altitude (MDA) of 600 feet for Category "C" aircraft; the Learjet was a Category "C" aircraft. In accordance with the remote altimeter setting procedures, 240 feet must be added to these altitudes as minima.

The aircraft's track during the instrument approach, as recorded by the ATS radar and the aircraft flight data recorder (FDR), closely matched the desired track as published on the CAP- West approach plate.

Appendix A (Instrument Approach at Masset) is a reproduction of the approved Masset NDB "A" instrument approach in effect at the time of the accident.

Appendix B (Altitudes Flown) is a representation of the actual approach altitude profile flown by C-GPUN, determined from both the ATC radar data and the aircraft FDR, compared with an approach profile flown at the indicated altitude, assuming that 30.17 was set on the altimeter sub-scale.

1.10.4 On Approach to Runway 12 at Night

On the night of the accident, the obstruction and security fence lighting on the CFB Masset communication complex was turned on, and the villages of Masset and Old Masset were illuminated with the usual village and street lighting. It could not be determined whether the Learjet crew saw any of this lighting.

During wreckage recovery, members of the investigation team in the recovery vessel, positioned in the area of the aircraft wreckage about eight miles offshore, at night, noted that the security fence lighting around CFB Masset was clearly visible. When accident investigators flew into Masset, their aircraft flew in on the NDB "A" approach to runway 12. During this approach, which was conducted during darkness and clear weather conditions, the DND facility lighting was visible from at least 10 miles offshore, and the runway lighting was not clearly visible until about three miles from the threshold of runway 12.

Because of the low intensity of the portable runway lights, the crew would not have seen them from an altitude of 800 feet asl during the final part of the procedure turn inbound to the aerodrome, or from a position of 8.8 miles from the runway, that is, the point of impact.

1.11 Wreckage and Impact Information

1.11.1 General

On 19 January 1995, a fishing trawler, seven miles north of the Masset aerodrome, pulled aircraft debris up in its net. These parts were later identified as sections of the cockpit and lower fuselage of C-GPUN. On 31 January 1995, underwater sonar located what appeared to be the wreckage in about 260 feet of water in a location that coincided with the final approach path for runway 12 at the Masset aerodrome.

The main wreckage of the Learjet was not positively identified until 08 February 1995. Underwater sonar mapping and optical inspection using a video camera mounted in a remotely operated vehicle (ROV)
revealed that the wreckage site was concentrated in an area of about 100 square metres. The wreckage consisted of most of the aircraft except the cockpit and cabin section forward of the wings, which could not be located.

The Learjet had broken apart into several major components; the rear fuselage section and vertical fin, the horizontal stabilizer and elevators, the central wing section, the wing extensions, the tip tanks, and the two engines and pylons. A portion of the cockpit central instrument panel containing some engine performance gauges was also found. The landing gear was not found. The only part recovered of the main aircraft wreckage was the rear fuselage and vertical fin section which contained the flight recorders.

1.11.2 Aircraft Wreckage Examination

The parts of the cockpit brought up by the fishing boat were examined by TSB investigators, and the gaugeshield warning panel and fire T-handles were sent to the TSB Engineering Branch for examination and analysis. The T-handles were found in the stowed position.

The aircraft wreckage was examined intensively using the underwater video camera on the ROV and was recorded on videotape. The portion of the instrument panel containing the engine gauges was examined using the underwater video camera; it was not possible, however, to clearly or accurately read any of the gauges, nor could the underwater vehicle successfully recover the instrument cluster for later examination. The panel also contained the "set altitude" alerter device used by pilots to alert them of the next pertinent altitude; it was found to have a setting of between 800 and 900 feet. Such a setting could have been consistent with conventional instrument approach procedures; however, that the one-hundred-foot digits "8" and "9" were both visible in the window, that is, in an abnormal "mid-way" position, indicated that the original setting had been disturbed, presumably during the accident sequence. As a result, the setting on the device at impact could not be determined, nor could it be ascertained if, or when, this crew had entered a setting.

The rear fuselage and vertical fin section were taken to the TSB Regional wreckage examination facility in Vancouver and examined by TSB investigators with the assistance of an aircraft airworthiness representative from Learjet. Nothing was found to indicate that any structural failure or system malfunction had occurred before impact.

Of particular importance, the condition of the following components was noted:

- Wing fuel crossflow valve was closed. (normal)

- Fuselage fuel transfer valve was closed. (normal)

- Left and right main fuel shut-off valves were open. (normal)

- Left and right motive flow fuel shut-off valves were open. (normal)

- Left and right hydraulic shut-off valves were open. (normal)

- Left and right fire extinguisher bottles were charged at 600 and 650 psi respectively, with both firing "squib" devices intact. (normal)

- Hydraulic accumulator was charged to 850 psi. (normal)

- Horizontal stabilizer actuator was found in the -5.04 degree position.

Pulling the T-handle closes the main fuel shut-off valves and the hydraulic shut-off valve, among other things. Because the T-handles were stowed and the afore-mentioned valves were in the normal position, it can be concluded that the T-handles were not pulled.
The position of the horizontal stabilizer actuator indicates that, at the time of impact, the stabilizer was trimmed to a position within the normal range of movement, consistent with the aircraft attitude and configuration during the final stages of an approach. There was no evidence of control cable irregularities.

In summary, the underwater video analysis and the examination of the tail section found no evidence to suggest that the aircraft was not complete, intact, or functioning normally at the time of impact.

1.11.3 Engine Examination

An examination of the engines was carried out and recorded using the underwater video camera on the ROV. The video reveals significant rotational damage to the No. 2 (right) engine fan blades; such damage is consistent with that caused when an operating engine strikes water. There was no evidence of engine fire or other malfunction on either engine.

1.11.4 Light Bulb Examination

A section of the gareshield containing the warning light panel, autopilot controller, and the two fire T-handles was examined by the TSB Engineering Branch. These components all contained lamps which may have been illuminated at the time the aircraft experienced high impact forces. Lamps are routinely examined to determine if the filaments exhibit any deformation caused by impact forces. Depending on the severity of the impact, a glowing tungsten filament will typically exhibit deformation or stretching of its coils, whereas a cold filament may not exhibit any deformation or it may exhibit brittle type fractures. The results of the lamps examination are contained in TSB Engineering Report 8/95 and are summarized below.

The report identified that the lamps in the No. 2 engine fire T-handle, the map light, the augmentation aileron system (AUG.AI) warning, and the right vertical gyro monitor (RVG MON) warning were likely on when they were subjected to impact forces sufficient to damage the filaments. The report continues, however, to say that it was unlikely that all three of these warning lights would have been on prior to impact; therefore, it is possible that some or all of the lights may have been activated during the initial impact.

The most critical item of concern raised by these findings was the possibility of fire in the No. 2 engine. A review of the electrical circuitry of the fire detection system reveals that it would have been possible to have had a false fire indication if the heat sensing elements were damaged or shorted out. The illumination of the No. 2 engine T-handle lights may have been the direct result of impact damage, and may be a false indication of an engine fire.

In summary, since the FDR had continued to record data for five seconds after the initial impact, electrical power was available to illuminate any warning lights that may have been activated because of associated structural or system damage during the breakup sequence. It could not be ascertained if any of the warning lights were illuminated before impact.

1.12 Medical Information

The LVC limitation that the captain had to wear eye-glasses during flight was imposed as a result of some deterioration in his long range vision; his short range vision was normal. Witnesses observed that the captain was not wearing his glasses at the time of departure from the ramp; however, he had reportedly worn contact lenses for some time and had flown with them regularly. It could not be determined if the captain was wearing glasses or the contact lenses at the time of the accident.

The medical examination and toxicological tests conducted on the captain did not identify any pre-existing medical conditions which could have affected his performance. There was no indication of incapacitation. A review of both pilots' medical records, examination results, and their most recent activities did not reveal any sign of physiological or psychological factors which could have affected their performance.

1.13 Flight Recorders

1.13.1 General

The aircraft was equipped with both a flight data recorder (FDR) and a cockpit voice recorder (CVR). Both
recorders were recovered intact from the wreckage and analyzed by the TSB Engineering Branch.

1.13.2 Flight Data Recorder

At the time of the accident, regulation regarding the installation of the flight data recorders was contained in ANO Series II, No. 13, the Flight Data Recorder Order, which, in part, required that turbine-equipped, pressurized aeroplanes weighing more than 12,500 pounds be equipped with a serviceable and functioning FDR. The ANO also required that, in addition to the five mandatory parameters, further specific parameters were also to be recorded. An exemption from this additional requirement had been formally granted by TC to the company for their Learjet aircraft, including C-GPUN, on 07 December 1988.

The FDR on board the aircraft, a Sundstrand Universal digital FDR, had captured the last 25 hours of flight information with respect to nine parameters. Altitude information captured by the FDR is referenced to the standard altimeter setting of 29.92 in. Hg and, except when the existing barometric pressure equals this value, does not reflect the true altitude of the aircraft above mean sea level (asl).

The data recovered from the FDR was of good quality, and it provided investigators with an accurate record of the aircraft parameters up to the point of impact.

FDR data revealed an unremarkable flight from Vancouver until the top-of-descent (TOD) at FL390 at about 0127.

From TOD, the Learjet descended to an initial altitude of about 3,400 feet standard pressure altitude (pa) based on 29.92 in. Hg; based on the actual barometric pressure setting at the time, this altitude was about 2,650 feet asl. The aircraft then gradually climbed to about 3,650 feet pa (2,900 feet asl). At 0144:20 PST, the aircraft began a descent to about 1,400 feet pa (650 feet asl). Twenty-five seconds later, the aircraft climbed to maintain 1,650 feet pa (900 feet asl) until 0149 PST, when it began a descent to the initial impact point of about 750 feet pa (0 feet asl). The aircraft struck the water at a recorded airspeed of 138 knots on a heading of 107 degrees.

Appendix C (Indicated Altitudes) is a representation of the last 12 minutes of the primary altitude trace from the FDR at 29.92 in. Hg, with the same altitude trace duplicated for two other pressure settings, namely, 29.17 and 30.17 in. Hg. The trace marked “29.17” represents the true altitude of the aircraft above the water; the trace marked “30.17” represents what the pilot would have seen had his altimeter been set to this value.

This descent profile, to the point of impact, accurately corresponds to the required transition and instrument approach procedures; the altitudes flown do not. Concomitant with this descent profile were headings, airspeeds, and intervals nearly identical to those required by the approach. At no time did the FDR data indicate that the aircraft deviated from the flight planned route, or that the crew was experiencing any difficulty in flying the approach.

The FDR data indicate that the impact was at an elevation of 750 feet above sea level; however, the aircraft actually crashed at sea level. The FDR records data at an atmospheric pressure of 29.92 in. Hg, but the actual atmospheric pressure at the time was 29.17 in. Hg, which corresponds to a 750-foot difference in altitude.

1.13.3 Cockpit Voice Recorder

At the time of the accident, regulation pertaining to the installation of the CVR was contained in ANO Series II, No. 14, the Cockpit Voice Recorder Order, which, in part, required that turbine-equipped, pressurized aeroplanes weighing more than 12,500 pounds be equipped with a serviceable and functioning CVR. The ANO also stipulated that when a CVR became inoperative, and the FDR remained functioning, the aeroplane might be flown only to complete a planned itinerary to a maintenance base.

The CVR on board the aircraft was a Collins, four-track unit, which, by design, recorded the last 30 minutes of both internal and external communication with the pilots. The tape cartridge in this unit was found jammed; a review of the tape contents revealed that the unit had last functioned 12 days before the accident. As a result, no information regarding the accident flight was available to the investigation.

A cockpit-mounted CVR control unit contains the cockpit area microphone, a “phone” jack, a test button,
and an associated meter. When the test button is pressed, a test signal is recorded onto the tape; a corresponding deflection of the needle on the meter indicates that the unit is serviceable. The test can be performed at any time electrical power is available to the CVR unit, but some companies carry out the test daily during the pre-start process. At the time of the accident, the company did not require pilots to conduct operational checks of the CVR units, nor was there any regulation requiring such tests.

Company aircraft maintenance schedules for the Learjet included a CVR performance check every 150 hours, which was scheduled to take place concurrently with a 150/300-hour engine zone inspection on both jet engines. This CVR test involved both aural and visual monitoring of the test signal using the "phone" jack and the meter. The last engine inspection was performed on 04 January 1994, but the CVR test was inadvertently omitted; the unit had jammed four days earlier. The cause of the malfunction could not be determined, but the character of the jam indicated that the tape would have suddenly stopped without warning and remained jammed.

1.14 Altimetry

1.14.1 Radio Altimeter

The Learjet was required by ANO Series II, No. 16, to be equipped with a radio altimeter (radalt). The aircraft was fitted with a radalt with direct scale reading of altitude from 0 to 2,500 feet, and incorporated a manual altitude setting knob and "bug," with an associated warning light. There were two repeater lights on each end of the central warning light panel, and all lights would have been illuminated whenever the radalt indicated an altitude less than the bug value set by the pilot. The bug can be set to below zero on the instrument, thereby disabling the warning light; some pilots find the warning light distracting, particularly at night, when flying at set minima. The electrical power to the radalt system is controlled by a single switch in the cockpit, operated by the left-side pilot.

Normal practice in the company was to set and maintain the radalt bug to below zero while the aircraft was en route. The MDA or the decision height (DH) for the approach was normally set on the radalt during descent from cruise altitude, or on passing the transition level at 18,000 feet.

The radalt was not found. TSB Engineering Branch analysis (LP 8/95) concluded that the altitude warning lights for the radalt, on the central warning panel, were not illuminated when they were subjected to accident impact forces; whether the lights were on immediately before impact could not be determined.

1.14.2 Pressure Altimeters

The aircraft was equipped with two altimeters, one on each side of the instrument panel. The left-side (captain's) instrument consisted of a Mode "C" encoding altimeter, an altitude alerter, and a Static Defect Correction Module. The pilot used and set the altimeter in the same way as a conventional barometric altimeter. The altimeter face scale was graduated in 20-foot increments from 0 to 1,000. The single pointer made one complete revolution for each one thousand feet of altitude. At the centre of the instrument face was a horizontal counter which read in hundreds and thousands of feet. Above and below this counter were the two altimeter sub-scale windows, graduated in both inches of mercury and millibars.

Directly associated with the captain's altimeter, the altitude alerter compares the indicated altitude to the value set in the "set altitude" device on the instrument panel. As the aircraft approaches 1,000 feet of a preset altitude, an altitude alert light and a momentary audio signal (chime) are activated. The light remains on until the aircraft is within 300 feet of the preset altitude. The chime will sound and the light will illuminate whenever the altitude deviates 300 feet from the preset value. Normally, company first officers set the alerter to either the MDA or the DH when extending the landing gear and flaps as the aircraft intercepts the final inbound leg of the approach.

The right-side (first officer's) altimeter was a conventional barometric altimeter, which indicated aircraft altitude in a presentation identical to the captain's altimeter. There was no altitude alerting device or static correction system connected to it. This would cause the right-side altimeter to read differently from the left-side altimeter. There is an acceptable differential published in the aircraft flight manual. This altimeter would not correspond to the captain's, with the normal differential of about 700 feet at FL390. By design, the differential decreases upon descent, and at lower altitudes, it diminishes to zero where the altimeters would indicate identical altitudes when set to a common sub-scale setting.
The FDR data for this accident flight indicated that this altimeter differential became negligible below 4,000 feet pressure altitude.

1.14.3 Altimeter Setting Procedures

In the Designated Airspace Handbook (TP 1820E), Canadian domestic airspace is divided into two finite areas, the Altimeter Setting Region (ASR) and the Standard Pressure Region (SPR). In summary, the ASR is an airspace of defined dimensions below 18,000 feet asl; airspace below 18,000 feet asl is also termed the "low level airspace." An SPR includes all the airspace at or above 18,000 feet asl and all low level airspace that is outside the specific dimensions of the ASR.

ANO Series V, No. 16, the Altimeter Setting Procedures Order, requires that pilots operating aircraft in the ASR continue to reset their altimeters to actual altimeter pressure settings at appropriate departure, en route, and destination aerodromes or reporting stations. Pilots operating aircraft in an SPR are required to set and maintain the standard altimeter setting of 29.92 in. Hg. Furthermore, when descending from the SPR into the ASR, pilots shall set their altimeters to the appropriate station altimeter setting immediately prior to entering the ASR. As a result of these procedures, professional pilots in high performance aircraft are constantly cognizant of the meteorological conditions, particularly barometric pressure, at destination aerodromes, and verifying and changing an altimeter setting is standard practice.

The Masset aerodrome lies within the ASR. During this accident flight, the aircraft would have been required to fly in the ASR for the departure from Vancouver and the approach at Masset, and in the SPR while en route at FL390.

1.14.4 Remote Altimeter Setting

Normally, pilots fly instrument approaches using the current altimeter setting for the destination aerodrome. At certain aerodromes, however, where a verified local pressure setting is unavailable, approaches are flown using a current altimeter setting from a nearby aerodrome. Such an altimeter setting is considered a "remote" setting, and authorization for its use is published in the top, left-hand corner of the CAP approach plate. When the remote altimeter setting is used, the pilot must apply an altitude correction factor to all published instrument procedure minimum altitudes.

In the Masset NDB "A" instrument approach, the remote setting procedure was authorized for the Sandspit pressure setting, and the approach plate advised that the altitude correction factor of 240 feet had to be added to all altitude minima. For example, the published procedure turn altitude was 1,600 feet, but to comply with the remote altimeter setting procedure, aircraft were required to conduct the turn at 1,840 feet, that is, 240 feet higher than published.

1.14.5 True Height versus Altimeter Setting

Altitude information indicated by an altimeter, although technically "correct" as a measure of air pressure, may differ greatly from the actual height of the aircraft above mean sea level or the ground. Such variation is the result of the continually changing barometric pressure, and it is compensated for by incorporating a pilot-controlled sub-scale mechanism in the altimeter.

This same altitude variation is also caused by the aircraft itself travelling between areas of differing air pressures, and unless the pilot again adjusts the altimeter sub-scale setting on the altimeter, the indication of the actual height above terrain will be erroneous. A similar situation would occur when an aircraft transitions between the ASR and the SPR.

Whether a pilot inadvertently sets an incorrect altimeter setting on the sub-scale, or flies into an area of differing pressure without adjusting the sub-scale, the result is the same--the altimeter reading will be erroneous. This error is an amount proportional to 1,000 feet indicated altitude for each in. Hg of barometric pressure that the sub-scale is in error. If the actual station pressure is a lower value than the one set in the altimeter sub-scale, the aircraft's true altitude is lower than the figure displayed by the altimeter. For example, if the station pressure is 29.17 in. Hg and the altimeter sub-scale is set to 29.92 in. Hg, the aircraft's true altitude is 750 feet lower than the altitude displayed by the altimeter.

1.14.6 C-GPUN Altimeter Settings
At 0110, the first officer acknowledged a message from Vancouver ACC which indicated that the station pressure at Sandspit, 48 miles south of Masset, was 29.17 in. Hg, and that the station pressure at Prince Rupert, about 70 miles east of Masset, was 29.26 in. Hg. At 0125, the first officer acknowledged another message from ACC which relayed the most recent Sandspit pressure of 29.17 in. Hg.

Sandspit was the nearest station to Masset issuing a current, verified altimeter setting, and, in accordance with procedures, both pilots were required to have set the Sandspit setting on their altimeter sub-scales before the aircraft descended below 18,000 feet on the descent to Masset.

Radar and FDR data confirm that the aircraft altitude was in accordance with the altimeter setting procedures from take-off until the descent from FL390; it cannot be determined what altimeter settings were used, or set, in the aircraft during the descent from FL390. The data in the following table do show, however, that the aircraft was consistently at an incorrect altitude from at least the Sandspit transition procedure to impact. Note that the values are averaged.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>CAP altitude required</th>
<th>Remote setting altitude required</th>
<th>FDR</th>
<th>Altitude difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition</td>
<td>3,600</td>
<td>3,840</td>
<td>2,900</td>
<td>700/940</td>
</tr>
<tr>
<td>Procedure Turn</td>
<td>1,600</td>
<td>1,840</td>
<td>900</td>
<td>700/940</td>
</tr>
<tr>
<td>MDA</td>
<td>600</td>
<td>840</td>
<td>0*</td>
<td>600/840</td>
</tr>
</tbody>
</table>

* impact

1.15 Company Operational Information

1.15.1 Crew Resource Management Training

There was no formal crew resource management (CRM) training provided to the company pilots. In August 1993 and September 1994, the company invited TC System Safety personnel to provide pilot decision making (PDM) training. The training was well received by the company and by those pilots who attended. The captain attended both courses, but the first officer had not yet been hired by the company.

Without the benefit of a functioning CVR, it is not possible to determine how this flight crew interacted during the accident flight. CRM methods are designed to improve the quality of communication, problem solving, and decision making; this creates an increased level of situational awareness and should reduce errors.

1.15.2 Crew Coordination

The company had no written standard operating procedures (SOPs) for their aircraft, nor did TC require air carriers to have them. TC recommends that companies have SOPs because they greatly improve crew coordination and overall operational safety. The procedures of flying the Learjet are introduced to the pilot during the initial ground and flight training phase, as well as in the line indoctrination.

During interviews with company pilots, it was determined that there was variation in the conduct of flight procedures between captains. Every six months, during ongoing flying training, the company training captains reviewed and identified standard flight procedures, but there was no formal standardization training.

In the absence of SOPs, normal company procedures for an approach would have included an approach briefing, descent checks, landing checks, and altitude calls. According to the company training captain, the pilot flying (PF) would brief the pilot not flying (PNF) before the descent, or at a convenient time, indicating his intentions for the approach and the altitudes to be flown in accordance with the appropriate approach plate.

During the descent, the PF would call for the descent checks and the checklist would be completed by the challenge and response method. The item "altimeter setting" was in the descent check. The company procedure required that the destination altimeter setting be set on the right-hand side altimeter, even though the aircraft might be well above 18,000 feet.

As the aircraft descended out of 18,000 feet asl, the PF would call for the transition checklist and both
pilots would acknowledge the altimeter setting. Throughout the approach, the PNF would call out any pertinent altitudes and any significant deviations from the approach profile. The standard altitude calls were 1,000 feet above minima, 100 feet above minima, and minima.

1.15.3 Crew Scheduling

There is presently no regulation that explicitly requires the pilot or the company to keep track of duty times; a record is required to be kept, however, which monitors pilot flight times. The new CARS addresses this issue by ensuring that the air carrier sets up a system that monitors the flight time, flight duty time, and rest periods.

The investigation revealed no signs of any deviation from any flight and duty time regulations with respect to the crew in this accident; they had been given the opportunity of adequate rest periods before flight, and had not flown, or been on duty, in excess of the limits imposed by regulation.

1.15.4 Flight Training

ANO Series VII, No. 2, the Air Carriers Using Large Aeroplanes Order, section 47(1) states, in part, the following with respect to pilot flight training:

The initial flight training provided by an air carrier for a pilot before he serves as a pilot flight crew member shall include, in each type of aeroplane he is to fly,

(b) flight instruction and practice in

(iii) take-offs and landings by day and by night.

The company's TC-approved operations manual did not state that the night flying training as specified in the ANO was required. Although the company did not specifically conduct the required night flying training, the company did conduct night flying line indoctrination with all company pilots.

The captain had received the initial night flying training when he joined the company, but the first officer had not. The first officer, however, had received about 20 hours of line indoctrination at night with the company chief pilot and the company training captains, which included night take-offs and landings.

1.16 Transport Canada

1.16.1 Program Approvals

TC assigns a Principal Operations Inspector (POI) to each air carrier. The POI responsible for the company at the time of the accident was assigned to them in 1991. One of the duties of the POI is to give the air carrier direction when it submits an Operations Manual amendment. The company training program, Section 12 in the Operations Manual, was approved by the POI on 06 October 1992.

1.16.2 TC Audits

The most recent TC operational audit conducted on the Canada Jet Charters Vancouver base before the accident was on 27 and 28 January 1992. The designated TC Audit Manager was the POI assigned to the company. The audit found no non-conformance findings. TC conducted an operational audit of the Canada Jet Charters Calgary base on 25 March 1992. Again, the TC Audit Manager was the POI for the company and there were no non-conformance findings. Both audit reports indicated that the company was "... maintaining a satisfactory standard in accordance with appropriate sections of the regulations."

The TC Manual of Regulatory Audit (MRA) was published in October 1991, and in part stated the following:

2.11 POI AND PAI RESTRICTIONS

To maintain the impartiality of the audit process, Principal Operations inspectors (POI) and Principal
Airworthiness inspectors (PAI) should participate in audits of their assigned companies only in an advisory capacity, assisting the appropriate Team Leader.

Chapter 3, Section 1.3 of the MRA required that a specialist inspection be conducted on an annual basis. The following areas of specific interest were identified as mandatory:

a. company check pilot programme;

b. flight crew training records;

c. dispatch and flight watch;

d. flight documentation;

e. passenger safety; and

f. dangerous goods control and records.

Note: Item "c" included a review of the flight and duty times.

During the review of the TC files, no reference to these specialist inspections was found, except for item "f" - dangerous goods. On 07 December 1993, a dangerous goods audit conducted by TC found that this aspect of the company operations was being conducted in accordance with the Dangerous Goods Act and Regulations.

The MRA further stated that all companies would be audited after initial certification and subsequently, regardless of compliance record, at least every three years. In accordance with this directive, the next TC operational audit was due in January 1995; at the time of the occurrence, there was no record of a written notice that the next audit had been scheduled.

In the MRA, Chapter 3, 4-3 Checklists, section OP-9, the items A.12, A.13, and A.14 required evaluation of certain flight and duty time issues. The forms used on previous TC audits did not contain reference to flight and duty times, nor was any related comment found therein.

Section OP-6 of the MRA, Flight Crew Training Programmes, required in part that the audit manager evaluate the flight crew training given by a company. There was no specific reference to the night flying training requirements specified in the appropriate sections of ANO Series VII, Nos. 2 or 3. The night flying requirements pertinent to the company were not commented upon in the last TC audit at either base.

1.16.3 Inspector Line Flying

In accordance with TC Policy Letter AARCB 1990, No. 47, TC Air Carrier inspectors could have flown as flight crew members with an air carrier. A Line Flying Program (LFP) had been implemented to allow TC inspectors to maintain current operational line experience and concurrently provide TC with a core of inspectors who have a more complete and present-day appreciation of the overall air carrier industry.

One of the qualifying conditions for inspectors on the LFP was that "... the Inspector should not be the Audit Manager or Team Leader for Audits of the Carrier that he flies with but may act as an Audit Team member or as an advisor for a Regulatory activity."

The TC inspector who has been assigned to the company as the POI since 1991 participated in the line flying program with Canada Jet Charters Limited until it was abandoned in about September 1994.

1.17 Additional Information

1.17.1 Radar Information

ATC radar tracked the aircraft as it flew from Vancouver to Masset and flight path data were analyzed. The altitude data transmitted by the aircraft's Mode "C" altitude encoder, and recorded by the ATS radar, were always referenced to the standard pressure setting of 29.92 in. Hg. The pressure source for the encoding unit on the aircraft was the captain's altimeter static pressure source corrected by the static defect correction module. The data were recorded in units of 100-foot increments and, for example, an
altitude of 3,420 feet would have been recorded as "035". The radar data corresponded with the FDR data.

The radar data reveal an unremarkable flight from Vancouver until the Learjet descended to about 3,500 feet, which it maintained until 0140:56 PST. The aircraft then held 3,600 feet until 0144:28 PST when it descended to 1,300 feet. Shortly thereafter, the aircraft climbed to maintain 1,600 feet. At 0148:35, it left 1,600 feet and reached 800 feet at 0149:18; radar contact was lost and the transmitted aircraft data ceased at this time.

The radar data indicated that the aircraft had followed normal and expected navigational progress and flight route procedures. The aircraft's headings, distances, and speeds during the transition and the instrument approach were seen to have been in accordance with the published procedures on the CAP-West approach plate.

1.17.2 Controlled Flight into Terrain

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

Various factors have been identified in CFIT accidents; generally they include some combination of perception limitations, attention/timing/task management, non-compliance, procedural errors, deficient intra-cockpit interactions, and loss of situational awareness.

1.17.3 Low Barometric Pressure

There are numerous documented cases concerning pilots applying incorrect altimeter settings in situations of unusually low barometric pressure. A common thread in most of these occurrences is that each pilot had entered a sub-scale setting which was 1 in. Hg in error, that is, the altimeter was mis-reading by 1,000 feet. In most of the occurrences, effective cockpit resource management identified the error after it had been made.

In Canadian domestic airspace, barometric settings in the low 29 in. Hg pressure region are infrequent. As a result, pilots can develop the habit of concentrating upon only the decimal part of the setting.

Ultimately, it is the flight crew's responsibility to ensure that the correct altimeter setting is applied, and to maintain good cockpit communication to catch any errors.

2.0 Analysis

2.1 Introduction

Nothing was found to indicate any mechanical defect or aircraft systems malfunction before impact; nor was there any direct implication of the relevant aviation systems, facilities, or services available and being used by the aircraft during the accident flight. There were no indications of any flight crew physiological and psychological factors that could be considered causal in this accident.

Weather was considered not to have been a causal factor in this accident. Rather, it was seen that the circumstances of the accident were principally affected by operational factors which occurred during the descent.

It was necessary, therefore, to concentrate on crew performance issues to determine how this accident occurred. The analysis focuses on the probable approach profile for C-GPUN leading to water impact, the possibility of unintentional altimeter setting error, cockpit crew coordination, and controlled flight into the water.

As well, the analysis includes information regarding the company and the role of TC as the approving and regulating agency.

Although data from the FDR were greatly beneficial to the investigation and helped establish the aircraft's complete flight profile, the absence of pertinent CVR data prevents any in-depth analysis of the crew's performance, their decision-making processes, their operational circumstances, or the influences leading
up to the accident. CVR testing and serviceability issues are also analyzed.

2.2 Descent Profile

Recorded Vancouver ACC radar data show that the aircraft followed the required track during the transition from Sandspit to Masset, and during the instrument approach procedure to the point where radar contact was lost. FDR and radar data both reveal that the aircraft was holding definite altitudes. This demonstration of positive control indicates that the pilot was flying the approach according to established procedures, and that the aircraft and crew were proceeding with the flight without any apparent difficulty. The lack of any emergency radio communication also supports the premise of normal inflight circumstances.

Just before descent from FL390, the first officer had acknowledged a Sandspit altimeter setting of 29.17 in. Hg. Although it could not be determined if he had adjusted his altimeter at that time, it should have been changed in accordance with normal practices. He would likely have not made any further change to his altimeter sub-scale after that time since no more pressure settings were relayed to the crew.

The captain was likely flying the aircraft. In this case, if his altimeter was set correctly, there is no apparent reason for him to have maintained consistently low altitudes and flown into the water. It must be concluded that his altimeter was incorrectly set.

The most likely causal element of the accident, the mis-setting of the altimeter, probably occurred during descent through the transition level at 18,000 feet but certainly before the Sandspit transition procedure to Masset, either by error or omission.

2.3 Masset Weather

Without quantitative weather reports from credible observers, the actual weather conditions at Masset are unknown. Nonetheless, the aerodrome manager, relying upon his exposure to, and experience of, previous weather conditions which were suitable for similar aircraft operations, assessed that the existing general weather conditions were not adverse.

Although the weather at the aerodrome does not necessarily reflect the offshore conditions, given the proximity of the accident site to the aerodrome, those conditions are likely to have been similar. The Masset weather aftercast identified the formation of fog patches and these may have been present offshore.

Regardless of the aerodrome or offshore weather conditions at the time of the accident, the circumstances precipitating the lower-than-required altitudes occurred without relation to the weather conditions.

2.4 Possible Scenarios

2.4.1 General

The absence of any pre-impact aircraft deficiencies, the absence of any emergency call from the crew, the conscientiously flown instrument approach, and the aircraft attitude at impact as interpreted from the FDR all indicate that the pilot was in control of the aircraft when it struck the water. There are three possible explanations, none of which can be refuted with certainty, as to why the aircraft flew the whole approach with a consistent altitude error.

The following scenarios are based on all of the available information. They are conjectural in that they describe what could have happened and do not necessarily represent what did happen. They are, however, the most plausible scenarios with respect to the crew's altitude mismanagement and their lack of awareness of that mismanagement. Reference to Appendices A and C will assist in understanding the scenarios. In the following discussions, each scenario is tested against all the available information.

Meaningful analysis can only be applied to that part of the descent profile where "hard" altitudes are required. For this accident, there are only six such altitudes:

- Sandspit transition at 3,600 feet;
- procedure turn altitude of 1,600 feet;
- MDA altitude of 600 feet;
- remote altimeter setting MDA altitude of 840 feet;
- Sandspit remote altimeter setting transition at 3,840 feet; and
- remote altimeter setting procedure turn altitude of 1,840 feet.

2.4.2 Altimeter Sub-Scale Setting 29.17

An altimeter set to the appropriate barometric pressure of 29.17 in. Hg would have indicated the true height of the aircraft above the water.

The pilot received this altimeter setting during his pre-flight weather check and it was also relayed to him by ATC. Available information shows that the aircraft flew at specific, controlled, and consistently low altitudes during the complete instrument approach at Masset, and if 29.17 in. Hg was set, the aircraft would have been flown in the final descent until the altimeter read zero. Consistently flying low and descending until the altimeter reads zero are not the actions of professional pilots. It can be concluded, therefore, that the aircraft was not being flown with reference to an altimeter set to 29.17 in. Hg.

2.4.3 Altimeter Sub-Scale Setting 29.92

This scenario assumes that the pilot flew the aircraft with reference to an altimeter set to the standard barometric pressure of 29.92 in. Hg.

The initial level off for the Sandspit transition was at an indicated altitude of 3,400 feet, after which the aircraft maintained an indicated altitude of 3,600 feet. This last altitude corresponds to the 3,600-foot standard transition altitude required, and is likely the altitude chosen by the pilot. This altitude profile suggests that the pilot undershot his minimum altitude by at least 200 feet, before climbing back up to maintain the required altitude.

The subsequent procedure turn level-off at an indicated altitude of 1,400 feet, followed by a quick climb to an indicated altitude of 1,650 feet, indicates that the pilot again undershot his minimum altitude on the approach plate, before quickly climbing back up to the 1,600 feet required. The inbound descent would have progressed until water contact at an indicated altitude of about 750 feet.

Although the 29.92 setting theory is plausible, it requires several other abnormal factors to have been in place.

Firstly, the captain would have had to miss resetting his altimeter on descent through 18,000 feet, and to have continued the flight without recalling the changeover requirement. The captain had flown high performance Learjet aircraft for the last five years and would have changed altimeters at the transition level at least twice on most flights. Furthermore, professional pilots in high performance aircraft are constantly attuned to the meteorological conditions at destination aerodromes, and verifying and changing an altimeter setting is a standard practice. With such long-engrained habits, it is most unlikely that he would not have reset his altimeter. As well, the first officer would have had to miss this changeover. A significant distraction, however, could have caused them both to overlook the sub-scale change.

Secondly, the approach profile suggests that the pilot undershot the 1,600-foot procedure turn minimum by about 250 feet and maintained that altitude for almost 60 seconds before correction. Although it is possible that the pilot missed his level-off altitude through inattention or distraction, such a deviation would have been a significant error for a pilot of his calibre, and in sharp contrast to the demonstrated precision during other parts of the approach. It is unlikely that low-level turbulence would have had such a marked effect on the precision of levelling out at this minimum.

Thirdly, the scenario does not consider the remote altimeter setting requirement. A pilot of the captain's
standard would likely not have ignored this additional altitude requirement. As well, since the crew did not request or receive a local altimeter setting from the Masset aerodrome manager during the time they were in communication with him, it could be assumed that the captain had decided to continue the approach procedure using the remote setting from Sandspit.

Finally, at the low altitudes where the two altimeters should have been consistent with each other, an altitude discrepancy of 750 feet would have been visually obvious during scans or cross-checks, since the angular difference of the pointers would have been 90 degrees on the instrument faces. This analysis assumes that the first officer had changed his altimeter at the TOD, in accordance with company standards. There is nothing to confirm that he did or did not; on the other hand, the first officer did acknowledge an altimeter setting just before descent from FL390, a time consistent with the company procedure regarding the first officer altimeter changeover.

2.4.4 Altimeter Sub-Scale Setting 30.17

This scenario assumes that the pilot flew the aircraft with reference to an altimeter set to an incorrect barometric pressure of 30.17 in. Hg but had applied the 240-foot correction factor to all the approach altitude minima.

The initial level-off for the Sandspit transition was at an indicated altitude of 3,650 feet, after which the aircraft maintained an indicated altitude of about 3,850 feet. This last altitude nearly corresponds to the 3,840-foot remote transition altitude required. The profile is consistent with the pilot erroneously levelling off at the 3,600-foot minimum before recalling his obligation to add 240 feet because of the remote altimeter requirements.

The subsequent procedure turn level-off at an indicated altitude of 1,650 feet, followed by a quick climb to an indicated altitude of 1,900 feet, was also consistent with the pilot descending to the original approach plate profile minimum, before quickly climbing back up to the 1,840 feet required. The inbound descent would have progressed until water contact at an indicated altitude of about 1,000 feet.

This scenario assumes two normal and expected actions: that the pilot changed his altimeter setting on descent through the transition level as required, and that the captain was applying the required remote altimeter correction factor to his minimum approach altitudes.

How the pilot was to set 30.17 instead of 29.17 on his altimeter sub-scale is not known. Because of the simple adjustment mechanism on the altimeter itself, it is physically easier and quicker to turn the altimeter adjustment knob to arrive at a figure of 30.17 from an existing value of 29.92, than it is to turn to 29.17. It has been shown that pilots can become accustomed to concentrate upon the decimal part of the altimeter setting and pay less attention to the whole number. It is possible that the pilot turned the altimeter setting knob in the shortest direction to 30.17, did not recognize his error, and mistakenly thought he had set 29.17. From then on, the altimeter reading would have constantly been 1,000 feet higher than the actual altitude.

It is conceivable that the pilots obtained an erroneous local altimeter setting for Masset. However, the airport manager, the only person who could have passed them a Masset altimeter setting, stated that he did not pass any altimeter setting to the crew. If the crew had received an erroneous altimeter setting, they should have noticed the large pressure differential between Sandspit and Masset, only 48 nm away, and they would have had to ignore the recent meteorological advice from three different sources of the barometric pressure in the area. Furthermore, any such altimeter setting from Masset would not be approved for the conduct of an instrument approach.

2.4.5 Summary

Regardless of the actual circumstances generated by the altimeter sub-scale settings, the principal event leading to the lower-than-required altitudes was either mis-setting, or omitting to set, one or both altimeters. The scenario that best fits the available information is that the crew mistakenly set 30.17 on the sub-scale of their altimeters. Why neither crew member detected the error could not be determined.

2.5 Controlled Flight into Water

In consideration of the weather conditions, the dark night, and the lighting conditions, there would have
been few visual cues to help the crew establish their altitude. Any peripheral lighting would probably have been of no benefit to the crew in being alerted to their low altitude. As well, at this particular phase of the approach, both pilots would likely have been concentrating upon their respective duties inside the cockpit and might not have had the opportunity to look outside.

Since the mis-set altimeter was indicating altitudes which the captain had planned and had expected to see, he would have been unaware of the actual low altitude over the water, except if he had observed the radio altimeter. Had the crew set the radalt bug to below zero to prevent the warning light distracting them, the only indication of low altitude would have been the reading of the instrument itself. As the crew continued to perform their normal approach and landing activities, they may have been distracted from their task of monitoring the radalt.

2.6 Flight Recorders

2.6.1 FDR

There is no doubt that the FDR data contributed greatly to the progress of the investigation into this accident. Without the information of the whole flight path, it would have been impossible to confidently assess that the aircraft was in controlled flight immediately before impact; the only other source of flight path information was the ATC radar data which, by itself, was insufficient for detailed scrutiny of the aircraft flight profile. These two independent sources of flight path information corroborate the determination of the aircraft profile.

2.6.2 CVR

It is highly likely that the last 30 minutes of the crew’s communications would have yielded valuable information concerning the circumstances leading up to the accident. Such information could have led to determining, for example, the reasons why the crew did not set the correct altimeter settings and why they did not detect their low altitudes.

The nature of the tape cartridge failure was such that any test performed before the failure would not have given reason to suspect the unit, or have given maintenance any indication of impending failure. Nevertheless, it was clear that because the CVR failed on 30 December 1994, 12 days before the accident, any test subsequently performed on the unit would have failed and identified the unit as unserviceable. The omission of the scheduled maintenance test on 04 January 1995, therefore, prevented the immediate detection of the failed recorder. The lack of pre-start CVR functional checks further reduced the potential of detection of the failure; had this simple pre-start test, even though not required by regulation, been performed on any of the flights before the accident, the unserviceability would have been found and the aircraft would not have been serviceable for initiation of the flight.

2.7 TC Monitoring

TC monitoring of the company was not in accordance with TC policies in several respects, as follows:

- the two most recent operational audits of the company had been conducted by the company POI, although TC recognizes that, to maintain impartiality, the POI should participate in an advisory role only;

- TC had approved the company operations manual which had no reference to the required night flying training in ANO Series VII, No. 2;

- the last TC audit reports did not contain reference to any flight and duty time inspection by the audit team;

- the company’s next scheduled audit was due during the month of the occurrence; there was no record of a written notice to the company that an audit had been scheduled;

- some annual mandatory specialist inspections had not been done; and,
- the POI had been line flying with the company.

### 3.0 Conclusions

#### 3.1 Findings

- Other than the first officer not receiving the formal night training as specified in ANO Series VII, No. 2, the flight crew were properly licensed and qualified for the flight.

- The weight and centre of gravity of the aircraft were within prescribed limits.

- With the exception of the CVR servicing, the aircraft was maintained in accordance with regulatory requirements intended to ensure the safe operation of an aircraft.

- Nothing was found to suggest that the aircraft was not intact or functioning normally before it struck the water.

- Some aspects of Transport Canada's audit and surveillance of the company before the accident were not in accordance with the Transport Canada Manual of Regulatory Audit.

- C-GPUN was not equipped with a GPWS, nor was there a regulatory requirement that it be so equipped.

- It is likely that the crew of C-GPUN unintentionally mis-set one or both altimeters to 30.17 in. Hg.

- The crew did not detect the altimeter error and unknowingly flew the aircraft into the water.

#### 3.2 Causes

The crew most likely conducted the instrument approach with reference to an unintentionally mis-set altimeter of 30.17 in. Hg, and unknowingly flew the aircraft into the water. The circumstances leading to the incorrect altimeter setting could not be determined, nor was it determined why the crew did not detect the mis-set altimeter.

### 4.0 Safety Action

#### 4.1 Action Taken

##### 4.1.1 Operator Actions

Since the accident, the operator has implemented a daily, operational, pre-flight check of the CVR. This check is performed by the pilot on the first start of the day and is recorded in a dedicated log.

