Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION OCCURRENCE REPORT

FRONTIER AIR LTD.
BEECHCRAFT C99 AIRLINER C-GFAW
MOOSONEE, ONTARIO
30 APRIL 1990

REPORT NUMBER A90H0002

Canada

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(To be released on 18 May 1993)

(Hull, Québec) - The Transportation Safety Board of Canada (TSB) has issued three recommendations following its investigation into the fatal accident involving a Frontier Air Ltd. Beechcraft C99, 30 April 1990, near Moosonee, Ontario.

The aircraft, with four persons on board, was making a night visual approach to land on runway 24 at the Moosonee Airport when it crashed seven miles short of the runway. The captain and two passengers escaped with serious injuries, but the co-pilot's injuries were fatal. The aircraft was destroyed by the impact and post-crash fire.

The Board determined that there were no mechanical problems with the aircraft and that the aircraft was inadvertently flown into trees in conditions conducive to black-hole illusion.

Black-hole illusion can be experienced during take-off or landing at night in conditions where a lack of visual references makes it very difficult to discern the horizon. This results in the pilot becoming disoriented with respect to the position of the runway. Visual illusions are just one of the many kinds of human factors that play a role in over 80 percent of all aviation occurrences. Transport Canada has taken action to make pilots more aware of the problem by increasing the human factors knowledge requirements for the issue of pilots licences and publishing the *Pilots Guide to Medical Human Factors* that includes a section on visual illusions.

Action has also been taken on other items evidenced from this occurrence, such as cockpit resource management training and the placement of onboard survival equipment.

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Crew pairings where both crew members were relatively inexperienced on aircraft type have been contributing factors in a number of aircraft occurrences around the world. In this occurrence, the captain and the co-pilot had been in their respective crew positions on this aircraft type for less than one month.

This flight was the co-pilot's first night flight on the C-99, first trip into Moosonee, and first flight with this captain. In view of the many factors which can contribute to unsuitable crew pairing and in view of the importance of crew pairing to effective cockpit performance, the Board has recommended that:

> The Department of Transport provide guidance for air carriers to assist in the effective pairing of flight crews.

When aircraft cockpits are laid out, designers use what is called a Design Eye Reference Point (DERP). This is the theoretical point where most pilots, when sitting in the cockpit, should have the best visibility of both the outside environment and the inside environment. Current pilot training and knowledge requirements do not address the importance of achieving optimum visibility, that is, positioning the eyes at the DERP. The TSB believes that many pilots unnecessarily and unknowingly restrict their visibility, jeopardizing the safe operation of their aircraft. To assist pilots in optimizing their visibility, particularly for the approach and landing phases of flight, the Board has recommended that:

> The Department of Transport take the necessary steps to ensure that pilots receive appropriate guidance for positioning their eyes at or close to the Design Eye Reference Point.

Even though the Air Navigation Orders require it, neither of the occurrence pilots had received night training on the Beechcraft C99. In fact, neither pilot had received night training for any of the other aircraft types they had previously flown for other air carriers. In view of the special skills needed for safe night operations, the Board has recommended that:

> The Department of Transport validate its current procedures for checking that air carriers provide the required multi-engine night training.

The Transportation Safety Board of Canada is an independent agency operating under its own Act of Parliament. Its sole aim is the advancement of transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

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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

Frontier Air Ltd.
Beechcraft C99 Airliner C-GFAW
Moosonee, Ontario
30 April 1990

Report Number A90H0002

Synopsis

The aircraft, a Beechcraft C99 Airliner, was on a scheduled domestic flight from Timmins, Ontario, to Moosonee, Ontario, with two pilots and two passengers on board. The aircraft crashed seven miles east-northeast of the Moosonee Airport while the crew was conducting a visual approach to land on runway 24. The aircraft was destroyed by the impact and a post-crash fire. The captain and passengers were seriously injured, and the co-pilot received fatal injuries.

The Transportation Safety Board of Canada determined that the captain inadvertently flew the aircraft into trees, during a condition of visual illusion, as a result of inadequate crew coordination in that neither pilot effectively monitored the altimeter. Contributing to the occurrence were the absence of approach lighting, the lack of company crew pairing policy, the captain's unfamiliarity with black-hole illusion and the seating position of the captain.

10 March 1993

Ce rapport est également disponible en français.

Table of Contents

Page

1.0 Factual Information

1.1 History of the Flight

At 2043 eastern daylight time (EDT)[1], Frontier Air Flight 1602, C-GFAW, a Beechcraft C99 Airliner, took off from Timmins, Ontario, on a scheduled domestic flight to Moosonee, Ontario. The aircraft carried a two-pilot crew, two passengers, and approximately 60 pounds of freight and baggage.

The flight proceeded, via airways, to Moosonee at 7,000 feet above sea level (asl)[2]. At 2121 EDT, the flight was cleared for an approach at Moosonee with a temporary altitude restriction of 5,000 feet. The crew elected to fly the very high frequency omni-directional range (VOR) runway 24 approach. (See Appendix A.) At 2129 EDT, the crew reported on the 061-degree radial of the VOR at five nautical miles (nm)[3] outbound.

Shortly after intercepting the 061-degree radial inbound, the crew initiated a descent to the 440-foot minimum descent altitude (MDA). While in the descent, the aircraft broke through the lowest cloud layer at 900 feet asl, approximately 9.2 nm from the VOR. At this point, both pilots had the runway lights in sight, and the captain decided to change to a visual approach and proceed inbound at 700 feet asl.

Shortly after advising the co-pilot of his intentions, the captain initiated the before-landing cockpit check and selected the landing gear lever to the DOWN position. Immediately thereafter, the aircraft struck trees and crashed seven miles east-northeast of the Moosonee Airport.

The aircraft struck terrain at latitude 51°22'N and longitude 080°28'W, at approximately 2138 EDT, during the hours of darkness, at an elevation of 20 feet asl. (See Appendix C.)

1 All times are EDT (Coordinated Universal Time (UTC) minus four 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.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	1	-	-	1
Serious	1	2	-	3
Minor/None	-	-	-	-
Total	2	2	-	4

1.3 Damage to Aircraft

The aircraft was destroyed by the impact and the post-crash fire.

1.4 Other Damage

The fuel, oil, and lubricants carried on board were either burned or removed with the wreckage. The accident site was cleaned with the exception of the broken trees and those trees that were cut to facilitate wreckage removal.

1.5 Personnel Information

1.5.1 General

	Pilot-In-Command	Co-pilot
Age	25	35
Pilot Licence	Airline Transport	Commercial
Medical Expiry Date	1-10-90	1-10-90
Total Flying Time	2,423 hr	1,038 hr
Total on Type	298 hr	102 hr
Total Last 90 Days	293 hr	133 hr
Total on Type Last 90 Days	292 hr	102 hr
Hours on Duty Prior to Occurrence	2 hr	2 hr
Hours Off Duty Prior to Work Period	47 hr	72 hr

1.5.2 Captain's History

The captain started his flying training in 1985, and, in November 1987, he obtained a Commercial licence and a Class II, Group I instrument rating. In October 1989, when he was accepted for employment with Frontier Air, he held a Class I, Group I instrument rating and a Senior Commercial licence. The captain also held a Category I medical with a restriction to wear glasses, which he was wearing throughout the accident flight.

Shortly after joining the company, he was selected for co-pilot training on the Beechcraft C99; this training was conducted in Timmins by a Flight Safety International (FSI) instructor using the FSI Training Syllabus. The captain completed his pilot proficiency check (PPC) and instrument renewal on the Beechcraft C99 on 26 January 1990, and upgraded to Airline Transport Pilot licence (ATPL) this same month. He was subsequently selected for captain upgrade training, which was conducted in-house by the Frontier Beechcraft C99 training pilot. He successfully completed his PPC as captain on 10 April 1990 on the C99. At the time of the accident, he had accumulated 20 hours as a captain on the C99.

The captain's last night flying training was on 24 August 1987 in a Piper 44 Seminole, a twin-engine aircraft. He has flown both the PA31 Navajo and the C99 aircraft, under Air Navigation Order (ANO) Series VII, No. 3, at night, without receiving any on-type night training, which is required by this ANO. His last night flight was on 10 April 1990.

1.5.3 Co-pilot's History

The co-pilot started his flying training in 1987, and, in December 1987, he obtained a Commercial pilot licence. In July 1988, he received a Class II, Group I instrument rating. In March 1990, when he was accepted for employment with Frontier Airlines, he held a Class I, Group I instrument rating. He held a Category I medical without restrictions.

Upon joining the company, he was selected for co-pilot training on the Beechcraft C99; this training was conducted in-house in Timmins by the company C99 training pilot. He successfully completed his PPC on the C99 on 10 April 1990.

The co-pilot's last night training was on 28 September 1987, in a single-engine aircraft. He had flown both the PA31 and the C99 under ANO Series VII, No. 3, at night, without receiving any on-type night training, which is required by this ANO. The co-pilot's last night flight was on a PA-31 on 25 February 1990. The occurrence flight was the co-pilot's first night flight in the C99, his first trip into Moosonee, and his first flight with this captain.

1.5.4 *Crew Personality Profiles*

The captain, a single man, was assessed to be a quiet, easygoing individual. He was regarded as a conscientious pilot, respected by his peers and supervisors in the company. He had no outside pressures.

Professionally, he was working his way up in the aviation industry. None of his associates noticed any behavioural or attitudinal changes prior to the accident flight.

The co-pilot, a happily married man with two children, was a well-adjusted individual who was in the early stages of a promising aviation career. He had overcome a protracted period of convalescence caused by a previous work-related back injury. He was new to the company; nevertheless, he was highly regarded as a pilot and an individual. His family had recently taken up residence in Timmins. He did not have any outside pressures, nor had his behaviour or habits changed prior to the accident flight.

