AVIATION INVESTIGATION REPORT
A98Q0194

LOSS OF CONTROL

AIR SATELLITE INC.
BRITTEN-NORMAN BN2A-26 C-FCVK
POINTE-LEBEL, QUEBEC
07 DECEMBER 1998

Transportation Safety Board
of Canada

Bureau de la scurit des transports

du Canada

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Synopsis

Air Satellite's Flight 501 was scheduled to fly from the airport at Baie-Comeau, Quebec, to Rimouski. After a five-hour delay because of adverse weather conditions, the Britten-Norman aircraft, serial number 2028, took off at 1109 eastern standard time. Eight passengers and two pilots were on board. The reported ceiling was 800 feet, the sky was obscured, and visibility was 0.5 statute mile in moderate snow showers. Shortly after take-off, the aircraft, which was climbing at approximately 500 feet above sea level, pitched up suddenly and became unstable when the flaps were retracted while entering the cloud layer. The pilot-in-command pushed the control column down to level the aircraft. After deciding that the aircraft could not safely continue the flight, he began turning left to return to Baie-Comeau. While turning, the aircraft rolled rapidly to the left and began to dive. The aircraft crashed into the St. Lawrence River approximately 0.5 nautical mile from shore and less than 1 nautical mile from the airport. Four passengers were fatally injured in the crash. Two passengers died while awaiting rescue, which came 98 minutes after take-off. The body of the co-pilot was carried away by the current and has not been recovered. The pilot-in-command and two passengers sustained serious injuries.

Ce rapport est également disponible en français.

1.0 Factual Information

1.1 History of the Flight

1.1.1 Pre-flight Planning and Activities

On 07 December 1998, the Britten-Norman BN2A-26, registration C-FCVK, operated by Air Satellite, was to take off at 0615 eastern standard time[1] for a scheduled flight (ASJ501) between Baie-Comeau and Rimouski, Quebec. The departure was delayed until an area of freezing rain, which was causing severe clear icing, left the Baie-Comeau and Rimouski areas.

The pilot-in-command arrived at the company's premises at the Baie-Comeau airport at approximately 0445 to conduct a walkaround inspection of the aircraft and carry out the pre-flight preparation. While the aircraft was in the Air Satellite hangar, where the aircraft had been placed the night before, the pilot-in-command checked all the systems described in the flight manual. No irregularities were found. At about 0900, the door of the hangar was opened to allow the aircraft to reach the outside temperature. This was done to prevent the snow that was falling from turning to ice on contact with the warm surfaces of the aircraft.

After receiving the relevant weather information, the pilot-in-command filed an instrument flight rules (IFR) flight plan with the flight service station (FSS) in Québec. The plan specified a flying time of 30 minutes to Rimouski and a flight endurance of four hours.

C-FCVK was brought out of the hangar between 1000 and 1015. The pilot-in-command and the co-pilot performed the runup and completed the usual inspection of the aircraft's systems, including the carburettor heat. After being informed that there would be eight passengers, the pilot-in-command asked Air Satellite's flight monitoring attendant to enter 500 pounds of fuel on the Air Satellite weight and balance sheet.

At about 1030, the pilot decided to fill the tanks up with 800 pounds of fuel in case landing would be impossible due to the adverse weather in Rimouski and the marginal conditions in Mont-Joli. The pilot-in-command decided that it was not necessary to de-ice the aircraft. He noticed a very light layer of snow on the wingtips, but the wing surfaces in general, and particularly behind the engines, looked clean. At about 1045, the passengers boarded the aircraft, and the baggage was loaded. At 1048, the co-pilot received the latest weather conditions for Baie-Comeau and Mont-Joli.

1 All times are eastern standard time (Coordinated Universal Time minus five hours). See Appendix D for a glossary of acronyms and abbreviations.