##### 4.1.2 Controlled Flight into Terrain (CFIT)

The circumstances of this occurrence are typical of a CFIT incident. CFIT occurrences are those in which an aircraft, under the control of the crew, is flown into terrain (or water) with no prior awareness on the part of the crew of the impending disaster. Over the eleven-year period from 01 January 1984 to 31 December 1994, 70 commercially operated aircraft not conducting low-level special operations were involved in CFIT accidents in Canada. In view of the frequency and severity of such accidents, the Board is conducting a study of CFIT accidents to identify systemic deficiencies. The study will include, *inter alia*, an examination of CFIT data involving the use of aircraft radar altimeter systems and Ground Proximity Warning Systems.
Transport Canada has recently produced a training package entitled "Preventing CFIT." The package, which includes a video, CFIT case studies, and questions, will be distributed to Regional Aviation Safety Officers (RASOs). The RASOs will present the material primarily to small air taxi operators in order to enhance pilot and operator awareness of those factors which can contribute to CFIT accidents. Flight Safety Foundation is currently producing a similar package targeted at regional air carriers, and Boeing Aircraft is producing a package for large air carriers.

4.1.3 Standard Operating Procedures (SOPs)

SOPs improve crew coordination and operational safety. The draft Canadian Aviation Regulations, expected to be promulgated in 1996, require air operators who operate aircraft requiring two or more pilots to establish and maintain SOPs. These regulations also require that SOPs be taken into account during pilot training and testing.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 03 January 1996.

Appendix A - Instrument Approach at Masset
Appendix B - Altitudes Flown
Appendix C - Indicated Altitudes

This is a representation of the last 12 minutes of the primary altitude trace from the FDR at 29.92 in. Hg, with the same altitude trace duplicated for two other pressure settings: 29.17 and 30.17 in. Hg. The trace marked "29.17" represents the true altitude of the aircraft above the water; the trace marked "30.17" represents what altitude the pilot would have seen on his altimeter had it been set to 30.17.

Appendix D - List of Supporting Reports

The following TSB Engineering Branch laboratory reports were completed:
LP 8/95 - Caution Lights Examination;
LP 23/95 - Flight Recorder Analysis;
LP 24/95 - Under Water Search Evaluation; and
LP 25/95 - Underwater Acoustic Beacon Analysis.

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

**Appendix E - Glossary**

ACC - Area Control Centre
AES - Atmospheric Environment Service
agl - above ground level
ANO - Air Navigation Order
asl - above sea level
ASR - Altimeter Setting Region
ATC - Air Traffic Control
ATPL - Airline Transport Pilot Licence
ATS - Air Traffic Services
AWOS - Automatic Weather Observation System
CAP - Canada Air Pilot
CAR - Canadian Aviation Regulations
CFB - Canadian Forces Base
CFIT - controlled flight into terrain
CRM - crew resource management
CVR - cockpit voice recorder
DH - decision height
DME - distance measuring equipment
DND - Department of National Defence
FDR - flight data recorder
FL - Flight Level
GPWS - ground proximity warning system
IFR - instrument flight rules
hr - hour(s)
in. - Hg inches of mercury
LFP - Line Flying Program (TC)
LP - Laboratory project (TSB)
LVC - Licence Validation Certificate
mb - millibar(s)
MDA - minimum descent altitude
MEDEVAC - medical evacuation
MHz - megahertz
MRA - Manual of Regulatory Audit (TC)
NDB - non-directional beacon
nm - nautical miles
pa - pressure altitude
PAI - Principal Airworthiness Inspector
PDM - pilot decision making
PF - pilot flying
PNF - pilot not flying
POI - Principal Operations Inspector
PPC - Pilot Proficiency Check
PST - Pacific standard time
radalt - radio altimeter
RASO - Regional Aviation Safety Officer
ROV - remote operated vehicle
SAR - Search and Rescue
SOP - standard operating procedure
SPR - Standard Pressure Region
SSR - Secondary Surveillance Radar
TC - Transport Canada
TOD - top of descent
TSB - Transportation Safety Board of Canada
UTC - Coordinated Universal Time
VOR - very high frequency omni-directional range

- degree(s)
- M degrees of the magnetic compass

<1> All times are Pacific standard time (Coordinated Universal Time [UTC] minus eight 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 the crew.
<4> This approach was conducted at night, in unknown weather conditions, with portable runway lights, but without any precision approach aids or approach lights.
<5> All references to cloud height are in feet above ground level (agl).

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.

Loss of Off-wing Slide in Flight
Air Canada Boeing 767-233 C-GAUH
Vancouver, British Columbia
06 April 1995

Report Number A95P0073

Synopsis
Following maintenance activity involving the right off-wing slide system, the aircraft had a slide door alert message illuminate while being de-iced. The aircraft was released for the flight under the authority of the minimum equipment list. During the approach to the Vancouver International Airport, the right off-wing slide compartment door opened, and the right off-wing slide separated from the aircraft. The aircraft landed without further incident.

The Board determined that the right off-wing slide compartment door opened in flight because the secondary lock shear-pin had been inadvertently sheared during recent inspection; this maintenance error remained undetected because existing required inspection procedures had not been followed. Contributing to the deviations from formal standard practices was inadequate understanding of the system on the part of the maintenance technicians and supervisor.

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1.0 Factual Information

1.1 History of the Flight

C-GAUH, a Boeing 767-233 aircraft, was undergoing a scheduled maintenance "A" check at Toronto during the night shift. The check was near completion when the right off-wing slide deployment system was inadvertently initiated, which fired the spoiler override actuator, the latch opening actuator, and the door opening actuators; a job ticket was raised to replace these actuators. The aircraft was ready for service at 0930 eastern daylight saving time (EDT) <1> and the aircraft arrived at the gate at 1020 for a planned push-back at 1045 as flight 899. Flight 899 completed loading, pushed back from the gate at 1116, and taxied to the designated de-ice area where the aircraft was de-iced. There were 2 pilots, 6 cabin crew, and 95 passengers on board.

During the taxiing following de-icing, the overhead EMERGENCY DOOR warning illuminated, and the engine indication and crew alerting system (EICAS) displayed a R WING SLIDE message. The flight crew consulted the minimum equipment list (MEL), and found that they were required to return-to-gate. They taxied back to
the ramp and advised Air Canada ramp maintenance by radio; maintenance dispatched a certified aircraft technician to investigate the problem. The ramp technician examined the door, which appeared fair and closed, and visually inspected the integrator to confirm that the door was latched and closed. During this examination, the door alert message went out, and the technician verbally released the aircraft.

The aircraft was de-iced a second time and, during de-icing, the right slide door alert message activated again and stayed on. Ramp maintenance was again advised of the situation; they did not investigate further but informed the flight crew that there was no actual problem with the door, and that the door indication system was faulty. They released the aircraft verbally with the steady door alert under the provisions of the MEL. The aircraft had been delayed a total of one hour and fifteen minutes when it finally departed at noon from Toronto/Lester B. Pearson International Airport, Ontario, on a scheduled domestic flight to Vancouver, British Columbia. The right slide door warning light and the EICAS message stayed on for the duration of the flight.

On the downwind leg for runway 08 at Vancouver, one of the flight attendants reported to the captain that a loud bang had been heard in the passenger cabin. The crew checked their instrumentation for any abnormality, and noted that the aircraft was performing normally. They suspected that cargo may have shifted and they radioed this information ahead for the ground crew. They landed and taxied to the gate at the terminal. After shutdown, the ground crew reported finding the right off-wing slide compartment door open, and the off-wing slide missing.

The occurrence took place at latitude 49-15'N, longitude 123-25'W, during the hours of daylight, at 1359 Pacific daylight saving time (PDT).

### 1.2 Injuries to Persons

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<td>95</td>
<td>103</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>95</td>
<td>103</td>
</tr>
</tbody>
</table>

### 1.3 Damage to Aircraft

The aircraft sustained only minor damage as the unfurled slide abraded the paint on the side of the fuselage before it separated.

### 1.4 Other Damage

The missing slide was not recovered, and is believed to have fallen into Georgia Straight and sunk. There have been no reports of other damage caused by the falling slide.

### 1.5 Personnel Information

<table>
<thead>
<tr>
<th>Age</th>
<th>Captain</th>
<th>First Officer</th>
</tr>
</thead>
<tbody>
<tr>
<td>54</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pilot Licence</th>
<th>ATPL</th>
<th>ATPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Expiry Date</td>
<td>01 June 95</td>
<td>01 June 95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Flying Hours</th>
<th>20,000</th>
<th>12,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours on Type</td>
<td>45</td>
<td>1,200</td>
</tr>
<tr>
<td>Hours Last 90 Days</td>
<td>45</td>
<td>160</td>
</tr>
<tr>
<td>Hours on Type Last 90 Days</td>
<td>45</td>
<td>160</td>
</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Hours Off Duty Prior to Work Period</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>

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

### 1.6 Aircraft Information

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>The Boeing Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and Model</td>
<td>767-233</td>
</tr>
<tr>
<td>Year of Manufacture</td>
<td>1983</td>
</tr>
<tr>
<td>Serial Number</td>
<td>22519</td>
</tr>
<tr>
<td>Certificate of Airworthiness (Flight Permit)</td>
<td>Valid</td>
</tr>
<tr>
<td>Total Airframe Time</td>
<td>40,100 hours</td>
</tr>
<tr>
<td>Engine Type (number of)</td>
<td>Pratt &amp; Whitney JT9D-7R4D (2)</td>
</tr>
<tr>
<td>Propeller/Rotor Type (number of)</td>
<td>N/A</td>
</tr>
<tr>
<td>Maximum Allowable Take-off Weight</td>
<td>140,615 kg</td>
</tr>
<tr>
<td>Recommended Fuel Type(s)</td>
<td>Jet A, Jet B</td>
</tr>
<tr>
<td>Fuel Type Used</td>
<td>Jet B</td>
</tr>
</tbody>
</table>

### 1.7 Meteorological Information

Weather at Vancouver at the time of the occurrence was as follows: scattered cloud layers at 1,800 and 2,200 feet, broken ceiling at 3,500 feet, visibility 15 miles in light rain, and the wind from 060- at 9 knots.

### 1.8 Off-wing Slide System

#### 1.8.1 System Overview
The Boeing 767 incorporates an inflatable slide at the inboard rear of each wing to allow the evacuation of passengers who use the over-wing exits during an emergency. Slide deployment is initiated by opening the exit hatch from the inside. The hatch opening motion actuates electrical switches that simultaneously (1) operate a relay to ground out any position command going to the main hydraulic spoiler power controller actuator, and (2) fire the spoiler override actuator which rotates the inboard spoiler to the down position. After a two-second time delay (from the spoiler actuator firing), the latch opening actuator is fired. The latch opening actuator opens the escape slide compartment door latches and fires the door opening actuators located in the escape slide compartment. The slide compartment door, with the escape slide packboard assembly attached, is rotated outboard by the actuators. When the door opens, a mechanical link to a high pressure inflation cylinder triggers the release of gas that inflates the slide. Proximity sensors monitor the position of the door latches, and are used to trigger warning lights and EICAS messages on the flight deck.

During maintenance such as “A” checks, the off-wing slide system is de-activated and a safety pin is inserted in the high pressure inflation cylinder to prevent inadvertent deployment and inflation which could cause injury to personnel and damage to equipment.

1.8.2 Design and History of the Integrator
The integrator was originally designed and manufactured without a secondary lock. After many incidents in the early 1980s of the off-wing slide compartment door opening in flight, the integrator was re-designed. A secondary lock mechanism was included on new integrators to prevent vibrations from causing the latch shaft to migrate to the unlatched position. Existing integrators were also modified to incorporate this feature. A key characteristic of the secondary lock is the shear pin which holds the secondary lock lever in place during normal operation, but easily shears to allow the actuator to release the door latches. The shear pin is designed to shear at a pre-determined force, and thus allow the opening of the door latches, and in turn, the door. The design of the off-wing slide system is such that the actuator cannot be fired without shearing the secondary lock shear pin.

Because of an ongoing number of incidents in the industry, even after the first rework of the secondary lock mechanism, the off-wing slide integrator was redesigned to simplify deactivation procedures. This elective rework was not incorporated on this aircraft.

1.8.3 Inspection after the Landing in Vancouver

Inspection of the aircraft after it had landed in Vancouver revealed that the slide inflation trigger was disconnected and the high pressure inflation cylinder was full; the door opening actuators and the latch opening actuator had not fired and the latch pins were in good condition; the sensors and the door warning system functioned normally; and the integrator was found unlatched but in good condition, except for the secondary lock shear pin which had sheared in three pieces but remained in place. A visual inspection of the secondary lock would not reveal that the pin was sheared.
1.9 Restoration of the Off-wing Slide System

1.9.1 Job Ticket

Following the inadvertent deployment of the off-wing slide compartment door actuator during the return to normal after the "A" check, a 12-page job ticket, entitled "Off-Wing Escape System - Restoration - 6-225", was generated which listed 31 sign-off items. Not all of the 31 items had to be actioned, because the safety pin that was inserted in the inflation mechanism for the "A" check prevented the slide from inflating when the off-wing slide compartment door opened. However, replacement of most items was required to restore the system, including replacement of the latch opening actuator, off-wing slide compartment door actuators, and the spoiler blow-down squib.

1.9.2 Disconnection of the Inflation Trigger

The night-shift certified aircraft technician who organized the restoration of the system disconnected the mechanical linkage from the off-wing slide compartment door to the trigger on the inflation cylinder both for safety reasons and to allow the slide to lie back down to facilitate maintenance. Disconnection of the inflation trigger was not an item on the job ticket; the job ticket assumes that the inflation cylinder has emptied as a result of the slide having been purposely deployed and inflated during operation of the aircraft rather than inadvertently deployed when the inflation cylinder was safetied with a pin during maintenance.

The work required to restore the system extended into the morning shift. The night-shift technician who had disconnected the inflation trigger verbally briefed one of the morning-shift certified aircraft technicians about the disconnection; however, the night-shift technician did not raise a snag or make a written record of it or attach a warning flag. The morning shift technician who had been briefed about the disconnection was subsequently assigned to work on a different aircraft, and the inflation trigger was not reconnected before the aircraft was released for service.

1.9.3 Replacement of the Secondary Lock Shear Pin

In addition to the replacement of the fired actuators, the job ticket also required the replacement of the secondary lock shear pin (item 16). The morning-shift certified aircraft technician who readied the aircraft for service signed item 18, which called for the replacement of the secondary lock shear pin, as being completed, but the shear pin was not replaced. The technician reported that there was no replacement shear pin available on the shear pin ring, as stated on the job ticket.

Although the pin was sheared into three pieces, the pieces stayed in place in the secondary lock. Thus, it was not readily apparent upon visual inspection that the pin was sheared. Instead of acquiring a new shear pin from the stores department, or from the left off-wing slide integrator, the technician conducted an external visual inspection of the shear pin, and concluded that it did not need to be replaced.

Previous shearing of the secondary lock mechanism shear pin and migration of the primary lock permitted the door latch train to migrate from vibration, thus allowing the door to unlatch and open under flight aerodynamic and inertial side loads.

1.10 Minimum Equipment List

1.10.1 Minimum Equipment List Inspection

The 767 MEL manual states that the R WING SLIDE message, which first appeared on the EICAS during taxi after the aircraft was de-iced the first time, indicates that the right off-wing slide compartment door is unlatched, and that it must be checked by maintenance personnel to confirm that it is closed and latched. The MEL procedure requires the completion of twelve steps before the aircraft is released as serviceable for each flight until the snag is rectified. These steps include a detailed inspection of the integrator and associated linkage, the actuation of the integrator to unlatch and properly re-latch the off-wing slide compartment door, the placarding of the cockpit warning light, and the placement of an entry in the journey log-book.

With the exception of opening the integrator access door to visually inspect the integrator, none of the required maintenance actions took place. Although the ramp maintenance supervisor had access to the requirements of the MEL, the certified aircraft technician conducting the inspection on the ramp was not given the MEL to work from. Furthermore, he did not have ready access to the MEL carried on board the aircraft. The inspecting technician and the ramp maintenance supervisor agreed that there was no need to delay the plane any further and carry out the MEL inspection. They informed the crew that they had determined that the off-wing compartment door was locked and that the steady warning light was an erroneous indication problem; however, there was no discussion between the flight crew and maintenance as to how this determination was made.

The ramp maintenance supervisor and the technician were aware of the inadvertent off-wing slide compartment door actuation during the "A" check, and the subsequent maintenance activity that had just taken place to restore the system. However, the maintenance personnel were generally apprehensive about handling anything associated with the slides for fear of an inadvertent deployment, which can result in personal injury and equipment damage, or delays in aircraft operations.

1.10.2 Flight Crew Acceptance of the Aircraft

When the fault warning illuminated and the EICAS message appeared, the flight crew followed standard procedure by consulting the MEL. They returned to the ramp to have the door inspection carried out by maintenance. Although they had no knowledge that the MEL inspection requirements were not carried out by maintenance, they did know that the requirement to placard the warning light and make a log-book entry was not met. They accepted the aircraft as airworthy based on a verbal release from maintenance.

1.11 Qualifications and Training of Maintenance Personnel

1.11.1 Certified Aircraft Technician who Replaced the Actuator

The morning-shift certified aircraft technician who completed the "A" check and readied the aircraft for service was an Air Canada employee who was licensed and endorsed on the Boeing 767-233. He received his initial training on the aircraft in 1991, and since then his only training relative to the B767 was a Difference course on the 767-300 model. He had never previously worked on his own on the off-wing slide system and had worked on the system under supervision on only one occasion, which had been more than two years previously.

1.11.2 Certified Aircraft Technician who Inspected the Aircraft on the Ramp

The certified aircraft technician who inspected the aircraft on the ramp was an Air Canada employee who was licensed and endorsed on the Boeing 767-233. He received his initial training on the B767 in early 1990, and had not received any recurrent training since then. In addition, although not endorsed, he had worked on Boeing 747, Lockheed L1011, and McDonnell Douglas DC-9. He had not seen an integrator in about four years; however, he had worked on the off-wing slide system a few times many years ago.

1.11.3 Ramp Maintenance Supervisor

The ramp maintenance supervisor was a certified aircraft technician employed by Air Canada. He was filling the position of acting mobile foreman the morning of
the incident, when he was called in to carry out the duties of the ramp maintenance supervisor. He had only taken the position for a few minutes when the flight 899 snag arose. Although endorsed for the Boeing 767, he did not have much experience with the aircraft or the off-wing slide system. He was not aware of what was required to release the aircraft in accordance with the MEL.

2.0 Analysis

2.1 Introduction

The separation of the off-wing slide during the approach into Vancouver was caused by an undetected maintenance error as a result of a series of actions and inactions that took place in Toronto prior to the departure of flight 899. The analysis examines how these events interacted to culminate in a potentially dangerous in-flight incident.

2.2 Restoration of the Off-Wing Slide System

The breakdown in acceptable and standard maintenance practices began when the inflation bottle was disconnected with no formal record made of the fact to ensure that the bottle was reactivated before the aircraft was released for service. Continuity was lost when the morning-shift technician who had been briefed about the disconnection was subsequently assigned to work on another aircraft. Contributing to the consequence of this error was the lack of requirement for an adequate inspection of the area before the access panel was reinstalled. The aircraft was eventually dispatched on flight 899 in an unsafe condition: the right off-wing slide was inoperative and would not have been available had an emergency required the evacuation of the occupants through the right over-wing exits.

From the standpoint of the in-flight opening of the off-wing slide compartment, the more significant deviation began when the morning-shift certified aircraft technician did not install a new shear pin in the secondary lock, as required by the job ticket. Had the technician understood the operation of the off-wing slide system, he would have realized that the shear pin had to have been sheared during the inadvertent actuation and, therefore, replacement of the shear pin was mandatory. Even though the presence of the sheared shear pin fragments in position on the integrator gave the false impression that the pin was intact, the morning-shift technician's decision not to replace the shear pin as required was influenced primarily by the lack of a replacement close at hand. Since the aircraft was already late, pressure to expedite the release of the aircraft possibly influenced the technician in his decision to certify on the job ticket that the shear pin had been replaced when it had not.

The shear pin problem would have been detected had the integrator been manually cycled, as called for by the 767 airplane Maintenance Manual procedures for replacement of the latch actuator.

2.3 Door Warning Inspection

The certified aircraft technician who was sent on the ramp to inspect the right off-wing slide compartment door had virtually no experience with this system and had retained limited knowledge of it from his endorsement course four years previously. The technician's unfamiliarity with the slide system and the history of inadvertent deployments reinforced his apprehension about handling anything associated with the slides for fear of an inadvertent deployment that might result in personal injury and equipment damage, or delays in aircraft operations. As a result, the inspection on the ramp was cursory and inadequate to ensure that the door warning was false, the premise under which the aircraft was released.

2.4 Minimum Equipment List Inspection Requirements

Although the ramp technician and the ramp maintenance supervisor knew that a detailed inspection was mandatory before the aircraft could be released, this inspection was not done. The complete actuation of the integrator as called for in the MEL inspection would have allowed detection of the sheared pin. The fact that maintenance activity had just taken place on the slide system should have raised greater concern about a potential problem. However, the MEL inspection was not followed; instead, an informal procedure was conducted which allowed the sheared condition of the pin to remain undetected.

Although the flight crew had no knowledge that the MEL inspection requirements were not carried out by maintenance, they did know that the requirement to placard the warning light and make a log-book entry was not met. They accepted the aircraft as airworthy based on a verbal release from maintenance, which again was a deviation from the required formal procedures.

2.5 Door Warning and Opening

The sheared shear pin allowed the secondary lock latch lever to rotate out of position and the latch shaft to migrate out of position towards the unlatched position, likely due to vibration. At the first movement, the proximity switches that monitor the system triggered the warning lights and the EICAS message during de-icing of the aircraft prior to departure. The warnings temporarily disappeared when the ramp technician handled the system during inspection, but the primary cause was not resolved.

Some of the previous incidents of off-wing slide compartment door opening in flight occurred during approach. It is likely that the off-wing compartment door became unlocked due to vibration and opened due to aerodynamic and inertial loads during approach. The slide did not inflate, but simply unfurled and tore away.

3.0 Conclusions

3.1 Findings

- The right off-wing slide compartment door and spoiler squib were inadvertently activated during the return-to-normal procedure after an "A" check.
- The right off-wing slide inflation trigger was disconnected during the actuator replacement, and was unintentionally not reconnected.
- Because the inflation cylinder was disconnected, the right off-wing slide was unserviceable for flight 899.
- The shear pin in the secondary lock sheared during the inadvertent actuation, and was not replaced during restoration of the system as required by the job ticket.
- The sheared condition of the pin allowed the latch shaft to migrate to the unlatched position, likely as a result of vibration.
- In response to the door warning light and the EICAS alert message, an informal inspection, which did not include the items listed for the MEL inspection, was done on the right off-wing slide compartment door.
- The sheared condition of the pin remained undetected as a result of the MEL inspection not being completed.
- The aircraft was released for the flight under the authority of the MEL, even though the MEL inspection had not been completed.
- The flight crew accepted the aircraft without the required placard and log-book entry.
The maintenance personnel who were directly involved with this incident had inadequate experience and knowledge of the system.

3.2 Causes

The right off-wing slide compartment door opened in flight because the secondary lock shear-pin had been inadvertently sheared during recent inspection; this maintenance error remained undetected because existing required inspection procedures had not been followed. Contributing to the deviations from formal standard practices was inadequate understanding of the system on the part of the maintenance technicians and supervisor.

4.0 Safety Action

4.1 Action Taken

4.1.1 Action by the Operator

Subsequent to this occurrence, Air Canada took the following actions:

- to confirm the integrity of the secondary lock shear pin, the MEL was revised to require turning one end of the pin while observing the other end; also, a once-around check is underway to ensure that five spare shear pins are stowed at the integrator on each side of the aircraft;

- "A" Check Job Tickets were changed so that the off-wing door is no longer deactivated during an "A" Check and a warning sign is placed over the interior of the door to reduce the possibility of inadvertent over-wing slide deployment; and

- maintenance procedures for the door indication system were revised, and two projects are in the approval process (Service Bulletin (SB) 25A0131 to replace the integrator, and SB 25-0212 to improve the off-wing slide arm/disarm mechanism).

4.1.2 Action by Aircraft Manufacturer

Boeing has released Service Bulletins 767-25-0051, 767-25A0104, and 767-25-0185 to provide more direct verification of slide door latching, and to improve the integrator locking and latching mechanism.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 28 February 1996.

Appendix A - Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATPL</td>
<td>Airline Transport Pilot Licence</td>
</tr>
<tr>
<td>EDT</td>
<td>eastern daylight saving time</td>
</tr>
<tr>
<td>EICAS</td>
<td>engine indication and crew alerting system</td>
</tr>
<tr>
<td>hr</td>
<td>hour(s)</td>
</tr>
<tr>
<td>kg</td>
<td>kilogram(s)</td>
</tr>
<tr>
<td>MEL</td>
<td>Minimum Equipment List</td>
</tr>
<tr>
<td>PDT</td>
<td>Pacific daylight saving time</td>
</tr>
<tr>
<td>SB</td>
<td>service bulletin</td>
</tr>
<tr>
<td>TSB</td>
<td>Transportation Safety Board of Canada</td>
</tr>
<tr>
<td>UTC</td>
<td>Coordinated Universal Time</td>
</tr>
<tr>
<td>°min</td>
<td>minute(s)</td>
</tr>
<tr>
<td>°s</td>
<td>second(s)</td>
</tr>
<tr>
<td>°</td>
<td>degree(s)</td>
</tr>
</tbody>
</table>

<1>All times are EDT (Coordinated Universal Time [UTC] minus four hours) unless otherwise stated.

Updated: 2002-10-06
Air 1995

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 and Evacuation
Air Canada
McDonnell Douglas DC-9-32 C-FTMD
Vancouver International Airport, British Columbia
27 June 1995

Report Number A95P0138

Summary

The Air Canada DC-9-32 (ACA216), with 5 crew members and 72 passengers on board, was being pushed back from Gate 1 at the Vancouver International Airport in preparation for departure to Calgary, Alberta. In accordance with standard company procedures, the captain initiated the starting sequence for the No. 2 (right side) engine during the push-back. The start was unremarkable and, while the first officer completed the required after-start engine and electrical checks, the captain initiated the starting sequence for the No. 1 (left side) engine. The engine did not start, however, and the captain informed the first officer that they had a wet start, discontinued the start, and began the Wet Start and Unsatisfactory Start procedures.

While the pilots were completing the engine shut-down procedures, they were informed by ground personnel and the crew of a passing aircraft that black smoke and flames were visible in the vicinity of the left engine. There were no cockpit indications of fire, but, based on these external reports, the captain activated the engine fire extinguisher bottle No. 1, and informed the flight-attendant-in-charge. A short time later, the pilots received a second report of fire from personnel working near the aircraft. The captain immediately activated the engine fire extinguisher bottle No. 2, and, because the aircraft had already been pushed back from the terminal gate, he ordered an emergency evacuation through the two forward doors. The flight attendants deployed the two forward escape slides and began the emergency evacuation. During the evacuation, the right-side escape slide partially deflated, but it remained sufficiently firm for the evacuation. There were four minor injuries during the evacuation, and the aircraft was not damaged.

Ce rapport est également disponible en français.

Other Factual Information

This Douglas DC-9 has two JT8D-7B turbo-fan engines mounted on the rear fuselage, each containing two igniter plugs to provide initial ignition of the fuel/air mixture during start; the plugs are identified as "A" and "B" systems. By design, an igniter plug is a consumable component, requiring replacement from time to time throughout the service life of an engine.
The two igniter plugs installed on this engine at the time of the incident were made by different manufacturers, Champion (part number AA725) and Auburn (part number JB3).

The normal engine starting procedures in the Air Canada DC-9 Operating Manual prescribe the specific phraseology that pilots must use during the critical elements of the starting cycle. The starting checklist and the required pilots' verbal calls, for either engine, are summarized, in part, as follows for the right engine:

<table>
<thead>
<tr>
<th>Item</th>
<th>Action</th>
<th>Pilot Phraseology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start switch</td>
<td>On</td>
<td>&quot;Starting Right&quot;</td>
</tr>
<tr>
<td>Start valve</td>
<td>'Open light' ON</td>
<td>&quot;Valve Open&quot;</td>
</tr>
<tr>
<td>N2 RPM</td>
<td>Rising</td>
<td>&quot;N2&quot;</td>
</tr>
<tr>
<td>Oil pressure</td>
<td>Rising</td>
<td>&quot;Oil Pressure&quot;</td>
</tr>
<tr>
<td>N1 RPM</td>
<td>At 20% N2, confirm N1 rotation</td>
<td>&quot;N1&quot;</td>
</tr>
<tr>
<td>Fuel control lever</td>
<td>Lever to ON</td>
<td>&quot;Fuel On&quot;</td>
</tr>
<tr>
<td>Fuel flow</td>
<td>Check at 800 pph</td>
<td>none</td>
</tr>
<tr>
<td>EGT gauge</td>
<td>Rising within 10 seconds</td>
<td>&quot;Light on Right&quot;</td>
</tr>
<tr>
<td>Start switch</td>
<td>Release at 35% N2</td>
<td>none</td>
</tr>
<tr>
<td>Start valve</td>
<td>'Open light' OUT</td>
<td>&quot;Valve Closed&quot;</td>
</tr>
<tr>
<td>Engine parameters</td>
<td>Check for normal indications</td>
<td>&quot;Right engine normal&quot;</td>
</tr>
<tr>
<td>Electrical systems</td>
<td>Check for normal indications</td>
<td>&quot;Right electrics normal&quot;</td>
</tr>
</tbody>
</table>

Figure 1 - Engine Starting Procedure Summary (right engine)

The engine starting procedures require the captain to confirm that the exhaust gas temperature (EGT) begins to rise within 10 seconds of moving the fuel control lever to ON. If the EGT does not rise, the captain discontinues the start, and proceeds with both the Wet Start and the Unsatisfactory Start procedures as follows:

"NO EGT RISE DURING START (WET START)

IF NO EGT RISE WITHIN 10 SECONDS OF FUEL ON:

DISCONTINUE START AND PROCEED WITH UNSATISFACTORY START PROCEDURE (QRH 1.25)

CAUTION: DO NOT SWITCH IGNITION SYSTEMS DURING ENGINE ROTATION

IGNITION C/B (K24 OR L24)... CHECK SET

WHEN ROTATION STOPPED, SELECT OTHER IGNITION SYSTEM AND ATTEMPT RESTART.

END OF CHECKLIST

FUEL CONTROL LEVER . . . . . . . OFF

IF START SWITCH IS STILL ENGAGED, CONTINUE MOTORING ENGINE FOR 15 SECONDS TO CLEAR UNBURNED FUEL.

START SWITCH . . . . . . . . . OFF

IGNITION SWITCH. . . . . . . . . OFF

IF START SWITCH DID NOT REMAIN OPERATING FOR AT LEAST 10 SECONDS AFTER FUEL CONTROL LEVER WAS MOVED TO OFF, ALLOW 30 SECOND FUEL DRAINING PERIOD PRIOR TO NEXT START ATTEMPT.

END OF CHECKLIST

Figure 2 - Wet Start Checklist

Figure 3 - Unsatisfactory Start Checklist

The aircraft had both flight data recorder (FDR) and cockpit voice recorder (CVR) units installed, and both had recorded information relevant to the occurrence. The following graph
is derived from the flight recorder Engineering Report.

Figure 4 - FDR Data of the Left Engine Start

The following table summarizes the FDR data pertaining to the unsuccessful start of the left engine:

<table>
<thead>
<tr>
<th>Ref</th>
<th>FDR time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3915</td>
<td>N2 rises from zero [Starter engaged on left engine]</td>
</tr>
<tr>
<td>2</td>
<td>3204</td>
<td>N2 reaches 25% / N1 reaches 8%</td>
</tr>
<tr>
<td>3</td>
<td>3213</td>
<td>Fuel flow rises from static [Fuel control lever 'ON']</td>
</tr>
<tr>
<td>4</td>
<td>3224</td>
<td>N2 maintained at 25% / No ignition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ground crew requests brakes</td>
</tr>
<tr>
<td>5</td>
<td>3232</td>
<td>N2 maintained at 25%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brake pressure rises [Captain applies brakes]</td>
</tr>
<tr>
<td>6</td>
<td>3235</td>
<td>N2 and Fuel flow begin to drop [Start discontinued]</td>
</tr>
<tr>
<td>7</td>
<td>3236</td>
<td>Brake pressure constant [Parking brake applied]</td>
</tr>
<tr>
<td>8</td>
<td>3260</td>
<td>Ground tells captain of engine fire</td>
</tr>
<tr>
<td>9</td>
<td>3264</td>
<td>N1 reaches zero</td>
</tr>
<tr>
<td>10</td>
<td>3286</td>
<td>Fuel flow reaches static / N2 reaches zero</td>
</tr>
</tbody>
</table>

Figure 5 - Flight Recorder Partial Summary

The CVR had recorded cockpit communication apparently without error. The FDR unit had
recorded data on only 3 of the 7 available tracks, reducing the available recording time from 25 hours to 11 hours; the quality of the FDR data was not affected. The FDR data captured for the engines' N1 and N2 rpm (expressed in terms of percentage rpm) contained anomalies during the start-up and shut-down phases; these anomalies were also evident for previous flights. The anomalies revealed sensor characteristics that resulted in some invalid or sporadic high values for the N1 and N2, when the N2 values were below 20 per cent. Thus, in the TSB FDR report, some engine N1 rpm values and N2 rpm values below 20 per cent were estimated. The EGT is not recorded by the FDR.

Concurrent with the events in the cockpit, the aircraft was being pushed back from the gate. FDR data revealed that the initial segment of the left engine starting cycle was normal. The captain did not use standard phraseology (see Figure 1) during either start; however, he did discuss passenger loading.

After the captain engaged the starter, the N2 increased and stabilized at about 25 per cent; the fuel flow then increased to about 750 pounds per hour (pph) in about a second, and stabilized at that value. FDR data recorded before this incident showed that the fuel flow on start normally rises to about 750 pph in 1 to 2 seconds. There was no further change in the N2 rpm or fuel flow. About 11 seconds after the captain moved the fuel control lever to ON, he informed the first officer that there was no ignition and continued to motor the engine. Both pilots later reported that the captain moved the fuel control lever to OFF at this time. Moving the fuel control lever to OFF cuts off the fuel supply to the engine and inhibits the ignition system. By design, the FDR does not record the movement of the fuel control lever; the sound of the fuel lever being moved may have been recorded on the CVR. Spectral analyses of certain recorded sounds were conducted by the National Research Council and the TSB Engineering Branch; they assessed that the sounds were dissimilar to the fuel control lever being shut off and locked in position.

At the same time that the captain informed the first officer that there was no ignition on the left engine (FDR ref. 3224), the ground crewman advised the cockpit on the intercom system that push-back was complete and requested the brakes be set. Eight seconds later, the captain replied that the brakes had been set. FDR data (3232) showed that the brake pressure rose to about 1,300 psi, and that pressure was maintained for the duration of the recorded data. Analysis of the FDR data showed that the N2 rpm began to drop immediately before the brakes were set.

After peaking at about 750 pph, the fuel flow dropped slowly to 700 pph over 26 seconds. The fuel flow then dropped markedly to maintain about 525 pph, before gradually decreasing to the original static value. Concomitant with this latter decrease in fuel flow, the N2 rpm also decreased. FDR data also revealed that on each previous engine shutdown from an N2 of about 56 per cent, the recorded fuel flow values characteristically decreased from a steady 800 pph to the original static value within about 7 seconds of the fuel control lever being moved to OFF. As well, the N2 rpm reduced to 20 per cent in about 15 seconds, and to zero in another 45 seconds.

None of the fire warning systems activated during the incident, and there were no cockpit indications of fire, nor of any other abnormal situation. The pilots assessed that the engine had experienced a minor malfunction during the starting cycle, and all cockpit indications supported this assessment.

The normal procedures of starting an engine require, in part, that the captain (in the left seat) move the fuel control lever, located in the control pedestal, with his right hand. At the same time, the captain's left hand operates the starter switch located in the forward overhead panel. The parking brake control is mounted on the nose-wheel steering wheel near the captain's left knee, and is also operated by the captain's left hand. During the initial
part of the starting sequence, because the start switch is spring-loaded OFF, the captain has to maintain pressure on the switch to continue turning the engine. The switch is normally released after the engine has ignited and reached self-sustaining rpm, that is, by 35 percent N2 rpm; if the switch is released before the engine has ignited satisfactorily, the engine rpm will decrease and coast down to zero in about 45 seconds.

Shortly after the captain received the first verbal report of fire near the left engine, he discharged the No. 1 fire bottle into the left engine. Following this initial response, the captain received conflicting information on the status of the fire. He was subsequently given a second verbal notification that flames were present near the left engine. Based on that information, it appeared to him that the fire had not yet been extinguished by the first fire bottle; the captain then discharged the No. 2 fire bottle and ordered an emergency evacuation using the forward slides.

Once the captain had ordered the emergency evacuation, the first officer performed a "Severe Aircraft Damage" check and informed Air Traffic Control of the emergency situation. The emergency rescue services (ERS) responded without delay and applied foam to the left engine. The evacuation was reportedly completed in a timely and orderly fashion, and was supported by the RCMP, ERS crews, ramp attendants, and Air Canada ground personnel. Although the right-hand escape slide partially deflated, it did not hamper the evacuation process, and of the four minor injuries, only one involved the right-hand slide.

Once the aircraft was taken to the Air Canada hangar, maintenance personnel checked the engine controls for security, the HP cock, the throttles for travel and movement, and binding of engine controls. They were satisfied that there was no restriction, malfunction, or abnormal behaviour of any of the engine controls.

Air Canada Maintenance then washed out the engine because it had been foamed. They successfully started the engine twice, on both A and B ignition systems. No abnormalities were noted. They checked all the engine controls again and no abnormalities were found.

The left engine was removed from the aircraft and taken to an approved maintenance facility for examination and testing. Before the engine test run began, a static examination of the engine revealed that the ceramic portion of the Auburn igniter plug "B" had cracked; such damage would have rendered it intermittent and unserviceable. The igniter plug "A" was unremarkable. A bench test of both igniter plugs revealed that the Auburn plug was firing from the crack in the ceramic and not the tip, while the Champion plug fired normally.

With the engine in the same configuration as it had been when installed in the aircraft, technicians made four attempts to start it. The first attempt was conducted using ignition system "A"; the start was normal and the engine performed in accordance with the manufacturer's specifications. The second and third starts were conducted using ignition system "B", which included the defective igniter plug. On each occasion, the engine did not start within the specified time limit, and the start sequence was intentionally aborted. During both of these unsuccessful start attempts, the technicians observed a steady stream of unburnt fuel issuing from the exhaust pipe. A fourth start attempt was conducted using ignition system "B" again, but with a serviceable igniter plug installed. The engine then started and performed in accordance with the manufacturer's specifications.

Bench-testing of the fuel control unit (FCU) on this engine revealed that the fuel shut-off lever indexing was correct, that moving the shut-off lever OFF immediately stopped the fuel to the FCU, and that the shut-off valve did not leak when closed. By design, the fuel control lever has no intermediate positions, that is, the valve was either open or closed; a part-way position was, therefore, improbable in the incident circumstances.

The defective escape slide from the right-hand galley door was removed for examination.
and testing at an approved maintenance and overhaul facility. Examination of the slide revealed that the slide fabric had been punctured in several locations by a metal guard (part number 30279) that is designed to protect the pressure gauge of the inflation bottle. Air Canada had recently modified their escape slide packing procedures, and, during the last repacking process on this slide, a protective pad for the pressure gauge guard had unintentionally been omitted. Although the slide unit was covered and protected by the galley door cover, with the internal protective pad missing from around the gauge guard, the slide fabric was punctured as a result of repeated impacts. The most likely source of the impacts was the food service carts that were regularly loaded and unloaded through the right-hand galley door.

**Analysis**

The engine wet start was caused by a defective igniter plug which had malfunctioned during the engine starting sequence. As a result, proper ignition did not occur and unburnt fuel pooled within the combustion chamber section. The igniter fired through the crack in the ceramic shield outside the combustion chamber itself, and ignited the pooled fuel, causing an internal engine fire. The engine fire was short-lived and was contained within the combustion, turbine, and tail-pipe sections of the engine, and it did not pose a significant threat to the aircraft or its occupants. There were no direct cockpit indications of engine fire because the fire was isolated from the fire sensor system.

It was not determined why the captain did not follow the standard phraseology during the engine start sequence; the initial discussion about passenger seating in the cabin seemed to take priority and replaced the standard engine starting phraseology.

Historical FDR data shows that the engine typically coasts down from 20 per cent N2 in about 45 seconds, and since engine stop was recorded at about FDR 3286, the starter was disengaged at or before FDR 3240. The drop in N2 rpm at about FDR 3235, however, indicated starter release, and was immediately followed by the parking brake being set at FDR 3236.

Because the recorded FDR data did not show the characteristic and rapid decrease in fuel flow to the left engine normally seen when the fuel control lever was selected OFF, it is concluded that the fuel lever was not moved to the OFF position during the starting sequence.

It was not determined why the captain did not return the fuel control lever to OFF at the appropriate time; it is likely, however, that his sequence of vital actions was momentarily interrupted by the request from the ground crew to set the brakes. Fuel continued to flow to the engine at a point in the shut-down sequence where continued motoring of the engine would normally have been effective in dispersing any pooled fuel and minimizing the possibility of engine fire. The continued motoring of the engine by the captain with the fuel control lever ON augmented the volume of fuel pooling in the engine and would have exacerbated any fire. Further, after the starter was released, fuel continued to flow into the engine as the engine rpm gradually decreased.

There was a time delay between the first and the second reports of the engine fire, and it is likely that the second report was not based on current or accurate information; however, from the captain's perspective, it would have appeared that the reported engine fire had persisted, despite his activating the No. 1 fire extinguisher bottle. Faced with uncertainty regarding the safety of his aircraft, crew, and passengers, the captain responded by activating the second fire extinguisher bottle and by ordering an emergency evacuation of the aircraft.

The following Engineering Branch report was completed:
LP 099/95 - FDR/CVR Analysis.

Findings

- The abnormal engine start was caused by a defective igniter plug.
- The engine tail-pipe fire was caused by the ignition of fuel that had pooled in the combustion chambers during the starting sequence.
- There were no direct cockpit indications of engine fire because the fire was contained within the combustion section of the engine, and was isolated from the fire sensor system.
- The captain did not return the fuel control lever to the OFF position when he identified a wet start situation.
- The amount of unburnt fuel introduced into the engine during the start was augmented as a result of the fuel control lever still being ON.
- The captain's decision to evacuate the aircraft was appropriate, given the untimely and inaccurate reports he received of an uncontained fire in the left engine.
- During the aircraft evacuation, the escape slide on the right-hand galley door partially deflated, but it remained sufficiently firm for the evacuation.
- The galley door escape slide had unknowingly been punctured prior to the incident as a result of incomplete slide packing procedures and by impact damage to the slide pack assembly.
- An intensive, fleet-wide inspection of all DC-9 escape slides did not reveal a systemic deficiency in the Air Canada slide maintenance process.
- The captain did not use standard phraseology during the engine starting sequences, nor did he completely follow the standard procedures for the wet start event.

Causes and Contributing Factors

The abnormal start and subsequent tail-pipe fire were caused by a defective engine igniter plug. Exacerbating the fire were the captain's incomplete Unsatisfactory Start procedures. Contributing to the incident were the inaccurate and untimely reports of a continuing and uncontained fire in the left engine.