1.6 *Aircraft Information*

1.6.1 *General*

Manufacturer	Beech Aircraft Corp.
Type	C99 Airliner
Year of Manufacture	1982
Serial Number	U197
Certificate of Airworthiness	Valid
Total Airframe Time	14,766 hr
Engine Type (2)	P&W PT6A-36
Propeller Type (2)	Hartzell HC-B3TN
Maximum Allowable Take-off Weight	11,300 lb
Recommended Fuel Types	Jet A, Jet A-1, Jet B
Fuel Type Used	Jet B

The aircraft was not equipped with an altitude alerter, Ground Proximity Warning System (GPWS), or a radio altimeter, nor were these required by regulation.

1.6.2 *Weight and Balance*

A copy of Flight 1602's weight and balance loading form was not left at the dispatch location, nor was this a practice required by the company or by regulation. It was possible, through weighing the baggage and reviewing the information with the surviving captain, to determine that the aircraft weight and centre of gravity were within the prescribed limits throughout the flight.

The last weighing of the aircraft took place on 02 January 1990. The weight of the survival kit was not included, as required by regulation, and the supplemental equipment list was not amended to reflect the addition of the survival kit.

1.7 Meteorological Information

1.7.1 Forecasts

The Northern Ontario FACN2 area forecast, which covers the area of the intended flight, was issued on 30 April at 1730 UTC and was valid from 1800 to 0600 UTC. It forecast a layer of broken, occasionally scattered cloud at 2,000 to 3,000 feet asl, with cloud layers to 19,000 feet, high broken clouds above 20,000 feet and visibilities ranging from three to five miles in light rain and fog. A few embedded altocumulus/towering cumulus topped at 19,000 feet asl were also forecast. Light to moderate icing was forecast in cloud above the freezing level; the freezing level was forecast to be at 10,000 feet asl, and lowering as time progressed.

The latest terminal forecast for Moosonee was issued on 30 April at 1230 EDT and was valid from 1300 to 2000 EDT. It forecast the following conditions: a scattered layer of cloud based at 3,000 feet above ground level (agl) and an overcast layer at 8,000 feet agl, with the 3,000 foot layer being occasionally broken. Light rain showers were forecast. Terminal forecasts for Moosonee are not issued for the period 2000 to 0700 EDT.

1.7.2 Moosonee Weather Observations

The Moosonee weather observation at 2100 EDT, approximately 35 minutes prior to the accident, was reported as an estimated ceiling of 400 feet agl broken, 1,000 feet agl overcast, four miles visibility in light rain, winds from 270 degrees at four mph. The surface and dew point temperatures were eight degrees Celsius. The weather reported for 2200 EDT, approximately 25 minutes after the accident, was measured ceiling 1,000 feet agl broken, 2,500 feet agl overcast, and five miles visibility in light rain.

The weather services available at the Moosonee Airport were the hourly weather observations that were taken by trained Air Creebec employees, who were under contract by Transport Canada (TC) to take and report these observations between 0500 local (L) and 2000 L. In addition, it had been normal practice for the weather observer to issue a 2100 L observation for the incoming Air Creebec and Frontier flights scheduled to arrive shortly after that time.

1.7.3 Pilot Reports

The captain of Flight 1602 reported that there were layers of cloud throughout his en route descent from 7,000 feet to the initial 1,500 feet approach altitude for the VOR approach to runway 24. There was no turbulence, precipitation or icing experienced during the descent. The lower layer of cloud was scattered to broken, and the captain reported that he could see the lights of Moosonee through the cloud breaks as he crossed over the VOR. He also reported that the lower layer of cloud was based at about 900 feet agl, that there was no turbulence during the approach, and that, when he broke out of the cloud on final approach at about nine nm on the distance measuring equipment (DME), he could see clearly the airport lights. The passengers also stated that the aircraft was clear of cloud, and that the airport was in sight before the accident.

At 2203 EDT, the pilots of the Air Creebec flight, which followed the accident flight on the instrument flight rules (IFR) approach, reported the bases of cloud at 700 feet agl with poor visibility and a loss of 20 knots on approach because of low-level wind shear. When questioned later, this crew reported that the ceiling was 1,100 feet agl over the airport but seemed to lower to the northeast to 700 feet agl or lower, and that visibility below the cloud was good. They did not recall any turbulence during the approach.

1.7.4 Wind Shear

An upper air sounding was conducted on 30 April at 2000 EDT by the Moosonee Upper Air Station, which is located approximately two km south of the airport. The winds at the surface and at 1,000 feet agl were 270 degrees at eight knots and 285 degrees at 22 knots respectively, indicating a wind speed decrease of 14 knots and back in direction of 15 degrees in the descent to the surface from 1,000 feet. This change in velocity from the surface to 1,000 feet is not abnormal.

1.8 Aids to Navigation

At the time of the accident, the Moosonee Airport was served by the following approach aids: one non-directional beacon (NDB), and a VOR/DME. Both the NDB and the VOR/DME were serviceable and were being used by the crew for their approach to Moosonee. The captain indicated that his navigation systems were functioning properly. Air Traffic Services (ATS) did not have any indications of problems with the Moosonee navigation aids before or after the accident. The Air Creebec flight, which was using the same navigation facilities, did not report any abnormalities.

1.9 Communications

Communications between ATS, other aircraft, and Flight 1602 had been established and were normal throughout the accident flight. There was no distress call; however, the emergency locator transmitter (ELT) survived the crash, activated, and functioned normally after impact. The ELT assisted local searchers in locating the crash site.

1.10 *Aerodrome Information*

The Moosonee Airport, at a reference elevation of 30 feet asl, is certified as a public-use aerodrome and is operated and maintained by the Moosonee Development Area Board (MDAB). Runway 14/32 is gravel, 3,500 feet long and 100 feet wide; runway 06/24 is asphalt, 4,000 feet long and 100 feet wide. Both runways are used for instrument approaches. Aerodrome lighting consists of a beacon and runway/threshold lights. At the time of the accident, the airport beacon was on and serviceable, and the runway edge and threshold lights on runway 24 were on medium intensity and were serviceable.

The lighting requirements for an aerodrome intended to be used at night are set out in TC publication TP 312E, Part 3, Aerodrome Standards and Recommended Practices. Because Moosonee has only an approved non-precision approach on runway 24, neither an approach slope indicator (ASI) nor approach lighting is required for the issue of an aerodrome certificate. However, TC recommends that both these services be installed and designates them as "operationally desirable." It is the prerogative of the aerodrome certificate holder to install these recommended services.

TP 9474, Part 114.311, Aerodromes-Provision for an Approach Slope Indicator, a policy document of the Air Navigation Services (ANS) Branch, identifies when and where an ASI is to be provided by TC. The policy is applicable to all civil airports in Canada, and, in part, allows the ANS Branch to require that ASI equipment be installed to serve a runway where the pilot of an aircraft may have difficulty judging the approach because of inadequate visual guidance during approaches over water, over featureless terrain by day or with insufficient extraneous light in the approach area by night.

The flight check performed by TC, as part of the aerodrome certification process, did not reveal any visual difficulties associated with the approved approach. It was conducted during daylight hours. Although several pilots interviewed indicated that the night approach into Moosonee on runway 24 is difficult, none of the pilots had filed a complaint.

1.10.1 *Approach to the Airport on Runway 24 at Night*

The Moosonee Airport is located on the north shore of the Moose River, east of the town and the old military radar site. (See Appendices A and C.) The surrounding terrain is flat, and the vegetation consists of poplar and tag alders approximately 25 feet high. When approaching the airport from the east-northeast, there are no lights until the runway lights can be seen. Behind these lights is the rotating beacon on the airport, and the town lights are behind that. The lights on Moose Factory Island are not visible until reaching three nm on the DME, at MDA.

Because the terrain is flat and because the Moosonee town lights are oriented more laterally than longitudinally on this approach, a pilot's ability to perceive angles is limited, especially from a distance. There are no approach lights on runway 24, nor is there a visual approach slope indicator system (VASIS). During the visual approach to the runway, the captain had the taxi light on. It was determined, by use of a helicopter at night, that the runway lights could be seen right down to the tree level at the accident site.

1.10.2 Terrain

On the night of the accident, the land area surrounding the approach to the airport was flooded with approximately two feet of water caused by the spring run-off and an ice jam in the Moose River, which flows into James Bay. The terrain is flat, and the grey poplar and tag alders were without foliage. The darkness, cloud cover, and flooding created a dark, featureless visual environment. There were no ground lights east of the threshold lights on runway 24, all the way east-northeast to James Bay, approximately 10 miles away.

1.11 Flight Recorders

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

1.12 Wreckage and Impact Information

The aircraft struck trees on a heading of 230 degrees magnetic in a shallow descent of approximately five degrees and a slight right-wing-low attitude, approximately six nm from the threshold of runway 24.

The first substantial piece of wreckage, a five-inch piece of a propeller tip, was found on the right side of the wreckage trail 153 feet past the point of initial impact. A six-foot section of the right wing tip and 2 three-foot pieces of the right aileron were found 253 feet along the trail. There were bits and pieces of the wing and baggage pod scattered along the right side of the trail. The complete empennage was on the left side of the trail, 342 feet from the initial impact point. The empennage had failed just ahead of the vertical fin. At 378 feet along the trail was an eight-foot section of the left wing tip and aileron. At 432 feet from the point of initial impact, in the centre of the wreckage trail, surrounded by burnt and downed trees, were the charred remains of the fuselage, inboard section of both wings, cockpit, and both engines and propellers.

The fire destroyed the cabin and cockpit roof and much of the right wing structure. There was no indication of an in-flight fire. Both of the wings, except for the parts consumed by fire, were accounted for.

The main cabin door was partially open, blocked by tree branches; it was still attached to the fuselage by the main door hinge. The locking pins and the door handle were in the locked position. The rear baggage door was in place, closed and latched. Fire damage precluded a determination of the status of the emergency exit doors at impact.

The flap control lever in the cockpit was set at approach flaps. It was determined, through measurements of the flap actuators, that the flaps were at the approach setting of 15 degrees, or approach flap. This setting corresponded to the captain's recollection.