1.1.2 Startup and Taxiing

The pilot-in-command gave the passengers a safety briefing, then taxied to taxiway Delta, where he stopped on the apron. At 1058, the co-pilot, who was in the right-hand seat, contacted the Mont-Joli FSS to request IFR clearance to Rimouski. The FSS specialist first asked the co-pilot to keep clear until five snow removal vehicles had left the runway, then informed her that the preferred runway was Runway 28 and that the wind was calm. He then informed the crew that, after take-off from Baie-Comeau, they would have to proceed to the MIWAK waypoint fix, where they could expect to wait 5 to 10 minutes before continuing the flight to Rimouski. To avoid the expected delay, the pilot-in-command decided to take off from Runway 10, as suggested by the specialist. Finally, at 1103, the pilot-in-command was informed that no delay was expected at the MIWAK fix and that he could take off from Runway 10 or 28. After observing from the wind sock covered with ice that the wind, although calm, was favourable for Runway 28, the pilot-in-command decided to take off from Runway 10.

At 1104, snow removal vehicles cleared the runway and taxiway Delta. Mont-Joli FSS issued a take-off clearance to ASJ501 for a MIWAK One standard instrument departure on Runway 10. The aircraft taxied onto taxiway Delta and turned left onto the runway, taxied toward the threshold of Runway 28, then turned around to taxi to the threshold of Runway 10.

1.1.3 Take-off and Flight

Before taking off, the pilot-in-command briefed the co-pilot on the division of tasks, critical speeds, and the procedure in case of problems. It was agreed that the pilot-in-command was the pilot flying and that the co-pilot would be responsible for air traffic control (ATC) communications, monitoring the instruments, and reporting any irregularities. The selected rotation speed was 65 knots. It was also agreed that, if a failure occurred in IFR meteorological conditions, the pilot-in-command would continue the flight under IFR rules and would return to Runway 10 for an approach using the instrument landing system (ILS). The appropriate communication and navigation frequencies were set accordingly. The pilot-in-command also started the propeller de-icing unit, the stall warning system, the pitot heating, and the windshield heat panel. This procedure is the appropriate procedure for the prevailing weather conditions.

The aircraft, flaps extended 25°, was aligned on the runway centreline, and the pilot-in-command advanced the throttle to full throttle. At 70 knots, he pulled back on the control column for take-off. At 1109, the co-pilot told the Mont-Joli FSS that they had taken off from Runway 10. Forty seconds later, she read back the instructions received from the FSS specialist to contact the Montréal Area Control Centre (ACC) on 134.65 MHz. This transmission was the last received from Flight ASJ501. Shortly after take-off, the pilot-in-command reduced engine power to a climb setting. The aircraft climbed on a runway heading at a climb rate of approximately 500 feet per minute and a speed of approximately 100 knots. At 500 feet above sea level (asl), the airplane turned right to intercept radial 182 outbound of the Baie-Comeau VOR (very high frequency [VHF] omnidirectional radio range), toward the MIWAK waypoint fix, in accordance with the MIWAK One standard departure procedure.

After initiating the turn but before entering the cloud layer, the pilot-in-command retracted the flaps. According to the after take-off checklist, flaps should be retracted before climbing power is set. Almost immediately, the nose of the aircraft pitched up suddenly; the aircraft's general stability seemed greatly reduced. The pilot observed that the aircraft's speed dropped to approximately 70 knots. In response to the aircraft's behaviour, he immediately extended the flaps to 25°, then lowered the nose of the aircraft. He could see the ground through the left window. While making a slightly banked left turn to land on Runway 28, he informed the co-pilot that he was returning to Baie-Comeau immediately. Shortly after beginning the turn, the left wing tilted toward the water, and the aircraft pitched downward. The pilot pulled on the control column and turned the control wheel to the right to level the aircraft. The aircraft crashed into the St. Lawrence River approximately 1 nautical mile (nm) from the end of Runway 10, 0.5 nm from shore. The accident occurred at 1111, in less than two feet of water, during a rising tide. C-FCVK was found at noon by a child watching the river. A helicopter arrived at the crash site at 1236 and had to make two trips. Three people were found on top of the cabin. The last survivors were evacuated at 1247. The three survivors were suffering from hypothermia and had serious injuries.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	—	6	—	6
Missing	1*	—	—	1
Serious	1	2	—	3
Minor/None	—	—	—	—
Total	2	8	—	10

* Missing and presumed drowned.