Safety Action Taken

As a result of discovering the incorrect packing process, Air Canada thoroughly reviewed and amended their escape slide repacking procedures. Additionally, an inspection campaign was immediately carried out to verify the serviceability of all escape slides in the Air Canada DC-9 fleet. This campaign required that all escape slides be opened, examined for punctures, and re-closed. During this fleet-wide campaign, only two slides were found to be similarly punctured and the problem, therefore, was not considered to be widespread.
After the most probable cause for the escape slide damage was identified, Air Canada issued an internal bulletin to all cabin crew and cabin servicing personnel, highlighting the potential for damage to the slides during ground servicing operations. Transport Canada is satisfied that the Air Canada maintenance programme for escape slides meets the requirements of the Airworthiness Manual.

Monitoring by Air Canada of the Auburn igniter plugs revealed instances of similar ceramic cracking. The maintenance history of this plug showed that it had not exhibited the longevity that Air Canada had expected, and, shortly after this incident, Air Canada discontinued using it in their engines; no similar occurrences have been reported since. Transport Canada is satisfied that the Air Canada maintenance programme for the ignition system meets the requirements of the Airworthiness 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 05 March 1997.
Air 1995

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.

Amended Report  
Aviation occurrence Report  
Collision with Trees  
Navair Charter Inc.  
Piper PA-31 (NAVAJO) C-GKNB  
Kamloops, British Columbia 7 nm ESE  
22 November 1995

Report Number A95P0268

Summary

The Navair Charter Piper PA-31, flight FCV705, a mail courier with a crew of two, was on a night, instrument flight rules (IFR) flight plan from Williams Lake, British Columbia, to Kamloops. While the crew was conducting an instrument procedure to the Kamloops airport, they flew into an area that was clear of cloud. The captain cancelled his IFR flight plan and descended for a visual flight rules (VFR) approach to the airport. At 1902 PST\(^1\), the aircraft collided with trees at an elevation of 2,400 feet above sea level (asl), seven nautical miles (nm) east-southeast of the Kamloops airport. The captain was fatally injured on impact, and the first officer was seriously injured; the aircraft was destroyed during the crash and post-crash fire.

Ce rapport est également disponible en français.

Other Factual Information

The flight had originated as Navair flight FCV704, which departed Vancouver at 0633 PST for a courier flight to Williams Lake. It arrived at Williams Lake at 0838; after securing the aircraft, the crew retired to their lodgings to rest until the late afternoon departure. The crew returned to the airport at 1730, and, while the first officer prepared the aircraft for departure, the captain obtained a weather briefing for the return flight.

The mail delivery vehicle arrived at the Williams Lake airport 10 minutes later than scheduled, and 210 pounds of freight was loaded onto the aircraft. The flight, now designated FCV705, departed Williams Lake at 1815 for the return trip to Kamloops, and then Vancouver. As they approached Kamloops at 11,000 feet asl, the crew made radio contact with company flight FCV719, an MU-2 aircraft which had arrived in Kamloops at 1846. Its crew reported finding a break in the cloud cover on the instrument approach localizer, about 8 nm from the airport, and they had cancelled their IFR flight plan and had flown a visual approach to the airport. The crew of FCV705 then discussed the conditions under which they too might cancel IFR. The first officer, who was flying the aircraft from the left seat, expressed concern about the prospect of a visual descent over dark terrain and
briefed the captain on the full IFR procedure approach.

At 1852, the crew commenced an instrument approach procedure to the Kamloops airport. The Navajo is a category B aircraft, and the lowest minimum descent altitude (MDA) for a category B aircraft at Kamloops is 3,200 feet asl. The Kamloops airport elevation is 1,133 feet asl, which means that the lowest the aircraft could descend during an IFR approach, without the crew seeing the runway environment, would be 2,067 feet above ground level (agl).

The 0200Z Kamloops weather was reported as 800 feet agl scattered, measured ceiling of 1,900 feet agl overcast, with a light wind, and a visibility of 10 miles. This weather sequence, although more than one hour old, was the last one the crew had requested and the one they were using. At the time of the accident, the Kamloops weather was reported as 800 feet agl scattered, measured ceiling of 1,600 feet agl overcast, with a light wind, and a visibility of 10 miles. It was a dark night, and the sky condition consisted of a 1/10 opacity of stratus fractus and 9/10 opacity of stratus type clouds. Both the forecast and the reported ceiling indicated that the weather was below the minimum required to successfully complete the approach.

As the aircraft began its approach, the captain contacted Kamloops Flight Service Station (FSS) and advised the FSS specialist that he anticipated cancelling the IFR flight plan as soon as possible. The FSS specialist acknowledged the call and provided the airport advisory information, including information that a DHC-8 and a company aircraft were awaiting departure from runway 08 on IFR flight plans. To minimize conflict between arriving and departing IFR traffic, regulations require that aircraft departing on an IFR flight plan not be allowed to take off until the arriving aircraft has either landed, or has cancelled IFR. Some flight crews cancel their IFR flight plans during an approach to facilitate or expedite the departure of other IFR traffic.

During the outbound leg of the approach procedure, the crew established visual contact with lights and other ground references through a break in the cloud layer. The break in the clouds was centred on the localizer, was about 10 nm wide, and extended from the Kamloops non-directional beacon eastward for about 15 nm. The captain cancelled his IFR flight plan at 1855, took over control of the aircraft, and began a circling descent, perpendicular to the localizer, in what appears to have been a figure-eight pattern. At 1858, the crew advised the FSS specialist that they were in descent at 10 nm; 40 seconds later they reported through 5,000 feet and still in the descent.

At 1901, ATS released a DHC-8 for take-off and departure from runway 08. The published IFR departure from that runway placed the DHC-8 on an opposing track with FCV705. The crew of FCV705 was well aware of the departing DHC-8 and of the potential traffic conflict with it. At 1901:26, the FSS specialist called the Navajo for an updated position report, to which the pilot replied that they were 8nm DME out and descending through 2,500 feet. There was no further communication from the aircraft. At 1905, the Kamloops RCMP informed the FSS specialist that an aircraft accident might have occurred in the Juniper Ridge area.

Although risks are always present during night visual flight operations, the risks are even higher in mountainous regions because of the high terrain that surrounds many airports. The published night circuit procedure for the Kamloops airport recommends that only pilots familiar with the local area use the airport during darkness, that all six hazard beacons which identify the circuit area be operational, and that all turns be completed within the perimeter of the hazard beacons. The hazard beacons were operating normally at the time of the accident.
The instrument approach procedure to runway 26 at Kamloops uses a non-directional beacon and a localizer that is aligned, in part, with the valley of the South Thompson River. Although the valley floor is at an elevation of about 1,200 feet asl, the terrain on both sides of the valley rises to at least 3,000 feet. The accident occurred on high ground, outside the area that is normally used for night VFR circuits.

VFR flight relies on the availability of adequate visual cues to allow a pilot to navigate using ground references, and to maintain safe clearance between the aircraft and any local obstacles. Air Navigation Order (ANO) Series VII, No. 3, details specific minimum weather requirements for VFR flight. However, in addition to adverse weather conditions, darkness and sparsely lit terrain often combine to reduce available visual cues, thus degrading a pilot's ability to judge his position and altitude by visual means. This accident occurred in a sparsely lit mountain valley.

The crew was appropriately licensed and qualified for the flight. The captain, employed by Navair for the previous three years, was familiar with the area surrounding the Kamloops airport since he had flown the same flights two to four times per week. The first officer, employed by Navair for the previous three and a half months, was not so familiar with the Kamloops airport, since he had flown this route about 14 times, and only once in IFR conditions at night.

The Piper PA-31 aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. Because of the destruction of the aircraft by the impact and post-crash fire, investigators could not determine if any pre-impact failure or system malfunction contributed to this accident; however, none was identified.

The first officer was wearing a shoulder harness at the time of the accident, and he believes it saved his life. The captain was not wearing a shoulder harness, although one was available.

A Transport Canada audit, conducted on 21 November 1995 in accordance with standard Transport Canada audit procedures, reported that the company was maintaining a satisfactory standard in accordance with appropriate sections of the Air Regulations.

Analysis

The crew began a full instrument approach procedure to runway 26 at Kamloops. The reported weather at the time of the approach was below the minima required to complete an approach to category B limits. Therefore, there was a possibility that the crew might miss the approach and divert to their alternate.

During the approach, the captain established visual contact with lights and other ground references, then cancelled his IFR flight plan. His decision to cancel was likely influenced by his knowledge of the weather, and by the fact that a previous company flight had successfully carried out a visual approach to Kamloops about 15 minutes earlier. It is also possible that the captain's action was intended to help expedite the departure of other aircraft waiting to take off from Kamloops on IFR flight plans. In practical terms, however, this delay would probably have been insignificant to the departing aircraft.

After the captain cancelled his IFR flight plan, ATS released a DHC-8 for take-off on runway 08. The published instrument departure procedure for that runway placed the DHC-8 on a conflicting track with the accident aircraft. It is possible that this traffic conflict influenced the pilot to descend lower than normal in order to ensure separation with the approaching aircraft.

A VFR descent procedure does not provide the benefit of guaranteed terrain clearance and,
in the absence of adequate visual references, may place the aircraft at a dangerously low altitude without the knowledge of the crew. Although the prevailing weather conditions were suitable for VFR flight, as detailed by the ANOs, the dark, overcast night, coupled with the sparsely lit, featureless terrain below, would have reduced available visual cues for the pilots to judge their actual height above the ground, or their position relative to local obstacles. As a result, the overall conditions would have impeded the ability of the pilots to continue the flight with visual reference to the ground.

**Findings**

- The crew was licensed and qualified for the flight.
- The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.
- A Transport Canada audit reported that the company had maintained a satisfactory standard in accordance with appropriate sections of the regulations.
- The Kamloops airport is surrounded by mountainous terrain on all sides, and cautions have been published about use of the airport for VFR flight at night.
- All instrument radio approach aids and all hazard beacons for the visual night circuit procedure were operating normally.
- The weather conditions at Kamloops were suitable for VFR flight, as detailed by the ANOs; however, the overall conditions, brought on by darkness and sparsely lit terrain, would have reduced the available visual cues, and would have impeded the pilots’ ability to navigate and maintain separation from the ground by visual means.
- The captain cancelled his IFR flight plan while conducting an instrument procedure to the Kamloops airport and descended through a break in the cloud layer.
- During the descent, the crew had insufficient visual cues to continue the flight safely with visual reference to the ground.
- The aircraft collided with trees, in mountainous terrain, approximately seven nautical miles east-southeast of the airport and slightly south of the localizer track.

**Causes and Contributing Factors**

The aircraft collided with trees during a night, VFR descent over mountainous terrain because the crew had inadequate visual cues to accurately determine their height above the ground. Contributing to this accident were the captain's decision to cancel his IFR flight plan and attempt a visual approach from well outside the published VFR circuit area, the inherent risks of VFR flight in mountainous regions, and a requirement by the crew to remain clear of departing IFR traffic from the Kamloops airport.

**Safety Action**

**Action Taken**

Since the accident, Navair Charter has hired an outside agency to provide all company flight
crew members with cockpit/crew resource management (CRM) training. All crews have received this CRM training, except for the recently hired pilots, who should receive it within a few months of their hiring.

At a company flight safety meeting held shortly after the accident, Navair reviewed company policy on cancelling IFR flight plans at night, and the night circuit procedures. Navair emphasized that cancelling IFR flight plans to accommodate other aircraft is not recommended.

Navair is presently developing a company Standard Operating Procedure manual which will comply with the new Canadian Aviation Regulations and will address the night IFR and night circuit procedures.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoit Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 23 October 1997.

Appendix A

1. All times are PST (Coordinated Universal Time minus 8 hours) unless otherwise noted.
Air 1995

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.

Elevator trim tab failure
Canadian Airlines International
BOEING 737-200 C-GCPS
Vancouver, British Columbia 60 nm E
05 December 1995

Report number A95P0272

Synopsis

The Canadian Airlines Boeing 737 (CDN 688) departed Vancouver, British Columbia, at 2036 Pacific standard time and was climbing through flight level 310 when the crew felt a severe airframe vibration. There were no other abnormal indications. The crew decided to return to Vancouver, and, as the aircraft slowed down in the descent, the vibration stopped. Moderate vibration was again experienced during the approach, with flaps extended, but an uneventful, normal landing was carried out with the emergency response services on standby. An examination of the aircraft revealed that a two-foot section of the right elevator trim tab (part number 65-73799-14) was missing.

Other Factual Information

The elevator trim tab was 90 inches long and had 4 hinge points, approximately 27 inches apart, with the control horn at the inboard end of the tab, inboard of the first hinge. It was the section between the first and second hinge points that broke off and was not found. The remaining small inboard section of the tab, with the control horn, broke free from the first hinge and was held to the elevator only by the attachment to the control rod. The outboard section was still attached by the remaining three hinges. Marks on the hinges indicated that this section was probably oscillating rapidly through its full range of movement.

The technician who removed the remaining portions of the trim tab noted that a fluid had flowed from the trim tab after he had removed it. Based on the fluid's appearance and odour, he assessed that it was de-icing fluid. The aircraft had been de-iced in Winnipeg about 24 hours before the occurrence flight, and since then, had flown 9 flights and accumulated 11.2 flight hours.
The small inboard section of the trim tab that had remained attached to the aircraft was examined by the TSB Engineering Branch. The examination revealed that the fractures all had occurred in composite material; however, it was not possible to determine their origin. The orientation of the cracks suggested that the final break had progressed from the leading edge towards the trailing edge. The outer layers of the composite surface material had debonded from the honeycomb core. Examination of the debonded material revealed no evidence of weathering or deposits of airborne contaminants, indicating that the debonding had occurred recently. The longer, outboard section of the trim tab showed no evidence of debonding.

The trim tab had a total flight time of 40,254 hours and 26,754 hours since it was last overhauled. It had been last repaired in July 1993 and had flown 6,564 hours since that time. There were, however, some irregularities in the records of the last repair. The initial defect report indicated that the leading edge was cracked and corroded, and that there were several loose rivets on the inboard end. The loose fasteners were replaced in the repair, but the description of the remainder of the repair was unclear. The description indicated that the leading edge was repaired "...per structural repair manual (SRM) 51-40-3, Fig. 1", but this section gives general information on the repair of any formed section and does not supply information that is specific to the trim tab leading edge. It was not possible to determine from the records the nature of the repair, nor the areas of the tab which had been affected. The technician who had performed the repair was a sheet metal repairman. He was unable to recall the nature of the repair, but since he had not repaired composite structures before, it was assumed that the metal leading edge had been replaced, and that no repair had been performed on the composite structure.

The inboard portion of the trim tab was sent to the Boeing Aircraft Company for an examination to determine if there was evidence of an improper repair. Their examination concluded that "...the materials are per drawing requirements and we see no indication of prior damage or repairs on the sample we examined." In addition, the Boeing report offered the opinion that the damage pattern was consistent with damage that occurred while the aircraft was on the ground, and that the damage reduced the trim tab's stiffness and would have allowed it to flutter to failure while the aircraft was in flight.

Transport Canada's service difficulty reporting (SDR) database recorded a number of incidents involving airframe vibration that resulted from worn elevator trim tab bearings. The occurrence trim tab bearings were measured for wear and were found to be within serviceable limits. The database did not record any instances of elevator trim tabs suffering structural failure. In addition, Boeing indicated that the elevator trim tab did not have a history of this kind of failure.

There were two trim tabs for the elevator; one on the left elevator and one on the right. The failure of the right trim tab did not endanger the aircraft from the standpoint of a loss of control; control surface flutter, however, can lead to further aircraft structural damage. The outboard
section of the tab was attached to the elevator without any restriction to its movement, and it oscillated uncontrollably. This in turn caused the elevator to oscillate, which resulted in the airframe vibration felt by the crew.

During the course of this investigation, persons frequently expressed concern about the frequency with which aircraft were damaged by ramp vehicles. People operating ramp vehicles near aircraft are not always trained in the field of aviation, and consequently may not appreciate the critical nature of any damage to a flight control surface. The world’s airlines estimate that the global cost of ramp accidents and incidents is about US$2 billion per year, and the International Airline Transportation Association (IATA) has established a committee to examine this problem. Individual airlines, such as Canadian Airlines International, are also researching the problem and attempting to reduce ramp damage through employee education programs. Transport Canada sponsors an annual symposium dealing with maintenance and ground crew errors.

Analysis

Although the records for the 1993 repair to the trim tab were insufficiently detailed to determine the exact nature of the repair work carried out, there was no evidence that the repair work was incomplete or improper. There was no history of trim tab fatigue failure; the typical cause for flutter was worn bearings, and this possibility was ruled out in this occurrence.

The trim tab structural failure was a direct result of the in-flight aerodynamic loads exceeding the structural strength of the trim tab, which had been weakened by either recent or existing damage, spontaneous composite debonding and/or fatigue, or a combination of both.

The presence of de-icing fluid inside the trim tab indicated that the damage to the composite structure had likely occurred before the aircraft was last de-iced. The trim tab may have been originally damaged as a result of a collision with a ground vehicle or an airport structure, but such a collision could neither be substantiated nor ruled out. Given the nature of the mode of failure and the lack of other plausible explanations, however, such a collision being the initiating event for the trim tab failure is considered most likely.

The following Engineering Branch report was completed:

LP 191/95 - Elevator Trim Tab Examination.

Findings

1. A 24-inch section of the right elevator trim tab separated from the aircraft in flight.

2. The records for the July 1993 trim tab repairs were incomplete, but there was no evidence that the repair was improper.

3. Ground handling damage to aircraft is recognized as an aviation
industry problem, and it is possible that the failure of the elevator trim tab was initiated by such damage.

**Causes and Contributing Factors**

The cause of the trim tab failure was not determined; however, the tab was most likely originally damaged in a collision while the aircraft was on the ground.

*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 27 August 1996.*

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**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 Vehicle Royal Air Maroc
Boeing 747-400 CN-RGA
Montreal (Mirabel) International Airport, Quebec
21 January 1995

Report Number A95Q0015

Synopsis

The Royal Air Maroc Boeing 747-400 was parked in the de-icing centre of Montreal (Mirabel) International Airport, Quebec. The aircraft was being prepared for a scheduled flight from Mirabel to Casablanca, Morocco, with a stop at New York, New York. The four engines were running during the de-icing operation. The crew heard "dégivrage terminé" (de-icing completed), and the captain asked the co-pilot to inform the apron controller that the aircraft was ready to taxi. Taxi instructions were issued.

The aircraft started to move forward and overturned the two de-icing vehicles that were still in front of the aircraft's horizontal stabilizers. The two vehicle drivers sustained minor injuries; the three occupants of the cherry-pickers received fatal injuries.

The Board determined that the flight crew started to taxi the aircraft before its perimeter was clear, following confusion in the radio communications. The following factors contributed to the accident: a lack of de-icing procedures within Royal Air Maroc; non-compliance with procedures on the part of the Canadian Airlines International Ltd. de-icing crew; inadequate or inappropriate communications equipment; incomplete training of Snowman 1 (the chief de-icing attendant); a regulatory framework less demanding of foreign air carriers than of Canadian carriers; a lack of operational supervision; and a lack of adherence to radio protocol.

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1.0 Factual Information

1.1 History of the Flight

On 21 January 1995, the Boeing 747-400, registration CN-RGA, operated by Royal Air Maroc, was preparing for scheduled flight AT 205 from Mirabel, Quebec, to Casablanca, Morocco, with a stop at New York, New York. The aircraft was parked at gate 124 near fuelling station 2 on the main apron. The passengers boarded at the scheduled time, and the co-pilot asked the apron controller for authorization to start the engines and taxi to the de-icing centre.

The aircraft taxied and stopped at the de-icing centre, where two Canadian Airlines International Ltd. (CAIL)\(^1\) de-icing vehicles were waiting for it. One de-icing vehicle moved to the front of the aircraft and raised its cherry-picker to flight deck level; the cherry-picker operator signalled to the pilot to tune his radio to 130.775 megahertz (MHz), the working frequency of CAIL, on the very high frequency (VHF) band. The crew had used this same frequency during engine start, but was unaware that it was the working frequency of CAIL.

The captain and the chief de-icing attendant (Snowman 1) agreed that only the wings and horizontal stabilizers of the empennage were to be de-iced with type I de-icing fluid. Snowman 1 initially asked the captain to shut down the engines. After the captain indicated that there would be a delay to start the APU, Snowman 1 suggested that the aircraft be de-iced with the engines running, and the captain agreed.

About seven minutes after the aircraft came to a stop, the apron controller tried unsuccessfully to contact Snowman 1 on the apron frequency. A few seconds later, the CAIL de-icing coordinator (Iceman), who was in the company offices, tried to raise Snowman 1 on the company frequency. The Iceman asked Snowman 1 to notify the apron controller when the de-icing was completed. The crew of the Boeing heard "dégivrage terminé" (de-icing completed) on 130.775 MHz. Neither the controller nor the Iceman received any acknowledgement from Snowman 1. The co-pilot then advised the apron controller that the aircraft was ready to taxi. Then the captain repeated "De-icing completed" twice on the CAIL frequency. The controller issued instructions for Royal Air Maroc to taxi to taxiway Kilo. As the pilot had not received a negative response or contra-indication from Snowman 1, he assumed that de-icing of the aircraft was completed and that the de-icing crew had left the area. At the time of these transmissions, the elapsed time since the beginning of the operation matched the time usually required for this kind of de-icing operation.

About 26 seconds later, after making an external visual check from the cockpit, the captain released the brakes. At that time, the two de-icing vehicles were positioned on either side of, and perpendicular to, the fuselage, forward of the horizontal stabilizers, and five de-icing personnel were still de-icing the horizontal stabilizers. After he had taxied 95 feet, the captain stopped the aircraft suddenly when he heard a radio
message directing him to shut down the engines. The horizontal stabilizers of the aircraft had struck the telescopic booms of the de-icing vehicles, causing the occupants of the cherry-pickers to fall and knocking the de-icing vehicles over on their sides. The two vehicle drivers sustained minor injuries. The three occupants of the cherry-pickers sustained fatal injuries when they struck the ground.

The accident occurred in daylight at 1652 eastern standard time (EST)\(^{(2)}\) on 21 January 1995, at latitude 4540'N, longitude 07402'W.

### 1.2 Injuries to Persons

<table>
<thead>
<tr>
<th></th>
<th>Crew</th>
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<tr>
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<td>-</td>
<td>-</td>
<td>3</td>
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</tr>
<tr>
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<tr>
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<td>18</td>
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### 1.3 Damage to Aircraft

The aircraft sustained substantial damage.

### 1.4 Other Damage

The two de-icing vehicles were heavily damaged by the collision with the aircraft and the impact with the ground. An undetermined quantity of de-icing fluid was spilled on the apron.

### 1.5 Personnel Information

#### 1.5.1 Royal Air Maroc Personnel

##### 1.5.1.1 General

<table>
<thead>
<tr>
<th></th>
<th>Captain</th>
<th>First Officer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>49</td>
<td>39</td>
</tr>
<tr>
<td>Pilot Licence</td>
<td>ATPL</td>
<td>ATPL</td>
</tr>
<tr>
<td>Medical Expiry Date</td>
<td>31 May 1995</td>
<td>31 May 1995</td>
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<td>Total Flying Hours</td>
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<td>7,000</td>
</tr>
<tr>
<td>Hours on Type</td>
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<td>500</td>
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<tr>
<td>Hours Last 90 Days</td>
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<td>24</td>
</tr>
<tr>
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<td>1</td>
</tr>
<tr>
<td>Hours Off Duty Prior to Work Period</td>
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<td>48</td>
</tr>
</tbody>
</table>

The flight crew was certified and qualified for the flight in accordance with existing regulations. The pilots flew the Casablanca-Mirabel route on a regular basis.

The flight crew was not aware of any particular de-icing procedure at Mirabel, and followed the instructions of the aircraft manufacturer.
1.5.1.2 The Captain

This was the first time the captain had been to the Mirabel de-icing centre. In the past, his aircraft had been de-iced at the gate with the engines shut down. The communication procedures had also been different; in the past, the station attendant had communicated with the captain via the interphone in the nose gear well and had acted as an intermediary between the flight crew and de-icing crew. When the de-icing was completed, the crew had started the engines, and a marshaller, visible to the pilot, had guided the aircraft using signals.

At the time of the accident, the captain occupied the left-hand seat, was at the controls, and was handling communications with the de-icing crew on the CAIL frequency. He speaks English and French fluently.

1.5.1.3 The Co-pilot

The co-pilot had used the de-icing service at Mirabel on one previous occasion, when the aircraft was de-iced at the de-icing centre the previous year. The operation involved a different aircraft, which required a flight engineer to be in charge of de-icing. The de-icing was performed with the engines shut down.

At the time of the accident, the co-pilot occupied the right-hand seat and was in charge of communications with Air Traffic Services. He speaks English and French fluently.

1.5.1.4 The Flight Attendants

There were four flight attendants in the aft section of the cabin, with about ten passengers. From their stations, the flight attendants were in positions to observe the de-icing vehicles and inform the pilots of the progress of the operation via the intercom system.

Before starting to taxi to the runway, the flight crew advised the cabin crew that the aircraft was ready to taxi. They did not consult the flight attendants to determine whether the aircraft perimeter was clear; there was no requirement to routinely check with the cabin crew before manoeuvring the aircraft. None of the flight attendants witnessed the collision.

The Royal Air Maroc training program included cockpit/cabin coordination training for the crews. Although this training is not a requirement, it is included in the course syllabus of many air carriers.

1.5.2 Canadian Airlines International Ltd. Personnel

On the day of the accident, CAIL had to de-ice only the Royal Air Maroc aircraft. The de-icing crew consisted of four persons: two truck drivers (one of whom was the chief de-icing attendant, Snowman 1) and two cherry-picker operators. One station attendant joined the crew as a trainee after the iceman authorized him to observe the de-icing from one of the cherry-pickers. The de-icing personnel held the required radio operator certificates.

1.5.2.1 De-icing Crew Training at Mirabel
In the fall of 1994, the de-icing crews attended a training course approved by CAIL on de-icing of aircraft with the engines shut down. Four of the five de-icing crew in this occurrence attended this course; the trainee who was observing from one of the cherry-pickers had not received any de-icing training. The manual used for the course, and available to all employees, stated that a person could not de-ice an aircraft while its engines were running unless that person had received appropriate "engines-on" training.

In the fall of 1994, some air carriers had asked CAIL to de-ice their aircraft with the engines running. On 03 January 1995, at the Mirabel base, 12 CAIL employees attended a course on de-icing the Boeing 727 and the Lockheed 1011 with the engines running. That was the first course given by CAIL on these aircraft. Three of the five de-icing crew involved in this occurrence had attended this course; Snowman 1 and the trainee had not.

The course was adapted from CAIL's "Engines On De-Icing/Anti-icing for the B737 and A320" training program. Support material on the B727 and Lockheed 1011 was incorporated into the course. The methods used by the CAIL instructor/developer included the following: a classroom lecture supported by overheads; distribution of documentation; familiarization on the aircraft types (B727 and L1011); practical demonstrations of vehicle movement around the B727 and Lockheed 1011 with the engines shut down; and a practical exercise using an Airbus A310 with its engines running. The employees would normally have been required to complete a written examination following classroom instruction. However, the short interval between the date of the request for de-icing service from one of the air carriers and the date that the carrier wanted the service to begin did not allow the trainer enough time to prepare a test specifically for the B727 and the L1011.

The employees who attended the course were authorized to de-ice only the B727 and L1011 with engines running. The employees stated that, during the course, the trainer had approved de-icing the B747 with the engines running. However, analysis of the electronic mail prior to the accident between the Manager, System Aircraft De-icing, the Manager of Client Services at Mirabel, and the instructor/developer revealed that the participants were not authorized to de-ice B747s with the engines running. However, the Manager, System Aircraft De-icing, acknowledged the need for a study of engines-on de-icing for the B747. The three de-icers involved in this occurrence who had taken the engines-on course had subsequently de-iced some smaller aircraft with their engines running; however, because of conflicting information, it could not be determined if any of them had de-iced a B747 with its engines running.

1.5.2.2 The De-Icing Coordinator (Iceman)

At the CAIL Mirabel base, the de-icing coordinator, who was called the Iceman, was responsible for the direction of all de-icing crews and for ensuring that the de-icing crews complied with CAIL standards and procedures. The Iceman was in the CAIL offices at fueling station 2, and he was aware that Snowman 1 had not taken the course for engines-on de-icing. However, he did not intervene when he heard Snowman 1 suggest to the captain of the B747 that he leave the engines running.

The Iceman held the qualifications required by CAIL. He had attended the engines-on de-icing and de-icing coordinator courses given on 03 January 1995.

1.5.2.3 De-icing Personnel
There are normally two persons in each de-icing truck. When de-icing requires more than one truck, the crew delegates a truck driver (Snowman 1) to handle communications with the flight crew. Snowman 1 had not attended any engines-on de-icing course; consequently, he was authorized by CAIL to de-ice only aircraft with the engines off.

The truck driver is required to drive his vehicle around the aircraft while following the instructions of the cherry-picker operator, whom he can see through an opening in the roof of the truck cab. He occasionally manoeuvres the cherry-picker. He must also convey relevant safety instructions to the cherry-picker operator, complete the appropriate forms and reports, and inform the pilot of the type of fluid used and the time of the last spray.

The cherry-picker operator aims the high-pressure spray of de-icing fluid at the contaminated surfaces. He is required to wear protective clothing and equipment when de-icing. Irritation of the eyes and skin will result if they come into contact with de-icing fluid. On the day of the accident, contrary to CAIL instructions, the cherry-picker operators were not wearing the protective eye wear, masks, or respirators provided by CAIL.

1.5.2.4 The Station Attendant

The station attendant who was in one of the cherry-pickers had no specific duties. He wanted to work as a Snowman and had been authorized to observe the de-icing.

1.5.2.5 The Lead Station Attendant

The lead station attendant provided informal training to the station attendant. The lead station attendant was responsible for serving clients safely in accordance with CAIL instructions and methods. Furthermore, he had to ensure that the de-icing crews operated effectively and complied with existing standards. He was also responsible for directing the work of, and providing practical training to, the de-icing personnel assigned to him.

1.6 Aircraft Information

1.6.1 General

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>The Boeing Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
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</tr>
<tr>
<td>Year of Manufacture</td>
<td>1993</td>
</tr>
<tr>
<td>Serial Number</td>
<td>25629</td>
</tr>
<tr>
<td>Certificate of Airworthiness</td>
<td>13 January 1994</td>
</tr>
</tbody>
</table>

(Flight Permit)

| Engine Type (number of) | General Electric CF6-80 (4) |

Examination of the relevant documents revealed that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The central maintenance computer indicated that the aircraft systems were functioning normally at the time of the accident.
1.6.2 Procedures for Engines-on De-icing of Boeing 747-400

In the interests of ground personnel safety, the maintenance manual for the Boeing 747-400 recommends de-icing the aircraft with the engines and auxiliary power unit (APU) off. However, the maintenance manual does not constitute a reference for the pilot. If it is necessary to de-ice with the engines or APU running, the pilot must follow the procedures contained in the operations manual, which is carried in the cockpit. The operations manual contains no restrictions regarding the de-icing of the aircraft with engines running. The crew followed all the procedures with one exception; the air conditioning unit was not turned off as required by the manufacturer.

1.7 Meteorological Information

The meteorological reports describing the atmospheric conditions at Mirabel at the time of the accident are the regular observations issued at 1600 and 1700.

1600: partially obscured, measured ceiling 900 feet overcast, visibility three miles in moderate snow showers, temperature -1C, dew point -1C, wind 040 at 18 knots, drifting snow.

1700: measured ceiling 900 feet overcast, visibility five miles in moderate snow showers, temperature -1C, dew point -1C, wind 030 at 19 knots, drifting snow.

1.8 Communications

1.8.1 General

All communications equipment was functioning normally. Radio communications on the apron and ground frequencies were recorded and transcribed and indicated no technical anomalies with the radio equipment. Communications on company frequencies, like that of CAIL, are not normally recorded.

1.8.2 Communications between De-icing Crew and Apron Controller

The truck drivers contacted the ground and apron controllers before entering the de-icing centre. At the de-icing centre, the de-icing crew left the apron frequency and selected the CAIL working frequency (130.775 MHz) without informing the apron controller; they were not required to do so. The CAIL frequency is used by CAIL employees and by the flight crews of air carriers that use CAIL services at Mirabel Airport. The frequency is generally used for ground operations, including de-icing operations.

1.8.3 Communications between Royal Air Maroc Crew and Snowman 1

The digital flight data recorder (DFDR) recorded the times that transmissions were made on the cockpit VHF radios. The DFDR indicates that the crew made at least 13 VHF transmissions on a frequency other than the apron, ground, or tower frequencies. The first 11 messages were transmitted between 1 minute 9 seconds and 2 minutes 47 seconds after the aircraft was parked. The twelfth and thirteenth transmissions were made within a short period just after the accident.

Because the communications on 130.775 MHz were not recorded, the precise content
of the conversations between the captain and Snowman 1 could not be determined. However, information compiled through interviews was used to make an approximate reconstruction of the communications on the CAIL VHF frequency while the aircraft was in the de-icing centre.

The pilot and Snowman 1 agreed on the type of de-icing fluid to be used and the surface to be de-iced. They did not discuss the manner in which the de-icing trucks would manoeuvre around the aircraft nor did they discuss the appropriate communication cues to expect when de-icing would be completed. Normally, flight crews are aware of the de-icing procedures and a briefing of this type is not expected prior to commencing de-icing.

The communications systems on the trucks were set up to allow the drivers to hear the captain and cherry-picker operators at the same time. After the pilot and Snowman 1 agreed on the de-icing method, the truck drivers selected the interphone buttons on their microphones in order to talk only with their cherry-picker operators. From that moment on, the drivers did not transmit on 130.775 MHz, nor did they hear any transmissions on that frequency, possibly because of background engine noise or low volume settings.

As the radio transmissions were not recorded, radio protocol could not be evaluated. It was established, however, that the message "dégivrage terminé" (de-icing completed) heard by the flight crew was not preceded by the aircraft call-sign or the de-icing crew call-sign. To avoid confusion, the rules of standard phraseology state that radio messages must be preceded by the receiving station call-sign, followed by the sending station call-sign, with some abbreviations to the call-signs permitted once good communications have been established.

### 1.8.4 Instructions to Taxi for Take-off

The co-pilot contacted the apron controller and said he was ready to taxi. In normal aviation practice, the expression "ready to taxi" means that the pilot-in-command of an aircraft has ensured that all maintenance operations and other operations on the aircraft have been completed and that the aircraft perimeter is clear. When the pilot confirms to the apron controller that his aircraft is ready to taxi, the controller indicates to the pilot by radio the route he is to follow on the apron and the order of priority assigned to him.

Before issuing instructions to the pilot to taxi to Kilo, the apron controller observed that the rotating beacon on top of the aircraft was on, and he concluded that the pilot had started the engines without authorization. As he was not familiar with CAIL procedures, he assumed that an attendant was in contact with the pilot via interphone and that the aircraft perimeter was clear.

The Royal Air Maroc crew interpreted the issuance of instructions to taxi to Kilo as also being a confirmation that the aircraft perimeter was clear.

### 1.8.5 Communications Equipment

The Royal Air Maroc Boeing 747-400 has three VHF radios. Two radios were used for routine communications, and one radio was used for the ARINC Communications Addressing and Reporting System (ACARS). At the time of the accident, the captain's and co-pilot's VHF radios were selected to the CAIL and apron frequencies,
respectively. The flight crew never left the apron control frequency and was monitoring both frequencies.

The CAIL offices were equipped with one VHF radio, a VHF scanner, and a UHF transceiver.

Each truck was equipped with one VHF radio, one portable UHF transceiver (walkie-talkie), and an interphone linking the cherry-picker with the truck cab. The VHF radios could operate on only one frequency at a time. The drivers wore headsets and used a push-button microphone to communicate with the VHF radio and the interphone. The cherry-picker operators wore headsets and used voice-activated throat microphones.

The truck drivers stated that communications with the pilot and cherry-picker operators were normal throughout the de-icing operation. Due to the high ambient noise level, the drivers heard the noise of the engines continuously over the interphone. Transmissions on the UHF walkie-talkies used for communications between the Snowman and the Iceman were practically inaudible due to the ambient noise.

The apron controller was not monitoring CAIL’s VHF frequency and was not required to do so.

1.9 Aerodrome Information

1.9.1 General

Since 1992, a private corporation called Aéroports de Montréal (ADM) has been managing Mirabel International Airport. Transport Canada and ADM share control, with Transport Canada controlling the manoeuvring areas (taxiways and runways) and ADM controlling the main apron (cargo ramp, de-icing centre, and industrial traffic area). Because of environmental regulations, ADM has required, since January 1994, that aircraft be de-iced in the de-icing centre, where the de-icing fluid is recovered. ADM does not issue de-icing permits to de-icing companies. ADM issues type "D" airport driving permits to de-icing company personnel provided that the company has a de-icing contract with an air carrier.

According to ADM, de-icing of aircraft was under the control of the de-icing company. ADM did not intervene in the internal procedures of the companies providing maintenance and mechanical services. ADM was aware that some aircraft were de-iced with the engines on.

1.9.2 Procedures for Flight Crews Published by ADM for Aircraft De-icing

The de-icing procedures for flight crews were developed by ADM, designed solely to achieve optimum utilization of the de-icing facility. Procedures No. 5 and 6 required that:

5. When aircraft de-icing is completed, the pilot shall obtain authorization to start the engines from the (apron) controller on frequency 122.4 MHz.

6. When ready to taxi, the pilot shall obtain clearance to taxi from the controller on 122.4 MHz.

A copy of these procedures was provided to air carriers, including Royal Air Maroc, as they were not published on the Mirabel aerodrome chart. These procedures were
conveyed by Royal Air Maroc to their flight crews on 03 February 1995, that is, after the accident.

1.9.3 Apron Control Tower

The control tower for the apron is located above the aeroquay 1,146 metres north of the de-icing centre and about 575 metres east of the main control tower. The apron control tower location is not indicated on the aerodrome chart, but it is indicated in the Canada Flight Supplement (CFS).

The south station of the de-icing centre was not visible to the apron controller because the central building obstructed his view of the aircraft fuselage and activities on the ground. Only the vertical stabilizer and upper deck of the B747-400 could be seen from the tower. ADM was considering installing a video camera, as it had done for the cargo ramp, linked to the apron control tower to enable the apron controller to observe operations in the de-icing centre and to facilitate the orderly conduct of de-icing operations. The video camera was not intended to enable the controller to observe ground operations while the aircraft was parked. This type of system is not mandatory, nor is it considered by ADM to be essential to the safety of aircraft movements on the apron.

The primary role of the apron controller is to direct traffic in a safe, expeditious, and orderly manner. The tools employed to do this included frequency 122.4 MHz and the procedures developed by ADM for controlling aircraft on the apron. The controller is not required to check with the de-icing crew or the pilot to confirm that de-icing is completed and the aircraft perimeter is clear.

The apron controller was not informed by his employer that aircraft were being de-iced with engines running in the de-icing centre. According to the controller, flight crew procedure No. 5 meant that the engines were shut down for de-icing. In addition, procedure No. 6 implied that the aircraft perimeter was clear when the pilot requested clearance to taxi.

1.10 Flight Recorders

The flight recorders were played back and analyzed at the TSB Engineering Branch. Since the APU was supplying alternating current (AC) to the aircraft after the accident, the cockpit voice recorder (CVR) continued running until it was removed from the aircraft. Given that the CVR retains only the previous 30 minutes of information, the information relating to this occurrence was lost when other information was recorded over it.

1.11 Wreckage and Impact Information

The leading edges of the horizontal stabilizers sustained substantial damage when they struck the telescopic booms of the de-icing vehicles. The impact was not sufficient to be detected by the horizontal acceleration sensor and was not recorded on the DFDR.

1.12 Survival Aspects

The three occupants of the cherry-pickers were wearing their safety harnesses. The fall from a height of approximately 15 metres was not survivable.

1.13 De-icing Aircraft on the Ground
1.13.1 Regulatory and Operational Framework of Ground De-icing

Transport Canada complies with article 33 of the Convention on International Civil Aviation with respect to the issuance of operating certificates to foreign air carriers. In short, Transport Canada recognizes as valid all operating certificates, certificates of qualification, and licences issued by a contracting state to the Convention on International Civil Aviation. Article 11 of the Convention requires that foreign air carriers abide by the laws and regulations in effect in the host country. In the event of operational problems, Transport Canada would inform the air carrier and the national civil aviation authority of the country concerned.

Air Regulations, paragraph 540.2(4)(b), states that where conditions are such that frost, ice, or snow may reasonably be expected to adhere to the aircraft, no persons shall take off or attempt to take off unless certain conditions are met. One of the conditions is that the operator establish a Ground Icing Operations Program (GIOP), in accordance with the standards specified in the Ground Icing Operations Standard, and comply with that program.

The GIOP contains a series of approved procedures, guidelines, and methods, as prescribed in Transport Canada official manuals, and is intended to ensure that no aircraft takes off with frost, ice, or snow adhering to any of its critical surfaces. Transport Canada requires that the operator's de-icing/anti-icing procedures be described in the appropriate manual. Transport Canada only approves the GIOP training program; it does not develop standards for de-icing procedures, nor does it approve the procedures and methods used for de-icing aircraft on the ground. Transport Canada inspectors ensure that aircraft are operated in accordance with the clean aircraft concept. Inspectors conducting in-flight inspections will monitor general de-icing procedures, including communications with the de-icing personnel. Transport Canada does not monitor the quality or compliance of the de-icing procedures used at airports.

Air Navigation Order (ANO), Series VII, No. 2 required that an air carrier establish a training program approved by the Minister on the adverse effects of surface contamination and provide such training annually to crew members and other persons designated by it to perform inspections pursuant to section 540.2 of the Air Regulations.

Transport Canada encourages air carriers to develop their own de-icing procedures for the aircraft they operate; consequently, there are differences between the various de-icing companies in terms of their methods of communication and aircraft marshalling. For instance, some use a marshaller, visible to the pilot, who guides the aircraft before and after de-icing, while others, when the aircraft stops, have the de-icing crew chief talk to the pilot via the aircraft interphone. CAIL procedures recommend that VHF radio be used to communicate with the pilot. Snowman 1 must act as the aircraft marshaller until the aircraft is brought to a halt.

Other private contractors have developed basic de-icing procedures that are suitable for all aircraft types whether the engines are on or off. These contractors are not required to develop an employee training program. An operator who contracts de-icing/anti-icing services from another organization is responsible for ensuring that the training program of the contractor and application of standards meet the operator's own Ground Icing Operations Program criteria. If a contractor provides de-icing services to a Canadian operator, the standard would require that training be provided to the
contractor. According to Transport Canada, the same basic techniques and similar procedures should be applied when providing de-icing services to foreign air carriers, even if no previous arrangements have been made in this regard.

1.13.2 Canadian Airlines International (CAIL)

The CAIL Maintenance Department was responsible for the implementation, monitoring, and compliance functions of the CAIL de-icing program. CAIL had developed de-icing procedures and training standards for the implementation of those procedures; they were published in the Ramp Services Manual, which employees could refer to at any time.

The latest operational audit carried out by CAIL concerning its own de-icing operations was done on 18 January 1994. However, because weather conditions were favourable, the auditor was unable to observe de-icing operations. The audit was a review of the personnel files of de-icing crew members, and the audit report noted no irregularities.