Because of the destruction of the aircraft, complete aileron control continuity could not be confirmed. The cockpit control wheels were jammed, but interconnected. The majority of the aileron cables were found in the main wreckage. The failure of the cables was determined to be from overload. All of the aileron hinges were able to move freely. Both ailerons were accounted for.

The elevators were found attached to the horizontal stabilizer. They were relatively undamaged and were free to move together. The failures of the cables were determined to be from overload.

The rudder and rudder trim tab were still attached to the empennage and were free to move normally. The mode of failure in the cables of the rudder control system was determined to be overload.

The pitch angle of the horizontal stabilizer is controlled from the cockpit via an electrically driven actuator located in the empennage. The actuator extension was measured at 5.1 inches, which corresponds to an approximate nose-up stabilizer position of 1.3 degrees. This, in turn, corresponds to a shallow, nose-down position.

The landing gear selector lever was found selected to the DOWN position. The right main gear actuator was found fully extended, and the left and nose landing gear actuators were both partially extended.

Fire damage to the generators precluded any determination of the pre-impact serviceability of the generators. They were both attached to their respective engines. Fire damage to the cockpit circuit-breaker panels made it impossible to determine whether there had been any pre-impact faults. The battery was found to still have a partial charge four days after the accident. The inverters were fire damaged and could not be tested.

The instrument panel was found intact and virtually undamaged under the aircraft; however, it had been under freshwater for at least 12 hours. Initial readings from the instruments were inconsequential, and subsequent evaluation was inconclusive. It is suspected that the cushioning effect of the water on impact prevented the usual impact markings. The DME was bench tested serviceable; however, it was not possible to determine the final reading prior to impact. Both altimeters were tested. The pilot's altimeter was found serviceable. The co-pilot's was slightly out of specifications; when at 1,000 feet asl, it displayed an altitude of 1,030 feet asl.

The instrument panel was shipped to the TSB Engineering Laboratory for analysis. The examination concluded that the co-pilot's attitude indicator was in the range of 15 to 30 degrees nose down at impact; that the DME was serviceable; that the caution, warning and annunciator lights examined were considered to have been OFF at impact; and that the instrument illumination lights were probably on at impact.

Both engines and propellers were transported to Pratt & Whitney in Montreal, Quebec, for analysis under TSB supervision. Engine teardowns determined that there were no discrepancies or evidence of malfunctions prior to impact. The symmetry of impact damage observed in both propellers suggests that the propellers were absorbing power at the time of impact. The propeller tip twisting observed on the right propeller suggests a power-on condition at the time of impact.

1.13 *Medical Information*

The autopsy on the co-pilot indicated that he was fatally injured on impact. There was no evidence that incapacitation, physiological or psychological factors affected the crew's performance.

1.14 *Fire*

It was not possible to determine the exact time that the fuel-fed, post-crash fire commenced; however, there was sufficient time for the passengers and captain to evacuate the aircraft and remove the body of the co-pilot. There was smoke around the aircraft prior to fuel ignition, and it is suspected that the ignition source was electrical arcing and/or hot engine exhausts. The fire consumed most of the aircraft structure that was above the water line after the aircraft came to rest.

1.15 *Survival Aspects*

After escaping out the front of the aircraft, the three survivors crossed a creek and climbed up into the small trees in an effort to get out of the cold water and in order to stay warm. The captain later tried to attract the attention of a civilian helicopter crew, which was conducting a search, by climbing down and moving into the illuminated area created by the helicopter lights. But on two occasions, the helicopter moved; so, he gave up and returned to his tree. The male passenger also made one attempt to attract attention, but with similar results.

Even if the helicopter crew had been able to locate any of the survivors, the darkness, brush, water and the lack of suitable equipment would have prevented the crew from landing or from dropping rescuers. The civilian helicopter crews were not trained in search and rescue procedures, and the helicopter was not equipped for such an operation.

The search was abandoned until first light when the survivors were found and airlifted by both the civilian and Canadian Forces helicopters to the Moose Factory Hospital.

The aircraft was equipped with a survival kit located in the nose baggage compartment. The location of the survival kit was not identified on any interior or exterior placards. The location of the survival kit was at the discretion of the crew and could be moved between the nose baggage compartment, the rear baggage compartment, and the rear of the passenger cabin, depending on the crew's preference and baggage loading requirements.

The nose section of the aircraft folded under the fuselage during the crash; therefore, the survival kit was not accessible to the passengers. When the survival kit was located, it was found intact, not damaged by fire, water, or impact. It was completely usable after the accident. However, the survivors did not know of its existence and location.

1.16 Tests and Research

On 14 May 1990, two flight checks were performed in another company Beechcraft C99, to establish flight characteristics at various speeds and configurations. These flights were conducted under the supervision of the TSB and with permission of the company chief pilot. One of the flights was conducted on the same route at the same time of night and in similar weather conditions as the accident flight. A video was taken from both the co-pilot's and passengers' perspectives.

Based on observations and calculations made during these two flight checks, it was determined that the pitch attitude of the Beechcraft C99 does not vary significantly with airspeed changes on final approach. In level flight, with approach flap selected, the pitch attitude is approximately zero degrees, and a one-degree, nose-down attitude results in a rate of descent of approximately 400 feet per minute (fpm). Also, when on a night approach, at 10 nm, and at a level 1,000-foot agl altitude, the runway lights were not visible above the instrument panel glareshield from the third-row passenger seats; whereas, when in a descent of approximately 700 fpm, the lights appeared to be about two-thirds up the windscreen. This was the location of the lights as observed by one of the surviving passengers during the last moments of the flight.

It was also observed that the pilots on these test flights straightened up in their seats in the flare to land. They stated that this was done in order to see better over the glareshield on landing. When asked why they positioned their seats so low, they replied that it was to best situate themselves for instrument flying.

The co-pilot's seat position on a flight check was measured. It was found that he had a zero-degree effective visual angle below the glareshield; when in level flight, he could not see objects externally below the nose of the aircraft, unless the aircraft was in a descent with the nose below the horizon or he straightened up and/or sat forward in his seat. On the check flight night approach into Moosonee, on runway 24 on 14 May 1990, the co-pilot could only see the runway lights after the descent was started.

1.17 Additional Information

1.17.1 Night Training

1.17.1.1 Company Training Requirements

Frontier's Flight Training Manual was approved by TC. Section 1.4.1 (c) of this manual required flight instruction and practice in take-offs and landings by night in each aircraft that the pilot would fly. Night training requirements were also implied in Section 3.2 (a) of this manual, Frontier's Beechcraft C99 Flight Training Syllabus; however, the aircraft activities listed in this section did not specifically include night take-offs and landings.

Section 5 of the company's Flight Training Manual directed that a pilot's training record was to contain the individual's flight training reports. These report forms listed, as check-off items, take-offs and landings, and day and night flight times; however, a specific requirement for night take-offs and landings was not specified in these forms.

1.17.1.2 Transport Canada Requirements

ANO Series VII, No. 3 Para 46. (1)(b)(iii) states that the flight training provided by an air carrier for a pilot before he serves as a pilot flight-crew member in a multi-engine aircraft shall include, in each type of aeroplane he is to fly, flight instruction and practice in take-offs and landings by night, if he is to fly at night. The company did not have a system to track night training and night flying requirements, nor is one required by regulation.

1.17.1.3 Out-of-company Training

FSI conducted the flight training of Frontier's initial cadre of Beechcraft C99 pilots in Timmins. TC approval of out-of-company training is required, according to TC's District Office; however, this initial training, using FSI instructors, was supposed to be conducted in accordance with Frontier's approved Training Manual. Therefore, because the training was being conducted in Timmins with Frontier aircraft, a separate approval of an FSI syllabus was not required, nor was it requested by the company. Based on a lack of specific directives from the company, which held the training by FSI in high regard, the FSI instructor conducted the training using only the FSI training syllabus. This syllabus does not include a requirement for night flying training.

1.17.1.4 *Evaluation, Inspection, and Approval of Training*

Chapter 8 of the TC Air Carrier Inspector Manual (TP 3783) states that training programs and amendments thereto, for air carriers operating under ANO Series VII, shall be reviewed by appropriate Regional Inspectors and approved by the Regional Manager Air Carriers. This includes any out-of-company training, which should be in conformity with the approved training in the company's Operations Manual. The company's Operations Manual and Training Manual had been approved by TC; however, the individual pages were not stamped and dated by the Ontario Regional Manager of TC, as required by TP 3783.

1.17.2 *Pilot Proficiency Check Requirements*

According to TP 3783, PPCs are conducted to assess the effectiveness and standard of the carrier's training and flight-checking system, and to qualify pilots for air carrier operations in accordance with the standards in ANO Series VII, No. 3. For air carrier operations under ANO Series VII, No. 3, a PPC is required on each pilot for initial type-rating certification and annually thereafter. Also, Section 5.1.2 of this same manual states that a TC inspector is required to do the PPC rides for initial PPCs and upgrade PPCs from co-pilot to captain status. TC inspectors conducted the Beechcraft C99 co-pilot PPCs on both accident pilots and the accident captain's upgrade PPC.

TP 3783 states that, before a request for a PPC is made, the air carrier's chief pilot is responsible for certifying that the candidate has completed the carrier's approved training program; a form memo must then be submitted to the TC inspector confirming that all ANO requirements have been met. In addition, TP 3783 requires that the pilot's training file be made available to the inspector before the check flight.

Effectively, at Frontier Airlines, the responsibility to ensure that all the training requirements were complete rested with the company's chief pilot, and the review of the training file to confirm that the training requirements had been met was the responsibility of the individual air carrier inspector.

However, because specific guidance was not given to check the training file, a review of a pilot's training file was not always done. In this case, the inspector doing the captain's initial co-pilot PPC stated that he did check the training file, but that he did not notice the lack of night training; the inspector who did the captain's upgrade and the co-pilot's initial PPCs, on the same check-flight, did not review the pilots' training files.