1.3 Damage to Aircraft

The TSB's investigators had to wait until the police search was completed three days after the accident before they were allowed to examine the crash site. The fuselage forward of the wing, including the cockpit and the first row of passenger seats, was bent 20° to the right of the cabin. The tail, immediately aft of the wing, was almost broken off. The skin of the aircraft was torn behind the rearmost passenger seat, leaving a large hole measuring approximately 60 cm in the left fuselage. The tail remained attached to the main body of the wreckage by the control cables and by some 20 cm of the roof's skin. The tail was bent 30° to the right of the cabin. The wings and the carry-through structure, above the second and third rows of the cabin, had collapsed, crushing the side panels of the fuselage. The floor was crushed upward, with heavy hydraulic deformation.

The two main landing gears tore off on impact and could not be found because they were washed away by the tides and the current. The left stabilizer was bent about 90°. The antenna of the emergency locator transmitter (ELT) was intact. The left wingtip was completely torn off. The right aileron was torn at the inboard end of the wing. The doors were not found.

1.4 Other Damage

An unknown quantity of motor oil was released into the St. Lawrence River when the fill tubes broke on impact.

1.5 Personnel Information

1.5.1 General

	Pilot-in-Command	Co-pilot
Age	40	24
Pilot Licence	Commercial	Commercial
Medical Expiry Date	April 1999	November 1999
Total Flying Hours	1098	679
Hours on Type	234	68
Hours Last 90 Days	82	66
Hours on Type Last 90 Days	82	34
Hours on Duty Prior to Occurrence	6.4	6
Hours off Duty Prior to Work Period	8	8

The crew was certified and qualified for the flight in accordance with existing regulations. The pilots flew regularly between Baie-Comeau and Rimouski, twice a day, five days a week.

1.5.2 Pilot-in-Command

The pilot-in-command obtained his commercial pilot's licence in February 1993. He passed the flight test for his instrument rating on his fourth try, in February 1996. At that point, he had completed 115 hours' instrument time: 57 hours' dual instrument time and 58 hours' instrument ground time, in a flight simulator. Transport Canada (TC) requires a minimum of 40 hours' instrument time, of which not more than 20 hours may be instrument ground time. The following table summarizes the pilot's first three flight tests.

Date of IFR Flight Tests	Evaluation	Comments by Transport Canada Examiner
16 December 1994	Failed	Tracking off centre during automatic direction-finder (ADF) approach. Difficulty with spatial orientation.
09 May 1995	Failed	Did not follow holding pattern entry procedures.
07 June 1995	Failed	During an engine fire exercise in the holding pattern, the pilot shut off and feathered the wrong engine.

From April 1996 to August 1996, the pilot worked for Patrouille aérienne du Québec as a Cessna R182 pilot. In April 1998, he began working for Air Satellite, where he completed just over 20 hours' flying time on the BN2A-26 during his line indoctrination. This was the first time he had been employed to fly multi-engine aircraft. It was also the first time he flew professionally in IFR conditions and with a co-pilot. He passed his pilot proficiency check (PPC) on the BN2A-26 on 12 May 1998; however, the TC inspector felt that seven exercises called for Sbs (satisfactory with briefing). The pilot-in-command had difficulty performing six of the exercises because he did not follow the checklist and the appropriate procedures. Among other things, deficiencies were noted during four IFR approach exercises and two emergency (power loss) exercises. Coordination of the BN2A-26's crew is not evaluated during a PPC for this category of aircraft. After completion of the PPC, the TC examiner mentioned to Air Satellite's operations manager that the pilot-in-command was a rather weak pilot.

Review of the pilot-in-command's training record for flights completed from May 1998 to the end of November 1998 and the information gathered revealed that he had difficulty with IFR flying and did not follow approved checklist procedures rigorously. The pilot-in-command seemed to be unusually nervous in icing conditions. However, during a training flight on a Cessna 335 on 25 November 1998, the company's chief pilot felt that the pilot-in-command's performance was satisfactory.