CAIL de-icing procedures used for contract aircraft were to be consistent with the procedures set out in the Ramp Services Manual. Section 3-7-18 of the manual provides as follows:

At NO time will a lesser standard be used. A formal contract covering the provision of de-icing service must exist between Canadian Airlines and the affected carrier, e.g. a Ground Handling Agreement. If the carrier's aircraft are different from Canadian aircraft, or if the carrier has specific requirements, then a qualified representative of the carrier must provide the required training to Canadian Airlines personnel.

If the carrier approves the use of Canadian Airlines De-icing procedures on its aircraft, this must be covered in the contract...

CAIL did not provide Royal Air Maroc with a copy of its de-icing procedures, and Royal Air Maroc did not request a copy.

1.13.3 Royal Air Maroc

Royal Air Maroc held an operating certificate issued by Transport Canada in accordance with article 33 of the Convention on International Civil Aviation. Under its operating certificate, Royal Air Maroc was subject only to the provisions of the following Canadian ANOs: Sparsely Settled Areas Order, Aircraft Speed Limit Order, Emergency Radio Frequency and Visual Interception Signals Order, and Sonic and Supersonic Flight Order.

As Royal Air Maroc was not subject to the provisions of ANO, Series VII, No. 2, Air Carriers Using Large Aeroplanes Order, Part V, respecting employee training and qualifications, it was not required to establish a ground icing operations program. Royal Air Maroc had not developed specific de-icing procedures for its operation; its pilots were required to comply with the instructions of local authorities, service companies, and the aircraft manufacturer.

Royal Air Maroc made three flights a week to Mirabel, with the aircraft stopping at Mirabel for a few hours before departing for New York and Casablanca. A station manager, who had held that position at Mirabel for the past two years, was in charge of administrative management at the station. His duties included controlling passenger
and baggage embarkation, arranging crew accommodations, and serving as liaison between Royal Air Maroc and CAIL and ADM. He received all information intended for the crew and forwarded it to Royal Air Maroc management, which then distributed it. The station manager had no experience with aircraft de-icing.

1.13.4 De-icing Aircraft with Main Engines On

On 22 August 1994, Transport Canada issued Air Carrier Advisory Circular No. 0072, intended to encourage air carriers to allow their aircraft to be de-iced/anti-iced with the main engines running where technically feasible; to describe, as part of their Ground Icing Operations Program, the procedures to be followed for each aircraft type; and to train their operational personnel in the proper use of these procedures. The purposes of this initiative were to improve the speed and efficiency of de-icing operations, to reduce departure delays in adverse weather, and to maximize the use of hold-over times.

According to the International Civil Aviation Organization (ICAO), the following information must be given to the pilot-in-command on completion of de-icing: the type of fluid used, the time of the last application, and confirmation that the aircraft complies with the clean aircraft concept. The captain released the brakes before receiving this information.

Aircraft de-icing was the responsibility of air carriers. Neither Transport Canada nor ADM monitored the quality or compliance of the de-icing operations of de-icing companies. ADM felt Labour Canada was responsible under the Canada Labour Code for the safety of employees performing de-icing, and that Transport Canada oversaw the aeronautical aspects under the relevant regulations. Consequently, the de-icing operations of several foreign air carriers were not controlled by the authorities.

1.14 Additional Information

1.14.1 De-icing Contractors at Mirabel

CAIL operated from its secondary base at Mirabel, which includes offices, maintenance facilities, and support staff. At the time of the accident, CAIL operated two flights a week at Mirabel. Service contracts with air carriers were the base's principal source of revenue. De-icing of aircraft was one of the services offered by CAIL.

Seven companies offered aircraft de-icing service at Mirabel. Two of these companies were air carriers and the other five were private de-icing contractors; the latter were not required to comply with ANO, Series VII, No. 2. As these contractors were not air carriers, they were not required to develop either a GIOP or de-icing procedures.

De-icing can be a lucrative business, and there is strong competition between the de-icing contractors at Mirabel. Because most were unregulated, they could respond quickly to client demands, whereas CAIL, by following all of the applicable provisions of the ANO, could not. Several of these contractors de-iced aircraft with their engines running.

Investigation revealed that there was considerable animosity between CAIL personnel and one of the private de-icing contractors, and that CAIL had complained to ADM about the practices of that contractor. CAIL alleged that the contractor took up a position at the de-icing centre without authorization and de-iced aircraft that were
already under contract to CAIL.

1.14.2 Coroner's Inquest

A coroner's inquest regarding this occurrence began on 15 May 1995 at the courthouse in Laval, Quebec. The inquest lasted 12 days, ending on 02 June 1995. The individuals and companies given standing as interested parties were the families of the three deceased employees, CAIL, ADM, the International Association of Machinists, the TSB, Royal Air Maroc, and the Attorney General of Canada. The TSB worked with the coroner on the inquest.

The coroner did not make recommendations regarding this occurrence. In the conclusion to his report, the coroner recognized the expertise of the TSB in the field of aviation and left it to the TSB to determine whether there were any safety deficiencies and to make recommendations if appropriate.

2.0 Analysis

2.1 Introduction

The investigation established that the VHF radios in the aircraft and de-icing vehicles functioned normally during the de-icing and at the time of the accident. However, there was a lack of communication between the flight crew and Snowman 1 that resulted in the captain believing that the de-icing was completed. The analysis will examine the reasons why the flight crew believed that the de-icing equipment and personnel were clear of the aircraft, the lack of positive procedures on the part of the de-icing crew, and the contributing factors which led to the accident.

2.2 Decision to Taxi

The flight crew did not realize that 130.775 MHz was the CAIL working frequency. They mistakenly concluded that this frequency was reserved for de-icing. In addition, the pilots assumed that 130.775 MHz was a communication system analogous to the interphone, although the frequencies used for air-ground communications are in the VHF band, 118-136 MHz. Consequently, the pilots presumed that the Iceman's message about the completion of de-icing came from Snowman 1, that the message was intended for them, and that it indicated that de-icing was completed.

The pilots heard the words "dégivrage terminé" (de-icing completed). Although this message was not preceded by the flight call-sign or the de-icing crew call-sign, the pilot read back "de-icing completed" twice. As the duration of the operation up to that point matched the time usually required for this type of de-icing, and as they received no acknowledgement from Snowman 1, the flight crew thought the de-icing crew had left the frequency and departed the area. The co-pilot then advised the apron controller that the aircraft was ready to taxi, and, in doing so, the co-pilot conveyed to the apron controller that de-icing was completed and the aircraft was clear. Relying on that information, the controller indicated to the co-pilot his assigned route for taxiing from his current parking spot to Kilo turn-off. The pilot mistakenly interpreted the issuance of taxi instructions as confirmation that the aircraft was clear.

According to the rules of standard phraseology, to avoid confusion, radio messages must be preceded by the receiving station call-sign, followed by the sending station call-sign. While these rules may not apply to interphone communications, the "open" nature of VHF radio communications requires that the international rules of radio
procedure be followed. In this case, the pilot heard the words "déglivrage terminé" and made a number of erroneous assumptions: that the radio transmission was directed to him; that the de-icing operation was completed; and that all equipment and personnel were clear of the aircraft's taxi path.

2.3 Communications Equipment

Except for the background noise of the engines on the interphone, communications between the drivers and cherry-picker operators were clear. During the de-icing, the Iceman and the pilot tried without success to communicate with the de-icing crew on the CAIL frequency. By all indications, the noise of the engines prevented Snowman 1 from hearing the pilot and the Iceman when they tried to communicate with him. The fact that the truck drivers did not hear these messages attests to the ineffectiveness of the vehicles' communication systems in blocking out the noise of the engines.

2.4 Regulatory Framework for Foreign Air Carriers

Transport Canada certified and controlled foreign air carriers in accordance with standards different from those applicable to Canadian air carriers. Canadian air carriers were required to comply with section 540 of the Air Regulations and with ANO, Series VII, No. 2. Foreign air carriers were not subject to the provisions of ANO, Series VII, No. 2. Consequently, Royal Air Maroc was not required to develop a program of procedures for de-icing aircraft on the ground, although it operated its aircraft in the same environmental conditions as Canadian air carriers.

Since, in accordance with ANO, Series VII, No. 2, air carriers were responsible for implementing their de-icing procedures, it was not necessary to regulate the services provided by de-icing contractors. Air carriers were responsible for the safety and effectiveness of de-icing operations. As Royal Air Maroc had neither an approved ground icing operations program nor de-icing procedures, it relied on Canadian Airlines International in regard to de-icing procedures. As Royal Air Maroc did not have a copy of the CAIL procedures in its possession, the captain was not in a position to monitor the work of the de-icing crew. The captain thereby accepted the de-icing of the aircraft but was not familiar with the de-icing procedures being used.

2.5 Training in Engines-On De-icing

Examination of the electronic mail between the Manager, System Aircraft De-icing, the Manager of Client Services at Mirabel, and the instructor/developer prior to 03 January 1995 revealed that the need for the engines-on de-icing course was somewhat urgent in order to satisfy client demand and to compete against other de-icing companies. The course given on 03 January 1995 was different from that given by CAIL for engines-on de-icing of the Boeing 737 and Airbus 320. The test on the theoretical portion, which is normally required, had not been devised for the course given on 03 January 1995, and the procedures for the Boeing 727 and Lockheed 1011 had not been developed.

The practical engines-on exercise was not conducted on the aircraft covered in the classroom; instead, an Airbus 310 was used, an aircraft on which the employees had not been trained, and which they were not authorized to de-ice with the engines running. It is possible that the course created some confusion for the employees as to which aircraft they were required to de-ice with engines off and which they could de-ice with engines running. Some employees mistakenly thought they were authorized to de-ice Boeing 747 aircraft with the engines running.
Contradictory testimony regarding the conduct of the course precluded a determination as to whether the employees had been told that they could de-ice Boeing 747s with the engines running. But correspondence between the instructor/developer and the System De-icing Program Manager indicates that the employees were not qualified to de-ice Boeing 747s with the engines on. Further, Snowman 1 had attended a de-icing course supported by an appropriate manual in which it was stated that de-icing an aircraft while its engines were running was not authorized unless the employee was trained to do so. As he had not attended any "engines-on" de-icing course, he had no reason to believe he was authorized by CAIL to de-ice an aircraft with its engines running.

### 2.6 Competition Between De-icing Contractors

Seven companies were authorized by ADM to de-ice aircraft according to their practices in the Mirabel airport de-icing centre. Rivalry was especially fierce between the employees of CAIL and those of other private contractors. Several de-icing contractors de-iced all aircraft types with the engines running. As private de-icing contractors were not regulated, they were able to respond quickly to client demands. The regulatory requirements applicable to CAIL, with the attendant requirement to develop procedures and provide training, meant that CAIL, working within the rules, could not provide as fast and ready a service as could the private contractors. This undoubtedly heightened competition between CAIL and private de-icing contractors in their desire for de-icing contracts, and this competition might have led some CAIL employees to take liberties with the established safety standards.

When the Royal Air Maroc captain indicated that there would be a delay in starting the de-icing if he had to shut down the engines and start the APU, Snowman 1 decided to de-ice the aircraft with the engines running, though he had not taken the necessary "engines-on" training. He was also aware, having taken the initial de-icing course, that he was not supposed to de-ice an aircraft with its engines running. Some factors that could have influenced his decision were a normal desire to improve the speed and efficiency of de-icing operations and to maximize the use of hold-over times for the de-icing fluid. It is probable that a significant additional factor was the competition between de-icing contractors.

### 2.7 Control of De-icing Area

The apron controller performed his tasks in accordance with established procedures and his assigned responsibilities. He guided the aircraft until it was stopped at the south station. The aircraft came fully under the responsibility of the captain after it was stopped for de-icing. Before issuing taxi instructions to the aircraft, the controller verified that the taxiway was clear. It was not his responsibility to consult the flight crew and de-icing personnel to determine whether the aircraft was clear and ready to taxi. That responsibility was assumed by the captain when the co-pilot declared the aircraft ready to taxi.

That the apron controller issued taxi instructions when de-icing was not completed indicates that he was not aware that de-icing was in progress. Although he fully discharged his responsibilities, the controller probably did not have enough information or sufficient tools to accurately assess the situation in the de-icing centre. ADM had recognized the value of video coverage of the manoeuvring area which the apron controller could not see from his work station. The cargo ramp was covered by a panning video camera and the same installation was being considered for the de-icing area.
2.8 Marshaller

Snowman 1 performed the duties of marshallers and truck driver. He was not in a position to prevent the aircraft from advancing, given that he was behind the aircraft and the noise of the engines prevented him from hearing the transmissions of the pilot and the Iceman.

Several air carriers prefer to place a marshallers in front of the aircraft to minimize the possibility of the aircraft moving until the de-icing procedure is complete and all personnel and equipment are safely out of the way. Some carriers utilize an interphone cord plugged into the aircraft to maintain constant communication between the ground crew and the flight deck. This procedure eliminates the risk of confusion between flight crew/marshallers communications and other VHF communications. CAIL has not chosen the direct interphone cord method of communication because it is felt that the area around the aircraft is too dangerous an environment in light of the slippery footing conditions due to the glycol, particularly with the engines running.

2.9 Supervision of De-icing Operations by Royal Air Maroc

The Royal Air Maroc station manager performed only administrative duties, and the company did not have capable personnel at Mirabel to evaluate operational procedure requirements. This task fell, by default, to the flight crew who, depending on the task, were not necessarily qualified. As a result, it is possible that Royal Air Maroc was not made aware of its responsibilities regarding ground de-icing. Consequently, Royal Air Maroc was not in a position to assess the importance of developing de-icing standards or, at a minimum, obtaining the CAIL procedures and distributing them to their crews. As Royal Air Maroc did not have a copy of the CAIL de-icing procedures in its possession, neither the station manager nor the pilot could monitor compliance with the existing de-icing standards.

2.10 Coordination between Flight Crew and Flight Attendants

The pilots did not consult the cabin crew before releasing the brakes. The flight attendants had been advised that the aircraft was about to taxi. Given that the pilots could not see the aft section of the aircraft from the flight deck and they did not see the de-icing vehicles depart the area, consulting the flight attendants was a conceivable and reasonable option in this particular situation. The aim of cockpit/cabin coordination training is to enhance the quality of this type of decision.

2.11 Communications

Analysis of the communications recordings indicates that, on some occasions, standard aeronautical phraseology and terminology were not used. For example, the co-pilot and de-icing attendants did not always state their own call-sign and the receiving station call-sign when communicating with the apron controller, and the captain read back "de-icing completed" twice without stating his call-sign.

2.12 Supervision of De-icing Operations by CAIL

The Iceman and the lead station attendant were chiefly responsible for day-to-day monitoring of the quality and the safety aspect of de-icing services. They were responsible for ensuring that the work was performed by qualified personnel and that the standards and procedures were adhered to. It was established that, at the time of the accident, the persons in the cherry-pickers were not wearing the required safety
equipment, and neither Snowman 1 nor the station attendant had the training or qualifications to de-ice aircraft with the engines running. Completion of the training would probably have sensitized Snowman 1 to some of the complications associated with engines-on de-icing, such as poorer quality radio communications. As two members of the crew had not received the required training, the crew, as a whole, was not qualified to perform the de-icing safely.

On two separate occasions prior to the accident, supervisors could have intervened to halt the sequence of events that culminated in the accident. First, the supervisors did not intervene when Snowman 1 did not follow his company's procedures when he suggested to the pilot that the engines be left running during de-icing. Later, the Iceman did not intervene when the co-pilot declared the aircraft ready to taxi; he apparently did not correctly analyze the previous communications in the short time available to him to make an intervention. It appears that the supervisors were not performing adequate supervision to intervene and take corrective action.

2.13 Summary

The Royal Air Maroc flight crew were not familiar with the engines-on de-icing procedures of CAIL, but de-icing their aircraft with its engines running was permitted by their operations manual. Training for the CAIL de-icing crew with regard to engines-on de-icing procedures was minimal, and Snowman 1 and a trainee had not received the training. The CAIL engines-on de-icing course attended by three of the five de-icers was poorly structured, apparently put together and delivered in a short period of time, and was incomplete in that there was no test required at the end of the training. The course did not include B747 training.

The regulations governing CAIL, a licensed Canadian air carrier, made it difficult for CAIL service crews to compete with other de-icing contractors, who could operate with virtually no Transport Canada overview. The competitiveness among the de-icing contractors at Mirabel certainly could affect the decisions of the participants regarding de-icing.

There was little supervisory overview of the de-icing operation in that the supervisor (the Iceman), knowing that de-icing of a B747 was taking place with its engines running and that the de-icing crew were not trained or qualified to do the job, did not stop the de-icing.

The de-icing crew's communications equipment may have been adequate for the job, but only if it was used in a manner such that the noise from the aircraft engines did not render the equipment ineffective. Some radio transmissions from the flight crew and the de-icers did not include call-signs, introducing confusion and ultimately leading to the flight crew commencing taxiing before the de-icing equipment was clear of the aircraft.

This occurrence was the result of a combination of factors, not a single omission or error. The above factors, in combination, led to deviations from safe operating practices and ultimately to the accident.

3.0 Conclusions

3.1 Findings

1. All communications equipment functioned normally before and after the accident.
2. Engine noise probably prevented the de-icing crew from hearing the pilot and the Iceman when they tried to communicate with the de-icing crew.

3. CAIL communication equipment was neither adequate for nor designed to be used in engines-on de-icing operations, as it did not block out engine noise.

4. The pilot and de-icing crew did not use standard aeronautical terminology and phraseology on some occasions.

5. The pilots thought that the Iceman's message to Snowman 1 was addressed to them and that it meant that the de-icing was completed.

6. Following confusion in the radio communications, the flight crew started to taxi the aircraft before its perimeter was clear.

7. Snowman 1 suggested that the pilot keep the engines running during the de-icing operation and the pilot agreed. The flight crew was not familiar with the de-icing procedures and methods approved by CAIL.

8. At the time of the accident, the cherry-picker operators were not wearing the protective equipment required for the de-icing.

9. Snowman 1 was not in a position to prevent the aircraft from advancing, given that he was behind the aircraft where he could not be seen by the flight crew and where the noise of the aircraft engines prevented his hearing the radio transmissions of the pilot and the Iceman.

10. As a signatory to the International Civil Aviation Organization (ICAO), Canada accepts the certification of other ICAO signatories to ICAO standards. As a foreign air carrier, Royal Air Maroc was not required to develop a set of procedures regarding de-icing of aircraft on the ground.

11. Royal Air Maroc did not have a copy of CAIL's de-icing procedures in its possession and had not asked CAIL for a copy of the procedures.

12. Royal Air Maroc did not have personnel at Mirabel capable of evaluating the de-icing procedural requirements.

13. CAIL had not developed procedures for de-icing a B747 with the engines running, and the de-icing crew was not authorized by CAIL to de-ice B747s with the engines running.

14. The CAIL engines-on de-icing course held in Mirabel on 03 January 1995 was presented in a manner that left some employees unsure as to which aircraft they were permitted to de-ice with engines running.

15. Several air carriers favour having a marshaller in front of the aircraft and using the interphone for ground communications during de-icing. CAIL recommends the use of VHF radio to communicate with the pilot and to guide aircraft on the ground.

16. The apron controller performed his tasks in accordance with established procedures and his assigned responsibilities.

17. The apron controller did not have enough information or sufficient tools to accurately evaluate the situation in the de-icing centre, which he could not see from his
work station.

18. Transport Canada did not monitor the quality or compliance of the de-icing procedures developed by the air carriers.

19. Private de-icing contractors are not regulated by Transport Canada, whereas air carriers such as CAIL must follow regulatory requirements set out by Transport Canada.

20. It is possible that competition between the de-icing companies and a concern for efficiency influenced Snowman 1’s decision to de-ice the aircraft with engines running despite the fact that he had not had the formal training.

21. There was no other de-icing operation in progress at Mirabel at the time of the occurrence.

3.2 Causes

The flight crew started to taxi the aircraft before its perimeter was clear, following confusion in the radio communications. The following factors contributed to the accident: a lack of de-icing procedures within Royal Air Maroc; non-compliance with procedures on the part of the CAIL de-icing crew; inadequate or inappropriate communications equipment; incomplete training of Snowman 1; a regulatory framework less demanding of foreign air carriers than of Canadian carriers; a lack of operational supervision; and a lack of adherence to radio protocol.

4.0 Safety Action

4.1 Action Taken

The Board notes that, following this occurrence, several changes were made to procedures, regulations, and manuals affecting the de-icing/anti-icing of aircraft operating in Canada. These measures, to a large extent, address the significant aviation safety deficiencies identified during the investigation, and therefore reduce the probability of a recurrence of this type of accident. As such, the Board believes that recommendations with respect to additional corrective actions are not warranted at this time.

4.1.1 ICAO Manual of Aircraft Ground De/Anti-Icing Operations

At the end of 1995, ICAO published "stand-alone" Document No. 9640, Manual of Aircraft Ground De/Anti-Icing Operations, for use by member state aircraft operators. This document, inter alia, states that:

7.3 The de/anti-icing program shall clearly define areas of responsibility for the operator. All persons involved in ground de/anti-icing activities shall be trained and qualified in the procedures, communications and limitations of their area of responsibility. The de/anti-icing programme shall cover all locations within the operator's route network including contract de/anti-icing accomplished by others.

10.1 The communications between ground and flight crews are an integral part of the de/anti-icing process and must be included in every de/anti-icing procedure....

10.3 Upon completion of the de/anti-icing procedure and the associated check of the
aeroplane, which ensures that it complies with the Clean Aircraft Concept, the following information shall be communicated to the flight crew:

a) fluid type;

b) fluid/water ratio (Type II fluids only);

c) start time of the last step in the de/anti-icing procedure;

d) confirmation that the aeroplane is in compliance with the Clean Aircraft Concept.

4.1.2 Canadian Aviation Regulations - Ground Icing Operations

At the time of the occurrence, foreign air carriers operating in Canada were not subject to the provisions of ANO, Series VII, No. 2. Consequently, Royal Air Maroc was not required to develop a program of procedures for de-icing aircraft on the ground.

In October 1996, the new Canadian Aviation Regulations (CARs) came into force. In addition to describing "General Operating and Flight Rules Standards Regarding Ground Icing Operations" in section 622.11, the new regulations state the following in section 701.25 (4) of "Foreign Airline Operations," Division III, "Inspection and Aircraft Icing Operations":

Where conditions are such that frost, ice or snow may reasonably be expected to adhere to an aircraft, no person shall conduct or attempt to conduct a take-off in the aircraft unless:

(a) the aircraft has been inspected immediately prior to take-off to determine whether any frost, ice or snow is adhering to any of its critical surfaces; or

(b) the foreign air operator or the holder of the flight authorization has:

(i) established, in accordance with ICAO Document No. 9640 entitled Manual of Aircraft Ground De/Anti-icing Operations, an aircraft ground icing operations program that has been approved by the state of the foreign air operator or of the holder of the flight authorization, or

(ii) submitted to the Minister an aircraft ground icing operations program that meets the applicable Commercial Air Service Standards.

4.1.3 Royal Air Maroc - De-icing/Anti-icing Operations

In October 1995, Royal Air Maroc published interim procedures pending the amendment of the "De-icing/Anti-icing Operations" section of the Royal Air Maroc policy manual.

Section 6, "Final Inspection Before Aircraft Dispatch," requires that ground crew now report the anti-icing code to the pilot-in-command when de-icing is completed, stating as follows:

Reporting the anti-icing code to the Pilot in Command confirms the correct and complete accomplishment of the de-icing/anti-icing of the airplane.

Section 10, "Communication," states that "For safety purposes it is important to establish a clear communication with the ground team." The policy manual describes in
detail the verbal communications required during de/anti-icing operations and requires that ground crew advise that ground materiel is removed and that flight crew stand by for a visual signal. Phraseology to be used by flight crew and ground crew during de-icing is outlined in a table.

4.1.4 CAIL - De-icing/Anti-icing Procedures

CAIL completed a review and made changes to their de/anti-icing procedures. CAIL's policy is now such that the engine-on de/anti-icing process will be used only on aircraft being operated by Canadian Airlines International or Canadian Regional Airlines.

The procedures indicate that both visual and verbal communication must be received and acknowledged by aircraft flight crew before the de-icing process can be started or terminated. Cue cards to support correct verbal radio communication have been developed and deployed to all de-icing vehicles and designated team members. The reporting structure, briefing, training, audit process, and base de-icing team leadership along with the use of designated VHF radios have been upgraded to further enhance the de-icing procedure with particular emphasis on team work and related communication. De-icing team check sheets and daily shift briefings have also been developed to further support this process.

A copy of CAIL's de-icing procedures has been provided to all contract carriers, both at the local base and head office levels, to which CAIL provides de-icing services. Particular emphasis has been placed on the communication procedures.

4.1.5 Labour Canada Directive

After the accident, a directive was issued by a Labour Canada Safety Officer under Part II of the Canada Labour Code requiring that CAIL provide its employees with the supervision necessary to ensure their health and safety.

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 March 1997.

Appendix A - Mirabel Airport De-icing Bay
Appendix B - List of Supporting Reports

The following TSB Engineering Branch Report was completed:

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

**Appendix C - Glossary**

AC - alternating current  
ADM - Aéroports de Montréal  
ANO - Air Navigation Order  
APU - auxiliary power unit  
CAIL - Canadian Airlines International Ltd.  
CARs - Canadian Aviation Regulations  
CFS - Canada Flight Supplement  
CVR - cockpit voice recorder  
DFDR - digital flight data recorder  
EST - eastern standard time  
GIOP - Ground Icing Operations Program  
ICAO - International Civil Aviation Organization  
MHz - megahertz  
TSB - Transportation Safety Board of Canada  
VHF - very high frequency

1 See Glossary at Appendix C for all abbreviations and acronyms.

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

**Updated: 2002-10-06**

**Important Notices**
Air 1995

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 Separation
Aérotech Aviation
Beaver RX650 C-IDFL
Saint-Mathias, Quebec
9 May 1995

Report Number A95Q0086

Summary

Shortly after take-off from Richelieu Airport, Quebec, when the ultralight was about 500 feet above ground level (agl) over the Chambly basin, the left wing of the aircraft separated. The ultralight and its two occupants crashed in the Richelieu River. The instructor and student pilot were fatally injured, and the ultralight was substantially damaged.

Ce rapport est également disponible en français.

Other Factual Information

Meteorological conditions were favourable for the flight. The sky was clear and visibility was over 10 miles. Winds were light and from the west.

The instructor and student pilot were qualified under existing regulations. It could not be determined who was flying the aircraft.

The aircraft had been purchased new, unassembled, by Aérotech Aviation in October 1990. It was sold to the builder shortly thereafter. The aircraft was issued a registration certificate in 1991.

The builder had no difficulty assembling the ultralight. During the first flights, the aircraft had a tendency to turn left in flight. To counteract this tendency, the builder modified the attachment of the left wing to the drag bar. He installed brackets that enabled the rear attachment of the wing to be moved one inch. As a result, the wing leading edge was moved forward a considerable distance. The modification was not in accordance with the drawings submitted by the aircraft designer. After subsequent test flights, the builder concluded that this modification did
not correct the left drift problem, but he left the modification in place.

The brackets added during the modification were made of stainless steel. The wing was held in place by a 5/32-inch aircraft-quality retaining pin. The pin was secured by a lock ring.

The builder had to transport the aircraft on a trailer every time he went flying, and he had to reinstall the wings, then fold them back again, before loading the aircraft on the trailer. The lock ring and retaining pin therefore had to be installed and removed at each flight. No wear was noticed on any of the pins. The builder logged about 150 flight hours on the aircraft before selling it to Aérotech Aviation in November 1994.

The ultralight had accumulated about 100 flight hours since it was purchased by Aérotech Aviation. The aircraft was used for pilot training. As it was stored in a hangar, there had been no need to assemble and disassemble the wings since the aircraft's purchase. The owner had been informed of the modification to the left wing attachment.

The left wing was not heavily damaged in the accident, and evidence indicated that the wing had not sustained stress at the rear attachment when it separated. Examination of the rear attachment revealed no particular evidence of wear. The retaining pin was not found, and there were no indications that it had failed. Markings on the attachment show that the retaining pin disengaged itself over the course of several flights. The other attachments showed deformation and evidence of failure in overload.

Analysis

The left wing of the aircraft separated in flight. Evidence on the left wing rear attachment indicates that the retaining pin disengaged in flight and that it was not secured by a lock ring. This evidence indicates that the pin could move freely and that it disengaged gradually, probably over the course of several flights. The other wing attachment points showed evidence that they had failed in overload following excessive movement of the wing.

Because the aircraft owner did not have to assemble the wings before each flight as the previous owner had, the condition of the attachments was not checked before each flight. It is clear that a pre-flight inspection of the left wing attachment was not performed.

The modification to this attachment did not conform to the drawings submitted by the designer of the aircraft. Although the modification was not suitable for the wing attachment, it does not seem to have contributed to the wing separation.

Findings

- The left wing attachment had been modified by the builder and was not in accordance with the design drawings.
- The retaining pin was not secured by a lock ring.
The retaining pin disengaged and allowed the left wing to twist, causing the other wing attachments to fail in overload.

- The left wing separated in flight.

- The left wing attachment was not visually inspected prior to the flight.

Causes and Contributing Factors

The retaining pin was not secured by a lock ring and it disengaged in flight. A pre-flight inspection was not performed.

Updated: 2002-10-06

Important Notices
Air 1995

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 U206F C-GJGM
Baie-Saint-Paul, Quebec 10 mi SW
13 May 1995

Report Number A95Q0090

Summary

The pilot and sole occupant departed Sept-Îles Airport, Quebec, at 0742 eastern daylight saving time (EDT)\(^{(1)}\) on a visual flight rules (VFR) flight to Jean Lesage International Airport, Quebec. At 1005, search and rescue (SAR) services at Trenton, Ontario, received an emergency locator transmitter (ELT) signal, and a search aircraft was dispatched immediately.

The aircraft was located at 1203. It had struck some trees and crashed on the side of a mountain about 42 nautical miles north-east of its destination. The pilot had sustained fatal injuries.

*Ce rapport est également disponible en français.*

Other Factual Information

The pilot was certified and qualified for the flight in accordance with existing regulations. He was experienced and had over 2 200 flying hours. He was very familiar with the route, having flown it over 200 times. He did not hold a Canadian instrument flight rating.

The pilot filed a flight notification prior to the flight, but he did not request a weather briefing from the Sept-Îles Flight Service Station (FSS). While taxiing, he informed the tower controller that his planned en route altitude was 4 500 feet above sea level (asl).

The pilot's most recent civil aviation medical examination was a few weeks before the occurrence. He was required to have his vision examined every year. His last examination, which he passed, was on 02 February 1995. The medical investigation revealed no sign that
incapacitation or physiological factors affected the pilot’s performance. The autopsy revealed that the aircraft struck the ground at high speed.

The accident occurred at an altitude of 2,650 feet asl on the north-west side of Liguori Mountain, Quebec, elevation 2,725 feet asl. The aircraft was proceeding south-west, which is roughly the correct heading for its route, when it struck some trees over 100 feet in height, on a horizontal trajectory. Several trees were severed or broken. The aircraft left a swath about 400 feet long on a heading of 236 degrees magnetic. There was severe propeller damage to the trees. Both wings separated from the fuselage and the other sections of the aircraft were heavily damaged in the impact with the trees and ground.

Examination of the aircraft at the accident site revealed no pre-impact failure or malfunction that could have degraded the performance of the aircraft. The flaps were up and the altimeter setting was correct. The weight and centre of gravity of the aircraft were within the prescribed limits, and the aircraft carried sufficient fuel to complete the flight. The aircraft was equipped for instrument flight.

The direct route from Sept-Îles to Québec requires the pilot to proceed in a south-westerly direction on the west side of the St. Lawrence River. The minimum obstruction clearance altitude (MOCA) for instrument flights in the portion of the air route between Charlevoix and Québec is 5,300 feet asl. An altitude of 4,300 feet, referred to as the obstruction clearance altitude, is published on the VFR navigation chart for the sector where the accident occurred. This altitude, indicated in the quadrangle bounded by the lines of latitude and longitude, is in thousands and hundreds of feet above sea level, and represents the highest terrain altitude plus 328 feet (100 metres) or the altitude of the highest known obstruction, whichever is higher.

An analysis by Environment Canada indicates that the forecast for the area where the flight was to take place reported an upper-level trough extending from 60 miles north-west of Sept-Îles to Montréal. This upper-level trough was expected to drift slowly east at a speed of 5 to 10 knots. The flight route ran along the front of this upper-level trough in an area where low broken clouds were forecast between 1,500 and 2,500 feet asl with a solid layer of altocumulus above them. Stratus ceilings of 200 to 1,000 feet above ground level (agl) in places and reduced visibility of two to five miles in rain, drizzle and/or fog were also forecast. The forecast for Sept-Îles indicated that VFR conditions would continue; however, the forecast for Baie-Comeau called for overall conditions until noon of ceiling 200 feet and visibility one mile in rain, drizzle and fog. For Québec, the main condition forecast was a ceiling of 600 feet with no restriction on visibility.

Two automatic stations, at Île Rouge at the mouth of the Saguenay River and at Rivière-du-Loup, although providing no ceiling information, reported reduced visibility in fog. The satellite photograph shows the extent of the clouds along the planned route.

Meteorological conditions on take-off from Sept-Îles were 6,000 feet
scattered, ceiling 8 000 feet overcast and visibility 30 miles. At 0820, while over the Godbout area, the pilot requested and received the latest sequences for Mont-Joli, Baie-Comeau, and Québec from the Mont-Joli FSS, as well as the forecast for the next two hours for Québec. The data indicated ceilings of 2 000 feet at Mont-Joli, 200 feet at Baie-Comeau, and 600 feet at Québec, with visibilities of five miles, two miles, and five miles, respectively, in rain, mist and fog.

The analysis also indicates that at the accident site the cloud base was very probably below 1 000 feet, and possibly much lower than that level, with reduced visibility. One witness observed an aircraft flying at low altitude below the clouds a few seconds before the occurrence. Other witnesses, who were at the base of the mountain and near the site, indicated that until about 1300 visibility was near zero in thick fog and the mountain was obscured by fog. Even road conditions were affected by the thick fog. However, no one heard any unusual sounds.

Analysis

Since there was no evidence of any pre-impact failure or malfunction that could have degraded aircraft performance, the analysis focuses on the meteorological conditions, flight preparation, and pilot decision making.

The weather forecasts and observations indicate that the weather along the planned route was not favourable for the flight. Low stratus accompanied by precipitation, drizzle and fog, as indicated in the forecasts, were present on the route and in the mountainous area. Even if the pilot did not request a weather briefing from the FSS before the flight and the conditions at the departure aerodrome were favourable for VFR flight, it was clear from his radio messages en route that he was aware of the adverse weather along the planned route. The pilot nevertheless continued the flight, having flown this route many times in the past.

Given the weather conditions at the time of the accident, all indications are that the pilot descended the aircraft in mountainous terrain below the safe altitude for instrument flight and the obstruction clearance altitude specified on the VFR navigation chart, in the hope that he could continue the flight. The observed damage to the aircraft indicates that it struck the trees at high speed in a horizontal attitude. It is highly probable that the pilot did not realize his situation when the Cessna struck the mountain.

In 1990, a TSB safety study on VFR flight in adverse weather conditions stated that this type of accident represents about 23 per cent of all fatal accidents. The study also indicated that experienced pilots tend to be involved in accidents related to decision making rather than a lack of flying skill.

Findings

- The pilot did not ask the FSS for a weather briefing for the flight.
- The weather conditions on the planned route were unfavourable for VFR flight.

- The pilot encountered adverse weather conditions en route and continued the flight.

- The mountain on which the aircraft crashed was obscured by fog all morning.

- The aircraft showed no evidence of pre-impact failure.

- The aircraft struck the trees at high speed.

### Causes and Contributing Factors

The pilot continued visual flight in adverse weather conditions. Contributing to the accident was the fact that he did not request weather information for the planned route prior to departure.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairman John W. Stants and member Zita Brunet, authorized the release of this report on 02 October 1995.*

1. All times are EDT (coordinated universal time [UTC] minus four hours) unless otherwise stated.
Air 1995

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 Air Transat
Lockheed L-1011 C-FTNC
and Inter-Canadien
Aérospatiale ATR 42 C-GXCP
Quebec VOR 19 nm SW
6 June 1995

Report Number A95Q0098

Summary

Air Transat flight TSC 234 took off from the Mirabel Airport around 00:01:00 Coordinated Universal Time (UTC) for a flight to Charles de Gaulle Airport, France. The initial route included a climb to flight level (FL) 280 on air route V316 to the Quebec VHF omnidirectional range (VOR), then directly to the MIILS way-point, located 195 nautical miles (nm) east of the Quebec VOR. Inter-Canadien flight ICN 1647 from Bagotville, Quebec, was approaching the Quebec VOR in cruise flight on FL 200 to intercept air route V98 and proceed to Montreal.

At 42 nm from the Quebec VOR, TSC 234 was cleared to FL 290 and to proceed directly to MIILS. On FL 200 and 19 nm southwest of the Quebec VOR, TSC 234 executed an avoidance manoeuvre following a resolution advisory (RA) from the Traffic Alert and Collision Avoidance System (TCAS). At the same time, ICN 1647, which was about 19 nm southwest of the Quebec VOR, also received an RA from the TCAS and executed an avoidance manoeuvre.

Separation between the two aircraft was 300 feet vertically and 2.25 miles horizontally. Required separation was 1,000 feet vertically or 3 miles horizontally. The two crews visually observed one another during their avoidance manoeuvres.

Ce rapport est également disponible en français.

Other Factual Information

TCAS is an independent system designed to support the air traffic control system and complement the "see and avoid" concept. TCAS continuously scans the airspace around an aircraft and seeks a response from the transponders of nearby aircraft. TCAS monitors flight paths based on the responses from the transponders. The system generates a traffic advisory (TA) or resolution advisory (RA) when any flight path is going to enter the collision zone around the aircraft.
A TA is displayed 35 to 48 seconds from the time it is predicted that an aircraft will enter the collision zone. Traffic information includes the distance, bearing, and altitude of the other aircraft. The flight crew must use this information as an aid in visually locating the other aircraft to avoid conflict.

An RA normally consists of a vertical manoeuvre that must be executed to increase or maintain separation from the other aircraft. The RA is generated visually and audibly. It consists of a suggested correction to change the aircraft vertical speed or a suggested preventive measure to limit changes in vertical speed.

For control purposes, airspace is divided into different sectors. At the time of the occurrence, the Air Transat aircraft was to transit the Rawdon, Quebec, and Lévis sectors.

The Rawdon sector extends east of the Mirabel Airport to about 18 nm from the Quebec VOR. The sector also extends to the north and south of air route V316; flights are controlled up to FL 280.

The Quebec sector is bounded on the west by the Rawdon sector. It includes all of the Quebec Airport and extends further north, south, and east. In the Quebec sector, flights are controlled up to FL 280.

In the Lévis sector, flights are controlled at FL 290 and higher. This sector extends above the Rawdon and Quebec sectors and beyond.

On departing from Mirabel, TSC 234 contacted the Rawdon sector at 00:04:31\(^1\). The aircraft was radar identified and cleared to FL 280. At 00:12:58, the Rawdon controller plotted the radar target with the Quebec controller, who accepted it. This procedure meant that the aircraft might enter the Quebec sector, but that radio communication was not transferred to the Quebec controller, although the Quebec controller was still responsible for ensuring proper separation. Meanwhile, at 00:13:48, ICN 1647 reported arriving at the Quebec VOR.

Flight TSC 234 was handed off to the Lévis controller when the aircraft was 43 nm west of the Quebec VOR at an altitude of 17,000 feet. In accordance with procedures, the Lévis controller was using a 5,000 feet altitude filter, which allowed him to observe aircraft only at FL 240 and higher; therefore, the Lévis controller was unable to see either TSC 234 or ICN 1647. At 00:13:32, the Lévis controller cleared TSC 234 to FL 290 and directly to MIILS, which requires a 12-degree right turn, in accordance with established procedures. The Lévis controller contacted the Quebec controller, who replied that he was verifying TSC 234. From that moment on, the two aircraft were on collision paths, and this triggered their TCAS around 00:16:37, according to radar data.

The Quebec controller stated that he did not think the aircraft could be in conflict. Believing that TSC 234 would continue as anticipated to the VOR, he had calculated that, given the closing speed of the aircraft and an assumed rate of climb of 1,000 feet per minute for TSC 234, vertical separation of the aircraft could not be less than 1,500 feet. He had also calculated that, when TSC 234 flew over the VOR, ICN 1647 would have already cleared it. The climb rate of TSC 234 was lower than the Quebec controller had anticipated because of high aircraft weight and high external temperature.

The Quebec controller was alone in the radio and data position while his co-worker was on break. He stated that, shortly before the occurrence, he performed an important coordination task with the Quebec tower due to the arrival of a medical evacuation flight on runway 06 while runway 24 was active. The controller’s attention was focused to the east of the Quebec VOR, while the risk of collision was occurring southwest of the Quebec VOR. His
workload was moderate with moderate to high complexity.

The Quebec controller was working his third shift since requalifying. He had spent the previous six months at the Montreal terminal. He was returning to his former position, but, during his absence, the upper limit of the Quebec sector had been raised from 17,000 feet to FL 280. The controller stated that, at the time of the occurrence, he was not familiar with overflights; he had not had specific classroom training on this subject but had received on-the-job training. The controller also said that he had previously managed overflights, although at lower speeds, when the Quebec sector airspace was limited to 17,000 feet.

Analysis

The air traffic controllers were qualified for the positions they occupied.

The Quebec controller had just requalified in his position and was familiar with all his duties. He acknowledged having previously managed, albeit at lower speeds, overflights at altitudes below 17,000 feet; however, he said he was not familiar with overflights because his airspace had been modified during his absence and it now extended up to FL 280.

The Quebec controller was alone when the workload suddenly increased. During the period prior to the risk of collision, the increased attention that the controller directed to coordinating the arrival of a medical evacuation flight at the Quebec Airport precluded his perceiving the risk of collision that existed between the two aircraft. In addition, although he was responsible for providing proper separation between the two aircraft, the controller accepted the hand-off of communications to the Lévis sector. Thus, the two aircraft had to execute avoidance manoeuvres 19 miles southwest of the Quebec VOR following a TCAS resolution advisory.

Findings

- Minimum separation between the two aircraft was not ensured by air traffic control.
- The crews executed an avoidance manoeuvre following a TCAS resolution advisory.
- The air traffic controllers were qualified.
- At the time of the occurrence, the Quebec controller’s attention was directed to coordinating the arrival of a medical evacuation flight at the Quebec Airport.
- The Quebec controller was alone in the radio and data position while his co-worker was on break.
- The Quebec controller was responsible for providing proper separation for TSC 234, but he was not in communication with the aircraft.

Causes and Contributing Factors

The Quebec sector controller did not ensure that minimum separation was maintained between the two aircraft. Factors contributing to the occurrence were the absence of direct communication, the sudden increase in workload due to the arrival of a medical evacuation flight, and the lack of a second controller at the position.

*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.

Appendix A

1. All times are UTC unless otherwise noted.

Updated: 2002-10-06
Air 1995

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 Adverse Weather
Ground Impact
Transportair
Cessna 182RG C-GBXO
Bégin, Quebec 3.5 nm N
17 June 1995

Report Number A95Q0104

Summary

The Cessna 182RG, with the pilot as the sole occupant, took off from Roberval Airport, Quebec, at 1031 eastern daylight time (EDT)(1) for a local forest fire surveillance patrol in visual flight rules (VFR).