1.17.3 *Flight Path Profile*

Based on the known weather conditions at Moosonee, the aircraft operating speed, and the captain's testimony that the aircraft broke through the lower layer of cloud at 900 feet agl and 9.2 nm DME, it was calculated that a descent angle of about five degrees would have been required for the aircraft to have crashed at the 6.9 nm DME. The initial descent path angle through the trees was measured at approximately five degrees. A five-degree descent angle at 135 knots equates to an aircraft rate of descent of approximately 1,200 fpm.

1.17.4 Design Eye Reference Point

U.S. Federal Aviation Regulation (FAR) 23.773 states, in part, that each pilot compartment must be designed so that the pilot's view is sufficiently extensive, clear, and not distorted, for safe operation. In meeting this certification requirement, Beechcraft Model C99, Model Specification BS 23370, indicates a Design Eye Reference Point (DERP) which ensures certain visibility ranges and visibility lines. There is no explicit FAR requirement for aircraft manufacturers to designate what range of pilot sizes their aircraft will accommodate while complying with the applicable FARs. Also, manufacturers are not required to provide guidance to pilots on how to locate themselves so that they achieve the DERP, and most do not.

As such, the DERP is a certain height above the floor and a certain distance from a datum line. (See Appendix B.) Consequently, if the pilot's eye is at this DERP while seated, he is assured of an optimum vision zone without eye rotation and an additional vision zone with eye rotation. The exact location of the DERP is not given in this report because the manufacturer requested that the information be treated as proprietary; therefore, all reference to the DERP is relative.

1.17.4.1 External Vision

External visibility is affected by such variables as windshield size, posts, glareshields, the height and fore/aft position of the seat. The one variable which the pilot can change is his seat position. This is done in the Beechcraft C99 by moving the seat both up and down and fore and aft. Simple geometry demonstrates that a change in either direction will affect the external visibility. (See Appendix B.) For example, if a pilot was sitting so that his eyes were at the DERP and he then moved rearward and downward, he would reduce his ability to see both above and below the nose of the aircraft. Similarly, if he were to move upward and forward from this point, he would increase his ability to see above and below the nose of the aircraft. Both of these changes would change his vision lines inside the cockpit as well.

1.17.4.2 Internal Vision

A change in the seating position from the DERP will affect the distance from the instrument panel, the number of instruments which the pilot can see and the parallax errors when looking at the instruments. Furthermore, the seat position will affect the pilot's ability to reach and manipulate controls in the cockpit. Therefore, a change from the

DERP is a compromise between external and internal vision and one's ability to manipulate the controls. In the Beechcraft C99, if one optimizes the seat position to view the instruments straight on, this may be done at the expense of external vision, depending on the size of the pilot.

1.17.4.3 Anthropometry

Anthropometry is the science that deals with the measurement of the size, weight, and proportions of the human body. Of interest here is the anthropometry of pilots relative to achieving the DERP. After the flight checks, two TSB investigators, who are also pilots, of differing heights and weights attempted to move the pilot seat to achieve this optimum position.

The taller investigator, who had a relatively long torso, could achieve the position with little difficulty. His external visibility was good and he could manipulate the controls without difficulty. His internal visibility was also satisfactory. The shorter investigator could not achieve the DERP despite being at the highest seat setting. This limited his external visibility, but internal visibility was satisfactory. However, he could not manipulate the flight controls from this position because his thighs would jam against the control column.

Another variable affecting the ability to achieve the DERP is leg length. For the taller individual, achieving maximum rudder travel was not a problem; however, for the shorter one, who also had shorter legs, the rudder pedals had to be fully rearward which resulted in the knees interfering with the control column. There is no indication in the cockpit of where the DERP is. For this investigation, it was measured manually, and markings were placed on the interior of the cockpit to facilitate measurements.

1.17.4.4 Experience In Company

None of the pilots interviewed, including the captain of the accident aircraft, were aware of the DERP in the C99, nor could any of them recall being instructed on where to sit in the cockpit, with the exception that, during their instrument training, some pilots were instructed to sit so that they were facing the instruments directly.

There is no requirement for the manufacturer to publicize the DERP, nor was it part of the flight instruction provided by FSI or the company pilots. The two pilots who flew the check flights were both measured in their seats to see how close they were to the DERP. It was determined that the captain, on the flight checks, was 3.7 inches below the DERP and the co-pilot was 4.7 inches below the DERP.

1.17.4.5 Captain's Position

The accident captain was measured in another C99 using the seat position obtained from the wreckage. It was determined that his eyes were 4.7 inches below and 2 inches forward of the DERP.

This gave him an angle between his forward horizontal vision line and the top of the glareshield of zero degrees. The net effect of this position is that the captain would not have been able to see anything below the horizon forward without lowering the nose of the aircraft, assuming that he did not change his body position and that the aircraft was at a zero-degree pitch angle.

The captain was then asked to raise his seat to achieve the DERP, but he was unable to raise the seat high enough. At the highest possible seat setting, his eyes were still one inch below the DERP and his legs were interfering with the flight controls to the extent that it would be impossible to fly the aircraft from that position; his visibility had improved, but at the expense of flight control operability. Furthermore, at this position, he could not apply full rudder control because his legs were too short. The captain is 168.5 centimetres (5 feet, 6 inches) tall and weighs 70 kilograms (154 pounds).

The captain reported that, after the roll-out on final approach, he had the runway lights in sight for the duration of the approach, right up to impact. He did not mention the town lights, only the runway lights. He also reported that he had done the approach to runway 24 at Moosonee many times in the past and was not particularly concerned about this approach. He indicated that, at no time during the approach, was there any indication of anything wrong. Moreover, he indicated that at no time did the co-pilot mention any problems. The passengers, both experienced air travellers, did not notice any problems with the aircraft or crew prior to impact. The female passenger did see the runway lights about two-thirds of the way up the windscreen during the final approach. Her effective visual angle below the windscreen was also measured and found to be zero degrees.

1.17.4.6 Video Results

On the first flight check flown on 14 May 1990, on the same route, and following the same profile as the accident aircraft, a video was taken from the co-pilot's perspective; specifically, the camera lens was held just to the left of and level with his left eye. Because of his visual angle below the windscreen of zero degrees, he was unable to see the runway on final approach to runway 24 at Moosonee until the aircraft was in a descent. The same was true of the passenger's vantage point.

The following day, on an instrument landing system (ILS) approach at Timmins, with a ceiling of 200 feet, the co-pilot, on visual break-out, could only see approximately the last 3,000 feet of runway, at the far end. He could not see the approach end, the approach lights, or the VASIS because of his low seating position and the approach angle of the aircraft.

1.17.5 Black-hole Illusion

Black-hole illusion occurs when darkness, absence of visual cues, and few lights may induce a false perception of altitude and/or attitude. When an aircraft is on approach to a runway and all is dark below and to the sides of the approach path with only the distant runway or airport lights providing visual stimuli, an illusory or false sense of height and/or attitude may be perceived.

In 1968, Drs. Kraft and Elworth of the Boeing Aerospace Company studied a number of major commercial jet accidents that occurred between 1959 and 1967, and noted a similarity in circumstances surrounding the accidents. These accidents occurred during night approaches over unlighted terrain or water (dark-hole approach), toward lighted cities. A series of night approaches without reference to an altimeter were conducted in simulators, and the resulting data indicated that, under certain conditions, during the night, clear weather, and an approach to land over dark terrain, even the most experienced pilots may visually overestimate their altitude, thus fly too low and, if undetected, land short of the runway. The research demonstrated that the most relevant source of visual information was the vertical angle.

The vertical angle is the angle subtended at the eye by the nearest and farthest lights. If, during a descent, a pilot maintains this angle at a constant value, the approach path follows the arc of a circle centred above the pattern of lights toward which the aircraft is descending with the arc's circumference contacting the terrain short of the lights. Specifically, the aircraft would be flown into the ground short of the intended runway threshold. (See Appendix D.)

Another significant visual cue determined in the simulator tests came from the motion of the light pattern relative to the pilot's eye. Under certain conditions, the changes in visual information from the airport lights to alert a pilot to his rate of descent were imperceptible. In addition, because of the black-hole environment, there were no other visual cues; consequently, the pilot had no visual indications that he was descending below the glide path.

Given that the motion of an object must exceed about one minute of visual angle per second to be perceived, Drs. Kraft and Elworth calculated that, at a speed of 240 mph and at an altitude of 3,000 feet, perception of motion would not occur until an aircraft was at a distance of 8.5 to 9 miles from touchdown. Drs. Kraft and Elworth also determined that, when an aircraft is slowing down and descending, the motion of the tilt in the plane of the lights would be perceived later. For example, at a speed of 120 mph and an altitude of 1,000 feet, the threshold for perceived motion would be 3.5 miles.

During the simulator tests, individual pilot differences accounted for the largest source of variation (25 per cent) in the perceived altitude; second to individual differences was distance from touchdown (20 per cent). In other words, the farther out, the larger the error. In this case, the accident aircraft was flying at an indicated airspeed of approximately 135 knots, between 9.2 nm and 7 nm from the airport, and between 1,300 feet agl and the ground.

Drs. Kraft and Elworth concluded, among other things, that problems associated with a black-hole approach appear to be aggravated by a long, straight-in approach to an airport located on the near side of a small city and by substandard runway and approach lighting.

1.17.6 *Visual Illusion Training*

It was determined that the captain had not received any formal education or training in aviation medicine or aviation psychology. With the exception of a one-hour introduction to the subject at the private pilot level, there is no formal training requirement for this type of training in the pilot licensing system. There is a description in the Aeronautical Information Publication (AIP) in the Medical Facts for pilots, which appears in the miscellaneous section of the airmanship chapter. There is no mention of the various visual illusions which are known to occur in aviation. No mention of black-hole illusion is made in the syllabus which accompanies the private pilot ground school. Several other visual illusions are not mentioned either; however, the issue of visual and other illusions is covered in many major aviation medicine texts.

The Canadian Forces and other military and civil organizations provide education and training in aviation medicine. This includes education and training in visual illusions.