The data available indicate that, at the time of the accident, the pilot-in-command had nearly 1000 hours' total flying time, including approximately 400 hours on the BN2A. A crosscheck between the aircraft logbook and the weather information shows that the pilot's commercial experience in IFR conditions amounted to about 50 instrument hours, including 30 hours with the occurrence co-pilot. According to the documents available, he had no previous winter experience. His total experience in snow conditions was four days: 20, 26, and 27 November 1998 and 04 December 1998.
The pilot-in-command had obtained his flying instructor and ground-school instructor ratings on the BN2A-26 on 29 September 1998. He received training on contamination of critical surfaces on 03 October 1998. He had not flown since 04 December 1998. On the day of the accident, he got up around 0400.

1.5.3 Co-pilot

The co-pilot began her flight training in February 1996. She received her IFR rating in May 1997, on her second attempt. From June 1997 to September 1997, she worked for Dynamair as an instructor. In September 1997, she was hired by Air Satellite as an instructor and a charter pilot; this was the first time she was employed to fly multi-engine aircraft. It was also the first time she had worked as a commercial pilot in IFR conditions and on an aircraft with a minimum of two pilots. Her PPC on the BN2A-26 took place on 19 June 1998. An SB was entered on the flight test report; the TC check pilot advised her to avoid losing altitude during the stall approach exercise.

She acted as co-pilot on the BN2A-26 when IFR conditions prevailed or as pilot-in-command when the conditions were visual flight rules. In September 1998, the chief pilot made an SB on the co-pilot's last line check for the pre-flight inspection and briefing. On the day of the accident, the co-pilot woke up at 0130 and 0515 to obtain the weather information from the Mont-Joli FSS.

1.5.4 Pilot and Co-pilot Training

1.5.4.1 Initial Company Training

The company required all new crew members to take a three-hour introductory course. The course was supposed to include such topics as flight planning and standard operating procedures (SOPs), wind shear, aircraft icing and other meteorological training relevant to the area of operations, anti-icing and de-icing procedures on the ground, and weight and balance control procedures. No documents indicated that either crew member had taken this course.

1.5.4.2 Flight and Stall Training

As with most small, piston-powered multi-engine aircraft, there is no flight simulator for the BN2A. Training was conducted on the particular aircraft type. During these flights, the aircraft was light and its balance was close to the middle of the prescribed range; these conditions favoured good stall characteristics. In-flight training was conducted in accordance with existing regulations.

1.5.4.3 Wind Shear Training

The dangers associated with wind shear and the recommended procedures when its presence is observed are described in the company operations manual, *Aeronautical Information Publication* (*A.I.P. Canada*), and the BN2A-26 flight manual. Because wind shear is a natural meteorological phenomenon, pilots who do not practise on a flight simulator can have only a theoretical understanding of wind shear or an understanding derived from in-flight simulations. The recovery procedure recommended in *A.I.P. Canada* and in Air Satellite's operations manual is to apply maximum power and the attitude corresponding to the maximum angle of attack. The investigation revealed that, although the pilot had received this training, he did not know the recommended procedures for wind shear.

1.5.4.4 Surface Contamination Training

On 03 October 1998, the crew took a course on aircraft surface contamination. One part of the course used material developed by TC. The information from the course was included in the company operations manual and specified the following:

- In frost or snow conditions, no pilot shall begin a flight unless the aircraft has been inspected to determine whether frost, ice, or snow is adhering to its surfaces.
- The performance of an aircraft may be seriously affected by frost, ice, or snow accumulating on the wings and the control surfaces, primarily because such accumulation disrupts the regularity and uniformity of the airflow over those surfaces.
- Frost or ice on a wing increases the stall speed and reduces the rate of climb.
- When an aircraft has been de-iced in a heated hangar and pushed outside in below-zero temperatures, the pilot should be particularly attentive to freezing of wet surfaces, formation of frost, and sublimation of water vapour into ice crystals.
- When an aircraft taxis through slushy or wet conditions, the crew should be particularly vigilant for contamination of the wheel wells, the lower surface of the aircraft, and the control surfaces.