About 10 minutes after take-off, an eyewitness saw the aircraft flying northwards at very low altitude. According to the witness, the aircraft was heading towards a mountain covered in a cloud layer. A few moments later, the witness heard a noise and heard the aircraft's engine stop. He immediately reported the incident to the police. The Flight Service Station (FSS) at Roberval picked up the signal of an emergency locator transmitter (ELT) and reported the matter to the police authorities. The local civil air search and rescue services (SERABEC) were advised, and a search was undertaken.

The aircraft was located at 1212 EDT. It had struck some trees and crashed on the south side of a mountain about 3.5 nautical miles north of Bégin, Quebec. The pilot had sustained fatal injuries.

Ce rapport est également disponible en français.

Other Factual Information

The pilot was certified and qualified for the flight according to existing regulations. He had accumulated a total of 342 flying hours. He held an instrument (IFR) rating and had a total of 50 hours dual-control instrument flight.
The pilot had been hired by the company to make surveillance flights for the Société de protection des forêts contre le feu and had completed ground and flight training on the Cessna 182RG for that purpose. The Society had given its pilots a briefing to familiarize them with surveillance flights, the global positioning system (GPS), and the procedures to be followed. It was suggested to the pilots that they make all surveillance flights in VFR conditions with a minimum ceiling of 2,000 feet above ground level (agl). They were also asked to avoid any dangerous manoeuvres, including low-level flying.

After the initial training, six pilots and their aircraft were based at Roberval Airport. For most of them, this was their first job as a professional pilot. Every day, a patrol was assigned to the pilots, and they took off at their discretion. There was no chief pilot or flight supervisor at the Roberval base. The pilots operated on their own and made their decisions without consultation or approval.

The patrol area lay north of the base in a mountainous area. Two aeroplanes and a helicopter had taken off that morning to fly over the same area, but had turned back after encountering adverse weather.

The accident occurred at an altitude of 750 feet above sea level (asl) on the south side of a mountain near Bégin, Quebec. A few moments prior to the accident, witnesses located at the foot of the mountain and in the surrounding area had observed the aircraft flying northwards at an altitude about 100 feet above the trees. It was found that the aircraft had hit trees over 100 feet tall while making a steep turn to the right. Several trees were severed and uprooted. There were large propeller marks on the trees. Both wings had come away from the fuselage, and other parts of the aircraft were heavily damaged by the impact with the trees and the ground. The aircraft left a trail approximately 400 feet long running southwards, that is, in the direction opposite to the intended track.

The pilot had passed his last civil aviation medical examination on 10 April 1995. The medical investigation did not reveal any evidence to suggest that incapacitation or physiological factors might have affected the pilot's behaviour. The investigation revealed that the aircraft hit the ground at high speed.

The examination of the aircraft carried out at the scene of the accident did not reveal any failure or malfunction prior to impact that might have reduced the aircraft's performance. The flaps were retracted. The aircraft's weight and centre of gravity were within prescribed limits, and the aircraft was carrying sufficient fuel to make the flight. The aircraft was equipped with the necessary instrumentation for IFR flight and was also equipped with GPS.

The pilot had told other pilots that he had had intermittent problems with the aircraft's attitude and course indicators, but he had not mentioned the problem to the company's aircraft maintenance personnel. The aircraft technical log was recovered and checked, and no defect of this kind was recorded. A check of the aircraft's vacuum pump determined that it was in working order at the time of the
accident.

The pilot had not requested a weather briefing from the Roberval FSS specialist. The weather conditions on take-off at Roberval were as follows: scattered clouds at 6,000 feet; ceiling 8,000 feet overcast; and visibility 30 miles. An analysis of the weather conditions by Environment Canada indicated that the forecast for the area of the flight reported a front moving through the area. There were cloud layers and fog over the accident site. The search and rescue pilot, who took off from the airport at Saint-Honoré, Quebec, at 1137 EDT, was unable to fly over the accident site because the mountain was covered in a thick layer of fog. He was compelled to wait until about 1212 EDT before he could fly over the area where he found the wreckage. According to him, the front reported in the forecasts moved slower than estimated, and it took some time for the cloud layers at low altitude to dissipate.

Analysis

As no failure or malfunction prior to impact could have reduced the aircraft's performance, the analysis deals with the weather conditions, the flight planning, and the pilot's decision-making.

The weather forecasts, observations, and the morning flights in the area indicate that the weather conditions over the intended track were not favourable for the flight. Low stratus accompanied by drizzle and fog, as reported by the search and rescue pilot, prevailed over the route and in the mountainous area.

The pilot did not request a pre-flight weather briefing from the FSS specialist, and, although conditions at the departure aerodrome were favourable for VFR, the evidence indicates that the pilot encountered adverse weather. As there was no supervision at the base, the flight planning was not checked prior to departure.

The pilot encountered adverse weather in flight. Probably not fully trusting the aircraft instruments, the pilot may have tried to maintain visual contact with the ground. Although the pilot was qualified for IFR, the evidence indicates that he first tried to keep visual contact with the ground by decreasing the flight altitude. Later, at low altitude, he may have made a steep turn to turn back. The damage to the aircraft indicates that it hit the trees at a banked attitude and high speed. The Cessna quite likely hit the mountain in the turn without the pilot's being aware of the situation.

In 1990, the Transportation Safety Board of Canada published a safety study on VFR flight under adverse weather conditions. Among other things, this study says that lack of planning and decision-making are recurring contributing factors, regardless of the pilots' level of experience.

Findings

- There was no chief pilot and no supervision of operations at the
There was no chief pilot and no supervision of operations at the base.

- The pilot did not request a weather briefing for the flight undertaken.
- The weather conditions on the intended track were unfavourable for VFR flight.
- The pilot encountered adverse weather en route and tried to turn back.
- The pilot probably did not fully trust the aircraft's instruments and tried to maintain visual contact with the ground.
- The accident site was obscured by fog throughout the morning.
- The aircraft was flying at high speed when it hit the trees.
- The aircraft did not show any evidence of failure prior to impact.

**Causes and Contributing Factors**

The pilot continued VFR flight under adverse weather conditions. Contributing factors to the occurrence were the fact that the pilot probably did not trust the instruments and the fact that he did not request weather information for the intended track prior to departure.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 18 March 1996.*

1. All times are EDT (Coordinated Universal Time (UTC) minus four hours) unless otherwise stated.
Air 1995

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 Loss of Propeller Blade
Classair Aviation Inc.
Normand Dubé Aviation
Aerocruiser (Ultralight) C-FCOL
Lavaltrie, Quebec
01 July 1995

Report Number A95Q0115

Summary

The pilot instructor and his student were making touch-and-go landings on an Aerocruiser advanced ultralight. Shortly after take-off from the private runway of École de pilotage de Lavaltrie, Quebec, at a height of approximately 300 feet above ground level, one of the propeller blades separated. The pilot instructor shut down the engine and landed the ultralight in an unprepared field. On the ground, the aircraft struck a tree and flipped over. The two occupants of the aircraft sustained serious injuries in the ground impact.

Ce rapport est également disponible en français.

Other Factual Information

The pilot was qualified for the flight.

The aircraft had been rented from a company that operated and maintained it. The aircraft had logged approximately 437 flying hours since new. It was equipped with a Rotax 912 four-stroke engine. A two-blade wooden propeller with a diameter of 72 inches (GSC International Inc.) was mounted on the engine. The propeller had been installed by the operator and had logged just over 300 flying hours since it was purchased in 1994. On several occasions, the operator of the aircraft had to adjust the pitch of one of the propeller blades. To rectify this problem, the operator had machined the propeller hub down 0.010 inch in order to apply greater torque at the blade roots.

The blade was recovered, and an examination of the propeller was conducted at the TSB Engineering Branch Laboratory. The marks
made by the bolts running through the two blades show that the blades were set at a medium pitch before the accident and that the pitch had not changed.

The broken section of the propeller indicated that the failure was progressive. Two anomalies were found on the broken blade: there was a crack in the wood of the root, and a black adhesive tape covered the circumference of the urethane capsule at the blade root, increasing the adjustment of the capsule in the propeller hub. The hub measurements were within the manufacturer's specifications.

At the root of the second blade, there was a crack at the same location as in the broken blade. No other damage was observed on the blades. According to the engineering report, these cracks could have been caused by contact of the blades with a soft object, such as water or snow, or by insufficient or excessive torquing of each blade root.

The propeller load calculations corresponded to those of the manufacturer, and fabrication of the propeller complied with the required and applicable standards.

The propeller manufacturer reported that there had been four similar occurrences out of the 10 000 blades in service. These occurrences were attributed to engine overspeed beyond the operating range specified by the manufacturer, impact with an object, or improper installation of the blades in the hub.

**Analysis**

Although the operator had machined the propeller hub down 0.010 inch to apply greater torque to the blade roots, the non-fractured blade presented a crack at the root at the same location as that observed in the fractured blade. This shows that the two blades were subjected to the same failure mechanisms.

Given that the propeller was fabricated with sufficient static load strength, and that the blade did not fail as a result of engine overspeed, pre-existing damage could be at the origin of the progressive failure and in-flight loss of the propeller blade.

The origin of this pre-existing damage could not be precisely determined, but it is plausible that it occurred when the blades struck a soft object such as water or snow, or as a result of insufficient or excessive torquing of each blade root in the hub.

The failures of this type reported by the manufacturer were due to factors external to the operating standards of the propellers.

The following laboratory report was completed:

**LP 115/95--In-Flight Propeller Blade Separation**

**Findings**

- The hub of the fractured propeller had been machined down
The hub of the fractured propeller had been machined down 0.010 inch.

- The non-fractured blade was cracked at the root, at the same location as in the fractured blade.
- The propeller was fabricated with sufficient static load strength.
- Failure of the blade was the result of a progressive failure caused by undetermined pre-existing damage.
- Contact with a soft object or insufficient or excessive torquing can cause this type of damage.

**Causes and Contributing Factors**

The blade failed in flight following a progressive failure caused by undetermined pre-existing damage. It is possible that this type of damage was caused by contact with a soft object or insufficient or excessive torquing.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairman John W. Stants and members Zita Brunet and Maurice Harquail, authorized the release of this report on 12 March 1996.*
Air 1995

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 Power
Air Alma Inc.
Bell 206L-1 Long Ranger (Helicopter) C-GLBA
Fontange, Quebec 1 mi W
04 July 1995

Report Number A95Q0118

Summary

The pilot-company maintenance director was at the controls of the Bell 206L helicopter and was conducting a sling load operation near maximum gross weight. All engine parameters were normal during the lift-off. Shortly after take-off, the pilot noticed a high engine temperature followed by a significant power loss.

The sling load was released and the pilot conducted an autorotation into a swamp. The helicopter touched down hard with the engine running, and sustained substantial damage. The two crew members were not injured.

Ce rapport est également disponible en français.

Other Factual Information

An examination of the maintenance records revealed that the engine (Allison 250-C20B, S/N CAE 832271) was removed 96 flight hours prior to the occurrence for a compressor replacement. A 300-hour inspection was also completed approximately 54 flight hours prior, while the fuel control unit was replaced 5 flight hours prior to the accident.

Some of the operations to be carried out at the 300-hour inspection are as follows:

- measure the oil flow from the scavenge passage of the external sump;
- inspect scavenge oil strut in the power turbine support;

- clean carbon deposits from the strut;

- inspect No. 6 and No. 7 bearing pressure oil nozzles; and,

- clean internal carbon deposits from the nozzle.

An examination of the engine was performed at the TSB Engineering Branch. The external visual and mechanical inspection of the engine, controls, and related lines did not identify any faults. The controls were removed and all drives were confirmed to be intact. All external air, fuel, and lubrication lines were in good condition and free of contamination.

The N1 and N2 rotors were initially reported to be seized together. However, both rotated independently with a slight rubbing noise. There was continuity in both gear train systems.

The turbine assembly was removed and it was noted that the O-ring packing, which provides a seal between the spur gear adapter shaft and the turbine-to-compressor coupling, was damaged. Two separate pieces were recovered and one small section was unaccounted for.

The oil filter element contained a moderate collection of carbon particles and several small metal particles. The amount of contaminant would not have significantly affected the oil flow.

The turbine-to-compressor coupling required excessive force to be removed. The shaft was heavily carboned, internally and externally, and was deformed due to torsional stress. The shaft had areas of blueing, indicating apparent heat distress. Necking down of the shaft was located axially in line with the fourth stage turbine wheel.

The gas producer and power turbine rotors were taken to a local repair facility and disassembled. It was determined that the No. 6 and No. 7 bearings were blackened and felt gritty. Their cages had some silver plating "melt out"; however, the bearings showed no reported distress. The No. 8 bearing outer race was capable of turning, and the stationary lab seal was cracked axially and circumferentially. The seal contained a significant amount of carbon, and a bearing failure was imminent.

The Allison Gas Turbine 250-C20B Series Operation and Maintenance Manual, as well as related Information Bulletins and Letters, cover a large number of points to be followed in order to prevent carbon build-up, and include lists of symptoms to help recognize the presence of carbon build-up. The main point is that the manufacturer, in effect, acknowledges that carbon accumulation is a known situation, and that he has gone to significant lengths to warn of the problem, to describe potential effects, and to state methods of avoiding and/or correcting the problem.
Analysis

The disassembly revealed that interference between the turbine-to-compressor coupling and the power inner shaft had occurred during operation, most probably because of an accumulation of carbon and oil sludge on the outer surface of the coupling and/or on the inner surface of the shaft. During operation, the coupling rotates at the N1 speed of approximately 50,000 revolutions per minute (rpm), while the N2 shaft speed is in the order of 33,000 rpm. Even very light contact will result in rapid frictional heating, which allows the normal torsional loads on the coupling to impart a twisting deformation. This results in further interference and an imbalance condition. The contact between parts tends to reduce the speed differential, sending conflicting information to the controls.

Ordinarily, the extent of the carbon build-up throughout the engine would be indicative of a long term problem. However, maintenance records indicate that the work to avoid this kind of problem had been performed shortly before the accident. The accumulation of carbon and sludge in the power turbine support assembly, in both the supply and scavenge struts and the bearing cavity, and also in the No. 8 bearing location, suggests a number of possibilities relating to both operation and maintenance.

The following laboratory report was completed:

LP 101/95 - Engine Examination, Bell 206L-1, C-GLBA.

Findings

- The packing was damaged between the turbine-to-compressor coupling and the spur adapter gear shaft.

- The oil filter element contained a moderate collection of carbon particles and several small metal particles.

- The turbine-to-compressor coupling shaft was heavily carboned, both internally and externally, and was deformed due to torsional stress.

- The No. 6 and No. 7 oil supply screen contained a significant amount of carbon.

- The No. 6 and No. 7 bearings were blackened and gritty, with some silver plating "melt-out”.

- The No. 8 bearing lab seal was cracked axially and circumferentially, and contained a significant amount of carbon.

- The No. 8 bearing showed signs that bearing failure was imminent.
Causes and Contributing Factors

The engine lost power as a result of interference between the turbine-to-compressor coupling and the turbine inner shaft, caused by a carbon accumulation between these components. The build-up of carbon in the turbine assembly is attributed primarily to operation and maintenance procedures, which did not obviate the formation of carbon or apply adequate corrective measures.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 28 February 1996.
Air 1995

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.

Power loss in left engine
ditching confortair
PIPER NAVAJO PA31-350 C-GVWM
Sept-Îles, Québec 24 mi S
27 July 1995

Report Number A95Q0142

Synopsis

The aircraft, with seven persons on board, was making a charter flight from Lourdes-de-Blanc-Sablon, Quebec, to Mont-Joli Airport, Quebec, in accordance with instrument flight rules (IFR). In flight, at a cruising altitude of 6,000 feet above sea level (asl) and about 50 nautical miles (nm) west of Port-Meunier, Quebec, the left engine lost power. The pilot applied full power on both engines, reported the power loss to the air traffic controller, and continued on his route. He tried to maintain the best rate-of-climb speed on one engine, but the aircraft continued to descend at a rate of about 400 to 500 feet per minute.

Two minutes later, at an altitude of about 4,800 feet asl, the pilot diverted the aircraft to Sept-Îles Airport, Quebec. About 25 nm south of Sept-Îles, the pilot requested assistance, declared an emergency, and said he was going to ditch the aircraft in the St. Lawrence River. At about 1,000 feet asl, the pilot feathered the left engine propeller. He carried out the safety checks for a water landing and advised the passengers of the measures to be taken. After the ditching, the seven occupants evacuated the aircraft via the aft main door. A few seconds later, the aircraft sank. The pilot and passengers treaded water, without life jackets, for about forty minutes before being rescued by a civilian helicopter. No one was injured. The accident occurred in daylight, in meteorological conditions favourable for visual flight.

Other Factual Information

The aircraft was certified and maintained in accordance with existing regulations. On take-off, the weight of the aircraft was at the maximum allowable and the centre of gravity was within the prescribed limits. The carrier was authorized to operate this type of aircraft without a co-pilot.
The pilot was certified and qualified for the flight in accordance with existing regulations. He was flying the aircraft from the left seat. He had a total of about 530 flying hours, including 230 hours on this aircraft type. He had joined the company two months before and had completed the company training on the Piper Navajo. The pilot had passed an in-flight test on type two months earlier. He was familiar with the route.

A commercial pilot with multi-engine and instrument ratings was in the right seat. He was undergoing training and was familiarizing himself with company operations. He had begun flying as an observer in the right seat about one week previously.

The engine (Lycoming 540-J2BD) had been installed one week previously and had accumulated 12 hours in-flight service since then. This engine is fitted with a turbocharger driven by exhaust gases. When the turbocharger is not functioning, about 75 per cent of engine power is still available. Examination of the technical log-books revealed no deficiencies. A fuel sample taken at the last refuelling airport revealed no evidence of water or contamination.

When the left engine lost power in flight, the pilot felt a yaw and speed decreased. The autopilot disengaged and the aircraft began to lose altitude. A passenger told the pilots that white smoke was coming from the left engine. The pilot initiated the emergency procedures, applying full power on both engines and trying to maintain the single engine best rate-of-climb speed of 109 knots. He observed that the intake pressure gauge indicated 23 inches. According to the pilot, this reading meant that the turbocharger was not functioning and the engine was still developing significant power. He left the engine running and did not consider it necessary to continue the checks and emergency procedures for an engine failure. These procedures include feathering the propeller.

According to the operating manual of the aircraft, with the engine failure checks completed and at the estimated weight, it is possible to obtain a rate of climb on one engine of about 230 feet per minute (fpm) at the indicated airspeed (IAS) of 109 knots. When the propeller is not feathered, drag increases and the aircraft is unable to maintain altitude.

Over a large part of its route, the aircraft was flying over the St. Lawrence River. When the power loss occurred, the aircraft was over water about 55 nm from Sept-Îles, where the company is based, and 15 miles from Sainte-Anne-des-Monts, Quebec, where there is a runway. The pilot felt that the meteorological conditions at that location were unfavourable for using that runway.

The pilot set a course for Sept-Îles and did not consider the situation sufficiently critical to declare an emergency. He thought he could reach his new destination. When the pilot realized that he could not reach the airport or the coast, and that he would have to ditch, he requested Coast Guard assistance. About five minutes later, the pilot declared an emergency. The controller, however, on his own initiative, dispatched a civilian helicopter to the site.
Shortly after the ditching of the aircraft and the evacuation of the occupants, the aircraft sank in about 850 feet of water. Consequently, it was not possible to recover the wreckage and examine the engine involved. Two aircraft flying over the area guided the helicopter, which arrived at the site about 30 minutes after the aircraft ditched. The accident pilot and passengers, who were treading water, boarded a raft that was dropped on the water and were hoisted aboard the helicopter a few minutes later. A second helicopter joined the rescue operation and all those who had been on board the ditched aircraft were transported to Sept-Îles Airport.

The aircraft was not equipped with life jackets. In accordance with Transport Canada Air Navigation Orders, a multi-engined aircraft that is able to maintain flight with the critical engine inoperative, and that is not operating more than 50 nm from shore, is not required to carry a life jacket for each person or life rafts with sufficient capacity for all persons on board. After this occurrence, all company aircraft were equipped with life jackets.

An analysis of the flight path was conducted by the TSB Engineering Branch Laboratory using radar data. It was determined that the rate of descent of the aircraft was approximately 500 fpm down to about 1,000 feet asl, where it decreased to about 100 fpm. This analysis showed that, in ideal conditions, with the left engine feathered immediately after the power loss, and speed maintained at 109 knots, the aircraft could have travelled an additional distance of about 130 miles, and would have arrived over Sept-Îles Airport at an altitude of about 2,500 feet asl.

**Analysis**

As the wreckage has not been recovered, the cause of the engine power loss could not be conclusively determined. However, the yaw, the loss of intake pressure, and the loss of altitude indicate a power loss more substantial than a turbocharger failure alone.

Due to his limited experience, the pilot interpreted the initial indications as a partial power loss and, after reporting it, he decided to continue on his route. According to a study by the University of Illinois, decision-making ability degrades during emergencies and highly stressful situations, and the pilot appears to have simplified his decision making by concentrating exclusively on some of the information available to him. In this case, the pilot did not verify all information: that is, whether the engine power loss was complete or only partial. Then, after interpreting the pressure gauge reading, he concluded that the engine was developing enough power to reach his diversion base. As a result, he applied full power on both engines and did not carry out the safety checks for a complete engine failure, which include feathering the propeller. As the propeller was not feathered immediately, drag increased considerably and, to maintain speed, the pilot was forced to descend the aircraft. During this time, the fact that he was the only authorized pilot on board did not make the situation any easier.
When the pilot realized that he could not reach his destination, he requested assistance and declared an emergency. However, it is highly probable that the vigilance of the air traffic controller and those participating in the rescue prevented a disaster and, possibly, loss of life.

The following laboratory report was completed:

LP 125/95 - Radar Data Analysis.

**Findings**

1. The cause of the power loss in the left engine could not be determined.

2. The pilot interpreted the indications of the power loss as a partial power loss.

3. The pilot did not feather the left engine propeller before 1,000 feet asl.

4. The pilot did not carry out all the safety checks for a complete engine failure.

5. The aircraft was unable to reach Sept-Îles and the pilot ditched the aircraft in the river.

6. The aircraft was not carrying life jackets, nor was it required to do so.

**Causes and Contributing Factors**

A complete power loss in the left engine occurred for an undetermined reason. The fact that the left engine propeller was feathered only at 1,000 feet asl contributed to the inability of the aircraft to reach its destination.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 24 April 1996.

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.

Propeller Failure Pelican C-IAZR
Chenail-du-Moine, Québec
01 October 1995

Report Number A95Q0199

Synopsis

The pilot of the float-equipped Pelican ultralight, registration C-IAZR, had just taken off from Chenail-du-Moine, Quebec, for a local pleasure flight. Shortly after take-off, the pilot executed a 180-degree right-hand turn to come back to the channel. While overflying the channel, the wings of the aircraft suddenly began to vibrate, and a continuous noise was heard. The aircraft then turned around again, creating the impression that the pilot intended to return to his point of departure. After crossing the channel, the aircraft executed a third 180-degree turn. During this turn, and at a height of about 100 feet above ground level, the aircraft stalled and crashed on an island.

Shortly after the accident, an explosion occurred. The aircraft caught fire and was destroyed. The pilot, the only occupant of the aircraft, died on impact.

Other Factual Information

The pilot was qualified for the flight. He had acquired his aircraft in October 1994, and he subsequently took his training on his own aircraft. He obtained his ultralight pilot licence in March 1995 and had accumulated 141 flying hours at the time of the accident. The pilot had always flown on his own aircraft.

At the time of the accident, the sky was clear and there was no wind. Several boats were in the channel.

The autopsy revealed that death was caused by multiple trauma sustained on impact when deceleration forces exceeded the limits of human tolerance. The results of toxicology tests conducted at the Civil Aviation Medical Unit (CAMU) of Health Canada located in Toronto, Ontario, were negative.
The Pelican is an advanced ultralight. The aircraft was built in 1988 by its first owner. The aircraft was flown for three years, then was parked at an airport until it was sold to its current owner.

The owner replaced the Rotax engine with a Subaru engine. He also removed the right-hand dual control and installed floats and a new carbon fibre propeller. The pilot later repaired the propeller. The leading edge of one of the blades had been damaged when the propeller came in contact with the engine cowling during a static power test sometime before the accident. The precise nature of the repairs could not be established.

The day before the accident, the owner mentioned that he was not satisfied with the repairs. On the flight made following the repairs, the engine had started to vibrate and the vibrations had damaged the engine mounts. That evening, he repaired the propeller again and also repaired the engine mount. He mentioned at the time that he had doubts about the quality of the repair.

The aircraft struck the ground at almost 90 degrees and flipped over. At the conclusion of the impact sequence, the aircraft fuselage lay flat on the ground, and the wings were upside down on the side opposite to their normal position on the fuselage. Both floats were on the same side of the aircraft. The aircraft was approximately 80 per cent destroyed by the fire.

When the wreckage was examined, only two of the three propeller blades had been found. In an information circular to owners, the propeller manufacturer indicated that the type of propeller used by the owner can be repaired by the user following a certain procedure. However, the manufacturer stated that only propellers with nickel-armoured leading edges should be used in floatplane operations. That type of propeller cannot be repaired by the user and must be returned to the manufacturer.

Witnesses stated that, during the flight, the engine seemed to be operating normally. Some witnesses heard variations in the sound of the engine after the vibrations started. They associated the sound with variations in engine power.

A fire broke out a few seconds after ground impact. The tanks in both wings contained fuel. When the owner had installed the engine, he had relocated the battery towards the aft fuselage area for balance. The battery cables ran along the bottom of the fuselage to the front. Evidence of a short circuit was observed on one of the battery cables in the forward cabin area.

The flight controls were examined for continuity. The elevator cables and rudder cables were intact. The aileron control had broken in the tube running between the left and right controls. The aileron bell cranks and the control tubes running from the cabin to each of the ailerons had melted in the intense heat of the fire.

The aileron control was forwarded to the TSB Engineering Branch.
Laboratory. A rupture test was performed on the end opposite to the one found ruptured in the wreckage examination. The end ruptured at 950 pounds. This evaluation determined that the control had been manufactured in accordance with established safety standards and complied with the manufacturer's standards.

Analysis

The pilot was qualified for the flight, and meteorological conditions were favourable for the flight.

The pilot had made repairs to one propeller blade. However, the precise nature of the repair could not be determined because that blade was never found. However, the pilot did not seem satisfied with the repair, as a previous repair to the same propeller had not produced the desired results.

When the aircraft started to vibrate in flight, all indications are that the pilot tried to come back to the channel and land the ultralight. To that end, he adjusted engine power several times to reduce the vibrations caused by the loss of the propeller blade.

As there were several boats on the water, the pilot executed a 180-degree turn to avoid them before setting the ultralight down. The evidence indicates that the aircraft stalled during this low-altitude turn before crashing on the island and catching fire.

The following Engineering Branch report was completed:

LP 141/95 - Aileron Pushrod Examination.

Findings

1. The pilot was qualified for the flight.

2. The pilot repaired one blade of the propeller and seemed unsatisfied with the results.

3. The pilot was authorized to repair the propeller.

4. One propeller blade separated in flight and was not found.

5. The cause of the loss of the propeller blade in flight could not be determined.

6. The wings of the aircraft started to vibrate shortly before the accident.

7. The aircraft stalled in a low-altitude turn and crashed.

Causes and Contributing Factors

The aircraft stalled in a low-altitude turn after one blade separated from the propeller. The repair to the propeller of the ultralight contributed to the accident.
This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 13 February 1996.

Updated: 2002-10-06  ▲  Important Notices
Report A95Q0206

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 Vehicle
Air France
Boeing 747-200 F-BPVV
Montreal International (Mirabel) Airport, Quebec
15 October 1995

Report Number A95Q0206

Summary

The Air France cargo Boeing 747-200 was parked at gate 111 at Montreal International (Mirabel) Airport, Quebec, and was being prepared for a flight to Charles de Gaulle Airport, France. The ramp operations, conducted by Air Canada employees, were almost completed when the co-pilot requested taxi clearance from the apron controller. Taxi clearance was issued and the captain started to taxi the aircraft.

A ground handler and a ground power unit (GPU) vehicle were still situated under the aircraft. After the aircraft had taxied about 85 feet, its right wing main landing gear struck the GPU vehicle and pushed it approximately three feet before the captain stopped the aircraft. There were no injuries; however, the aircraft sustained minor damage to two main wheel tires and to a wheel-well door. The incident occurred in daylight conditions.

Ce rapport est également disponible en français.

Other Factual Information

The aircraft was being prepared for flight by two ground handlers and one aircraft maintenance engineer, all Air Canada employees. One ground handler, the signalman, was located forward of the right wing at approximately the three o’clock position relative to the co-pilot. Both Air France and Air Canada ground operating procedures state that the signalman must take up a position forward of the aircraft, within view of the flight crew. However, the open ramp concept at Mirabel does not
allow the signalman to operate safely forward of the aircraft because of other vehicle traffic and the possibility of jet blast from other aircraft. The aircraft maintenance engineer was situated just slightly forward of the signalman and was observing the engine start-up sequence. The other ground handler, who was in charge of communications, was situated under the nose of the aircraft and had his headset connected to the intercom system during the engine start-up sequence. He told the pilots that the aircraft was clear before the commencement of the engine start-up sequence.

The ground power unit (GPU) vehicle was situated on the right forward side of the aircraft. The ground handling procedures of both companies state that the GPU vehicle should be driven clear of the aircraft as soon as it is disconnected and no longer in use. However, according to local practice, the GPU vehicle is kept close to the aircraft so that the ground handler can use it to transport the wheel chocks and himself away from the aircraft. The policies of the air carrier (Air France) and of the company handling ground operations (Air Canada) specify that the ground handler in charge of communications with the crew shall not disconnect the intercom communication cord before all staff and equipment are outside the security perimeter (designated as 25 feet around the aircraft). The ground handler disconnected his intercom and gave the "all clear" to the pilots; however, he had difficulty securing the intercom trap door. The flight crew was not aware of this difficulty. The aircraft maintenance engineer drove his vehicle to the nose of the aircraft in order to assist his colleague. The members of the flight crew did not see the aircraft engineer drive his vehicle toward the aircraft because they were busy with cockpit duties. They believed that the ground handler in charge of communications and the signalman were one and the same person. To the crew members, it was, therefore, impossible that someone could still be positioned under the aircraft. They also believed that all vehicles were clear from under the aircraft as required by the operational procedures of both the air carrier and the company handling ground operations.

When the co-pilot requested taxi clearance, the controller's response was: "Air France 6443, circulez autour de la bâtisse par la droite pour la sortie Québec." Translated, this means, "Air France 6443, taxi around the building to the right for the Québec exit." The flight crew mentioned that, from the way it was pronounced, they had understood the word "bâtisse" as "Bât. 6."

All three crew members looked at their airport area charts and searched for the building or area designated as "Bât. 6." After searching the charts, they realized that the apron controller meant "bâtisse," which means building in French. The accepted radio phraseology used to designate the building in question is the word "cluster" or "ilot"; both may be used in French.

From the apron control tower, the controller is unable to see the whole aircraft parked at gate 111. The cluster building blocks his view of the area surrounding the aircraft and makes it impossible for him to confirm that the aircraft is clear of all obstacles before he issues the taxi clearance. Even if the position of the aircraft had allowed the controller
a better view of the area surrounding the aircraft, the controller is not responsible for confirming that that part of the apron is clear. The responsibility for ensuring that the aircraft is clear of all obstacles before advancing lies with the flight crew.

The co-pilot recalls seeing that the signalman had only his closed right hand positioned against his right shoulder. According to the co-pilot, the signal was distorted because the signalman seemed to be talking on the walkie-talkie. The co-pilot interpreted this signal as a somewhat lax signal to proceed. The hand signal to proceed consists of holding the right arm straight out to the side, at shoulder height, and holding the left arm across the chest with the left hand pointing to the right, indicating the direction of travel. The signalman mentioned that he kept his hands in the "stop" signal position during the engine start-up sequence and that he did not make eye contact with the co-pilot. The hand signal used to indicate "stop" consists of holding both arms above the head to form an "X" pattern.

The signalman was wearing the same uniform as his colleagues. Only his orange fluorescent gloves differentiated him from the others. These gloves were somewhat dirty and faded, and were not as conspicuous as when they were new. The signalman mentioned that, after the aircraft started to advance, he continued to hold the "stop" hand signal, moving forward as the aircraft moved forward. He indicated that the co-pilot did not look in his direction.

When the aircraft maintenance engineer and the ground handler under the aircraft heard the engines spool up, they rapidly went to their respective vehicles. The aircraft maintenance engineer drove his vehicle away from the aircraft; however, the ground handler's GPU vehicle stalled. The ground handler rapidly exited his vehicle and ran to the left side of the aircraft. At that moment, the captain noticed someone on the left side, by the No. 1 engine, and immediately brought the aircraft to a complete stop.

The co-pilot's request for taxi clearance was made 41 seconds after the captain told the intercom ground handler to disconnect and to revert to hand signals. The aircraft started to move approximately 20 seconds after taxi clearance was given, and the aircraft advanced for approximately 33 seconds before coming to a stop.

An internal audit of the company handling ground operations for Air France at the Mirabel airport was scheduled for the following month. There was no record of any audits taking place before the occurrence. It is the responsibility of the group supervisors to monitor the ground operations and ensure that they conform to handling company procedures and safe operations.

Analysis

Contrary to company procedures of the air carrier and of the company handling ground operations, the GPU vehicle was not removed from beneath the aircraft prior to engine start-up; it was left near the aircraft so that the ground handler in charge of communications could use it to
transport the wheel chocks and himself away from the aircraft after engine start-up and the completion of the aircraft ground checks. Prior to the engine start-up sequence, the ground handler in charge of communications with the crew told the pilots that the aircraft was clear; the crew was, therefore, unaware that the GPU vehicle remained beneath the aircraft. The flight crew members were also unaware that a problem existed with the intercom trap door; they believed that the aircraft was ready to taxi.

The non-standard phraseology used in the taxi clearance interrupted the flight crew's normal ground operation sequence and check-list, and distracted them. The total elapsed time from the crew's acceptance of the taxi clearance to the actual taxiing of the aircraft was longer than normal; therefore, the co-pilot anticipated a "proceed" signal because he assumed that the aircraft was clear and that everything would be in place for the aircraft to advance.

Because of the open ramp concept, the signalman was situated approximately at the three o'clock position relative to the co-pilot, rather than in front of the aircraft. This position is at the limit of the co-pilot's peripheral vision when he is looking forward; it therefore becomes more difficult to notice the signalman and any signal changes he might make.

The co-pilot stated that he saw the signalman's closed right hand positioned against his shoulder; the signalman seemed to be talking on the walkie-talkie. The co-pilot interpreted this signal as the signal to proceed.

The signalman stated that he did not make eye contact with the co-pilot and that he held his hands in the signal to stop during the entire ground operation. Due to the conflicting statements of the signalman and the co-pilot, the position of the signalman's hands could not be determined. Given that the signalman's fluorescent gloves were dirty and faded, they may not have been as conspicuous as necessary.

After hearing the engine spool up, the ground handler under the aircraft attempted to drive the GPU vehicle clear of the aircraft, but the vehicle stalled.

No recent internal company audit had been performed to ensure that ground personnel were conforming to procedures, or to verify the state of wear of safety equipment used during ground operations.

Findings

- The GPU vehicle was not removed from within the aircraft's safety perimeter after it was disconnected. The procedures used at Mirabel by the company handling ground operations are different from the procedures at other airports.

- The ground handler in charge of communications with the crew told the pilot that the aircraft was clear and was ready for engine start.
The communications ground handler disconnected his intercom before all staff and equipment were clear of the aircraft.

The flight crew members did not see the aircraft maintenance engineer approach the aircraft with his vehicle, and they were unaware of the intercom panel problem.

The total elapsed time from the crew's acceptance of the taxi clearance to the actual taxiing of the aircraft was longer than normal; this led the co-pilot to anticipate that he would receive the "clear to proceed" signal from the signalman.

The co-pilot interpreted the signalman's hand signal as a signal to proceed.

The signalman's fluorescent gloves were dirty and faded, and may not have been as conspicuous as necessary.

The GPU vehicle stalled when the ground handler attempted to drive it away from under the aircraft.

The aircraft struck the GPU vehicle with its right main wing landing gear and pushed it approximately three feet.

No internal audit of the company handling ground operations had been performed recently.

**Causes and Contributing Factors**

After interpreting the signalman's hand signal as a signal to proceed, the flight crew advanced the aircraft, which struck the GPU vehicle. Contributing to this occurrence was the fact that the ground handler incorrectly stated to the flight crew that the aircraft was clear when the GPU vehicle remained under the aircraft; this local practice was not in accordance with published procedures of the air carrier or the company handling ground operations.

**Safety Action Taken**

After this incident, the Direction générale des affaires techniques et de la qualité (Technical Affairs and Quality Department) of Air France implemented the following corrective action:

- The departure procedures prescribed in the Manuel Généralités Lignes (General Line Manual) (MGL) were amended to ensure more comprehensive and accurate ground/aircraft communications.

- Ground handling contracts will make reference to the procedures in Air France manuals to describe the services provided by the
ground handling company.

- The persons in charge of logistical operations will ensure that all en route ground operations are executed in accordance with the procedure described in the MGL.

- Verification of crew compliance with the departure procedures described in the MGL will be added to the skills review program for all flight crew.

- The areas for preventive action proposed following a company survey on taxiing will be analyzed and appropriate corrective measures will be taken if necessary.

- The instructions regarding departure procedures provided in the various company manuals will be brought in line with those prescribed in the MGL.

- All manual revisions will be accompanied by a note drawing the attention of personnel to the changes.

- Information regarding this incident will be distributed to the persons concerned.

In addition, Air Canada has amended its procedures at Mirabel Airport so that all vehicles will be clear of the aircraft before the signalman disconnects his intercom and gives the "all clear" signal to the crew.

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.

Updated: 2002-10-06

Important Notices
Air 1995

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
Cessna 402 N67850
Wabush, Newfoundland 23 nm NW
22 October 1995

Report Number A95Q0210

Summary

The Cessna 402, with five persons on board, took off from Auburn, Indiana, USA, around 0630 local time (1130 Coordinated Universal Time (UTC)) for Schefferville, Quebec, with stops en route. Their final leg was from Montreal International (Dorval) to Schefferville, with Wabush, Newfoundland, as the alternate, and they took off at 1523 EDT (1923 UTC). The flights were conducted in accordance with instrument flight rules (IFR). While in cruising flight and west of Wabush, the pilot requested the weather conditions for Schefferville and Wabush. Because of poor conditions in Schefferville, the pilot decided to fly to his alternate, Wabush. During the ILS approach for runway 01, the aircraft was too high to complete the approach, and the pilot requested and received clearance to execute another one.

During the missed approach, the pilot proceeded an unknown distance outbound and turned back toward the airport. During the inbound leg, the aircraft contacted trees on the side of a mountain, at an indicated altitude of 2,460 feet asl, and decelerated over a distance of about 900 feet. The aircraft came to rest 23 nautical miles north of the airport, on the extended centre line of runway 01, on a heading of 186 degrees magnetic. The aircraft crashed probably at just after 1907 ADT (2207 UTC) during the hours of darkness.

The occupants were picked up safe and sound early the next morning by Search and Rescue personnel of the Canadian Forces.

Ce rapport est également disponible en français.

Other Factual Information

The pilot was certified and qualified for the flight in accordance with existing regulations. For the flight, the pilot used Jeppesen flight publications, which were consistent with Canadian publications. The pilot was not familiar with this airport.

Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The aircraft was not equipped with a ground proximity warning system (GPWS), nor is that equipment required. There was no evidence found of any pre-impact mechanical deficiency or aircraft system malfunction.
The pilot had checked the weather conditions for the route before take-off. On departure, he was aware of the possibility that he would go to the alternate airport if the weather at the destination airport did not improve.

About 2130 UTC, when the aircraft was at an altitude of 11,000 feet above sea level about 74 nautical miles (nm) west of Wabush, the pilot was informed by the Wabush FSS specialist that the condition of the Schefferville runway was ice-covered and that the VHF omni-directional range (VOR) was not functional. Also, runway cleaning operations were not to begin until the next morning. The runway at Wabush was wet, and the weather conditions were as follows: broken cloud at 600 feet, overcast at 1,200 feet, visibility 2.5 miles in light rain, and winds from 150 degrees magnetic at 10 knots with gusts to 15 knots. Based on this information, the pilot decided to divert to the Wabush Airport.

At 2156 UTC, the pilot received from Wabush the relevant weather information for a runway 01 approach, for which he had been cleared by Moncton Control Centre. The weather information was similar to that received earlier. Five minutes later, the pilot requested another approach because he had missed the first one. The clearance was issued by the FSS specialist at about 2203 UTC, but it was not received by the pilot because of poor radio reception. At about 2207 UTC, the clearance for another approach to the Wabush airport, not above 6,000 feet, was received and acknowledged by the pilot, and he requested confirmation of the minimum altitudes for a missed approach. He was informed that the minimum altitude for the south-east quadrant was 3,600 feet, and for the rest of the area, 4,000 feet. Acknowledgement of this information was the last recorded radio transmission from the aircraft.

According to the published instrument approach procedure, a pilot executing a missed approach for ILS runway 01 at Wabush is required to climb to 2,300 feet asl on the runway heading, make a right climbing turn to 022 degrees magnetic and climb to 4,000 feet asl, then make a right turn to the WK non-directional beacon (NDB) maintaining 4,000 feet asl. See Appendix A.

The aircraft came to rest 23 nm north of the airport, almost on the extended centre line of runway 01. The axis of the wreckage was on a track of 186 degrees magnetic, which is the direction toward the airport. At the site, the left altimeter was set to 29.85 inches of mercury and the indicated altitude was 2,460 feet. The last altimeter setting provided to the pilot was 29.84 inches of mercury. Impact marks indicate that the aircraft struck the trees on the side of the mountain while in cruising flight. Deceleration occurred over a distance of about 900 feet before the aircraft came to rest on the mountainside.

The frequencies of the aircraft's navigation equipment were checked at the site. VOR 1 was set to a frequency of 112.30 MHz, the Wabush VOR, with the standby frequency set to 110.3 MHz, the localizer transmitter (ILS). The horizontal situation indicator takes its information from receiver 1. Its course display window showed 190 degrees and the heading marker indicated 180 degrees. VOR 2 was tuned to the frequency 108.00 MHz (unknown). Automatic direction-finder (ADF) 1 was tuned to 203 kHz (unknown) and ADF 2 was tuned to 218 kHz, which is the Wabush NDB frequency. The pilot indicated that he selected these parameters to return to the airport.

When the aircraft came to rest, the passengers evacuated because gasoline vapours were escaping. When the odour dissipated, they went back into the aircraft, where they spent the night. Around 0140 UTC, Search and Rescue personnel arrived in the area to begin the search. They stayed near the site all night, and early in the morning they inserted a team by parachute. The pilot of the accident aircraft had a sore back and the passenger in the front seat had a fractured wrist. The other occupants had only minor injuries. All were evacuated to the airport at the same time.
The occupants of the aircraft reported that, during the approach, the aircraft was momentarily between two cloud layers. As the lower layer was thin, some passengers could see the ground a few minutes before the impact. The pilot saw trees at the last minute and had tried to avoid them.