1.17.7 *Crew Coordination*

Although the crew had changed from IFR to visual flight rules (VFR), no plan was in effect about how that visual approach would be conducted. The crew had not discussed maintaining a certain altitude to a certain DME or other limitation. The captain stated that it was his intention to level the aircraft at 700 feet until they were closer to the runway. The crew had not received any formal training in Cockpit Resource Management (CRM) or Pilot Decision Making (PDM).

During interviews with the captain and other company pilots, it was determined that there was little company training conducted in crew coordination and, as a result, there was variation between captains on procedures. In fact, on the pilot initial training, FSI and the company training pilot conducted C99 pilot training for single-pilot operations rather than for a crew operation. Furthermore, the company pilots interviewed consider the runway 24 approach into Moosonee at night to be a challenging one because of the lack of approach lighting and VASIS. As a result, most of them conduct visual approaches as a combination IFR/VFR procedure. There was no formal crewing policy in the company whereby inexperienced captains and inexperienced co-pilots would be precluded from flying together.

The captain indicated that the last altitude call made by the co-pilot was at 800 feet, or 100 feet above the intended level-off altitude of 700 feet asl. Also, the co-pilot was about to alert the Air Creebec flight that the weather was good and that they were visual. The subsequent lack of altitude calls by the co-pilot is unexplainable and not in accordance with company standard operating procedures (SOPs), which require that the pilot not flying call the airspeed and altitude at every 100-foot interval below 500 feet above ground, as well as excessive sink rate or any other anomalies that he notices. The captain commented during interviews that he was not paying attention to the co-pilot actions or activities during the visual approach, nor was the captain monitoring the altimeter.

2.0 *Analysis*

2.1 *Introduction*

Because it was determined that the aircraft was airworthy prior to impact, it was necessary to concentrate on the human and environmental areas in order to determine why the accident occurred. The following analysis, therefore, concentrates on the black-hole illusion, visibility in the cockpit, ergonomics, aviation medicine and aviation psychology training, crew coordination, and the PPC process.

2.2 *Black-hole Illusion*

During night visual approaches, an absence of ambient or peripheral visual cues between the airport and the aircraft can foster a dangerous visual illusion commonly referred to as black-hole illusion. After descending below cloud, the captain of the accident aircraft, in the presence of limited visual cues, decided to conduct a visual approach to runway 24 at the Moosonee Airport. The approach was over unlighted, flat terrain toward the runway lights. The captain stated that, when at 900 feet agl and approximately nine nm back, he saw the runway lights and never lost sight of the lights until tree impact at 6.9 nm from the runway. At the time of impact, the captain believed that the aircraft was at an altitude of 700 feet asl and at a distance of 5.2 nm. In fact, the aircraft crashed six nm from the threshold of the runway. Unaware of the effects of the lack of visual cues, the captain flew the aircraft with reference to the runway lights.

It is recognized, from research presented earlier, that lights viewed from a distance from over unlighted terrain, in the absence of ambient visual cues and reference to instruments, may give an illusion of false height. Moreover, most pilots, including the very experienced and instructors, making a visual approach to such an area of limited visual cues could overestimate their height. It is likely that the captain of the accident aircraft overestimated his height on the night visual approach to runway 24 at Moosonee.

Because the aircraft was already in a descent, it is unlikely that the captain would have perceived any significant change in the visual information from the runway lights. Based on the research data into visual illusions, the captain, in the existing circumstances, would not have been alerted to the continuing descent until the aircraft was closer to touchdown, possibly within three miles of the runway. Without any other visual cues, such as VASIS or approach lighting, the captain, viewing the runway lights from a distance, would have been confident and comfortable, as he indicated, with the perceived constant angle. ASIs, such as VASIS or Precision Approach Path Indicator System (PAPI), provide a continuous positive indication of an aircraft's position relative to the correct glide path. The use of such a system could contribute to the prevention of accidents such as this one.

The captain had flown day and night visual approaches to runway 24 at Moosonee many times before, and it was possible that, because of this experience, he felt confident with his visual estimates of height and, therefore, trusted the visual cues present. At a critical stage of flight, such as an approach and landing, when faced with multiple tasks, a pilot may assign a lower priority to checking his altimeter if he feels confident that what he sees outside the cockpit is an accurate representation of his height. Moreover, without a back-up reference, such as an altitude alerter, a GPWS, a radio altimeter, or a co-pilot monitoring the approach, he may be unaware of significant deviations from the intended flight path.

Even though the taxi light was on and should have illuminated the terrain below the aircraft to a certain extent, certainly in the last few moments, the captain did not perceive the trees. This, too, is understandable, considering that the captain was concentrating on the runway lights. If the landing lights had been on, there might have been some additional warning that the aircraft was approaching terrain.

Research has demonstrated that, once a pilot has decided that his situation is satisfactory, it requires a significant event or stimulus to prompt a reassessment of his situation. The captain on this flight was completely surprised when the aircraft struck the trees, so surprised, in fact, that he did not react at all. There is also a certain degree of stress relief when a transition to a visual approach is possible after completing an instrument approach. This situation can sometimes lead to relaxation or a lack of vigilance on the part of an individual pilot or crew. This, too, may help to explain the crew's conduct of the flight from break-out below the cloud on final to impact with the trees.

2.3 *Cockpit Visibility*

The cockpit visibility in this type of aircraft can be limited because of the interface between height and fore/aft position of the pilots' eyes, height of the glareshield, and control column location and movement. Without clear reference or guidance regarding where to position oneself in order to optimize external visibility, it is possible to position oneself where one cannot see anything outside the aircraft that is below the horizon. For example, on approach, it is possible to be seated in a position where, when breaking out of cloud at 200 feet, neither the approach lights nor VASIS nor even the approach end of the runway can be seen, as was the case in the Timmins approach observed during one of the flight checks.

The result of such eye positioning leaves the pilot with a reduced potential to see adequately to carry out a normal or safe landing. On the ground, this sort of position restricts visibility out the front of the cockpit to the point where pilots lean to the side to ensure safety. When airborne, in addition to the problems associated with landing, there is also the problem of seeing other aircraft or obstacles, especially those which might be approaching from below and from the front.

Training techniques which maximize visibility for instrument flying, for example, reducing the parallax error, do so at the expense of external visibility. Since the ultimate result of most instrument approaches is to terminate with a visual landing, it would then be appropriate to sit where the visibility is optimum for the transition to visual cues and the subsequent approach and landing.

The captain was seated in a position to facilitate instrument flying which was clearly at the expense of external visibility. In level flight, in approach configuration, he could not see below the horizon externally; therefore, the fact that he could see the runway lights throughout the visual approach demonstrates two things: first, he would have had to be in a descent; and second, his intention to level off at 700 feet asl was not accomplished.

2.4 *Ergonomics*

The fact that there is a design eye position that guarantees certain fields of visibility, but which cannot be achieved for a pilot the size of the captain because of cockpit layout and control interference is a problem in this type of aircraft. The captain on this flight was unable to adjust his seat to achieve the DERP and, therefore, was unable to see anything below the nose of the aircraft without either leaning forward and/or stretching or lowering the nose, thereby introducing a descent. Measuring the captain in the C99 seat position he used during the accident flight and later repositioning him to achieve the DERP resulted in two specific findings. First, in order for him to see the runway lights, from break-out below cloud to impact, as he indicated, the aircraft would have had to be in and continue to be in a descent. Second, he could not achieve the DERP because the seat could not be elevated high enough. A coincidental problem, in his case, was that at the maximum height of seat travel, his thighs would have caught in the control column and he would not have been able to achieve full rudder travel.

The problem in achieving the DERP was not unique to the accident captain, nor was his practice of sitting in a position to maximize instrument visibility. Other pilots could not achieve the DERP because of their particular shapes and sizes. During the flight checks, it was similarly evident that other pilots had acquired techniques to overcome limited external visibility derived from their seating position. Also common to the pilots of this company was a lack of guidance about where to sit to obtain the best vision in this aircraft. In fact, the pilots were not even aware that seat location could be a problem.

2.5 *Aviation Medicine and Aviation Psychology Training*

The TC approved training syllabus for the private licence requiring only a one-hour lecture on basic aviation medicine is insufficient to cover to any degree many of the medical problems associated with flying. After this brief introduction, it is possible to proceed with the licensing process right up to the ATPL without any additional required exposure to education or training in human factors. In short, it is up to pilots to find out about such things as visual illusions. TC has published some medical facts for pilots in the AIP; however, many of the visual illusions, such as black-hole, are not mentioned. Furthermore, the information is limited and does little more than identify the subject.

The Canadian Forces and other military organizations provide much more coverage of this critical aspect of aviation safety. The Canadian Forces require education, training, retraining and examination in these subjects. They emphasize the need and ability for pilots to anticipate physiological and psychological problems when flying, the ability to detect those problems, and the correct and timely remedial action to prevent incidents/accidents which may result from such events.

The accident captain and other pilots in the company were generally unaware of the number, severity and circumstances surrounding these physical and psychological problems associated with flying. In particular, the captain was unaware of the black-hole illusion.

2.6 *Crew Coordination*

The captain had not given detailed instructions on crew coordination. It cannot be determined with certainty whether the co-pilot, after being informed that they were continuing visual to the airport, continued to monitor altitudes. He may have been devoting his time to looking outside the cockpit. The captain was not directing his attention to the co-pilot and was unaware of his activities in the last portion of the flight. According to the company SOP for this type of aircraft, during a night visual meteorological conditions (VMC) approach, the pilot not flying is required to call the airspeed and altitude at every 100-foot interval below 500 feet agl, as well as excessive sink rate or any anomalies that he notices. According to the captain, this was not done. Moreover, it is clear that the captain was not referring to his altitude throughout the visual approach. If either of these two requirements had been done, it is likely that the descent would have been arrested prior to impact.

When the crew changed from the instrument approach to a visual one, they essentially went from a detailed plan to no plan. Under these circumstances, without clear guidance from the captain, and without training in night operations, the co-pilot may have been confused. He, too, may have been subjected to the illusion, since at no time did he take action to change the situation.