1.5.4.5 Crew Resource Management and Pilot Decision-Making Training

Neither the pilot nor the co-pilot had taken TC-recognized courses on pilot decision making (PDM) or crew resource management (CRM). Although CRM and PDM training are known to improve air safety, Air Satellite's pilots were not required to take these courses.

1.6 Aircraft Information

1.6.1 General

Manufacturer	Britten-Norman Ltd.
Type and Model	BN2A-26
Year of Manufacture	1986
Serial Number	2028
Certificate of Airworthiness	27 October 1988
Total Airframe Time	9778
Engine Type (number of)	Lycoming O-540-E4C5 (2)
Propeller Type (number of)	Hartzell HC-C2YK-2CFU (2)
Maximum Allowable Take-off Weight	6600 pounds
Maximum Allowable Landing Weight	6300 pounds
Recommended Fuel Type(s)	Avgas 100 LL
Fuel Type Used	Avgas 100 LL

1.6.2 Aircraft Information

The Britten-Norman Islander is a high-wing twin-engine aircraft that can carry eight passengers and two pilots. The tops of the horizontal surfaces are more than six feet above the ground. The aircraft was certified for flight in known icing conditions. Because the aircraft did not have an autopilot system, the minimum crew for IFR flight was two pilots. The aircraft has three doors that are also used as emergency exits.

A 100-hour inspection was done on 23 November 1998, approximately 26 flight hours before the accident. The maintenance records indicate that all components were functioning on the morning of the accident. All irregularities indicated in the logbook had been corrected, except a high oil temperature reported on 23 November 1998.

1.6.3 Weight and Balance

The maximum allowable take-off weight was 6600 pounds, and the maximum allowable landing weight was 6300 pounds. Air Satellite's flight monitoring attendant completed the weight and balance form and the load sheet, both of which indicated a total weight of 6368 pounds. The weight of the occupants was based on the approved standard summer weights, without carry-on baggage, given in the company operations manual. According to regulations, summer weights may be used until December 14, unless it is obvious that the actual weights are higher.

	Summer Weight	Winter Weight
Man	174 pounds	180 pounds
Woman	127 pounds	133 pounds

The baggage of the passengers (three women and five men) was weighed at the company's counter. The weight of the pilots' baggage was not entered on the load sheet, however; nor was it calculated on the weight and balance form. According to the company's form, the aircraft's weight and balance were within the prescribed limits for take-off from Baie-Comeau and for the scheduled landing in Rimouski 30 minutes later.

To determine whether the aircraft's weight and balance could have affected the BN2A's flight characteristics and performance, the actual weights and their distribution on board the aircraft were estimated. The weight of the occupants was obtained from autopsy reports, information gathered, and medical reports. An additional 8 pounds per person was added, because the weights indicated did not include the weight of clothing. *A.I.P. Canada* indicates that, based on a survey, at least 8 pounds should be added to the summer weight and 14 pounds to the winter weight. The baggage could not be weighed after the accident because it was lost in the tide before the aircraft was salvaged. For weight and centre of gravity calculations, the TSB used the baggage weight as given by the company, that is, 180 pounds. An additional 20 pounds was added for the crew's baggage. This weight is conservative because no weight was entered for the total weight of the passengers' carry-on baggage.

The company's fuelling log indicates that the pilot added 233 L (380 pounds) of fuel to the aircraft's tanks before boarding. Given that the aircraft's fuel capacity was approximately 780 pounds, it may be concluded that 400 pounds of fuel was on board the aircraft before fuelling. Existing regulations required the pilot to take off with enough fuel for a flight lasting 1 hour 55 minutes. Because hourly fuel consumption was 200 pounds, the flight needed 385 pounds of fuel.