The pilot had taken off early in the morning and was operating the aircraft alone. In aviation, mental fatigue is typically associated with tasks demanding intense concentration, rapid or complex information processing, and other high level cognitive skills. Examples of flight operations likely to engender this type of fatigue might include single-pilot, night, instrument approaches at unfamiliar airports.\(^1\)

This occurrence was classified as a controlled flight into terrain (CFIT) accident. CFIT occurrences are those in which an aircraft is inadvertently flown into terrain, water, or an obstruction with no prior awareness on the part of the crew of the impending disaster. Investigations into CFIT occurrences have revealed a number of factors which normally include a combination of the following: management of time and tasks; procedure errors; and, loss of situational awareness.

**Analysis**

The pilot initiated the missed approach at his alternate airport because he was too high and close to the airport to intercept the ILS glide path. In the descent, the pilot had not taken into consideration the strong tailwind component which modified the descent slope of the aircraft.

During the missed approach, the pilot requested confirmation of the quadrantal altitudes, which tends to show that part of his planning for the approach was inadequate. This is supported by the fact that the aircraft crashed 23 nm north of the airport although, in accordance with the approach plate, during the missed approach the aircraft should have stayed within about 20 nm of the airport to stay within the 25 nm minimum safe altitude area.

For the conduct of this approach, it would be normal to have navigation receiver 1 displaying the ILS frequency of 110.3 MHz rather than the VOR frequency of 112.3 MHz, with 005 in the course display window rather than 190. Also, it would be normal to have both ADFs tuned to the Wabush NDB (218 kHz). Finally, the missed approach requires the use of only the ILS and ADF, and that the pilot maintain the minimum altitudes and fly a track to the WK NDB. The pilot reported that he was using the VOR to return to the airport. The parameters displayed on the navigation instruments show that, at some point during the missed approach, the pilot lost the mental picture of what he had to do.

The aircraft struck trees at an altitude of 2,460 feet asl, but the aircraft, based on its heading and position, should have been at least 4,000 feet asl, the minimum safe altitude within 25 nm of the WK NDB and the missed approach altitude. Although the pilot requested confirmation of the minimum quadrantal altitudes, and the approach chart indicated the same information and more, the aircraft descended below the published minimum altitudes.

As the occurrence happened at the end of a long day’s work in a complex environment, the pilot executed a night approach when his performance and vigilance were not necessarily optimal. All of these factors possibly contributed to mental fatigue which affected the pilot’s performance during the missed approach.

**Findings**

- The pilot was not familiar with the Wabush Airport and its approaches.
- During the descent for the first approach, the tailwind modified the descent slope and the aircraft was too high and too fast to intercept the localizer course.

- During the missed approach, the pilot lost the mental picture of what he had to do.

- The pilot requested from the FSS specialist the minimum safe altitudes, an indication that the pilot was not adequately prepared for the approach.

- The pilot did not maintain the published minimum safe altitude.

- The pilot did not follow the missed approach procedure.

- The pilot had been on duty for a long period, which possibly affected his performance.

- The aircraft came to rest on the side of a mountain, 23 nm north of the airport at an altitude of 2,460 feet.

**Causes and Contributing Factors**

The pilot did not follow the missed approach procedure as published, particularly with regard to minimum altitudes, and the aircraft crashed on the side of a mountain.

*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 25 October 1996.*

**Appendix A**

APPROACH CHART FOR THE WABUSH AIRPORT
Note: This chart is from the Canada Air Pilot; however, all of the pertinent information is the same as on the Jeppesen chart used by the pilot.

Air 1995

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

Aviation Occurrence Report
Mid-Air Collision
Between Cessna 180 C-FYKD and Cessna 150 C-GLHJ
Saint-François-de-Laval, Quebec
26 October 1995

Report Number A95Q0215

Summary

The pilot of a Cessna 180 was on final approach for a private runway at Saint-François-de-Laval, Quebec. Meanwhile, the pilot of a Cessna 150, with one passenger on board, was taking off from the same runway. Both aircraft were on visual flight rules (VFR) pleasure flights. The aircraft collided over the runway approximately 100 feet above ground level (agl). After the collision, both pilots lost control of their aircraft. Both aircraft crashed in a plowed field, a few metres east of the runway. The pilot of the Cessna 150 sustained fatal injuries, and the passenger was seriously injured. The pilot of the Cessna 180 was seriously injured.

Ce rapport est également disponible en français.

Other Factual Information

The pilot of the Cessna 180 took off from Mascouche Airport, Quebec, at 1542 eastern standard time (EST)\(^1\) on a flight to Laval Aviation (Contant runway). At 1545, he advised the Mascouche controller that he had left the control zone and was proceeding to Contant runway. He was then cleared to select the en route frequency of 126.7 megahertz (MHz). The controller was unaware that Laval Aviation and Contant runway were the same location. The weather conditions were favourable for visual flight. The winds, from 200 degrees magnetic and five to ten knots, favoured runway 19 for landing and take-off.

At the same time, the pilot of the Cessna 150 moved out of his parking area at Laval Aviation. The pilot positioned the aircraft at the end of runway 19 and completed the usual engine checks, which lasted about
five to ten minutes.

Contant runway is an uncontrolled private aerodrome. It is neither certified by Transport Canada nor listed in the Canada Flight Supplement. It is located two miles south of Mascouche Airport, just outside the control zone. The only runway is 4 000 feet long by 40 feet wide and is oriented 190/010 degrees magnetic. Runway 19 is asphalt-surfaced for the first 800 feet; the remainder of the surface is gravel. Two electrical transmission lines, one 150 feet and the other 140 feet above ground, cross runway 19 at 475 feet and 700 feet, respectively, from the threshold.

Around 1546, the Cessna 180 commenced the first of two left-hand circuits approximately 1 000 feet above sea level (asl) over runway 19. A witness saw the pilot of the Cessna 150 look towards the Cessna 180, which was overflying the aerodrome in a westerly direction. On his first circuit, the pilot of the Cessna 180 saw the Cessna 150 parked at the north end of runway 19. On the cross-wind leg, the pilot of the Cessna 180 reported on frequency 126.7 MHz his intention to land on runway 19. There was no acknowledgement of this message.

On the second circuit at 500 feet asl, the pilot of the Cessna 180 thought he saw that the propeller of the Cessna 150 was stopped. He concluded that the aircraft was parked and that a take-off under the transmission lines was not possible. The pilot of the Cessna 180, who was not familiar with Contant runway, planned a final approach for runway 19.

While the Cessna 180 was on approach, the pilot of the Cessna 150 advised the Mascouche controller on frequency 118.6 MHz that he was going to take off from Laval Aviation on a flight to Joliette, Quebec, via Repentigny, Quebec. He took off on runway 19 around 1551, after he was advised by the controller to call back over Repentigny. The controller did not inform the pilot of the Cessna 150 that the Cessna 180 was going to land at Laval Aviation. On approach, the Cessna 180 flew over the transmission lines. He aimed to touch down 2 000 feet from the runway threshold. Both aircraft were on the runway centre line and flying the same track. The Cessna 150 was in the climb while the Cessna 180 was in the descent above it. The aircraft collided 1 500 feet from the end of the runway, about 100 feet agl. No avoidance manoeuvres were observed. The Cessna 180 had two radios; one displayed the frequency 126.7 MHz and was set to ON; the other radio displayed the frequency 118.6 MHz and was set to OFF. The radio of the Cessna 150 displayed the frequency 118.6 MHz and was set to ON.

Pilots familiar with the aerodrome usually took off in a southerly direction on the asphalt-surfaced part of runway 19 and passed under the power lines. They would land in the opposite direction, on runway 01, to avoid flying over the transmission lines on approach. No radio frequency was assigned to the aerodrome, and no procedures specific to the aerodrome had been developed. According to Transport Canada, pilots of radio-equipped aircraft operating over unlisted, uncontrolled aerodromes must monitor the frequency 123.2 MHz.
According to current practice and the *Flight Training Manual*, engine checks and pre-take-off checks are completed off the runway. Before proceeding onto an active runway, the aircraft must be positioned so as to ensure that all traffic on approach from any angle can be seen. When the pilot is certain that the way is clear, she/he must proceed onto the runway and take off without delay.

According to *Air Regulation* 529: "Where an aircraft is in flight or manoeuvring on the ground or water, the pilot-in-command shall give way to other aircraft landing or about to land."

**Analysis**

Pilots flying VFR in known high-traffic areas must maintain external surveillance at all times, and they must warn other pilots of their intentions when approaching or departing an uncontrolled aerodrome. They bear full responsibility for seeing and avoiding other aircraft.

The two pilots were not monitoring a common frequency; the pilot of the Cessna 180 set the frequency to 126.7 MHz, and the pilot of the Cessna 150 set the frequency to that of the Mascouche tower, 118.6 MHz. It is possible that the pilot of the Cessna 150 monitored the Mascouche tower frequency, given the proximity of the Mascouche control zone, and because he had to contact the controller shortly after take-off. The Mascouche controller did not inform the Cessna 150 that the Cessna 180 was going to land at Laval Aviation because he did not know that Laval Aviation and Contant runway were the same aerodrome. The Cessna 180 had departed the Mascouche control zone five minutes earlier. Therefore, neither pilot was aware of the other's intentions. As a result, collision avoidance was totally dependent on the principle of "see and be seen".

By doing his engine checks on the runway, the pilot of the Cessna 150 was not in a position to watch the approach and spot the Cessna 180. The pilot of the Cessna 150 probably did not expect any aircraft to land on runway 19, as landings were usually made in the opposite direction. Evidently, the pilot of the Cessna 150 saw the Cessna 180 overfly the aerodrome, but he did not realize that it was executing a landing circuit.

The pilot of the Cessna 180 was not familiar with the customs of the aerodrome. He executed an upwind landing on runway 19, which was not the current practice. He did not ensure that the pilot of the Cessna 150 knew he intended to land, and he executed a landing approach while the Cessna 150 was aligned for the take-off.

The Cessna 150 initiated its take-off run just before the Cessna 180 flew over it. The Cessna 180 was practically over the Cessna 150 on final approach and could not be seen by the Cessna 150. The Cessna 150 was hidden by the floor of the Cessna 180.

**Findings**

- The two pilots were not monitoring a common frequency.
Neither aircraft was displaying the frequency recommended by Transport Canada.

Neither pilot was aware of the other's intentions.

The pilot of the Cessna 150 was not in a position to watch the approach and spot the Cessna 180.

The pilot of the Cessna 180 did not ensure that the pilot of the Cessna 150 knew he intended to land.

Each aircraft was hidden by the fuselage of the other aircraft.

The pilots did not execute avoidance manoeuvres.

Causes and Contributing Factors

Neither pilot saw the other aircraft in time to avoid a collision. Contributing to the accident were the fact that the pilots were not monitoring a common frequency and neither was aware of the other's intentions.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairman Benoît Bouchard and members Maurice Harquail and W. A. Tadros, authorized the release of this report on 26 November 1996.

1. All times are EST (coordinated universal time [UTC] minus five hours).
Air 1995

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
Niagara Helicopters Ltd.
Bell 206L-3 Long Ranger III (Helicopter) C-FLYO
Montreal International (Mirabel) Airport,
Quebec 20 mi SW
02 November 1995

Report Number A95Q0218

Summary

Two helicopters departed from Niagara Falls, Ontario, on a flight to the Bell Helicopter Textron factory at Mirabel, Quebec. At the start of the trip, the aircraft flew in formation in visual meteorological conditions. Helicopter C-FLYO, with the pilot and one passenger on board, followed the aircraft flown by the formation leader. En route, the weather deteriorated; the distance between the helicopters was reduced to 200 feet and the flight continued at low altitude and at a reduced speed. While in hovering flight above an electrical transmission line running across a highway, the C-FLYO pilot made a sudden manoeuvre to avoid a wire, then attempted to land. The helicopter touched down sideways and rolled over onto its right side. The pilot sustained minor injuries; the passenger was uninjured.

Ce rapport est également disponible en français.

Other Factual Information

By arrangement between the pilots, the two skid-equipped Bell 206L-3 helicopters departed Niagara Falls in formation flight. The formation leader, flying the lead helicopter, was in charge of radio communications and navigation. The helicopters stopped at Toronto, Ontario, where one passenger boarded each aircraft, and again at Kingston, Ontario, in order to refuel. The two helicopters took off from Kingston around 1321 eastern standard time for a flight to Bell Helicopter Textron in Mirabel.
The C-FLYO pilot was certified and qualified for the flight in accordance with existing regulations. He had been flying for the company for eight years. Previously, he had flown helicopters for the Philippine armed forces, where he gained his experience in formation flying. The pilot was responsible for the safety of the aircraft and the passengers on board. Accordingly, he had ultimate authority with respect to the operation of the aircraft during the flight. He reported to the chief pilot.

The formation leader was the company owner, who was also chief of operations and chief pilot. The chief of operations is responsible for ensuring that flights are conducted safely, in accordance with government laws and regulations, and in accordance with the standards, practices, procedures, and specifications prescribed in the company operations manual.

The two pilots obtained the meteorological information available on actual and forecast conditions along the route prior to the flight. The aerodrome forecast for the Mirabel and Dorval airports indicated a partially obscured sky condition with a ceiling of 300 feet above ground level (agl) and visibility of one mile in rain and haze. At the time of the accident, Mirabel reported a partially obscured sky condition with a ceiling of 300 feet agl, and visibility of one and one-half miles in light rain, light drizzle, and haze.

Along the way from Kingston to Mirabel, the meteorological conditions deteriorated. The flight continued at low altitude to about two thirds of the way where, with poor visibility in rain, the C-FLYO pilot landed in a field after losing sight of the formation leader. About 25 minutes later, the pilot of the lead helicopter located the second helicopter and landed beside it. The pilots discussed flight procedures for the remainder of the journey and agreed on the route to be followed to destination. They followed a railway, then a highway, in a northwesterly direction at altitudes between 700 and 100 feet agl.

A short time later, the helicopters, at 100 feet agl, crossed a lake 20 miles southwest of Bell Helicopter Textron. The radars stopped receiving the altitude of the lead helicopter when the formation leader switched off his transponder. The aircraft followed a highway to a point about two kilometres east of Saint-Eustache, Quebec, where three electrical transmission lines intersected the flight path. The first two lines were close together at a height of 120 feet; the third line, at a height of 270 feet, was 100 metres further east and was obscured by low cloud. To continue the flight, the formation leader flew over the towers of the first two lines, then hovered to the left and descended before flying under the cables of the third line.

Wanting to maintain separation between the two helicopters, the C-FLYO pilot hovered above the first set of cables and watched as the lead helicopter manoeuvred between the power lines about 50 metres ahead of him. At that time, the passenger noticed that the aircraft was moving left and losing altitude. He promptly told the pilot that they were in danger of colliding with the wires. The pilot immediately backed up the helicopter, entered a right-hand turn, and descended for a landing.
The aircraft touched down while it was moving sideways to the right. The helicopter bounced twice on the right skid, the main rotor blades sliced through a metal road sign, and the aircraft rolled over on its right side at the edge of the highway congested with rush-hour traffic. The accident occurred in uncontrolled airspace between the Mirabel and Dorval control zones.

A helicopter can fly in uncontrolled airspace when the visibility exceeds one-half mile, provided that it flies at a sufficiently reduced speed to allow the pilot to see obstacles in time to avoid them. When the weather is adverse and the pilot must fly at low altitude, he is required to comply with the Air Regulations. Section 534 provides that no person shall fly an aircraft over any open air assembly of persons at an altitude less than 1,000 feet above the highest obstacle within a radius of 2,000 feet from the aircraft or elsewhere than over the built-up area of any city, town, or other settlement or over any open air assembly of persons at an altitude of less than 500 feet above the highest obstacle within a radius of 500 feet from the aircraft.

Analysis

The pilots departed when the meteorological forecast gave reason to believe that, in order to reach their destination, the helicopters would have to fly in adverse weather conditions, at low altitude, and over an urban area traversed by electrical transmission lines. As it is difficult to read a chart and identify obstacles and reference points when flying at low altitude, the formation led by the company owner had to follow a highway congested with rush-hour traffic. The fact that the formation leader was the company owner may have influenced the decision of the C-FLYO pilot to continue the flight in adverse weather conditions and to contravene the regulations.

Company management was responsible for controlling the operation of its aircraft and for ensuring that the pilots abided by existing regulations. However, for undetermined reasons, the lead pilot chose to guide the formation in adverse weather conditions at an altitude that compromised the safety of the aircraft and its occupants, and persons and property on the ground.

While in hovering flight above the first set of cables, the C-FLYO pilot was using the lead helicopter as a visual reference to determine his position in relation to the ground. It was difficult to perceive changes in aircraft attitude because he was hovering high above ground, his field of view was reduced, and the visual reference was moving. The pilot appears to have inadvertently caused the helicopter to drift slightly and lose altitude. When the pilot realized that the aircraft was moving toward the wires, he made a sudden avoidance manoeuvre which culminated in the aircraft landing sideways and rolling over.

Findings

- The pilot was certified and qualified for the flight in accordance with existing regulations.
The flight was initiated when the meteorological forecast indicated that, to arrive at their destination, the helicopters would have to fly in adverse weather.

The formation leader was the owner of the company, chief of operations, and chief pilot.

The formation followed a highway at low altitude, over an urban area.

The flight was conducted partially at an altitude lower than that prescribed by regulation.

The pilot hovered above an electrical transmission line, at a height where it was difficult to perceive changes in aircraft attitude.

The pilot lost control of the aircraft after making a sudden manoeuvre to avoid a wire.

**Causes and Contributing Factors**

While in hovering flight high above the ground, the pilot lost control of the aircraft after executing a manoeuvre to avoid colliding with a wire. Contributing to the accident were the pilot's decision to continue the flight in adverse weather conditions and the pilot's inadequate visual references while he was hovering above the electrical transmission line.

**Safety Action Taken**

Transport Canada is developing guidance material for the interpretation of Canadian Aviation Regulations 702 and 703 (Aerial Work and Air Taxi) which will include the suggestion that operators appoint dedicated Operations Managers and Chief Pilots, separate from the corporate or financial arm of the company.

Transport Canada will be reviewing the issue of formation flying through the Canadian Aviation Regulation Advisory Council (CARAC) with a view to establishing further regulatory parameters for this activity. Additionally, hazards associated with formation flying will be the focus of a feature article in the Aviation Safety Newsletter Vortex.

*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.*
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 in Baggage Compartment
Inter Canadien
Fokker F-28 MK 1000 C-FCRI
Jean Lesage International Airport, Quebec
05 December 1995

Report Number A95Q0232

Summary

Inter Canadien flight 668 from Montreal, a Fokker F-28 MK 1000, parked at boarding gate 3 of Jean Lesage International Airport, Quebec City. The attendant opened the forward baggage compartment and saw thick white smoke and reddish flames coming out of the compartment. He immediately closed the door and alerted the crew. The pilot-in-command immediately ordered the evacuation of the aircraft and told the co-pilot to notify emergency services.

The passengers were evacuated rapidly via the airstair at the left forward door and the evacuation slide at the right forward door. The airport fire-fighters arrived at the scene. They checked the baggage compartment and saw the flames. Fire-fighters equipped with respirators fought the fire inside the baggage compartment using extinguishers. One fire-fighter discharged a dry chemical extinguisher in the baggage compartment then closed the door to suffocate the fire. When the fire was extinguished, the fire-fighter entered the baggage compartment and removed the fire-damaged baggage. The aircraft was inspected, and was ferried that evening to the company maintenance base at Montreal.

The occurrence happened around 1827 eastern standard time (EST) in clear night conditions. There were no injuries.

Ce rapport est également disponible en français.

Other Factual Information

The flight crew was certified and qualified for the flight. The cabin crew consisted of two flight attendants who were also qualified for the flight.
The evacuation of the aircraft ordered by the pilot-in-command was conducted rapidly and without incident.

The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. In accordance with airworthiness standards, the baggage compartment of the F-28 is fitted with a fire-resistant inner wall to delay the spread of fire. This aircraft was equipped with two doors to the main baggage compartment. Most Fokker 28 aircraft do not have the aft door. A floodlight is located at each access door to the baggage compartment. The light is recessed into the ceiling and protected by a grille. The floodlights are located about 11 inches above the edge of the door. Nets are provided at each door to restrain the cargo in the compartment when the door is opened. The anchor hooks for the nets are about seven inches from the door edge. The restraint nets were installed in this aircraft. The baggage compartment was about three-quarters full. Baggage for this destination had been stowed in the forward part of the compartment, and the other baggage had been stowed aft.

Communications between ground control, the aircraft, and rescue units were normal during the occurrence. When the alarm was sounded, airport emergency response personnel arrived promptly at the scene in two emergency vehicles. The first fire-fighter arrived at the front of the aircraft with a dry chemical extinguisher. He asked the pilot-in-command whether the extinguishers in the baggage compartment had been activated. The pilot told him the aircraft was not equipped with extinguishers for the baggage compartment. The fire-fighter then opened the baggage compartment door, saw the flames, and discharged his extinguisher, then closed the door to suffocate the fire. He then donned a respirator and re-entered the baggage compartment to remove the baggage. First he unloaded the forward section, then the aft section. As he moved further aft, the pieces of baggage caught fire as soon as they were exposed to the open air. The burning articles were sprayed with a mixture of dry chemical and water from the fire hose. All items of baggage were then laid out on the loading ramp.

Heat damage was observed in the baggage compartment. Soot was found on the upper panels enclosing the baggage compartment. The area most affected by heat was in front of the aft compartment door, under the ceiling light and towards the centre of the compartment.

Two black folding travel bags, three hand bags, and one plastic box for carrying mail were damaged by the fire. Examination of the baggage established that the fire had initiated between the travel bags and two of the hand bags. The plastic container that was under the travel bags had been melted by the heat of the fire. The fire had started to spread towards the hand baggage and the cardboard boxes above the centre of the fire. The origin of the fire could not be determined. Dangerous goods that are permitted to be carried on board aircraft in the baggage compartment under existing regulations were found in the baggage, including an aerosol can of hair spray and a container of shaving cream.

The back panels, baggage compartment light, fire-damaged baggage
and baggage contents, and boxes were transported to the TSB Engineering Branch Laboratory for analysis.

Tests were conducted on the baggage compartment light to determine whether objects could ignite after prolonged contact with the light base. These tests were negative. The highest temperature produced was 400°C. When the canvas of one of the mail bags was placed in direct contact with the base of the bulb at this high temperature, the canvas melted but no flame was produced. Next, the aerosol can of hair spray was sprayed on the light at a temperature of 150°C. No flame was produced. The exact position of the switches for the baggage compartment lights could not be determined. None of the baggage handlers remembers having seen the baggage compartment lights illuminated either on departure or on arrival of the aircraft.

At the TSB Engineering Branch Laboratory, with the assistance of the handlers involved, the pieces of baggage were repositioned as they were when the aircraft departed. It was determined that the grey plastic box containing mail had been placed on the floor. The travel bags had been placed one against the other, and the cardboard boxes containing brochures had been placed on top, very close to the ceiling. Based on this reconstruction, the evidence indicated that the fire originated between the travel bags and spread upward. A small travel bag, a canvas bag containing mail, and a down coat were considerably burned. The cardboard boxes were also burned. The flames rose to the ceiling and spread in all directions, reaching the baggage closest to the ceiling, including the cardboard boxes.

A container of hair spray was found damaged by the fire. The plastic cap, button, and plastic stem had melted, but X-ray examination revealed that the valve spring was still in place. The container did not explode. A test conducted previously by the US Federal Aviation Administration (FAA) demonstrated that an aerosol can that explodes in flight can cause the pressure to increase inside the baggage compartment and damage the baggage compartment bulkheads. In that test, damage to the bulkheads allowed toxic gases to escape and spread throughout the cabin.

All indications are that the fire originated in flight, but the exact time at which it started could not be determined. The fire was extinguished as more carbon dioxide was released and the oxygen supply was depleted. Examination of the baggage and baggage contents did not establish the origin of the fire.

Following this occurrence, the company installed protective covers on all baggage compartment lights to avoid all contact with the bulbs and reduce the possibility of baggage compartment fires.

Analysis

After an aircraft fire, some items of evidence may be missing due to the necessarily rapid response of on-board personnel and fire-fighters. These persons are properly trained to combat the fire as quickly as possible and prevent it from spreading. In this case, despite the full
cooperation of the fire-fighters, several items of evidence were
damaged in the response and were not available. Although it was
determined that a fire occurred in the baggage compartment, and very
probably in flight, the origin of the fire could not be conclusively
determined.

However, examination of the passenger baggage established that the
baggage selected for analysis contained dangerous goods that are
permitted to be carried on board aircraft in the baggage compartment
under existing regulations, including a container of hair spray and a
container of shaving cream. If these containers had exploded, there is a
strong possibility that the consequences could have been more
disastrous and that the fire could possibly have spread within the
aircraft. However, due to its design, the baggage compartment was
able to contain the fire as expected.

To further enhance baggage compartment safety, measures were
immediately taken by the company to prevent the baggage
compartment lights from coming into contact with baggage.

The following laboratory report was prepared:

LP 188/95 - Fire Examination Fokker F-28, C-FCRI.

Findings

- The aircraft was evacuated rapidly and without incident.

- The baggage contained dangerous goods that are permitted to
be carried on board aircraft in the baggage compartment under
existing regulations.

- The fire probably originated in flight.

- The origin of the fire could not be determined.

- Due to its design, the baggage compartment was able to contain
the fire as expected.

Causes and Contributing Factors

A fire occurred in the baggage compartment, probably during flight. The
cause of the fire could not be determined.

Safety Action

As a result of this occurrence, the manufacturer is evaluating the
possibility of modifying the lamp guard in the cargo compartment on all
Fokker F-28 models to reduce the potential for heat accumulation.

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 12 November 1996.
Air 1995

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 Person
Viking Helicopters Ltd.
AS350 BA (Helicopter) C-GDLY
Sept-Îles, Quebec 160 nm NW
12 December 1995

Report Number A95Q0236

Summary

The helicopter, an Astar AS350 BA, registration C-GDLY, was engaged in aerial work and transporting passengers from the Gabriel relay to a generator site located about a 20-minute flight away, 160 nautical miles (nm) north of Sept-Îles, Quebec. The site was just off the Kay Subdivision of the railway owned by the Cartier Railway Company and leading from Port-Cartier to Fermon. The aircraft was carrying two passengers and hand luggage in addition to the pilot. Shortly after the aircraft landed on sloping ground, the passenger sitting on the right, behind the pilot, left the aircraft to go to a shelter located on the left side. As the passenger was proceeding towards the front of the helicopter, the main rotor touched his head. The passenger was taken immediately to the Sept-Îles hospital where he was declared dead.

The occurrence took place in daylight under visual meteorological conditions.

Ce rapport est également disponible en français.

Other Factual Information

The pilot was licensed and qualified for the flight according to current regulations. He underwent his last annual proficiency test on 24 January 1994 with a check pilot. The pilot had accumulated 7,750 hours on helicopters over a period of 20 years in the industry. The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The helicopter was configured with high skids and Airglass skis.

The weather conditions, as reported by the pilot, were a ceiling of 3,000
feet with visibility of five miles; temperature -28°C; and winds from the west at 20 knots.

The occurrence flight was the fourth trip the pilot had made that day to the same location. The pilot slung cargo on the first two trips, and had two passengers with hand baggage on board during the last two. On the first of the two passenger flights, the pilot set the helicopter down in front of the generator shack, with the aircraft's longitudinal axis on the alignment of a small road with an upslope of 8.5 degrees, covered with six to eight inches of snow. The passengers left the aircraft, one by the left door, on the opposite side from the pilot, and the other by the right door. The latter passenger walked round the aircraft to the front and then proceeded 90 degrees to the left of the aircraft towards the generator shack, as recommended by the pilot before the flight.

The pilot then returned to the Gabriel relay to refuel and pick up two other passengers. On the ground, prior to departure, he noticed that one of the passengers seemed to be more apprehensive and disoriented around the helicopter than the other. The pilot therefore gave them a second safety briefing in which he stressed the procedures to be followed on boarding and disembarking, including lowering the head, not passing behind the aircraft, and remaining in view of the pilot.

On boarding the aircraft, the apprehensive passenger decided to sit behind the pilot, saying that he felt better if he did not see in front. The flight duration was 20 minutes. At destination, the pilot set the aircraft down in the tracks of the previous landing, lowered the collective, and advised passengers that they could exit the helicopter. The passenger sitting in the left front seat got out and proceeded to the shack. The passenger sitting behind the pilot left the aircraft and walked towards the front, as had the other passenger before him, following more or less in the same tracks.

Meanwhile, the pilot had lowered full down the collective pitch control, centred the cyclic and was preparing to shift to the ground idle detent when he heard a thud which seemed to come from the rear of the aircraft. At that time, the departing passenger was about 30 degrees to the right of the aircraft's longitudinal axis, coming round to the front, as suggested in the briefing. The pilot then turned his head back and felt the aircraft tilt back. To get out of that position, the pilot pulled on the collective pitch and pushed on the cyclic pitch control.

The aircraft left the ground, but the pilot had trouble controlling it. The pilot then noticed someone caught on the tip of the HF antenna, without, however, realizing what was happening. The aircraft was in an excessively nose-down attitude, and it was only when the HF antenna, which projects in front of the aircraft, broke that the pilot actually regained control of the aircraft. The HF antenna projects in front of the aircraft to a distance approximately one foot less than the main rotor diameter.

The pilot set the aircraft down. He then noticed that someone was lying on the ground and had been hit by the main rotor about 10 inches from
the tip. Nobody had seen what had happened. The pilot, assisted by
the passengers, administered first aid to the victim before transporting
him to the hospital by helicopter. He was declared dead on arrival.

Eurocopter mentioned that, when the helicopter is at full rotor rpm, the
clearance between the ground and the tip path plane may be between
ten and eight feet when the cyclic control is being moved from neutral
to full forward. The AS350 flight manual states that the nose-up attitude
of the aircraft should not exceed 10 degrees when the aircraft is resting
on the ground; the purpose of this requirement is to avoid tilting
backwards. Because the skids are aligned with the direction of the
slope, the requirement also serves to decrease the possibility of
slipping. It is hard to judge the distance between the ground and the
main rotor because it is a function of, among other things, the slope
and the position of the cyclic pitch control.

According to TSB statistics, helicopter flying hours in Canada have
averaged 433,000 hours per year over the past 10 years. During those
10 years, there have been six deaths due to either a main rotor or a tail
rotor strike, making for one fatal accident of this kind about every
720,000 flying hours. Figures are not available, however, for the
number of passengers carried and the number of times they entered or
left the aircraft during those flying hours.

Analysis

The aircraft was maintained in accordance with existing regulations.
The pilot was qualified for the flight.

It is common practice for helicopter pilots to take on and drop off
passengers with the rotor running after an appropriate briefing has
been given, as set out in Air Navigation Orders (ANO) Series VII. The
practice is widespread in the industry and is accepted by both
companies and passengers even though it involves some risk. To
further decrease the risk on this occasion, the pilot had given this group
of passengers a second briefing.

Shortly after the pilot's attention was attracted by a noise behind him,
he felt the aircraft tilt. He acted by reflex to try to regain control of
the aircraft and thus prevent it from tipping over. At all stages of training,
instructors stress that the pilot must react quickly and effectively when
the aircraft tilts in one direction or the other. In general, helicopters do
not tolerate strong tilts. They result in a static or dynamic rollover, often
with serious consequences. Slipping backwards could be perceived in
the same way and cause the same reactions.

When the last passenger to disembark passed in front of the aircraft,
he was struck by the main rotor. Since nobody saw what happened, it
is difficult to determine whether the passenger was hit solely because
of the slope, the slip or the tilt, or whether he did not follow the safety
precautions given by the pilot. It is just as likely that the accident was
caused by a combination of these events.

Findings
- The pilot was qualified on the aircraft.

- All the passengers received a safety briefing.

- The landing ground sloped up at a grade of 8.5 degrees.

- The flight manual for the aircraft specifies that the maximum slope for landing and stopping the aircraft is 10 degrees in a nose-up attitude.

- Other passengers were disembarked at the same place earlier.

- On the ground, the pilot felt the aircraft tilt back and immediately regained control of it.

- The last passenger to exit the aircraft was hit on the head by the main rotor.

- Disembarking passengers while the aircraft is running is a common practice accepted by the industry and the authorities, but involves some risk.

**Causes and Contributing Factors**

One of the passengers was hit by the main rotor while passing in front of the aircraft; it was impossible, however, to determine the exact moment and circumstances of 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 19 March 1997.*
Air 1995

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.

Runway Overrun
Lignum Ltd.
Mitsubishi MU-300 Diamond C-GLIG
Jasper-Hinton Airport, Alberta
01 March 1995

Report Number A95W0034

Synopsis

The Mitsubishi MU-300 Diamond business jet was on an instrument flight rules flight, from Williams Lake, British Columbia, to Hinton, Alberta. There were two pilots and two passengers on board. While on a visual straight-in approach to runway 02 at the Jasper-Hinton Airport, the crew encountered light turbulence and subsiding air. The captain increased the aircraft's speed from 105 to 115 knots on final approach, and the aircraft touched down about 1,000 feet down the runway at 110 knots. The captain first applied maximum braking and then, when he determined that the aircraft would not come to a stop in the remaining runway distance available, he initiated commanded swerving to assist in stopping the aircraft; the aircraft skidded to a position 255 feet off the end of the runway. The aircraft sustained substantial damage; however, the occupants were uninjured.

The Board determined that the aircraft overran the runway because the crew landed with a 14- to 21-knot tail wind. Contributing to the occurrence were the crew's belief that the calm winds given to them by the Area Control Centre for Jasper townsite were for the Jasper-Hinton Airport, and their decision to continue with the straight-in approach procedure without overflying the airport.

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Appendix A - Glossary

1.0 Factual Information

1.1 History of the Flight

The Mitsubishi MU-300 Diamond business jet was on an instrument flight rules (IFR) flight from Williams Lake, British Columbia, to Hinton, Alberta. There were two pilots and two passengers on board. Prior to issuing the descent clearance from flight level 270 (FL270), the Edmonton Area Control Centre (ACC) advised the crew of the Jasper townsite, Alberta, weather. The winds were reported as calm. The crew cancelled the IFR during the descent and continued for a visual approach and landing to runway 02 at the Jasper-Hinton Airport. During the approach, the crew encountered moderate turbulence on short final. The captain increased the reference airspeed (Vref) from 105 to 115 knots to allow for subsiding air and airspeed fluctuations. The crew noted that the wind sock for runway 02 was fully extended and was varying in direction frequently. They elected to continue the approach and landing on runway 02. Power was reduced to idle at 50 feet. The aircraft touched down at about 1,000 feet down the runway. During the landing roll, the captain first applied maximum braking and
then, when he determined that the aircraft would not come to a stop in the remaining runway distance available, he initiated commanded swerving to assist in stopping the aircraft; the aircraft skidded to a position 255 feet off the end of the runway. The aircraft sustained substantial damage; however, the occupants were uninjured.

The accident occurred at latitude 53·19'N, longitude 117·45'W, at an elevation of 4,016 feet above sea level (asl)<2>, at 0920 mountain standard time (MST)<3>, during the hours of daylight.

1.2 Injuries to Persons

<table>
<thead>
<tr>
<th></th>
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<td>4</td>
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</tbody>
</table>

1.3 Damage to Aircraft

The aircraft sustained substantial damage.

1.4 Other Damage

Slight environmental damage occurred when several hundred pounds of jet fuel leaked onto the ground from a punctured wing fuel tank. A municipal fire truck was used to apply foam to the aircraft and fuel-drenched soil several hours after the occurrence.

1.5 Personnel Information

1.5.1 General

<table>
<thead>
<tr>
<th></th>
<th>Captain</th>
<th>First Officer</th>
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</thead>
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<tr>
<td>Age</td>
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<td>48</td>
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</tr>
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<td>Medical Expiry Date</td>
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<tr>
<td>Hours on Type Last 90 Days</td>
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</tr>
<tr>
<td>Hours on Duty Prior to Occurrence</td>
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<tr>
<td>Hours Off Duty Prior to Work Period</td>
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1.5.2 Captain's History

The captain holds an Airline Transport Pilot Licence (ATPL) with an Aeroplane Class 1, Group 1 instrument rating. He has a Single, Multi-Engine Land and Sea (SMELS) rating, with Cessna 500 and Mitsubishi MU-300 endorsements. His last Class 1 aircrew medical was on 29
December 1994, valid to 01 July 1995. The only restriction is that corrective eye glasses must be worn. The captain successfully completed his pilot proficiency check (PPC) in January 1995. He had flown into the Jasper-Hinton Airport once previously, several months before this occurrence. He is also the chief engineer for Lignum Air, and performs all routine maintenance on their aircraft.

1.5.3 First Officer’s History

The first officer (co-captain) holds an ATPL with an Aeroplane Class 1, Group 1 instrument rating. He has a SMELS rating, with Cessna 500, Mitsubishi MU-300, and Hawker-Siddeley HS25 endorsements. His last Class 1 aircrew medical was on 02 December 1994, valid to 01 July 1995. His only restriction is that corrective eye glasses must be available. The first officer successfully completed a PPC, as a captain, in January 1995. He had flown into the Jasper-Hinton Airport several months prior to this occurrence. He is the chief pilot for Lignum Air.

1.6 Aircraft Information

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Mitsubishi Heavy Industries Ltd.</th>
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<tr>
<td>Type</td>
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</tr>
<tr>
<td>Serial Number</td>
<td>A0076SA</td>
</tr>
<tr>
<td>Certificate of Airworthiness (Flight Permit)</td>
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<tr>
<td>Total Airframe Time</td>
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</tr>
<tr>
<td>Engine Type (number of)</td>
<td>Pratt &amp; Whitney JT15D-4D (2)</td>
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<tr>
<td>Propeller/Rotor Type (number of)</td>
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<tr>
<td>Maximum Allowable Take-off Weight</td>
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<td>Recommended Fuel Type(s)</td>
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<tr>
<td>Fuel Type Used</td>
<td>Jet B</td>
</tr>
</tbody>
</table>

1.6.1 Additional Aircraft Information

The twin-engine business jet was imported into Canada in 1993 by Lignum Air. The aircraft had been previously modified in the United States in accordance with the Branson Aircraft Corporation Supplemental Type Certificate No. SA3891NM, on 03 June 1989. This modification increased the gross take-off weight from 14,700 to 15,500 pounds. The aircraft was not equipped with thrust reversers, nor is it required to be by regulations.

Weight and balance calculations determined that the aircraft weight was 13,000 pounds at the time of the occurrence. The centre of gravity (C of G) was 22.45 per cent mean aerodynamic chord (MAC). Both the weight and the C of G were within prescribed limits. The maximum
authorized landing weight, with 30 degrees of flap, is 13,200 pounds. The factory-specified maximum tail wind component for take-off or landing is 10 knots. Maximum anti-skid braking must be used to achieve the charted stopping distances. The use of anti-skid braking will provide a consistently shorter landing roll for all runway conditions.

The aircraft records/logs indicate that the aircraft was certified and maintained in accordance with the existing regulations and approved procedures. It was reported that the aircraft was serviceable, with no identified or deferred deficiencies, on departure from Williams Lake.

1.6.2 Aircraft Flight Planning and Performance Data

On the day prior to the occurrence flight, the crew consulted the aircraft flight manual and determined that the aircraft could safely take off and land at the Williams Lake and Jasper-Hinton airports. During a pre-flight weather briefing, the Vancouver Flight Service Station (FSS) provided the crew with the Jasper townsite weather. The crew’s destination, however, was Jasper-Hinton Airport.

1.7 Meteorological Information

The Environment Canada weather for Jasper townsite at 0900 MST was 20,000 feet thin scattered, visibility 25 miles, winds from 210 degrees True at two knots, temperature minus 21 degrees Celsius, and dew point minus 23 degrees Celsius. The Jasper townsite weather office is about 30 nautical miles (nm) from the Jasper-Hinton Airport, and 7 nm from the Jasper airstrip. The weather office is behind 8,000-foot-high mountains. The weather from the Jasper townsite weather office is readily available to the public, flight crews, and the Edmonton ACC.

At the Jasper-Hinton Airport, the automated weather observation system (AWOS) reported that the 0920 MST winds were from 200 degrees magnetic at 14 gusting to 21 knots. The temperature and dew point were minus 16.7 and minus 21 degrees Celsius, respectively. The altimeter setting was 30.30 inches of mercury. The AWOS weather is recorded and stored every 20 minutes, and reported to the Environment Canada weather office in Grande Prairie, Alberta, by the airport manager twice daily, usually at 0700 and 1500 hours. A review of the recorded winds showed that they had been out of the southwest for several hours prior to the occurrence. The AWOS weather can be obtained by telephone through an automated voice sequence; however, the telephone numbers are not generally known to the aviation public, or the Edmonton ACC. Weather information for the Jasper-Hinton Airport is not available from ATC or an FSS.

1.8 IFR Procedures Jasper-Hinton Airport

In accordance with section 471.2 of the Transport Canada Air Traffic Control (ATC) Manual of Operations (MANOPS) and Air Navigation Order (ANO) Series V, No. 16, the Edmonton ACC passed the nearest official weather (Environment Canada weather office at Jasper townsite) and altimeter setting to the crew when they were still in
controlled airspace at FL270, prior to the descent into the Jasper-Hinton Airport. At approximately 0911 MST, after descending below 18,000 feet, the flight was cleared out of controlled airspace. The crew cancelled IFR when descending the aircraft through 16,000 feet and did not change to a visual flight rules (VFR) flight plan, nor were they required to do so. However, without a flight plan, ATC flight following is not guaranteed.

1.9 Jasper-Hinton Aerodrome Information

1.9.1 General

The Jasper-Hinton Airport is operated by the Alberta Transportation Department. It has one 4,500-by-100-foot asphalt runway, oriented on 020/200 degrees magnetic. The reference point elevation is 4,026 feet asl. An early morning inspection, carried out by airport staff prior to the occurrence, revealed that the runway was dry and bare. This airport is located in the designated mountainous region. Because of the unpredictable variable winds, the airport has three wind direction indicators: one at each end of the runway, and a lighted indicator situated about mid-field. The prevailing westerly winds are generally stronger at the Jasper-Hinton Airport because of the funnelling effect of the mountainous valley to the west. Subsiding air from the mountains to the west of the Jasper-Hinton Airport is generally present, especially with a westerly wind. The airport is uncontrolled, and often unmanned. At the time of the occurrence, there was no one operating the airport radio.

1.9.2 Jasper-Hinton Runway Data

The Canada Air Pilot (CAP) shows that the Jasper-Hinton runway 02 threshold elevation is 4,025 feet asl, and slopes down to 4,006 feet asl at the threshold of runway 20. The first 400 feet has a very slight upslope, then the remainder of the runway has a downslope varying from 1.0 per cent to 0.36 per cent. A downslope increases the landing distance of an aircraft.

1.9.3 Jasper and Jasper-Hinton Airport Name/Location Exchange

The Jasper Airport is operated by the federal government and is located within the Jasper National Park, about 23 nm from the Jasper-Hinton Airport.