The objective of CRM and PDM training is to improve coordination and monitoring in the cockpit so that critical errors do not go undetected.

2.7 *Pilot Proficiency Check Process*

TC procedures place the responsibility for ensuring that the training requirements for PPCs have been met with the air carrier's chief pilot. The chief pilot stated that he unintentionally overlooked the night-training requirement stated in the company's Operations Manual and the ANO for both the occurrence pilots. He indicated confidence in the quality of the instruction being provided by the FSI and the company training pilot, and in the integrity of the TC approved training syllabus.

The PPC is normally regarded as a day, VFR check of a pilot's competency to fly a specific aircraft type. Night training appears to be a separate issue and only a prerequisite qualification for night flying. Notwithstanding, Frontier's Beechcraft C99s were certified and scheduled for day, night and IFR operations, and, therefore, it should have been anticipated that these two pilots would fly in night conditions.

TC procedures do not state specifically that the inspector must review the pilot's training files, and, based on information collected during interviews, it appears that the inspectors rarely do. The responsibility for ensuring the fulfillment of training requirements and other ANO requirements is on the company management. In this instance, the degree of scrutiny applied by the inspectors involved in both pilots' PPCs did not detect the lack of the required night training.

The length of time that had elapsed since both pilots had received such night training, and the fact that both had previously flown other aircraft types without receiving the required night training, suggest that the TC process for ensuring compliance with night-training requirements is inadequate. It also suggests that the problem may extend beyond this particular company.

3.0 *Conclusions*

3.1 *Findings*

1. The co-pilot sustained fatal injuries at impact.
2. Based on the autopsy, toxicology, and medical records, there was no evidence to indicate that the co-pilot's performance was degraded by physiological factors.
3. Based on medical examination and medical records, there is no evidence to indicate that the captain's performance was degraded by physiological factors.
4. This was the first time the co-pilot had flown at night in the C99, had flown into Moosonee and had flown with this captain.
5. The approach into Moosonee at night on runway 24 is conducive to black-hole illusion, a phenomenon of which the captain was unaware.
6. The captain likely could not achieve the design eye reference point because of the cockpit design and his physical characteristics.
7. Neither of the crew members had received night training in the aircraft type as required by ANOs.
8. Neither of the crew members had received any training in aviation medicine or aviation psychology.
9. Neither of the crew members had received formal Cockpit Resource Management or Pilot Decision Making training.
10. The crew did not follow the company SOPs for a night visual approach.
11. The aircraft was complete, intact, and functioning normally before it struck trees.
12. There were no flight recorders on board, nor were any required by regulation.
13. Although such services are considered operationally desirable by TC, the Moosonee Airport did not have approach lighting or ASI on runway 24.
14. The survival kit survived the impact, flood, and post-impact fire, but was inaccessible to the survivors.
15. The aircraft's weight, balance, and centre of gravity were within limits.
16. The aircraft's basic weight did not include the weight of the survival kit, nor had the weight of the survival kit been included in the aircraft's last re-weigh.

17. The aircraft was not equipped with an altitude alerter, a radio altimeter, or a GPWS, nor were any required by regulation.

18. The crew were flying a night visual approach to runway 24 after making the transition from an instrument approach with no plan in effect as to how that approach would be conducted.

19. Both pilots had valid medicals, licences, PPCs and instrument ratings.

20. The company's Operations Manual and Training Manual had been approved by TC; however, the individual pages were not stamped and dated by the Ontario Regional Manager of TC, as required by TP 3783.

21. The company overlooked the requirement for night training as required by ANO Series VII, No. 3.

22. The TC inspectors who conducted the PPCs on the captain and co-pilot did not detect the lack of night training which was required by ANO Series VII, No. 3.

23. The company did not have a system for tracking night training requirements or night currency.

24. The captain inadvertently flew the aircraft into trees and subsequently crashed during a condition of black-hole illusion.

25. Neither the captain nor the co-pilot monitored the altimeter during the visual approach.

3.2 *Causes*

It was determined that the captain inadvertently flew the aircraft into trees, during a condition of visual illusion, as a result of inadequate crew coordination in that neither pilot effectively monitored the altimeter. Contributing to the occurrence were the absence of approach lighting, the lack of company crew pairing policy, the captain's unfamiliarity with black-hole illusion and the seating position of the captain.

4.0 Safety Action

4.1 Action Taken

4.1.1 Cockpit Resource Management

In multi-crewed aircraft, teamwork is essential to the detection of errors (such as the premature descent in this accident), and effective cockpit communications are essential to good teamwork.

Following an incident involving a Boeing 737 in which poor intra-cockpit communications led to a near collision with terrain, it was recommended that the Department of Transport promote the adoption of CRM training by commercial operators (CASB Recommendation 90-53). Subsequently, TC has encouraged the adoption of this training through articles in the Aviation Safety Letter and has provided related courses such as PDM.

The TSB recently conducted a survey on Canadian commercial pilots. Of the pilots surveyed that were employed on multi-crewed aircraft with level III to VI air carriers, 42 per cent indicated that their employer provided formal CRM training. The continuing implementation of CRM training for commercial pilots should reduce the risk of recurrence of this type of accident.

4.1.2 Approach Slope Indicator

Subsequent to this accident, the TSB forwarded an Aviation Safety Advisory suggesting that TC evaluate the need for an ASI and/or approach lighting for runway 24 at Moosonee. TC subsequently recommended that the Moosonee Airport authorities install ASIs and indicated that TC was prepared to render any assistance necessary to obtain the ASIs.

4.1.3 Survival Kit Location

Post-accident survivability often depends to a large extent on the contents and availability of aircraft survival equipment. TC published an article in the 6/92 issue of Aviation Safety Letter encouraging operators to carry survival equipment in rear baggage areas where, in the event of an accident, the equipment would be less likely to be damaged or become inaccessible.

4.1.4 Human Factors Training

The Board determined that the accident aircraft was inadvertently flown into trees in conditions conducive to black-hole illusion. Pilots must contend with many types of visual illusions. Between 1977 and 1990, visual illusions were identified as a contributing factor in 19 other accidents. Visual illusions, in turn, are only one of many "human factor" issues which play a role in 70 to 85 per cent of all aircraft accidents. Training and awareness programs have the potential for reducing the number of accidents attributable to human factors.

The International Civil Aviation Organization (ICAO) has undertaken several initiatives, including the production of a series of digests on various aspects of human factors in aviation and a requirement for training in human factors for all aircrew licence holders in ICAO member states. TC is advancing pilot knowledge through promotional activities, by upgrading study and reference materials (such as the Pilot Decision Making Manual for Private Pilots, and the soon to be released Pilot's Guide to Human Factors), and by increasing the human factors knowledge requirements for the issue of pilot licences. Visual illusions (including black-hole illusion) are discussed in the draft Pilot's Guide to Human Factors, and have been included in a recent update of the data bank of questions used by TC for pilot written exams.

4.2 *Action Required*

4.2.1 *Crew Pairing*

The lack of a company crew pairing policy was identified as contributing to the accident. The captain and co-pilot had been in their respective crew positions for less than one month, and the accident flight was the co-pilot's first night flight in the C99, his first trip into Moosonee, and his first flight with the captain.

Crew pairing has been identified as a contributing factor in other occurrences. In July 1987, a Lockheed 1011 was involved in a near collision with a Boeing 747 as a result of a navigational error over the Atlantic Ocean. The Lockheed 1011 flight crew, who did not perform adequate navigational cross-checks, had limited experience in North Atlantic flying, with no crew member having more than six return trips (Report 87-A74947 refers). Furthermore, in 1987, the crew of a Boeing 737 Combi flew off track while on approach to Prince George, British Columbia, because of an improper navigation switch selection. Neither pilot had been in the cockpit of a Combi before (Report 87-P74128 refers). In August 1989, the flight crew of a Boeing 727 apparently failed to notice a navigation error, resulting in a loss of separation with another aircraft. The captain was not accustomed to the type of approach being flown, the co-pilot was new to the aircraft, and neither pilot was familiar with the destination (Report A89A0209 refers).

The U.S. National Transportation Safety Board (NTSB) has recognized the importance of proper crew pairing. In October 1986, following the investigation of three commuter air carrier accidents in which crew pairing was identified as a contributing factor, the NTSB recommended that the U.S. Federal Aviation Administration (FAA) caution commuter air carrier operators not to schedule on the same flight crew members with limited experience in their respective positions. Furthermore, following the crash of a McDonnell Douglas DC-9-14 on 15 November 1987, in which crew pairing was again identified as a contributing factor, the NTSB recommended that the

FAA establish minimum experience levels for each pilot-in-command and second-in-command pilot, and that such criteria be used to prohibit the pairing of pilots who have less than the minimum experience in their respective positions. The FAA responded to these recommendations by bringing the crew pairing issue to the attention of air carriers and requesting that they develop, to the extent possible, appropriate crew pairing policies and procedures.

Crew pairing was also recently addressed by the Commission Of Inquiry into the Air Ontario Crash at Dryden, Ontario. It was recommended that TC encourage air carriers which lack pilots with sufficient experience on a new aircraft type to provide highly experienced pilots from outside the air carrier to assist in training the air carrier's pilots and to fly with them until an adequate level of flight experience is gained on the new aircraft type. Additionally, it was recommended that TC proffer for enactment legislation with respect to flight crew pairing. That legislation would require that one of the flight crew members, either the pilot-in-command or the first officer, have substantial flight experience on the aircraft type.

Many factors must be considered when flight crews are made up. Not only must the crew be familiar with the aircraft type, but it should also be familiar with the aspects of the operating environment specific to a particular aircraft, an operating area, the type of operation, the time of day, and, if possible, the crew members should be familiar with each other.

In view of the importance of crew pairing to effective cockpit performance and in view of the many factors which can contribute to poor crew pairing, the Board recommends that:

> The Department of Transport provide guidance for air carriers to assist in the effective pairing of flight crews.

A93-03

4.2.2 Design Eye Reference Point

The accident investigation determined that the captain could not achieve the DERP; his thighs would have interfered with the control column and he would not have been able to achieve full rudder travel. Consequently, from his selected seat position, the captain could not see below the horizon while the aircraft was in level flight in the approach configuration. Like many other company pilots, he was not fully aware of how the safe operation of the aircraft could be compromised if his eyes were not positioned near the DERP.

The Beechcraft C99 was type-certified to FAR 23 which establishes certain cockpit visibility requirements. However, manufacturers are not required to provide guidance to pilots to enable them to position their eyes near the DERP. Furthermore, current pilot training and knowledge requirements do not address the importance of achieving optimum visibility, that is, positioning the eyes at the DERP. Hence, the Board believes that many pilots unnecessarily restrict their visibility, jeopardizing the safe operation of their aircraft, as evidenced by this accident. To assist pilots in optimizing their visibility, particularly for the approach and landing phases of flight, the Board recommends that:

> The Department of Transport take the necessary steps to ensure that pilots receive appropriate guidance for positioning their eyes at or close to the Design Eye Reference Point.
>
> A93-04

4.2.3 *Night Training on Type*

ANOs require air carriers to provide their pilots with certain training before they can serve as flight crew members. This training includes take-offs and landings at night in each type of multi-engine aircraft that the pilot is to fly at night.

Neither of the occurrence pilots had received the required night training on the Beechcraft C99 nor had they received night training for any of the aircraft types that they had flown in the past for any company. For these two pilots, five different companies had not conducted night training on four different aircraft types.

The questionnaire used in the recent TSB survey on Canadian commercial pilots did not specifically address night training on type; however, it did contain a question concerning required recurrent aircraft/emergency training. Fourteen per cent of the pilots surveyed indicated that this training either had never occurred or that it had occurred less frequently than required. The survey also indicated that many pilots feel that TC audits do not go far enough towards actually verifying entries in training records.

In view of the special skills needed for safe night operations, the Board recommends that:

> The Department of Transport validate its current procedures for checking that air carriers provide the required multi-engine night training.
>
> A93-05

4.3 *Safety Concern*

4.3.1 *Terrain Avoidance Equipment*

Altitude alerters, radar altimeters and GPWS can warn flight crews of an inadvertent approach to terrain. Since GPWS became mandatory equipment on larger passenger-carrying aircraft, the number of controlled flight into terrain (CFIT) accidents has decreased markedly for these aircraft. However, smaller aircraft, such as the one in this occurrence, do not require this type of warning equipment.

The Board notes with concern that, between 1976 and 1990, there were 170 CFIT accidents with 152 fatalities involving Canadian-registered, commercially operated small aircraft. In view of the frequency and severity of such accidents, and the improved safety that has resulted from the use of GPWS in larger aircraft, the Board may conduct a study of CFIT accidents in small commercial aircraft.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Gerald E. Bennett, Zita Brunet, the Hon. Wilfred R. DuPont and Hugh MacNeil, has authorized the release of this report.

Appendix A - VOR Approach 24

VOR RWY 24 D.E M.&R MOOSONEE MOOSONEE ONTARIO

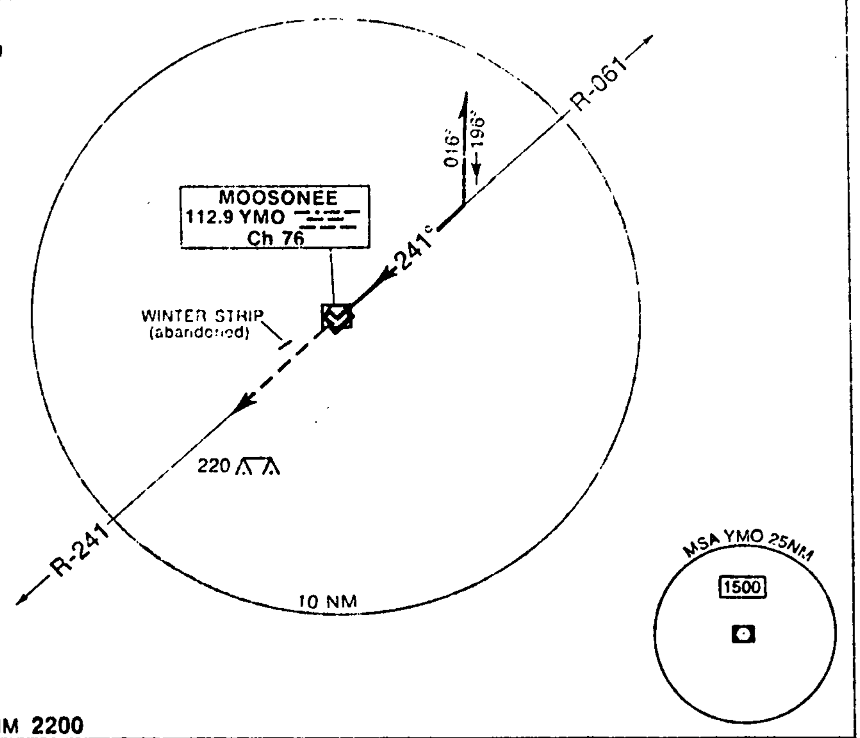
ARR	UNICOM	DEP	
TIMMINS 126.7	122.8 (ATF 5NM) O/T TFC 122.8	TIMMINS 126.7	ELEV 30 / TDZE 24 25

CYMO

Winter strip abandoned. Do not use.

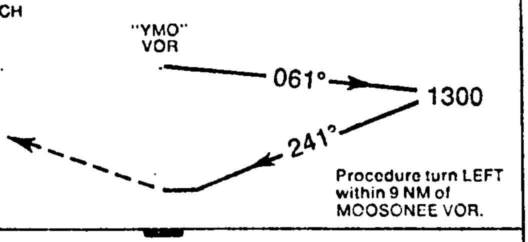
Obtain Moosonee altimeter setting from Timmins radio or Moosonee UNICOM before commencing IFR procedure.

Verify runway unobstructed when A/G advisory not available.

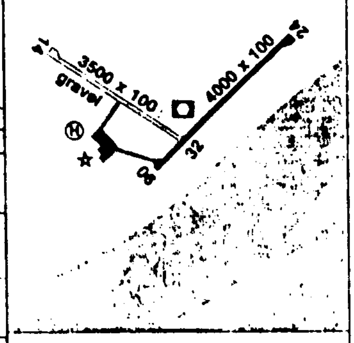


SAFE ALT 100 NM 2200

MISSED APPROACH Climb to 1300 on R-241. Return to MOOSONEE VOR.