The Jasper-Hinton Airport is operated by the provincial government and is remotely located about 9.5 nm southwest of the town of Hinton. Because of the locations and surrounding terrain applicable to each airport, the winds and weather may vary considerably.

The Alberta Transportation Department constructed the Hinton airport in the Hinton area to service both Hinton and Jasper. This airport would be of suitable size and equipped to handle most turbo prop and business jet aircraft. Because this airport was built to accommodate both the Jasper and Hinton traffic, it was named the Jasper-Hinton.
airport. The Hinton location was chosen because it would be nearly impossible to plan an instrument approach procedure within the confines of the mountainous terrain at the Jasper Airport. The Jasper Airport is also within a National Park.

1.10 Flight Data/Cockpit Voice Recorders, and Emergency Locator Transmitter

The aircraft was not equipped with a flight data recorder (FDR). A cockpit voice recorder (CVR) was installed; however, it had been deactivated by the company because it caused a feedback noise in the pilot's headsets. Neither the FDR nor the CVR was required by regulation; however, the International Civil Aviation Organization (ICAO) has made recommendations that all turbine-powered airplanes be equipped with these recording devices. The accuracy and quality of this investigation would have been enhanced by the availability of FDR and CVR data.

The aircraft was not equipped with an emergency locator transmitter (ELT) as required by Air Navigation Order, Series II, No. 17, the ELT Order. This ANO states that no person shall operate an aircraft in Canada or a Canadian aircraft outside Canada unless it is equipped with one or more serviceable ELTs. An aircraft need not be equipped with an ELT if the aircraft is "a multi-engine turbo-jet aeroplane of more than 12,500 pounds (5,700 kilograms) maximum certificated take-off weight that is being operated (i) over land under IFR within controlled airspace, and (ii) south of latitude 66°30'N."

The ELT was not installed when the aircraft was imported into Canada because of the exemptions provided in the applicable ANO. In this case, when cleared out of controlled airspace on the descent below 18,000 feet, and upon cancellation of the IFR flight plan, the flight no longer met the conditions of the exemptions.

1.11 Wreckage and Impact Information

Evidence of the initial touchdown and main wheel tire spin-up marks was located at about 900 feet from the runway 02 threshold for the left-hand tire, and at about 1,070 feet for the right-hand tire. The nose wheel was lowered and braking applied, as evidenced by the skid marks starting at 1,350 feet for the left main wheel and 1,400 feet for the right main wheel. The main wheel tire skid marks were then continuous, but varying in intensity, until the aircraft came to rest. The uneven skid patterns indicate that brake anti-skid modulation occurred. A nose wheel skid mark occurred at 1,900 feet. Skid patterns indicate that the aircraft commenced a series of "S" turns about 2,950 feet from the threshold, and continued until the end of the runway. The captain used a swerving technique because he believed that it would most likely increase the chance of stopping the aircraft on the runway, since, by swerving, the aircraft would travel a greater distance to the end of the runway. It is unknown whether this procedure increases the likelihood of an aircraft stopping on the runway.

The aircraft came to rest about 255 feet beyond the pavement on a
heading of 112 degrees magnetic. The nose wheel and left main landing gear had collapsed. The right main gear was damaged. All tires appeared to be intact and inflated. There were numerous wrinkles in the fuselage skin and structure, and the left wing lower skin had been scraped and punctured.

1.12 Fire

There was no evidence of fire either before or after the occurrence. Emergency Response Service (ERS) is not available at the Jasper-Hinton airport, although the local fire department will respond from Hinton, if requested.

1.13 Survival Aspects

There were no injuries to the crew, or to the passengers. The crew had not utilized the available shoulder harnesses. They reported that the installed harnesses restricted their movements.

1.14 Airmanship/Pilot Decision Making

The crew carried out a visual straight-in approach and landing to the Jasper-Hinton Airport. They cancelled IFR at 16,000 feet, and did not refile or change to a VFR flight plan; therefore, they were not on a "flight plan" during the descent and landing. They were, however, on a company flight itinerary throughout the flight, with company personnel in Vancouver being aware not only of who was on board, but of all departure and arrival times for the aircraft.

The Aeronautical Information Publication (AIP) Canada, "Aircraft Operations - Uncontrolled Aerodromes," describes the recommended procedures to be carried out by VFR aircraft at uncontrolled aerodromes. Section 4.5.2, "Traffic Circuit Procedures - Uncontrolled Aerodromes" describes the recommended procedure to be followed to join the circuit for a landing. Where pilots lack any necessary information, they are expected to make a visual inspection. Pilots should determine the wind and verify that the runway is unobstructed before landing. The Jasper-Hinton aerodrome has an aerodrome traffic frequency (ATF) of 123.2 MHz; however, this aerodrome is not always attended, and the ATF is not always monitored. At the time of this occurrence, the aerodrome was not attended and the ATF was not monitored.

2.0 Analysis

2.1 General

The aircraft was considered to be both mechanically serviceable and suitable for the intended flight. The crew was current on the aircraft, and had flown into the Jasper-Hinton Airport before. Although the runway used by the crew has a slight downslope, it was bare and dry, and of suitable length for the landing. Therefore, the analysis will concentrate on the decision-making factors that contributed to this
occurrence, in particular the reasons why the crew opted to carry out a straight-in approach. The confusion between the Jasper townsite and Jasper-Hinton Airport weather reports will also be discussed.

2.2 The Jasper Townsite and Jasper-Hinton Weather Reports

The Jasper and the Jasper-Hinton airports are located close to each other and have similar names. When the crew was given the weather by ATC, they were given the Jasper townsite weather and winds. However, since the crew's destination was the Jasper-Hinton Airport, they believed that ATC had abbreviated the name, and that the information was for the Jasper-Hinton Airport. Thus, when advised by ATC that the Jasper wind was calm, the crew relied on weather information for the wrong airport. This confusion between the two airports was seen earlier, when the crew received a pre-flight weather briefing from the Vancouver FSS. They were given the weather for Jasper, which they interpreted as being for the Jasper-Hinton Airport, their destination. With this misinterpreted information in place, they elected to conduct a straight-in approach.

2.3 Pilot Decision Making

A straight-in approach for a landing is not recommended at uncontrolled airports where Air-to-Ground Advisory is not available to provide the wind, weather, and runway condition reports required to conduct a safe landing. Where pilots lack any necessary information for landing, they are expected to make a visual inspection by overflying the airport. They should determine the wind and verify that the runway is unobstructed before proceeding for a landing.

The crew understood that the winds at Jasper-Hinton were calm, they could see that the runway was clear of other traffic, and they were also monitoring the airport radio and other traffic. The crew, therefore, did not feel that it was necessary to join the circuit and conduct a visual inspection of the field prior to landing. The presence of the surface wind was not known to the crew until they were on short final, when they observed the windsock extended parallel to the ground and varying in direction frequently.

The crew had increased the Vref speed by about 10 knots to compensate for subsiding air, turbulence, and airspeed fluctuations experienced on the approach. The touchdown occurred on the first quarter of the runway; however, the higher-than-normal approach speed, combined with a downsloping runway and 14-knot, gusting to 21-knot, tail winds, resulted in an unusually high ground speed at touchdown. Consequently, the crew was unable to stop the aircraft within the available runway distance.

The uneven skid patterns indicate that brake anti-skid modulation occurred several times, suggesting that the anti-skid system was functioning normally. The captain, after judging that the aircraft would not stop in the runway distance remaining, believed that he could increase the chance of stopping on the runway by swerving the aircraft down the runway, thereby increasing the distance travelled by the
aircraft before the end of the runway. It is unknown whether this procedure increases the likelihood of an aircraft stopping on the runway.

3.0 Conclusions

3.1 Findings

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

- The aircraft was certified and maintained in accordance with existing regulations and approved procedures.

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

- The weight and C of G were within the prescribed limits.

- The aircraft was not equipped with an ELT as required by ANO Series II, No. 17.

- The crew carried out a straight-in approach, and did not accurately assess the airport surface winds.

- The crew were issued the surface wind for Jasper townsite, which they misunderstood to be for the Jasper-Hinton Airport.

- The crew landed on a downsloping runway with a tail wind of 14 to 21 knots, which exceeded the maximum authorized landing tail wind component.

- A significant fuel leak occurred due to a punctured left wing fuel tank; however, there was no post-incident fire.

- A CVR was installed in the aircraft, but had been deactivated by company maintenance.

- The crew used a higher-than-normal approach speed to compensate for turbulence and subsiding air on final.

- There is no ERS at this airport, nor was it required.

- When the crew cancelled their flight plan they did not refile a VFR plan, and were without the benefit of any ATC flight following.
3.2 Causes

The aircraft overran the runway because the crew landed with a 14- to 21-knot tail wind. Contributing to the occurrence were the crew's belief that the calm winds given to them by the Area Control Centre for Jasper townsite were for the Jasper-Hinton Airport, and their decision to continue with the straight-in approach procedure without overflying the airport.

4.0 Safety Action

The Board has no aviation safety recommendations to issue at this time.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 08 February 1996.

Appendix A - Glossary

ACC - Area Control Centre
AIP - Aeronautical Information Publication
ANO - Air Navigation Order
asl - above sea level
ATC - air traffic control
ATF - aerodrome traffic frequency
ATPL - Airline Transport Pilot Licence
AWOS - Automated Weather Observation System
CAP - Canada Air Pilot
C of G - centre of gravity
CVR - cockpit voice recorder
ELT - emergency locator transmitter
ERS - emergency response service
FDR - flight data recorder
FL - flight level
FSS - flight service station
hr - hour(s)
ICAO - International Civil Aviation Organization
IFR - instrument flight rules
lb - pound(s)
MAC - mean aerodynamic chord
MANOPS - Air Traffic Control Manual of Operations
MHz - megahertz
MST - mountain standard time
N - north
nm - nautical miles
PPC - pilot proficiency check
SMELS - Single, multi-engine land and sea rating (Endorsement on Pilot's Licence)
TSB - Transportation Safety Board of Canada
UTC - Coordinated Universal Time
VFR - visual flight rules
Vref - reference speed
W - west
· degree(s)
' minute(s)
" second(s)
< less than

<1>See Glossary (Appendix A) for all abbreviations and acronyms.
<2>Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.
<3>All times are MST (Coordinated Universal Time [UTC] minus seven hours) unless otherwise stated.
<4>Estimated hours on type

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  
Loss of Control - Collision with Terrain  
Piper PA-34-220T Seneca III C-GTOG  
Teslin, Yukon  
18 August 1995

Report Number A95W0153

Summary

The pilot and three passengers departed Teslin, Yukon, at approximately 1635 Pacific daylight time (PDT)\(^1\) on an instrument flight rules (IFR) flight to Ponoka, Alberta. The contractor/pilot had arrived in Teslin to pick up two company employees. The third passenger was invited by the employees to accompany them on the aircraft.

The aircraft lifted off runway 26 (5,000 feet long) after a take-off roll of about 3,000 feet, and climbed to approximately 100 feet above ground level (agl) in the next 4,200 feet. The aircraft then entered a steep left turn and descended to the ground in a nose-down attitude. A witness described the aircraft as being low, going really slowly for a twin engine, and wavering from side to side before banking and nose-diving to the ground. Two other witnesses described the take-off run as being long, and said that the aircraft looked mushy and the wings were rocking after lift-off. Several individuals arrived at the scene within seconds and found no survivors. Aircraft damage and ground scars revealed that the aircraft contacted the ground in a vertical, nose-down attitude on a reciprocal heading to the take-off runway.

_Ce rapport est également disponible en français._

Other Factual Information

The pilot held a private licence with a Class I instrument rating, and was qualified for the flight in accordance with existing regulations. He received his private pilot licence (PPL) in 1981, and had approximately 1,780 hours total flying time, of which 1,067 hours was on the Seneca III.
The Atmospheric Environment Service weather record for Teslin at 1500 shows broken cloud bases estimated at 4,600 feet, visibility 30 miles, temperature 17 degrees Celsius, and the wind from 350 degrees magnetic at 4 knots. During the period, towering cumulus buildups were reported to the northeast and southwest of the airport. Near the cumulus buildups, the wind velocity was variable at five knots or less.

The aircraft was certified and equipped in accordance with existing regulations. The maximum allowable take-off weight for the Seneca III is 4,750 pounds. The forward and aft centre of gravity (C of G) limits are 90.6 and 94.6 inches aft of datum respectively. The personal baggage and tools were weighed and, after an allowance for wet clothing, the take-off weight of the aircraft was calculated to be approximately 5,150 pounds, 400 pounds (8 per cent) over the maximum allowable take-off weight. While the load distribution within the aircraft could not be determined with certainty, the C of G was likely near the aft limit. No witnesses were found who observed the aircraft being loaded or boarded.

During the on-site wreckage examination, it was discovered that the key lock on the forward baggage door was in the UNLOCKED position, there was no key in the lock, and the latch was in the UNLATCHED position. The key was later found in the pilot's pocket. Disassembly of the key and lock revealed that the key and tumblers were worn sufficiently to allow the key to be removed in any position.

Further examination of the forward baggage door lock-and-latch assembly provided evidence that was consistent with the door being open prior to impact. There was no apparent damage to the pins, the guide bushings in the door, or the latch plates in the door frame. A significant bend in the forward push rod, connecting the drawbolt to the latch mechanism, was consistent with the pins not being engaged on impact. Damage to the hinge on the top of the door indicates that the door was open when struck on the leading edge, as evidenced by a diagonal crease on the lower front corner. The hinge was partially pulled away from the structure at the front, and the door was trapped in the open position.

The aircraft controls and systems were examined on site to the degree possible, and, other than the forward baggage door lock being in the UNLOCKED position and the key missing, no other abnormalities were found. The landing gear selector was in the DOWN position, and the landing gear was down and locked.

Disassembly of both engines did not reveal any defects that would have prevented the engines from producing power. Damage to the blades on both propellers was consistent with what is found when power is being produced during impact with the terrain.

The forward baggage door is located on the left side of the nose, is hinged at the top, and opens upward. The door latching and locking mechanism consists of a recessed door latch handle and a key lock. The door is secured in the CLOSED position by rotating the spring-loaded latch handle 90 degrees clockwise, to the horizontal position,
which extends two pins into the door frame. The key lock is then rotated 90 degrees clockwise to the LOCKED position, and the key removed from the lock.

Federal Aviation Administration (FAA) Airworthiness Directive (AD) 88-04-05, issued 16 February 1988, requires a one-time compliance with Piper Service Bulletin (SB) No. 872, which mandates an inspection of the forward baggage door for positive latching and locking. Piper SB 872 states the following:

**NOTE:** The key should turn through a ninety degree arc between fully locked and fully unlocked. If the key can be removed from the lock at any point other than fully locked, the lock and key must be replaced.

An entry in the aircraft log-books indicates that SB 872 and AD 87-04-05 were complied with in May 1988. There was no requirement in the SB or AD for periodic inspections.

The *Piper Aircraft Maintenance Manual*, Section D, "Cabin Group," outlines the inspection procedures for 100-, 500-, and 1,000-hour inspections. The first item listed in the group reads as follows:

Inspect the cabin entrance doors, cargo, and baggage doors for damage and operation. Check condition and security of locks, latches, and hinges. (Refer to Service Bulletins No. 633 and 872, latest revisions).

An entry on the Piper 100-hour Inspection Report for C-GTOG indicates that this inspection was completed on 05 July 1995.

The Seneca was first manufactured in 1972. Aircraft manufactured between 1972 and 1983 did not have a Baggage Door Ajar Light as standard or optional equipment. Such a light was incorporated in Senecas built after 1983. C-GTOG was manufactured in 1981 and therefore did not have a Baggage Door Ajar Light installation.

The possibility exists that aircraft pitch and/or directional control could have been affected by aerodynamic forces created by the open baggage door; however, the magnitude of these forces could not be determined. The sudden opening of the door would have been an unexpected and visually distracting event, accompanied by a change in noise levels and flight control feedback, possible airframe vibrations, and increased drag.

A review of TSB accident data from 1977 to 1993 showed 33 accidents involving small aircraft, resulting in 10 fatalities, in which a cabin, baggage, or other compartment door opened during flight. Six of the 33 accidents involved the opening of a baggage door. In June 1993, the TSB issued five Aviation Safety Recommendations to Transport Canada (TC) concerning in-flight opening of doors (recommendations A93-06 to A93-10).
Witnesses observed the pilot and one of the two company employees/passengers arguing prior to departure. The pilot was a building contractor, and had been contracted to build the Teslin arena. Construction of the arena was behind schedule, and four of his employees had gone to Whitehorse for the day.

Post-mortem and toxicological tests conducted on the pilot and the front-seat passenger were negative for alcohol, drugs, and carboxyhemoglobin. The toxicology report on one of the employees revealed a blood alcohol concentration of 37 millimoles per litre (mmol/l) or 0.17 per cent. The second employee had a blood alcohol concentration of .09 per cent.

**Analysis**

A combination of factors probably contributed to the loss of control shortly after take-off. The pilot's reported distressed emotional state from the argument with the employee and from being behind schedule on his work projects may have distracted the pilot during the pre-flight and during flight. However, it could not be determined to what extent the pilot's emotional state affected him.

Because the aircraft was over the maximum certified take-off weight, the performance degradation would have resulted in a longer than normal take-off roll, a reduced climb rate, and an increased stall speed. It is likely that the pilot had not selected the landing gear up after take-off because he was distracted by the open baggage door. The open baggage door, the overweight condition, and the extended landing gear decreased the aircraft's performance and probably resulted in the aircraft being flown at a lower than normal airspeed.

When the baggage door opened, it was an unexpected and distracting event, and it probably distracted the pilot's attention from his primary task of maintaining control of the aircraft. The pilot may have elected to maintain a low airspeed to reduce the chance of the door being torn away from the aircraft. It is concluded that the pilot allowed the airspeed to decrease to the point where the aircraft stalled, and because of the low altitude, the pilot was unable to recover in time to prevent the crash.

The following TSB Engineering Branch reports were completed:

- LP 130/95 - Forward Baggage Door Examination, and
- LP 131/95 - Instrument Examination.

**Findings**

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

- At take-off, the aircraft was approximately eight per cent over the maximum allowable take-off weight.
Examination of the engines and propellers indicated that power was being produced by both engines on impact.

The forward baggage door was open at impact; it was not locked and likely not latched properly prior to take-off.

The key and tumblers in the baggage door key lock were worn, and the key could be removed in the UNLOCKED position.

SB 872 and AD 87-04-05 do not require periodic repetitive inspections of the forward baggage door latching mechanism.

The Piper Aircraft Maintenance Manual requires an inspection and operational check of cabin entrance doors and baggage doors, including security of locks, latches, and hinges, every 100, 500, and 1,000 hours.

The pilot did not raise the landing gear after take-off.

The distraction(s) created by the open door likely contributed to the loss of airspeed and aerodynamic stall.

Causes and Contributing Factors

The aircraft stalled at an altitude from which the pilot was unable to recover. Contributing to the occurrence were the opening of the forward baggage door, the overweight condition of the aircraft, the extended landing gear, and the worn key lock on the forward baggage door.

Safety Action

Action Taken

Inspection of Baggage Door Key Lock

As a result of this accident, the TSB forwarded a Safety Advisory to Transport Canada concerning inspections of the key lock. Transport Canada has indicated that work is in progress to either amend AD 88-04-05 to require repetitive inspection of the key lock, or revise the maintenance schedule so that the forward baggage door key lock is function checked at each 100-hour or annual inspection.

In-Flight Opening of Doors

In response to previous Board recommendations concerning the in-flight opening of doors, Transport Canada addressed the subject in pilot training manuals, pilot and maintenance newsletters, and in flight-instructor refresher courses. Also, crew action in the event of a door opening in flight was added to the items that commercial pilots might be assessed on during proficiency checks.
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.

1. All times are PDT (Coordinated Universal Time minus seven hours) unless otherwise noted.
Air 1995

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.

Airframe Failure
Wing
MAGAL CUBY II (ULTRALIGHT)
C-IEXR LEGAL, Alberta 4 NM W
09 September 1995

Report Number A95W0166

Synopsis

The instructor and student departed the St. Albert Airport, Alberta, at about 1800 mountain daylight saving time (MDT)(1), in the student's Magal Cuby II ultralight aircraft. The purpose of the flight was to conduct commercial ultralight student training exercises. At about 1830, witnesses near Legal heard a loud report emanating from an aircraft flying overhead. The aircraft was in level flight and heading in a northeast direction. They also observed pieces falling from the aircraft, which was about 500 feet above ground level (agl), and noticed that the outer section of the left wing was missing. Seconds later the aircraft entered a steep descent, and was destroyed when it struck the ground. Both pilots were fatally injured.

Other Factual Information

Witnesses at the accident site reported that, at the time of the accident, the sky was clear and there were light winds from the southwest.

The pilots were certified and qualified for the flight in accordance with the Transport Canada (TC) Ultralight Aeroplane Policy. The right seat position was occupied by the qualified ultralight instructor. The left seat position was occupied by the commercial ultralight student, who was also the owner. A witness reported that he was in attendance during the pre-flight briefing and that he overheard the pilots discussing their intention of practicing unusual attitudes and spins during the upcoming flight. The
The aircraft was manufactured in 1985, and the owner purchased it, ready to fly, in May 1995. No maintenance history of the aircraft was found; however, a sales receipt and TC registration form indicate that the aircraft was recently re-equipped from a 50 hp (Rotax model 502 GU) to a 65 hp (Rotax model 582) engine.

The Cuby II aircraft is a two-place, side-by-side, high-wing, conventional-gear monoplane. The designer's sketch specifies the cross-sectional dimensions of the spar caps as follows: the top main wing spar caps are to be constructed of 1¾ inch high by ¾ inch wide Sitka spruce; the lower spar caps are to be 1 inch high by ½ inch wide, and also of Sitka spruce. The main spar caps are to be joined by ¼ inch wide Douglas fir shear webbing.

The wreckage examination revealed that the outer section of the left wing was missing from the main wreckage, and was located in a field about 279 feet to the northeast. Other pieces of fabric and aluminum ribs from the left wing were strewn in a northeast direction up to a maximum distance of about 1,740 feet from the main point of impact. The left wing wooden front and rear spars were found with a vertical break near the lift strut attachment fittings. Examination of these surfaces by the TSB Engineering Branch determined that the fractures were a result of compression damage. There was no evidence to indicate that the left wing spars had been replaced since original manufacture in 1985.

Examination of the aircraft's failed left wing spars indicated that they were not constructed in accordance with the designer's sketch. The wood grain orientation of the failed spar caps was found to be at 90°.
degrees to the direction recommended and was unsatisfactory for straightness. The spar caps and webs were under-dimensional; 3/16 inch mahogany had been substituted for the ¼ inch fir plywood shear web called for in the sketch. In addition, the spar cap wood material was fir and not sitka spruce, as specified. Further examination reveals that the structural stability of the aircraft's wing design was questionable. Any sort of aerobatic manoeuvre, particularly ones requiring positive high angles of attack for entry, would be hazardous. There was also evidence of previous damage to the left wing in the form of a left wing tip spar and fabric repair. There were no wing inspection ports to allow for adequate periodic inspections of the internal wing structure.

The effect of the spar failure on the flight characteristics of the aircraft would be such that the left wing would experience a loss of lift, and that the aircraft would enter an uncommanded roll to the left.

Ultralight aeroplanes are exempt from airworthiness certification requirements, and neither a Certificate of Airworthiness (C of A) nor a Flight Permit is required. At the time this aircraft was built, there were no TC-regulated design, construction, or assembly standards established for ultralight aircraft. There are now TC design standards for advanced ultralight aircraft. The current Cuby II is designated as an advanced ultralight and must meet these design standards.

The engine was examined, and no evidence of any pre-existing malfunction was found. The lack of propeller blade damage was consistent with reduced power being produced at the time of impact. An examination of the flight control system did not indicate any discontinuities, and all controls were capable of normal operation. Gap seals were not installed between the trailing edge of the wing and the leading edge of the ailerons. The manufacturer advises that tape gap seals reduce turbulence around the ailerons and improve the lateral stability of an aircraft. The magnetos and key were found in the OFF position. There were two fuel tanks installed: one in the right wing and one behind the front seats. In addition, a plastic five-Imperial-gallon fuel container was located in the baggage compartment. All were ruptured and contained residual fuel. The ground, at the point of main impact, was saturated with fuel.

The centre of gravity (C of G) and wing loading could not be calculated because of the undetermined amount of fuel on board. However, considering the weight of both pilots, the additional weight of the newly installed engine, and the fuel-saturated ground, it is possible that the aircraft was at the maximum allowable weight and wing loading.

An autopsy of the deceased pilots by the Provincial Medical Examiner revealed that the cause of death has been attributed to multiple blunt injuries. The accident was not survivable because of the high deceleration forces and the destruction of the front of the cockpit. Postmortem toxicology of the instructor revealed the presence of tetrahydrocannabinol (Cannabis-containing substance) within the blood. During the field investigation, a marijuana cigarette was found in a cigarette package located in the cockpit.
Analysis

The analysis will focus on the structural failure of the left wing spars. The weather was not considered to be a factor in the occurrence.

The left wing structural failure may have been the result of a previous occurrence where the left wing tip had been damaged then inadequately inspected at the time of the repair. Given the leverage that existed during the wing tip strike, damage may have been done to the spar further inboard. Since ultralight aircraft are exempt from the requirement for a licensed engineer to reference a repair in an aircraft log-book, it was not possible to determine what had occurred. Normal load reversals on the spar while in service would include flight loads, landing loads, and the loads experienced while tied down. The questionable design and construction of the wing would typically result in a reduction in bending strength. Although wooden spars are susceptible to deterioration because of age and damage to a far greater degree than other spar materials, the means of actually examining these spars on the aircraft was very limited. Inspection of the wooden spar surfaces would be almost impossible without the installation of additional inspection ports.

A witness reported that, during the pre-flight briefing, the pilots had discussed practising unusual attitudes and spins. Manoeuvres such as these would place higher-than-normal aerodynamic flight loads on the aircraft. The combination of factors such as previous damage, orientation of the wood grain, wing loading, and the flight profile may have exceeded the strength of the already weakened and inadequately assembled wing spars. A sudden loss of lift following the left wing spar failure would have resulted in the aircraft entering an uncommanded left roll. Recovery would not have been possible. Examination of these surfaces determined that the fracture was a result of compression damage, since the spars appeared to have been original to the aircraft, which was manufactured in 1985.

The postmortem toxicology report revealed the presence of a cannabis-containing substance within the blood of the instructor; however, it could not be determined what effect the amount specified would have had on his flight performance.

The following Engineering Branch report was completed:

LP 137-95 - Wing Analysis.

Findings

1. The pilots were certified and qualified for the flight in accordance with the TC Ultralight Aeroplane Policy.

2. The pilot lost control of the aircraft when the left wing spars failed in flight, and the aircraft entered an uncommanded left roll followed by a vertical descent into the ground.

3. The left wing spars were not constructed in accordance with the
designer's specifications.

4. The aircraft's wing, as designed and constructed, had a questionable margin of safety in bending strength.

5. There was evidence of previous damage to the left wing tip, which had been inadequately inspected and repaired.

6. There were no wing inspection ports to allow for adequate periodic inspections of the internal wing structure.

**Causes and Contributing Factors**

The in-flight structural failure of the left wing was likely caused by pre-existing damage, and by questionable design, construction, and inadequate inspection procedures. Contributing to the occurrence may have been the aircraft's gross weight and the aerodynamic flight loads placed on the wing during the training flight.

**Safety Action Taken**

**Wing Construction**

Examination of the wreckage revealed that the aircraft had not been constructed in accordance with the manufacturer's suggestions. An article in issue 2/95 of Transport Canada's *Aviation Safety Ultralight and Balloon* discussed this aspect of the accident and indicated that the manufacturer was sending a related Air Safety Advisory to all known Cuby I and Cuby II owners.

**Wing Design**

In light of the identified wing design deficiencies, and the number of Magal Cuby II ultralights on the Canadian Civil Aircraft Register, a TSB Aviation Safety Advisory was sent to Transport Canada on the need to inform the ultralight community of the design shortcomings with at least some Cuby II aircraft.

**Ultralight Placarding**

The accident aircraft was not required to meet any design standards, nor was it required to be so placarded. It is not known if the student pilot was aware that the aircraft did not need to meet design standards.

The draft Canadian Aviation Regulations (expected to be promulgated in 1996), include a requirement for ultralights to have a placard affixed to a surface in plain view of any occupant seated at the flight controls that states, "THIS AIRCRAFT IS NOT REQUIRED TO MEET ANY AIRWORTHINESS STANDARDS/CET AÉRONEF N'EST PAS ASSUJETTI AUX NORMES DE NAVIGABILITÉ." This action should better enable occupants to manage their own risk.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Zita Brunet and Maurice*
Harquail, authorized the release of this report on 16 April 1996.

1. All times are MDT (Coordinated Universal Time minus six hours) unless otherwise noted.

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.

Separation in flight Cowling
Contact Airways Ltd.
BEECH KING AIR 100 C-GNAA
Edmonton, Alberta 50 NM N
26 September 1995

Report Number - A95W0180

Synopsis

The Beech King Air 100 was on a night instrument flight rules (IFR) medevac flight from Fort McMurray to the Edmonton Municipal Airport, Alberta. On descent through 18,000 feet, at approximately 200 knots indicated air speed (IAS), the aircraft yawed and began to vibrate excessively. The flight crew observed that the upper aft section of the left engine cowling was detached and lodged against the leading edge of the left wing, outboard of the engine. They declared an emergency, continued the descent at 150 knots IAS, and landed without further incident or injury. The detached cowl fell to the runway during the landing roll. Subsequent visual examination of the empennage determined that the outboard 22 inches of the left elevator had also departed from the aircraft before landing.

Other Factual Information

Clear skies, smooth flight conditions, and light surface winds existed at the time of the occurrence. The aircraft was dedicated to medevac flights, and was normally fuelled and hangared to be available for a prompt departure.

Both crew members were licensed in accordance with existing regulations. The captain had approximately 2,500 hours of flight experience on King Air aircraft. The first officer had approximately 80 hours on type.

The captain and first officer were telephoned at their residences at approximately 0230
mountain daylight time (MDT)\(^{(1)}\) and assigned to the flight. They arrived at the airport at 0300, towed the aircraft from the hangar and conducted the pre-flight inspection on a partially lit area of the ramp. The captain opened the cowling on the right engine, checked the security of the oil cap, and resecured the cowling. The first officer did a similar check on the left engine. The captain assisted with the examination of the left engine with his flashlight when the first officer's flashlight began to dim. The first officer subsequently closed the left cowling and secured it in what he believed to be the normal fashion. The preflight inspection was completed approximately one-half hour before the arrival of the medevac passengers, and there was no evidence that it was done in a hurried manner.

The flight departed Fort McMurray at 0355 with the two crew members and three passengers on board. The aircraft climbed to flight level 200 (FL200) and proceeded en route without incident for approximately 45 minutes. During the initial descent into Edmonton, the cowling opened and separated from the nacelle.

The upper aft cowling on the King Air 100 is a hoop-shaped panel that is approximately 30 inches long. It is secured by two hinges on the left side and two latches on the right side. The cowling hinges upward and outward from the inboard side of the left nacelle to expose the plenum and accessory sections of the Pratt and Whitney PT6 turboprop engine.

The aircraft was fitted with Part No. H296K854 cowling latches, which were manufactured by Hartwell Corporation and shipped to Beech for production from 1967 to 1970. These latches were replaced by Part No. H296K1135 latches in 1970 and the

Part No. H296K854 latches were supplied only as spares when requested. The current production Part No. H296K1135 latches have stronger trigger springs and steel hooks for improved service life. Beechcraft Service Instruction (SI) No. 0597-242 recommends that the aft cowl door latches on King Air 100 and other models be inspected at each scheduled inspection for conditions that could allow the cowling to come open in flight. The SI indicates that the latch may be subjected to internal pressure while in flight, and recommends replacing the earlier latches with the improved version if excessive wear, distortion, or other

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**Figure 1 Engine Cowl Latch Assembly (P/N) H296K854**

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\(^{(1)}\) Mountain Daylight Time
deterioration of the latch is noted.

The intact condition of the latch assemblies indicated they were unlatched at the time the cowling separated from the aircraft. The forward latch was twisted slightly; however, it operated smoothly. The rear latch was difficult to operate due to misalignment. Wear patterns indicated this condition had existed for some time; however, there were no reports that the rear latch had been difficult to operate before the occurrence.

Both the H296K854 latches and the H296K1135 latches are an overcentre toggle-type latch. The primary locking action is due to tensile loading and the toggle effect between the handle and the hook arm. The edges of the trigger are notched pawls that engage pins on the hook arm to act as a secondary locking device. The top of the trigger must be pushed to release the latch. The trigger is retained in the closed position by a spring. The trigger hinge is set toward the top of the trigger. A pressure differential between the inside and outside of the cowling will tend to open the trigger if the pressure is great enough to overcome the spring and friction resistance. Light tensile loading on the hook will permit the handle to open if the trigger releases.

The aircraft manufacturer reported that the plenum area of the cowling may reach a differential pressure of up to 1.1 psi at 200 knots IAS, due to the combination of ram air effect in the inlet and airflow over the nacelle. Post accident testing determined that the trigger on the forward latch would disengage with an internal air pressure of about one pound per square inch. Calculation determined that with the trigger disengaged, at least 300 pounds of hook tension would be required for the toggle mechanism to keep the handle shut. The rigging of the cowling and the tensile loading on the latches before the occurrence could not be determined.

The left cowling forward latch trigger reportedly protruded into the airstream during flight, and the latch had disengaged on at least one previous flight. Maintenance personnel had visually examined and function-checked the forward latch approximately five weeks before the accident, following the report of the in-flight opening. The latch closed securely, there was no evidence of wear, and no maintenance was accomplished.

Examination determined that the elevator had failed slightly inboard of the outboard hinge, and that the outboard 22 inches had departed with the balance weight. The balance weight was recovered in a field approximately 20 miles north of the Edmonton Municipal Airport. The remainder of the missing elevator structure was not recovered. Examination indicated the failure was a result of a severe up/down bending vibration. The concentrated nature of the damage indicated that there may have been pre-existing damage in the vicinity of the failure; however, no such damage was identified on the recovered components. Control of the aircraft could have been lost had the elevator sustained more damage.
A review of the aircraft logs identified that the left elevator had been inspected in accordance with Airworthiness Directive (AD) 76-22-03 on 11 September 1994; 368.8 hours before the occurrence. A crack was found in a tip rib. Beechcraft repair kit Part No. 100-4005-1S was installed to reinforce the area, and the aircraft was returned to service. The failure occurred inboard of the reinforced area, at the next weakest point.

Analysis

It could not be determined if the left upper aft cowl latches were secured properly before the aircraft departed. It is considered probable, however, that the cowlings would have opened sooner if the latches had not been engaged before take-off, as there is normally a pressure differential across the cowlings that tends to force it open. The rear latch was misaligned following the accident and wear patterns indicated that the condition had existed for some time. This discrepancy would have made it more difficult to operate the rear latch, and would have increased the likelihood of the rear latch being improperly secured when the cowlings was closed. Testing demonstrated that differential air pressure could disengage the trigger on the forward latch because of the weak trigger spring. If the front latch disengaged in flight, as had occurred on at least one previous occasion, the front of the cowlings may have lifted as the airspeed increased during the descent. The rear latch could have subsequently disengaged because of the effect of ram air flow in the accessory compartment or because it was not secured properly to begin with.

The detached cowlings lodged on the leading edge of the left wing immediately forward of the outboard end of the left elevator. The buffeting generated by the displaced cowlings was sufficient to excite a destructive vibration in the elevator. There may have been pre-existing discrepancies in the vicinity of the failure; however, no such condition was identified on the components available for examination.

The following Engineering Branch reports were completed:

LP 138/95 - Performance Analysis

LP 173/95 - Engine Cowl Latch Assembly

Findings

1. No physical evidence was found to indicate whether the latches were engaged before flight.

2. The aircraft was fitted with early production Part No. H296K854 cowlings latches that have weaker trigger springs than the current version Part No. H296K1135 latches.

3. The design of the latches is such that a pressure differential across the latches results in a force on the latches in the direction in which they open.
4. The forward latch had reportedly unlatched in-flight previously.

5. Testing determined that the forward latch could be triggered open by a differential pressure equal to that present across the cowling in flight.

6. Wear patterns indicated the rear latch may have been misaligned for some time, which would have made it more difficult to operate.

7. The left elevator tip failed as the result of a severe up/down bending vibration that was induced by buffeting from the displaced cowling.

**Causes and Contributing Factors**

It is probable that the left cowling opened in flight because of the combination of weak latch trigger springs and pre-existing damage on the rear latch. The left elevator failed because of buffeting induced by the displaced cowling.

**Safety Action Taken**

As a result of this occurrence, Contact Air has made the following change to the Company Standard Operating Procedures:

When possible all night flight walk-arounds are to be completed inside the hangar, with all necessary hangar lighting on. This assists the crew to prepare the aircraft for flight and eliminates the need to use a flashlight for the walk-around.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 04 April 1996.*

1. All times are MDT (Coordinated Universal Time minus six hours) unless otherwise noted.

Updated: 2002-10-06

**Important Notices**
Air 1995

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.

Fuel Exhaustion
Canadian Helicopters Ltd.
Aerospatiale AS 350B ECUREUIL
(Helicopter) C- GVMS
Canmore, Alberta 25 nm SW
19 October 1995

Report Number - A95W0194

Synopsis

The Aerospatiale AS 350B Ecureuil helicopter had been chartered to sling equipment and materials from the Haig Glacier, Alberta, to the nearby Haig camp, and from the camp to the Ranger Creek staging area located on the Smith Dorian Highway. During the third trip from the glacier to the camp, the pilot observed the fuel low-level warning light illuminate. The fuel quantity gauge indicated there was 18 per cent fuel remaining. The pilot dropped the load at the camp, returned to the glacier, and transported another load to the camp. The fuel quantity gauge was now indicating 11 per cent. At that point he was asked to relocate one sling load at the camp. He moved the load, picked up a net containing 900 pounds of empty propane bottles, and proceeded to the staging area to refuel. About five minutes later and approximately one and one-half miles from the staging area, the pilot noticed that the fuel pressure was fluctuating and that the fuel quantity gauge indication had dropped to

three per cent. Immediately thereafter, at an altitude of approximately 300 feet above ground and an indicated airspeed (IAS) of 55 miles per hour (mph), the engine (Turbomeca Arriel 1B) flamed out. The pilot instantly lowered the collective and released the sling load. He attempted to increase airspeed to the recommended autorotative speed of 70 mph and selected a landing area on the highway. When it became evident that he would not reach the highway, the pilot flared the helicopter to land in a creek. The helicopter struck the creek bank at a high rate of descent and slow forward speed. The pilot was seriously injured, and the helicopter was substantially damaged. The emergency locator transmitter (ELT) did not function, and it took about seven hours to effect the pilot's rescue.
Other Factual Information

The pilot departed Canmore at 1444 mountain daylight time (MDT)\(^{(1)}\) and arrived at the Haig camp approximately 15 minutes later, with the fuel quantity gauge indicating 30 per cent fuel remaining. The camp was located at approximately 9,000 feet above sea level (asl). Because of the high altitude, the pilot intended to sling lighter loads from the glacier to the camp until he had the minimum fuel necessary to transport the net load from the camp to the staging area. The staging area was located approximately six miles from the camp, at about 6,000 feet asl. When he arrived at the camp, he shut down the helicopter, removed and stowed the right side doors, and attached the longline. He commenced slewing at about 1600, and the accident occurred at 1700.

The right side of the helicopter and the main rotor blades struck the near vertical creek bank. The impact buckled the cabin floor, severed the tail boom, and fragmented the canopy. The pilot sustained two broken legs, seven fractured ribs, and several upper body lacerations as a result of the accident. Because of his injuries, he was unable to extricate himself from the cockpit, and remained in his seat until he was found. Approximately seven hours after the occurrence, a ground searcher located the accident site, in darkness, when he walked to the edge of the road above the wreckage.

Good visual flight rules weather conditions existed at the time of the occurrence. The temperature was approximately minus six degrees Celsius.

The pilot had 6,600 hours of flight experience, with approximately 5,000 hours on Bell 206B helicopters, and about 220 hours on the Aerospatiale AS 350B. The Bell 206B fuel quantity indication system utilizes a fuel quantity gauge only. The AS 350B fuel quantity indication system utilizes a fuel quantity gauge that is supplemented with a fuel low-level warning light.

The helicopter fuel tank remained intact during the accident. Following the recovery of the wreckage, the fuel tank was drained and found to contain 11 litres of fuel. The flight manual stated that 11 litres of fuel was unusable.

The helicopter was fitted with a float-operated resistor-type fuel quantity transmitter that also activated the amber, low-level fuel warning light. Post-crash testing of the fuel quantity indication system determined that 61 to 70 litres of fuel remained in the tank when the low-level fuel light illuminated, and that the fuel quantity gauge indicated 18 per cent at that time. The fuel quantity transmitter was removed for further examination. Testing determined that there was some friction resistance in the transmitter float assembly, which resulted in indication errors of up to six per cent. The maintenance manual states that when the low-level fuel warning light illuminates, the fuel quantity indicator pointer should be above 10 per cent, and that there must be more than 60 litres of fuel remaining in the tank. The fuel quantity transmitter cannot be adjusted in the field. It is common knowledge among flight
crews that resistor-type fuel quantity indicating systems cannot be relied upon to indicate the exact amount of fuel in the tank, especially at a low fuel state.

Aerospatiale Service Letter (SL) No. 867-28-88 advises operators that, although the resistor-type fuel indication system provides an accurate reading of fuel remaining in the fuel tank, it is not a defect-free measurement system. Eurocopter SL No. 1190-28-93 states that there have been a number of reports from operators of incorrect operation of the fuel gauging system. Eurocopter AS 350 Service Bulletin (SB) No. 28.12 R1 identifies that a capacitor-type fuel gauging system is available to increase the reliability of fuel quantity measurement, and to render the low-level warning independent of the measurement. The SB also states that this modification is of particular interest for all operators required to work with low fuel levels, as in slinging, by providing perfect information redundancy. AS 350 SB No. 28.02 provides for a new fuel tank installation that reduces the unusable fuel from 11 litres to 1.25 litres. The helicopter had not been modified in accordance with either SB.

Eurocopter SL 1215-28-94 advises flight crew to check that the fuel gauge reading corresponds to the quantity of fuel added at each refuelling. The pilot reported that he verified the fuel quantity gauge indication once a day, after the first refuelling, by observing the fuel level in the translucent tank relative to quantity markings on the side of the tank.

The AS 350B Flight Manual states that when the low-level fuel warning light illuminates, the remaining usable fuel allows approximately 25 minutes of flight. The light may illuminate with only 50 litres of usable fuel in the tank. At a typical fuel consumption of 160 litres per hour, this would provide less than 20 minutes of flight time. The view among pilots was that there was 20 minutes of fuel remaining when the light flickered, and the normal procedure was to land as soon as possible after the light began to flicker.

Canmore is located near Banff National Park in the Canadian Rockies. Canmore-based helicopter pilots are frequently assigned to 20-minute tourist sightseeing flights, and the pilot had flown numerous local tourist flights in the past. The AS 350 tourist flights normally departed with as little as 25 per cent fuel in order to keep the helicopter within the gross weight and density altitude limitations.