CATEGORY	A	B	C	D
VOR	440	(415)	1	
CIRCLING	540 (510) 1½		540 (510) 2	640 (610) 2



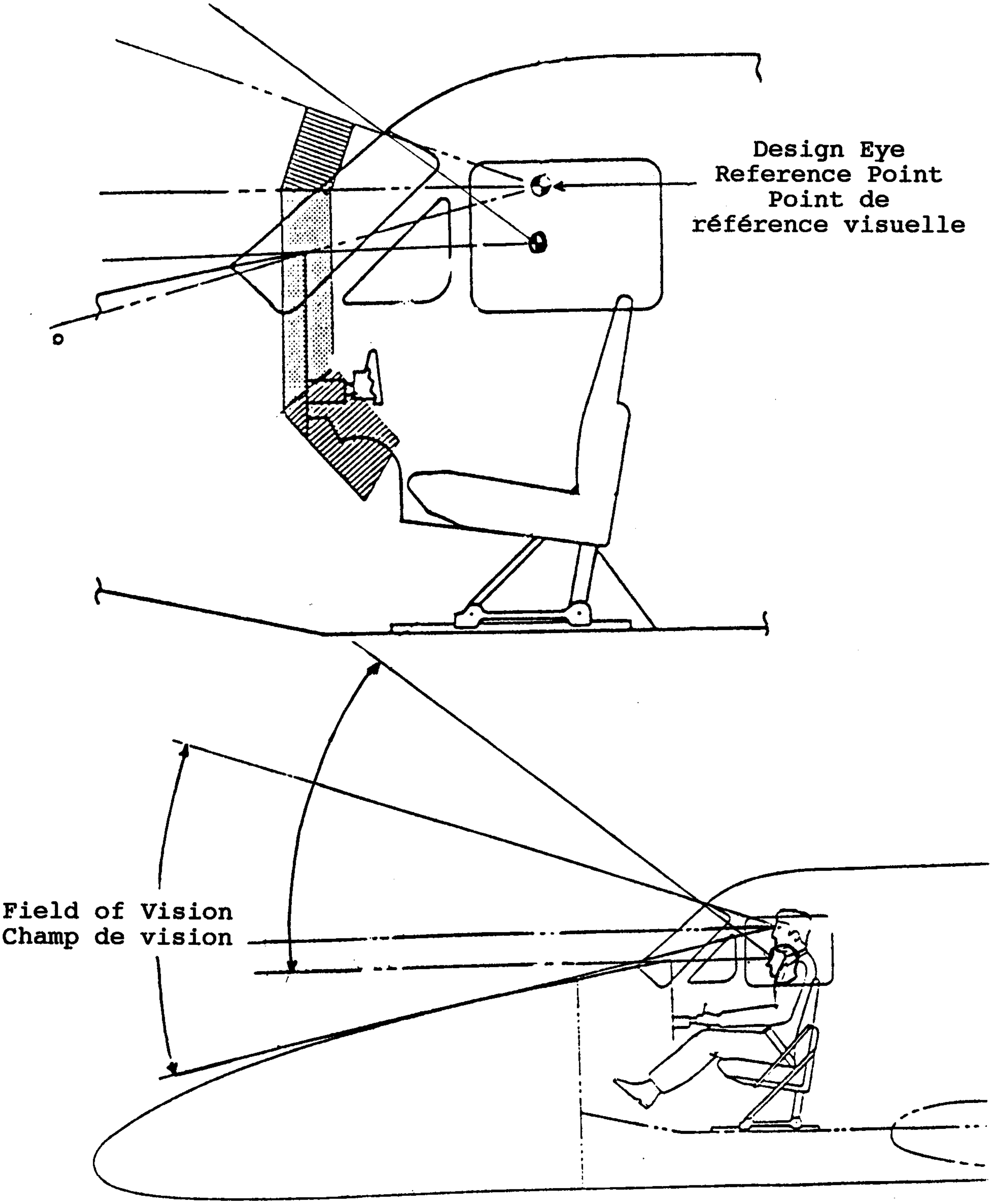
Knots	70	90	110	130	150
Min: Sec					

VOR RWY 24 N51 17 20 W80 36 29 VAR 13°W MOOSONEE ONTARIO MOOSONEE

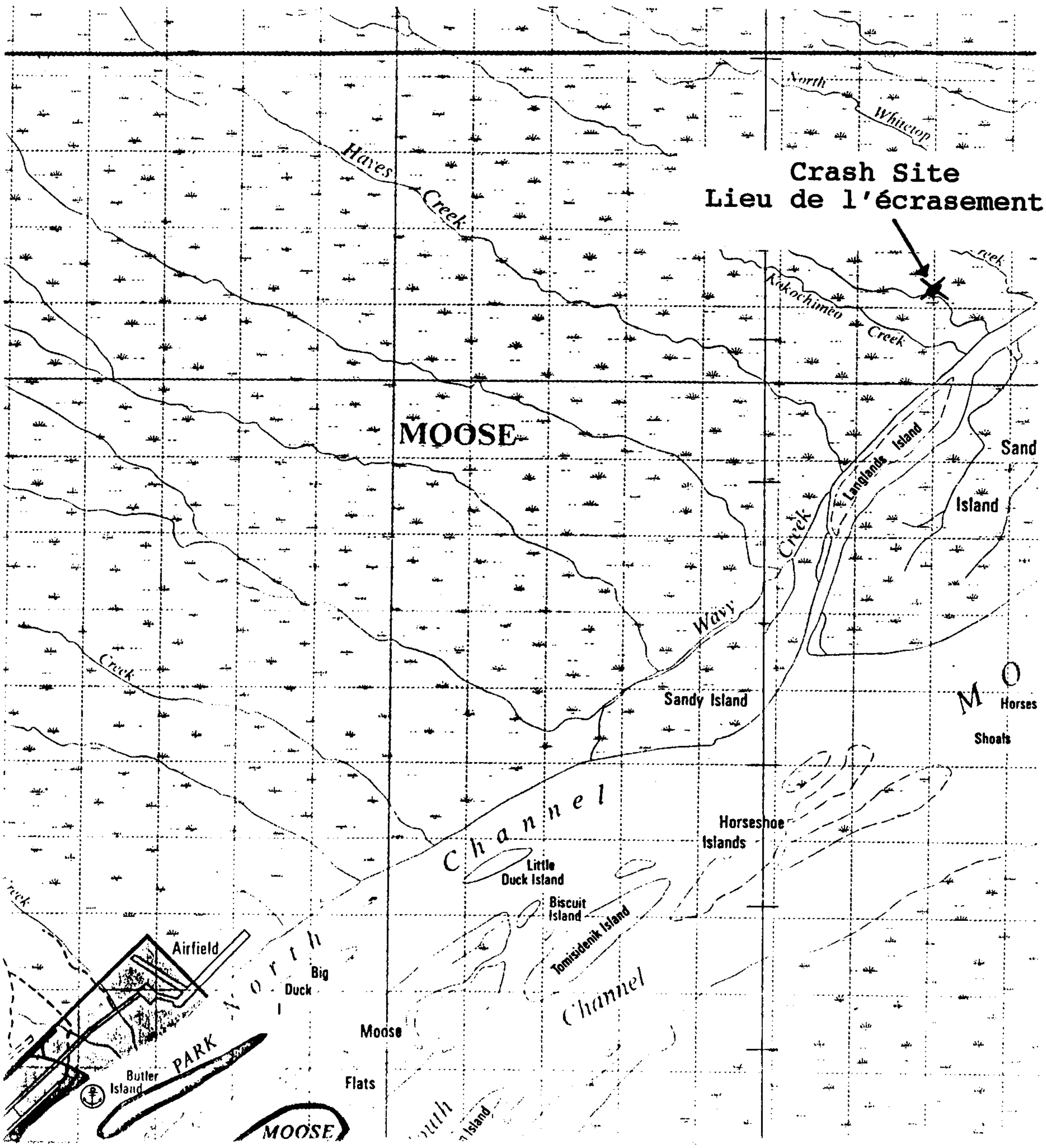
EFF 11 JAN 90 *CHANGE:* ARR & DEP freqs added

Appendix B - Visibility Changes

VARIATION IN FIELD OF VISION BASED ON EYE POSITION
VARIATIONS DU CHAMP DE VISION SELON LA POSITION DES YEUX

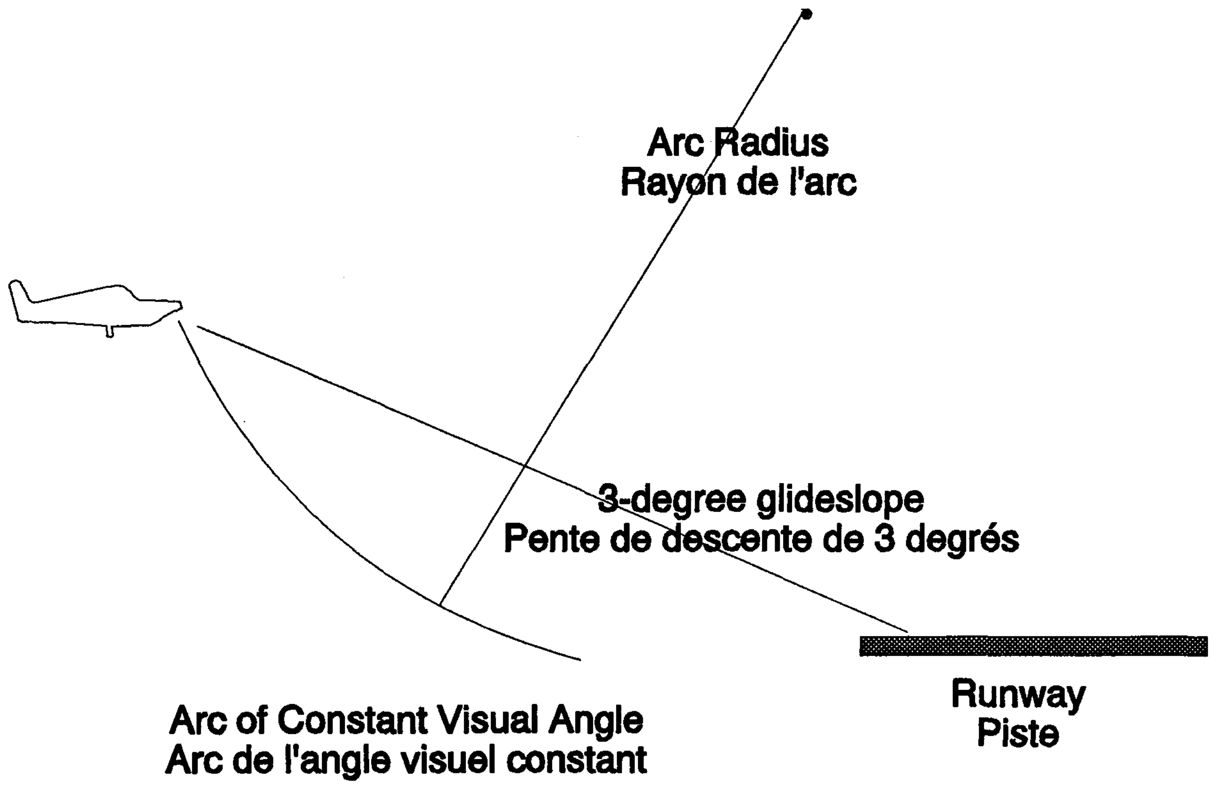


Appendix C - Crash Site and Surroundings



Moosonee Airport
Aéroport de Moosonee

Appendix D - Arc of Constant Visual Angle



Appendix E - List of Laboratory Reports

The following laboratory report was completed:

LP 63/90 - Instrument and Light Bulb Analysis.

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

Appendix F - Glossary

agl	above ground level
AIP	Aeronautical Information Publication
ANO	Air Navigation Order
ANS	Air Navigation Services
ASI	approach slope indicator
asl	above sea level
ATPL	Airline Transport Pilot licence
ATS	Air Traffic Services
CASB	Canadian Aviation Safety Board
CFIT	controlled flight into terrain
CRM	Cockpit Resource Management
CVR	cockpit voice recorder
DERP	Design Eye Reference Point
DME	distance measuring equipment
EDT	eastern daylight time
ELT	emergency locator transmitter
FAA	Federal Aviation Administration
FACN2	Area forecast be area CN2 (Northern Ontario)
FAR	Federal Aviation Regulations (U.S.A.)
FDR	flight data recorder
fpm	feet per minute
FSI	Flight Safety International
GPWS	Ground Proximity Warning System
ICAO	International Civil Aviation Organization
hr	hour(s)
IFR	instrument flight rules
ILS	instrument landing system
km	kilometre(s)
L	local
lb	pound(s)
MDA	minimum descent altitude
MDAB	Moosonee Development Area Board
NDB	non-directional beacon
nm	nautical mile(s)
NTSB	National Transportation Safety Board
PAPI	Precision Approach Path Indicator System

PDM	Pilot Decision Making
PPC	pilot proficiency check
SOP	standard operating procedures
TC	Transport Canada
TP	Transport Canada Publication
TSB	Transportation Safety Board of Canada
UTC	Coordinated Universal Time
VASIS	visual approach slope indicator system
VFR	visual flight rules
VMC	visual meteorological conditions
VOR	very high frequency omni-directional range
°	degree(s)
'	minute(s)
"	seconds