On C-GVMS, the low-level fuel warning light illuminated when the fuel quantity gauge was indicating 18 per cent, whereas on the other AS 350B helicopter based at Canmore, the light illuminated at 12 per cent. The pilot had noted this in the past, and had discussed the condition with maintenance personnel. He was advised that the fuel quantity indication system on C-GVMS had recently been checked, and that the indications were accurate.

The fuel quantity indication check had been accomplished in June of 1995 when the helicopter had been refuelled from the empty state. An attending company aircraft maintenance engineer had requested that
fuel be added in 53-litre, or 10-per cent increments, in order to verify that the fuel quantity gauge indications corresponded to the amount of fuel in the tank. He reported that the fuel low-level warning light illuminated at 18 per cent, and that the tank contained 96 litres or 18 per cent fuel at that time.

Although not considered a factor in the accident, it was determined during the investigation that the current AS 350B Canadian Type Approval, the current Federal Aviation Administration (FAA) AS 350B Type Certificate Data Sheet, and the AS 350B flight manual were not in agreement regarding the helicopter's total fuel capacity.

Existing regulations state that the amount of fuel carried on board a helicopter at the commencement of any VFR flight must be sufficient to fly to the place of intended landing and thereafter for 20 minutes at normal cruising speed.

The helicopter was fitted with a NARCO 10 ELT. Several ELT signals were picked up by the Search and Rescue Satellite (SARSAT) following the accident; however, the signals were of very short duration, and the system was unable to pinpoint the accident site. A company helicopter flew over the wreckage about two hours after the accident. The pilot did not hear an ELT transmission and, because of lighting conditions, did not see the downed helicopter. The injured pilot saw the search helicopter but was unable to signal his location. Examination determined that the ELT did not function properly because of a faulty transistor.

**Analysis**

The pilot commenced slinging with a reported fuel quantity indication of 30 per cent, which would normally provide approximately one hour of flight time. When the low-level fuel warning light illuminated, the pilot believed, based on the fuel quantity gauge reading, that there was still 18 per cent, or about 35 minutes of fuel remaining. He considered this sufficient to move two more sling loads at the camp and to transport one net load six miles to the staging area. Post-crash testing determined that there could have been as little as 50 litres of usable fuel in the tank when the warning light illuminated. The fuel quantity gauge should have indicated this amount as 10 per cent, which would normally have provided less than 20 minutes of flight time during slinging. An in-flight check of fuel gauge indications against fuel consumption and flight time might have alerted the pilot to the fuel gauge discrepancy.

The pilot was accustomed to flying the helicopter at a low fuel state as he frequently conducted short tourist flights. Five thousand hours of flying experience on the Bell 206B, which does not have a low-level fuel warning light, may have conditioned him to consider the fuel quantity gauge more accurate than the warning light. This would have been reinforced by his understanding that the fuel quantity indications had recently been checked by a company maintenance engineer and found to be accurate.
It would appear, from the amount of safety information published by the manufacturer, that problems with the resistor-type fuel quantity indication system on the AS 350B helicopter were well recognized. As helicopters are frequently operated at a low fuel state, manufacturers should endeavour to ensure that the installed fuel indicating systems are the most accurate available.

The AS 350 flight manual states that if the amber, low-level fuel warning light illuminates, the remaining usable fuel allows approximately 25 minutes of flight, when in fact less than 20 minutes of flight time may be available.

The flame-out occurred at low altitude and low airspeed. The pilot immediately released the load, initially selected the nearby road as a forced landing site, and attempted to increase the airspeed to that recommended for autorotation. The ensuing rapid loss of altitude precluded successful autorotation to the road, and resulted in the helicopter striking the creek bank at high vertical speed.

The malfunctioning ELT resulted in a long delay in the rescue.

The following Engineering Branch report was completed:

LP 158/95 - Emergency Locator Transmitter Examination.

Findings

1. The engine flamed out due to fuel exhaustion.

2. The pilot continued to operate the helicopter for some time after the fuel low-level warning light illuminated.

3. The fuel quantity gauge was reading up to six per cent high.

4. The low-level warning light illuminated at 18 per cent on this helicopter, whereas it illuminated at 12 per cent on the other AS 350B based at Canmore.

5. The pilot was comfortable operating the helicopter at a low fuel state because he frequently conducted short tourist flights.

6. The pilot was slinging at low altitude and 15 miles per hour below the best autorotational airspeed when the flame-out occurred, which precluded a successful autorotation.

7. The ELT did not function properly because of a faulty transistor, and as a result, the rescue took about seven hours.

8. Less than 20 minutes of usable fuel may be available following illumination of the amber, low-level fuel warning light; however, the AS 350B flight manual states that approximately 25 minutes of usable fuel is available.

Causes and Contributing Factors
The engine flamed out because of fuel exhaustion. Contributing to the occurrence were the pilot's decisions to rely on the fuel quantity indication at a low fuel state and to continue to operate the helicopter with the fuel low-level warning light illuminated.

**Safety Action**

Immediately following this occurrence, Canadian Helicopters maintenance personnel checked the fuel quantity indication systems on the remaining 21 company-operated Aerospatiale AS 350 helicopters. As a result of this inspection, two fuel quantity transmitters were found to be unserviceable and were replaced.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 19 June 1996.*

1. All times are MDT (Coordinated Universal Time minus six hours) unless otherwise noted.

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Updated: 2002-10-06  

[Important Notices](http://www.tsb.gc.ca/en/reports/air/1995/a95w0194/a95w0194.asp)
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.

Component Failure/Landing gear torque link  
Canadian Regional Airlines  
FOKKER F28-Mk1000 C-FCRK  
Calgary International Airport, Alberta  
01 November 1995

Report Number A95W0202

Synopsis

The left main landing gear of the Fokker F28-Mk1000 began to shimmy immediately after touchdown when landing at Calgary. Brakes were applied to slow the aircraft in an attempt to control the shimmy, but the oscillations continued until both left main wheels and brake assemblies separated from the axles.

After the aircraft came to a stop, the passengers and crew were evacuated without incident through the forward main cabin door.

Site examination revealed that the upper torque link failed within the first 200 feet of the landing roll, and the wheels separated about 1,450 feet from touchdown. There was substantial damage to the oleo lower sliding member, wheels, tires, brakes, and left inboard and outboard flaps.

The crew reported that the lift dumpers (spoilers) had been armed on the approach. They were found to be deployed when the aircraft came to a stop, but the crew was uncertain as to when they had deployed.

Other Factual Information

The aircraft had recently been out of service because of a shimmy problem. The problem had been isolated to the right main gear and was rectified by the replacement of an out-of-balance inboard wheel and tire. A successful flight test and positioning flight had preceded the occurrence flight when the left main gear developed a shimmy.

In normal operation, any torsional loads on the lower oleo sliding member from the wheel assemblies on the dual axles are transferred through the torque links (T/Ls) to the stationary upper oleo member.
The T/Ls prevent rotation about the vertical axis to maintain wheel alignment in the fore-and-aft direction throughout the vertical range of oleo travel. In maintaining proper wheel alignment, the T/Ls stabilize any torsional oscillations (shimmy). By their design, T/Ls have their maximum mechanical advantage and control when the oleo is compressed, and minimum advantage when the oleo is fully extended.

![Diagram of T/Ls and oleos](image)

**Figure 1**

Both left and right oleo assemblies were disassembled and examined in the operator's overhaul (O/H) shop. Dimensions were generally found to be within service limits, with the exception of the fit of the T/L pins to the main oleo lug bushings and the sliding member lug bushings. The clearances in the main bushings were from 0.0012 inches to 0.0034 inches, and in the sliding member bushings were from 0.0021 inches to 0.0154 inches. The manufacturer's O/H Manual specifies an interference fit, whereby the pin is pressed into the bushings without any clearance. This interference fit is necessary to minimize free play and ensure stability of the moving parts of the landing gear -- that is, to prevent shimmy. The pins are locked in position in the bushing, and wear in service is minimal. The increased clearances on the occurrence aircraft, beyond overhaul manual limits, would have reduced stability. It was reported that a former operator had used a non-factory-approved O/H procedure for a period of about two years, in which the bushings were reamed for a loose fit on the pins.

Both upper and lower torque links (T/L)s and pins were examined at the TSB Engineering Branch, and all materials and dimensions met the manufacturer's specifications. It was determined that the upper link failed in overload, with no evidence of pre-existing damage. The dimensions of both pins were equal to new parts limits, with no wear evident. The Engineering Branch report further states: "There appears little doubt that the problem relates to the overall landing gear design.
and an inability to tolerate looseness or slack in the component build-up."

The left oleo pressure and fluid had been discharged following the accident. The nitrogen pressure in the right oleo was 278 pounds per square inch (psi), and the fluid quantity was 10.5 litres (L). Servicing of both main oleos had taken place four days prior to the accident, and it was reported that the two oleo extensions had been equal prior to the flight. Specified nitrogen pressure in the oleos is 195/215 psi, and fluid quantity should be 13.1 L.

This accident is the 29th occurrence of this type recorded in the aircraft manufacturer's data base. Numerous investigations and considerable research have been conducted over the previous 20 years and 28 occurrences, with the causes of landing gear shimmy emerging as a combination of any or all of the factors listed below (with comparison to this occurrence):

<table>
<thead>
<tr>
<th>SHIMMY INITIATION FACTORS</th>
<th>CONDITIONS PRESENT IN THIS OCCURRENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F28-Mk1000 gear on F28-Mk4000 aircraft</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Boeing 707 nosewheel tires on F28 main gear</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Non-approved maintenance practices such as introducing clearances between lugs and link pins at overhaul</td>
<td>Additional clearances introduced at previous overhaul</td>
</tr>
<tr>
<td>Excessive wear or play on all T/L connect points</td>
<td>Clearances at or within limits, (except as above)</td>
</tr>
<tr>
<td>Tires - pressures/balance/profile, different makes on 2 axles of the same oleo</td>
<td>Tires normal, pressures not available, approx. 50% wear, same make &amp; model</td>
</tr>
<tr>
<td>High nitrogen pressure, and high or low fluid quantity</td>
<td>Nitrogen pressure above specs., fluid quantity below</td>
</tr>
<tr>
<td>Brakes - uneven drag on one wheel or the other</td>
<td>Unknown</td>
</tr>
<tr>
<td>Soft landing, possibly with a crosswind</td>
<td>Soft landing, no crosswind</td>
</tr>
<tr>
<td>Low gross weight, around or below 50,000 lb</td>
<td>Landing weight 46,800 lb</td>
</tr>
<tr>
<td>Flaps set to max. lift (42°)</td>
<td>Flaps set 42°</td>
</tr>
<tr>
<td>Higher than normal touchdown speeds</td>
<td>Touchdown speed normal; 109 kts (V ref)</td>
</tr>
<tr>
<td>Lift dumpers not armed, or not deployed (squat switch not activated)</td>
<td>Lift dumpers were armed, but may not have deployed until aircraft almost stopped</td>
</tr>
</tbody>
</table>

The aircraft had been in operation with the regional airline for about 11
months, and had previously been operated in the United States. Since O/H in 1987 by the former operator, the landing gear had accumulated about 7,157 cycles. The operator's mid-life inspection of the gear was due at 8,000 cycles, with O/H required at 12,000 cycles. The T/L Apex Joint End Float inspection had been completed three days prior to the accident, and the clearance reset to specifications.

The aircraft manufacturer had previously decided that the installation of a Torque Link Apex Damper (TLAD) would be the most effective means of eliminating or controlling the shimmy. Dutch Airworthiness Authorities (RLD) had proposed to require the installation of the TLAD kit on all Dutch-registered F28-Mk1000 and -Mk2000 series aircraft before 31 December 1993 by means of an Airworthiness Directive (AD) based on Fokker Service Bulletin (SB) F28/32-151. SB F28/32-151 was based on the original Dowty SB 32-169R. Because of problems with the TLAD development program, SB F28/32-151 was not issued, resulting in the compliance date of the proposed AD being postponed indefinitely.

The aircraft manufacturer had previously taken the position that the probability of a T/L failure was relatively low, and the consequences minimal. However, because of the continuing failures of torque links and the recent incidences of substantial secondary damage to the aircraft involved, finding a solution to the shimmy problem has received higher priority.

The regulatory authorities of Canada, the United States, and the Netherlands are monitoring further developments.

**Analysis**

The original excitation of the oscillations which resulted in the shimmy could not be determined, but it would appear that two factors allowed the oscillations to continue and amplify:

1. The additional clearances in the T/L pins and bushings which reduced the dampening capability of the T/Ls; and
2. The excessive nitrogen pressure in the oleo, which prevented the oleo from compressing immediately at touchdown.

With the T/Ls extended in a position of minimum mechanical leverage, considerable unchecked torsional movement of the sliding member had occurred, and the severity of the shimmy overloaded the T/L to failure.

The current operator was unaware of the non-approved fit of the T/L pins and bushings. The aircraft had not been in service for a sufficient length of time to require this operator's mid-life inspection on the gear, which would have revealed the excessive clearances.

The conditions listed as being shimmy initiation factors appear to be normal landing conditions for this class of aircraft; therefore, it would appear that the problem relates to the overall landing gear design. Changes in tolerances, whether from wear, overhaul, servicing, etc., compromise the margin of shimmy control, which can lead to torque
link failure.

The following TSB Engineering Branch reports were completed:

LP 157/95 - FDR/CVR Analysis; and

LP 171/95 - Torque Link Analysis.

Findings

1. The left main gear began to shimmy immediately after touchdown, resulting in failure of the upper torque link and eventual separation of the wheels from the axles.

2. The aircraft landing configuration and other landing conditions were conducive to the initiation of landing gear shimmy.

3. The loose fit of the torque link bushings and pins from the previous overhaul prevented the torque links from controlling and eliminating the shimmy.

4. The nitrogen pressure in the oleo exceeded the pressure specified in the maintenance manual, and contributed to the oleo's stiffness.

5. The landing gear design is intolerant of looseness or slack in the component build-up.

Causes and Contributing Factors

The left landing gear torque link failure and wheel separation was caused by a shimmy, which developed when the shimmy dampening capability of the torque links was degraded by a combination of non-standard clearances in the torque link pins and bushings, and a delay in oleo compression. The oleo did not compress on initial touchdown because of excessive nitrogen pressure, a 42-degree flap angle, low descent velocity, and low aircraft landing weight.

Safety Action

Immediately following this occurrence, three changes were implemented by the operator's maintenance department on all aircraft in their fleet:

1. All landing gear will have had the nitrogen pressures rechecked and serviced in strict accordance with the maintenance manual within 21 days, to reduce the possibility of increased stiffness from over-serviced oleos.

2. All undercarriages for which the status of the T/Ls cannot be confirmed as having been overhauled to "new" limits will have the mid-life inspection performed as soon as possible.

3. All future additions to the fleet will have the mid-life inspection incorporated as part of the initial inspection.

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.
Air 1995

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
Uncontrolled Descent/Collision with Terrain
Aero Commander 700 N9920S
Castlegar, British Columbia 15 nm SE
28 November 1995

Report Number A95W0210

Summary

At about 1826 mountain standard time (MST)\(^{(1)}\), the aircraft, with the pilot and four passengers on board, departed the Calgary International Airport, Alberta, on a night instrument flight rules (IFR) flight to Hillsboro, Oregon, USA. At about 1946 the aircraft disappeared from the Vancouver Area Control Centre (ACC) radar screen in the vicinity of Castlegar, British Columbia. The Victoria Rescue Coordination Centre (RCC) was notified, and search aircraft were dispatched. Despite bi-national search cooperation and radar fixes of the aircraft's last known position (LKP), a seven-day search failed to locate the missing aircraft. An emergency locator transmitter (ELT) signal was not received.

On 14 June 1996, the wreckage was located at latitude 49°14'48"N, longitude 117°03'20"W, at an elevation of approximately 6,700 feet above sea level (asl). The aircraft was destroyed by impact forces and a post-crash fire. The pilot and four passengers were fatally injured.

Ce rapport est également disponible en français.

Other Factual Information

The purpose of the flight was to return company personnel to Hillsboro in their corporate aircraft after attending a business meeting in Calgary. The pilot received a weather briefing from Edmonton Flight Service Station (FSS) and filed an IFR flight plan with Springbank FSS. On filing the flight plan, he requested 15,000 feet asl direct to Battleground, Washington, then direct to Hillsboro, the destination. He reported that the estimated time en route (ETE) would be 3 hours and 15 minutes and that he had 4 hours and 30 minutes of fuel on board.
The Castlegar weather during the time of the incident was partially obscured with an overcast ceiling estimated at 1,500 feet above ground level (agl), and 1½ statute miles (sm) visibility in light rain and fog. A warm front in the vicinity was forecast to cause 500- to 1,500-foot ceilings with visibility reduced to one-half sm in a mix of rain and snow. The area forecast called for a probability of severe clear icing in freezing drizzle and occasional moderate turbulence below 14,000 feet asl for the route of flight. A pilot report (PIREP) from an aircraft at flight level 200 (FL200), over the LKP indicated he was experiencing light rime icing in clear air. He also reported turbulence and solid cloud layers above and below his position. The forecast freezing level was 4,000 feet agl. During the pilot's weather briefing with Edmonton FSS, the probability of encountering severe clear icing during flight was not mentioned. It could not be determined if the pilot obtained weather information from the Total Aviation Briefing System (TABS) available at his hangar facility. Approximately 35 minutes after the aircraft was towed out of the hangar in Calgary, the pilot asked to have it de-iced before departure. Snow was accumulating on the wings during the brief time outdoors, and the outside air temperature was minus 14 degrees Celsius.
At 1735 the aircraft was refuelled to maximum capacity, with the addition of 520 litres of Avgas. Moments later the pilot and passengers boarded the aircraft and it was de-iced with a type 1 fluid. At about 1750, the pilot requested taxi clearance from Calgary ground control, and the aircraft departed the service facility hangar. Runway 16 was the active departure runway, and the pilot requested the full length (12,675 feet) for take-off. At about 1812 the pilot began the take off roll; however, before reaching rotation speed, he rejected the take-off. He then advised the tower that the right engine (Lycoming TIO-540) was not developing full rpm and requested another run-up on taxiway Alpha. Approximately 10 minutes later he informed ground control that the problem had been corrected. N9920S was re-cleared to taxi for runway 16, and the pilot taxied the aircraft the full length of the runway for departure. Shortly after becoming airborne, N9920S was further cleared en route to 16,000 feet by Calgary Terminal Control.

Radar data indicate that the aircraft climbed initially at about 870 fpm, and by 15,000 feet asl the rate of climb was about 340 fpm. The TSB Engineering Branch analyzed the magnetic tape of the communication between the pilot of N9920S and Calgary Terminal. The spectral analysis indicates that at 1828, as the aircraft was climbing through 4,400 feet asl, both engines were operating at a propeller speed of approximately 2400 rpm. During the en route segment of flight the aircraft's airspeed, altitude, and track remained relatively constant. At 1903 Edmonton ACC terminated radar service with N9920S and instructed the pilot to contact Vancouver ACC on 133.6 megahertz (MHz). The last transmission received from N9920S was at about 1937, when the pilot reported to Vancouver ACC that he was level at 16,000 feet. The controller noted that the pilot's voice sounded normal. Radar data indicate that, from 1941 to 1945, the ground speed of the aircraft decreased from its cruise speed of about 140 knots to 90 knots. At about 1946 the aircraft disappeared from Vancouver ACC radar screen, over the Selkirk mountain range, near Castlegar, during the hours of darkness. The aircraft's LKP was latitude 49°15'11''N and longitude 117°03'18''W. The highest terrain elevation near the LKP is about 8,000 feet asl. The sparsely populated mountainous terrain is heavily forested, and was under a thick mantle of snow.

Vancouver ACC radar tapes revealed that N9920S lost about 50 knots of ground speed and about 300 feet of altitude during the final seconds of radar contact. Seattle ACC, which had also been tracking the aircraft, reported that, at about 1946, N9920S descended from 16,300 feet to 11,800 feet asl in about 35 seconds, and did not reappear on radar. The rate of descent was calculated to be about 7,700 fpm.

The aircraft's LKP, as reported by Vancouver ACC and by Seattle ACC, were within two nm of each other. No distress call was heard by ACC, FSS, or any other station including an aircraft that was overhead at the time of the occurrence; nor were there any known eye-witnesses to the accident.

The aircraft was equipped with a fixed ACK E-01 ELT; however, a signal was not received at the time of the occurrence nor during the seven-day search period.
Canadian search resources consisted of five Canadian military aircraft and two to six civilian (CASARA) aircraft. American participation consisted of an Oregon Air National Guard C-130, United States Air Force aircraft, and United States Army Uh-1 helicopters at various times. The Search and Rescue (SAR) Operations Report indicates that a grand total of 306.9 search hours were conducted before the search was officially reduced on 05 December 1995.

The aircraft type is a pressurized, low-wing, twin-engine, retractable gear airplane equipped with two reciprocating TIO-540 (turbo-charged) Lycoming engines, with a single-engine service ceiling of 10,600 feet, and a twin-engine service ceiling of 27,400 feet. The occurrence aircraft was equipped with all the instruments and radios necessary for IFR operation at night and was certified in accordance with existing regulations. It also had de-icing equipment and was approved for flight in known icing conditions in accordance with Federal Aviation Regulations (FAR) 25, Appendix C. The conditions defined by FAR, Part 25, Appendix C, are finite and do not take into account unlimited operation in icing conditions or operation in freezing rain. The aircraft was also equipped with an altitude reporting (Mode "C") transponder, which functioned continuously on code 7313 from take-off to the LKP.

Witnesses who observed the aircraft being boarded prior to departure reported that the weight of each of the five male occupants was greater than the standard winter weight of 188 pounds per person. In addition, the occupants were each equipped with overnight baggage; however, none was dressed in winter survival clothing and footwear. The on-board aircraft emergency winter survival equipment consisted of an axe, flares, candy bars, solar blankets, a two-way transceiver, and a first-aid kit. Estimated weight calculations indicate that the take-off weight may have exceeded the aircraft's allowable limits.

The pilot held an airline transport pilot licence (ATPL) and was considered to be a proficient instrument pilot. His flying experience consisted of about 3,000 flying hours, including 100 hours on type. Prior to the occurrence flight, the pilot spoke with the chief pilot; no problems were noted during the conversation. The normal procedure for such a flight was to fly IFR with the global positioning system (GPS) coupled to the auto-pilot.

On 14 June 1996, the aircraft wreckage was discovered by a company search aircraft, and the accident site was located about one nm south of the LKP. The RCMP were notified and members attended the crash site. The aircraft registration marks (N9920S) and personal identification bearing the pilot's name confirmed the wreckage to be that of the missing Aero Commander 700.

TSB investigators conducted a field investigation on 25 June 1996. Examination of the wreckage trail revealed the aircraft struck the ground in a steep nose-down attitude, indicative of an uncontrolled descent. The final impact point was exhibited by the right and left wings complete with the respective engines, propellers, and landing gear. A post-crash fire had consumed the cabin section; however, parts of the
empennage were unburned. The pilot seat, co-pilot seat, cabin contents, and pieces of plexiglass were scattered about 80 feet south, down a 28-degree mountain slope, beyond the final impact point. Prominent ground scars depicted where the nose section, engines, and propellers struck the ground. The major components of the airframe and control surfaces were accounted for, and all observed damage was attributable to the severe impact forces and a post-crash fire. The flaps and landing gear were in the retracted position. Propeller blade damage and twist was similar for both propellers, and was consistent with minimal power being produced at the time of impact. The ELT was damaged by fire and impact forces and did not activate. Because of the almost complete destruction of the aircraft by the impact forces and post-crash fire, it could not be determined whether any pre-impact structural failure or system malfunction contributed to the accident; however, none was identified. The engines, propellers, and flap actuator were transported to the TSB regional wreckage examination facility. The propellers (Hartzell Propeller Model HC-E3YR-2ATF) were dismantled for examination, and it was determined that they were likely operating with minimal power at the time of impact. The engines (Lycoming TIO-540) were examined by TSB and Textron Lycoming personnel. There were no abnormalities found to indicate a pre-impact malfunction, or evidence that the engines were incapable of producing full power.

The aircraft wreckage and occupants were located approximately six and one-half months after the accident, and the state of the human remains precluded the possibility of obtaining meaningful autopsy and toxicological data.

**Analysis**

There were no witnesses to the accident, no evidence found of any airframe failure or systems malfunction during flight, and no evidence available to indicate whether incapacitation or physiological factors could have affected the pilot's performance. Concurrent with this, it could not be determined why the aircraft departed cruise flight, began a rapid descent, and struck the mountain side. Wreckage distribution and impact signatures indicate that the aircraft was in a steep nose-down attitude at impact. It is possible that, prior to the rapid descent, the aircraft's performance was affected by one or more factors such as airframe or engine icing, mechanical malfunction, or heavy weight. The ACC radar data, however, reveals that the aircraft's airspeed, altitude, and track remained relatively constant during the en route segment of flight. During the final moments of flight, from about 1941 to 1945, the aircraft's ground speed decreased from about 140 knots to 90 knots. If airframe icing was a factor in the occurrence, then it is probable that the accumulation occurred during the final five minutes of flight. If the pilot experienced engine difficulties during the flight, it would also have been during the last five minutes of flight. Examination of the engines, however, reveals that they were capable of producing power at the time of impact. The evidence gathered strongly suggests that a catastrophic event resulted in the precipitous uncontrolled descent of the aircraft from which the pilot did not recover.
The following Engineering Branch report was completed:

LP 193/95 - ATC and Radar Data Analysis

Findings

- The pilot was licensed and qualified for the night IFR flight, and the aircraft was certified in accordance with existing regulations.

- Based on estimated weights, the take-off weight of the aircraft may have exceeded the allowable limit.

- The area forecast predicted a probability of severe clear icing in freezing drizzle for the route of intended flight. During the pilot's weather briefing, this information was not mentioned.

- The pilot aborted the initial take-off from Calgary because the right engine was not developing full rpm.

- There was no evidence found that the engines were incapable of producing full power. Based on the propeller examination, it is likely that the engines were operating with minimal power at the time of the impact.

- The aircraft struck the ground in a steep nose-down attitude, with the flaps and the landing gear in the retracted positions.

- The state of the human remains precluded the possibility of obtaining meaningful autopsy and toxicological data.

- The spectral analysis indicates that at 1828, both engines were operating at a propeller speed of approximately 2400 rpm.

Causes and Contributing Factors

It could not be determined why the aircraft departed cruise flight and began a rapid descent from which the pilot did not recover. It was determined, however, that the pilot attempted flight through an area where the probability of severe clear icing, in freezing drizzle, was predicted by the area forecast.

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 25 October 1996.

1. All times are MST (Coordinated Universal Time minus seven hours) unless otherwise noted.
The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Near collision with stationary aircraft between
Canadian Airlines International Ltd.
BOEING 737-200 C-FCPN and Carson Air Ltd.
PIPER PA-42 CHEYENNE C-FWCC
Calgary International Airport, Alberta
20 December 1995

Report number A95W0234

Synopsis

The Piper Cheyenne had landed on runway 34 at Calgary International Airport, Alberta, and was instructed to exit on ice-covered taxiway Uniform. During the turn to exit, the Cheyenne began sliding near taxiway Uniform, and came to rest with the nose gear just off the edge of the runway. A Boeing 737, which had been cleared to land, touched down and the pilot was applying reverse thrust before noticing that the Cheyenne was not clear of the active runway. The flight crew of the Boeing reported passing behind the Cheyenne, with about 15 feet of clearance, at about 100 to 115 knots.

Other Factual Information

The Cheyenne had departed Kelowna, British Columbia, and the Boeing had departed Dorval, Quebec. Both aircraft were inbound to Calgary and arrived during the hours of darkness.

The runway conditions for the Calgary International Airport were reported as bare and dry within 50 feet either side of the centre line. The runway sides and some of the taxiways were ice-covered. Taxiway Uniform was ice-covered. The weather was ceiling and visibility okay (CAVOK).

The Boeing was about three miles behind the Cheyenne on final approach to runway 34. The Cheyenne was instructed to plan a left exit, onto runway 25, after landing. Following touchdown, the Cheyenne was unable to exit onto runway 25, and the airport controller instructed the pilot to continue and exit on taxiway
Uniform, with minimum delay, as there was a Boeing on a one-mile final. The Cheyenne crew was also advised that the closer taxiway, Alpha 3, was extremely slippery and undergoing maintenance by snow removal and chemical spreading equipment. The Boeing was advised to expect landing clearance on extremely short final. At about 2100 mountain standard time (MST)\(^1\), the Cheyenne crew advised the tower that they were "slipping here at Uniform." During the left turn to exit runway 34, the Cheyenne skidded and came to rest about 200 feet north of taxiway Uniform. The aircraft's nosewheel was just off the edge of the runway asphalt, in about six inches of snow. The main gear remained on the runway. The captain attempted to free the Cheyenne from its snowbound location using reverse power, but was unable to do so.

On short final, the Boeing crew were advised that the twin (Cheyenne) would be clearing on Uniform. A few seconds later, when the Boeing was descending through about 250 feet above ground level (agl), the flight crew received landing clearance, and were told to plan exiting on Charlie 4. At about 150 feet agl, the Boeing crew observed the navigation lights of the Cheyenne moving toward taxiway Uniform, and it appeared that the Cheyenne would be clear of the active runway before their touchdown. However, shortly after touchdown, the Boeing crew were surprised by the presence of the Cheyenne still partially on the active runway. With limited choices, because of the snow- and ice-covered sides of the runway, the crew took evasive action to avoid a collision. In doing so, they manoeuvred their aircraft as far as possible to the right and passed behind the Cheyenne with about 15 feet of clearance. The Cheyenne crew then advised the airport controller that they were still on the runway, requested a tow vehicle, and shut down the engines. The Boeing taxied to the ramp without further incident, and the Cheyenne was subsequently towed off the runway to a hangar facility.

The Boeing captain later reported that, after touchdown, the navigation lights of the Cheyenne were nearly impossible to distinguish as they intermingled with the runway lights.
The Transport Canada (TC) Air Traffic Control Manual of Operations (MANOPS), section 352.2, states:

Separate an arriving aircraft from a preceding aircraft using the same runway by ensuring that the arriving aircraft does not cross the landing threshold until one of the following conditions exists:

A. The preceding aircraft has landed and taxied off the runway.

B. The preceding aircraft has landed or is over the landing runway; and

1. is at a distance from the threshold sufficient to allow the arriving aircraft to complete its landing roll without jeopardizing safety; and

2. The arriving aircraft is advised of the preceding aircraft's position and intentions.

Section 352.2 B. 1. Note 1, states: "Controllers are cautioned to take into consideration the aircraft types, their performance, the runway condition and other factors that may impact on the operation."

Section 352.2 B. 1. Note 2, states: "The sufficient distance... need not be equal to the anticipated stopping of the second aircraft, provided the second aircraft is a light aircraft and you are satisfied no danger of collision exists."

A controller is expected to use the best judgement in handling a situation not specifically covered in MANOPS.

Staffing in the tower met TC unit standards, and the controller's workload was assessed as moderate and fairly complex. The tower supervisor was performing the duties of the airport controller. He was highly experienced in this position and was following procedures as outlined in MANOPS based on aircraft performance factors. All necessary tower equipment was serviceable and in operation. Runway 34 was in use for arrivals, and standard runway 34 and 28 co-active operation was used for departures. Traffic was arriving and departing normally in a "one in and one out" basis with no spacing restrictions given to arrivals.

Although taxiway Uniform was ice-covered, other aircraft had used this exit just prior to the occurrence without reporting any problems. After landing, the Cheyenne slowed to taxi speed by taxiway Alpha 3; at this time, the Boeing was about two miles on final. The airport controller observed the Cheyenne start its turn toward taxiway Uniform, and he then directed his attention to the landing Boeing and other departure traffic. As the Boeing was touching down, the controller noticed that the Cheyenne had become stuck in the snow and was still partially on the runway. He realized, however, that there was space for the Boeing to manoeuvre past the Cheyenne. As the Boeing passed behind the Cheyenne, the tower controller apologized for the inconvenience, and issued exiting instructions. The Boeing crew responded in an ordinary tone that the Cheyenne was off to the side.

The flight crew of both aircraft were certified and qualified for flight in accordance with existing regulations. The aircraft were certified, equipped, and maintained in accordance with existing regulations and approved procedures.

Expectancy describes the state of a person who expects to perceive certain environmental cues and tends selectively to search for those cues more actively than others. Channelized attention exists when a person's full attention is focused on one stimulus to the exclusion of all others.

Analysis
The Boeing crew and the airport controller observed the Cheyenne turning to exit on taxiway Uniform, and were satisfied that the landing could be completed safely. However, when the unexpected happened, there were minimal available safety options. In this case, the airport controller's expectancy, based on the habitual pattern of aircraft exiting the active runway without problems, may have been so strong that he perceived aircraft exiting cues that were misinterpreted. Channelized attention may have existed when the controller's full attention was focused on the landing Boeing and departing traffic. Rather than process information of a higher or more immediate priority, he focused his attention on the landing and departing traffic; thus, he had little time to respond to cues requiring immediate attention. Although it is impossible to detail procedures for all situations because of the many different circumstances that may arise, a controller is expected to use his or her best judgement in handling a situation not specifically covered in MANOPS. The icy runway exits compromised the after-landing efficiency of the crew and their ability to expeditiously exit their aircraft from the active runway. The icy sides of the runway also compromised the ability of the Boeing to manoeuvre and to pass behind the Cheyenne with an extra margin of safety. This situation would have been prevented had the controller ensured that there was the minimum required separation as detailed in Section 352.2 of MANOPS; however, it is recognized that the controller thought that the runway was clear for the landing aircraft. In addition, the Cheyenne crew did not assertively and explicitly communicate the importance of their not being clear of the active runway. The advisory statement made by the Cheyenne crew that they were slipping at Uniform was misleading, in that it implied that they were clear of the active runway and on taxiway Uniform. Further potential for a runway collision would have existed had the Cheyenne crew been able to free their aircraft from the snowbound location using reverse power and subsequently backed into the landing path of the Boeing.

Findings

1. Both flight crews were certified and qualified, and both aircraft were certified, equipped, and maintained in accordance with existing regulations and approved procedures.

2. Staffing in the tower was in accordance with Transport Canada unit standards.

3. All necessary tower equipment was serviceable and being used.

4. Icy runway sides and exit conditions prevailed, and the lighting conditions were conducive to poor traffic detection.

5. Considering the airport surface conditions, the spacing between the arriving and the preceding aircraft was insufficient.

6. The Cheyenne crew did not explicitly (assertively and accurately) communicate that they were not clear of the active runway.

Causes and Contributing Factors

The spacing provided between an arriving and a preceding aircraft did not allow for unforeseen contingencies during unfavourable airport conditions. Contributing to the occurrence was the unexplicit traffic advisory by the Cheyenne crew that they were not clear of the active runway.

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.

1. All times are MST (Coordinated Universal Time minus seven hours) unless otherwise noted.
These documents are the final versions of occurrence investigation reports as approved by the Transportation Safety Board. The TSB assumes no responsibility for any discrepancies that may have been transmitted with the electronic versions. The printed versions of the documents stand as the official record.

1995 Air Investigation Reports

A SAFETY STUDY OF EVACUATIONS OF LARGE, PASSENGER-CARRYING AIRCRAFT - Report Number SA9501

20 December 1995 - Near collision with stationary aircraft between Canadian Airlines International Ltd. BOEING 737-200 C-FCPN and Carson Air Ltd. PIPER PA-42 CHEYENNE C-FWCC Calgary International Airport, Alberta
Report number A95W0234

12 December 1995 - Collision with Person Viking Helicopters Ltd. AS350 BA (Helicopter) C-GDLY Sept-Îles, Quebec 160 nm NW
Report Number A95Q0236

05 December 1995 - Fire in Baggage Compartment Inter Canadien Fokker F-28 MK 1000 C-FCRI Jean Lesage International Airport, Quebec
Report Number A95Q0232

05 December 1995 - Elevator trim tab failure Canadian Airlines International BOEING 737-200 C-GCPS Vancouver, British Columbia 60 nm E
Report number A95P0272

28 November 1995 - Uncontrolled Descent/Collision with Terrain Aero Commander 700 N9920S Castlegar, British Columbia 15 nm SE
Report Number A95W0210

25 November 1995 - Collision with Frozen Lake Eagle Air Services Piper PA-31-325 Navajo C-GOLM Wollaston Lake, Saskatchewan 1 nm NE
Report Number A95C0250

Report Number A95P0268
14 November 1995 - Engine Failure Air Canada Airbus A320-211 C-FFWJ Montreal International (Dorval) Airport, Quebec 45 nm W
Report Number A95O0232

02 November 1995 - Collision with Terrain Niagara Helicopters Ltd. Bell 206L-3 Long Ranger III (Helicopter) C-FLYO Montreal International (Mirabel) Airport, Quebec 20 mi SW
Report Number A95Q0218

01 November 1995 - Component Failure/Landing gear torque link Canadian Regional Airlines FOKKER F28-Mk1000 C-FCRK Calgary International Airport, Alberta
Report Number A95W0202

26 October 1995 - Mid-Air Collision Between Cessna 180 C-FYKD and Cessna 150 C-GLHJ Saint-François-de-Laval, Quebec
Report Number A95Q0215

22 October 1995 - Aviation Occurrence Report Controlled Flight into Terrain Cessna 402 N67850 Wabush, Newfoundland 23 nm NW
Report Number A95Q0210

19 October 1995 - Rejected Take-off/Runway Overrun Canadian Airlines International McDonnell Douglas DC-10-30ER C-GCPF Vancouver International Airport, British Columbia
Report Number A95H0015

19 October 1995 - Fuel Exhaustion Canadian Helicopters Ltd. Aerospatiale AS 350B ECUREUIL (Helicopter) C- GVMS Canmore, Alberta 25 nm SW
Report Number A95W0194

15 October 1995 - Collision with Vehicle Air France Boeing 747-200 F-BPVV Montreal International (Mirabel) Airport, Quebec
Report Number A95Q0206

01 October 1995 - Propeller Failure Pelican C-IAZR Chenail-du-Moine, Québec
Report Number A95Q0199

27 September 1995 - 27 September 1995 - VFR into IMC Controlled Flight into Terrain Western Straits Air de Havilland DHC-3 (Turbine) Otter C-FEBX Campbell River, British Columbia 7 nm NW
Report Number A95H0012

26 September 1995 - Separation in flight Cowling Contact Airways Ltd. BEECH KING AIR 100 C-GNAA Edmonton, Alberta 50 NM N
Report Number A95W0180

16 September 1995 - Loss of Separation between Canada 3000 BOEING Company 757 C-FOOH and American Airlines Inc BOEING Company 767 N322AA Natashquan, Québec
Report Number A95A0167
09 September 1995 - Airframe Failure Wing MAGAL CUBY II (ULTRALIGHT) C-IEXR LEGAL, Alberta 4 NM W
Report Number A95W0166

18 August 1995 - Loss of Control Collision with Terrain Piper PA-34-220T Seneca III C-GTOG Teslin, Yukon
Report Number A95W0153

28 July 1995 - Collision with terrain in adverse weather CESSNA 310Q C-FAKW Caledon, Ontario 2 mi W
Report Number A95O0150

27 July 1995 - Power loss in left engine ditching confortair PIPER NAVAJO PA31-350 C-GVWM Sept-Îles, Québec 24 mi S
Report Number A95Q0142

07 July 1995 - Engine power loss mechanical malfunction Skyteck Aviation Ltd. BELL 206B JETRANGER (HELICOPTER) C-GXNM Drydec, Ontario 4 mi NW
Report Number A95C0149

04 July 1995 - Loss of Power Air Alma Inc. Bell 206L-1 Long Ranger (Helicopter) C-GLBA Fontange, Quebec 1 mi W
Report Number A95Q0118

01 July 1995 - In-flight Loss of Propeller Blade Classair Aviation Inc. Normand Dubé Aviation Aerocruiser (Ultralight) C-FCOL Lavaltrie, Quebec
Report Number A95Q0115

28 June 1995 - Collision with Water Northern Mountain Helicopters Bell 205A-1 (Helicopter) C-GNMR Leaf Rapids, Manitoba
Report Number A95C0139

27 June 1995 - Engine Fire and Evacuation Air Canada McDonnell Douglas DC-9-32 C-FTMD Vancouver International Airport, British Columbia
Report Number A95P0138

18 June 1995 - Risk of Collision Between Air Canada Airbus Industrie A320 -FNNA and Canadian Airlines International Boeing 737 C-GFCP Broadview, Saskatchewan
Report Number A95C0127

17 June 1995 - Flight into Adverse Weather Ground Impact Transportair Cessna 182RG C-GBXO Bégan, Quebec 3.5 nm N
Report Number A95Q0104

06 June 1995 - Risk of Collision Between Air Transat Lockheed L-1011 C-FTNC and Inter-Canadien Aéropatielle ATR 42 C-GXCP Quebec VOR 19 nm SW
Report Number A95Q0098

05 June 1995 - Landing Gear Failure Capsizing Enterlake Air Services Ltd. (Selkirk Air) Beech Aircraft Corporation 3T Beech 18 C-FSFH
Bradburn Lake, Manitoba
Report Number A95C0110

13 May 1995 - Collision with Terrain Cessna U206F C-GJGM Baie-Saint-Paul, Quebec
Report Number A95Q0090

11 May 1995 - Runway Overrun Royal Aviation Inc. Boeing Company
727-217 C-GRYR St. John's, Newfoundland
Report Number A95A0093

09 May 1995 - In-flight Separation Aérotech Aviation Beaver RX650 C-IDFL Saint-Mathias, Quebec
Report Number A95Q0086

01 May 1995 - Mid-Air Collision Between Bearskin Airlines Fairchild
Metro 23 C-GYYB and Air Sandy Inc. Registration PA-31 Navajo C-GYPZ Sioux Lookout, Ontario 12 nm NW
Report Number A95H0008

06 April 1995 - Loss of Off-wing Slide in Flight Air Canada Boeing 767-233 C-GAUH Vancouver, British Columbia
Report Number A95P0073

08 March 1995 - Risk of Collision Between Delta Air Lines Lockheed L1011 N740DA and British Airways Boeing 747 G-AWNH North Atlantic
Report Number A95A0046

01 March 1995 - Runway Overrun Lignum Ltd. Mitsubishi MU-300
Diamond C-GLIG Jasper-Hinton Airport, Alberta
Report Number A95W0034

01 March 1995 - Altitude Related Event - Uncontrolled Deviation
TAROM - Romanian Air Transport Airbus Industrie A310-325 YR-LCA
Near Rivière-du-Loup, Quebec
Report Number A95H0004

25 February 1995 - Wirestrike Government of Canada, Canadian Coast
Guard Bell 206L (Helicopter) C-GCHN Margaree River, Nova Scotia
Report Number A95A0040

21 February 1995 - Controlled Flight into Terrain Bearskin Lake Air
Services Ltd. Beechcraft A100 C-GYQT Big Trout Lake Airport, Ontario
3 mi NW
Report Number A95C0026

21 January 1995 - Collision with Vehicle Royal Air Maroc Boeing 747-400 CN-RGA Montreal (Mirabel) International Airport, Quebec
Report Number A95Q0015

11 January 1995 - Controlled Flight into Water Canada Jet Charters
Limited Learjet 35 C-GPUN Masset, British Columbia 8 nm NW
Report Number A95P0004