According to the TSB's estimates, the aircraft's actual weight at take-off was 6813 pounds. This estimate varies from the weight calculated by the flight monitoring attendant because of two significant discrepancies: the weight of the occupants and the weight of the fuel. It can be concluded that the aircraft was overweight at take-off and that it would have been overweight if it had landed at Rimouski after a 30-minute flight, as intended by the pilot.

Another factor that influenced the aircraft's performance at take-off was the snow accumulation on the aircraft before take-off, because the aircraft spent an hour outside while moderate snow, with a relatively high water content, was falling.

1.6.4 Flight Controls

Witness marks on the aileron hinge points and the hydraulic deformations that they sustained on impact indicate that the aileron controls were set to bank the aircraft to the left. The elevator was not damaged, except for a slight upward deformation on the left. Its servo tab was set to exert upward pressure on the elevator. The tail fin was not damaged. The recommended flap settings are 56° for landing, 25° for take-off, and flaps up for the best rate of climb. The flaps were extended 25°.

The control system was significantly damaged, but its integrity was confirmed. Examination of all components recovered showed no pre-impact failure or malfunction.

1.6.5 Electrical System

After the aircraft was salvaged, examination of the circuit-breaker panel showed that the circuit breakers for the engine revolution indicator and the audio system were open. Examination of the cables revealed no irregularities. Because no defects were reported by the pilot, it was concluded that the impact blew the breakers.

Functional testing of the two alternators was not possible because of the extent of the damage from corrosion caused by prolonged immersion in the river. Examination of the components revealed that the four alternator brushes were severely worn. The brushes, which measure 0.500 inch, are normally replaced when wear reaches the witness mark at 0.250 inch. The four brushes were worn to 0.220 inch, 0.242 inch, 0.090 inch, and 0.140 inch, respectively. According to the company's inspection program, the alternator and its belt were supposed to be checked at the 100-hour inspections. No irregularities were detected during the last inspection, performed on 23 November 1998.

1.6.6 Anti-icing and De-icing System

The anti-icing and de-icing system included a heating plate in the windshield in front of the pilot-in-command, electrically heated de-icing strips on the two propellers, de-icing boots on the wings, tail fin, and stabilizer, and a heating element for the pitot heat and the stall warning system. The switches for the pitot / stall warning system and the propeller system were switched to "on"; the other two were in the "off" position. The integrity of the electrical system was established.

1.6.7 *Flight Instruments*

The basic flight instruments—namely the attitude indicator, airspeed indicator, altimeter, turn and bank indicator, vertical speed indicator, and horizontal situation indicator—were in front of the pilot, on the left side of the instrument panel. The radio panel and the stall indicator were in front of the co-pilot, on the right side of the instrument panel. Because of corrosion, examination of the flight instruments did not reveal any relevant information.

1.6.8 *Stall Warning System*

The stall warning system includes a stall indicator that gives an audible and a visual warning, a lift sensor vane in the leading edge of the left wing, and an electrical circuit connecting the sensor to the indicator. Examination of the wreckage revealed that the right screw and nut attaching the lift sensor to the wing were missing. Although analysis of the sensor showed that the screw was not in place before the accident, it was not possible to determine how long the screw had been missing. On the ground, the system functioned normally; but in flight, the housing for the detector could pivot around the left screw and prevent the vane from closing the circuit when the aircraft approached a stall. The stall warning alarm did not sound during stall exercises performed shortly before the accident. The missing screw was not recorded in the aircraft logbook.

1.6.9 *Seat Belts*

The passengers were in their seats with their seat belts fastened at the time of impact. The crew members were wearing a lap belt and a diagonal harness that are part of a common system, a shoulder harness, that cannot be separated. The shoulder harness was attached to an inertia reel mounted on either side of the internal partition, close to the door mounts.

The pilot-in-command's nylon harness was partly frayed and showed signs of air friction heating. This damage probably occurred as the strap rapidly deployed and then suddenly stopped. These signs indicate that the shoulder harness functioned correctly, preventing the pilot from striking the instrument panel.

The co-pilot's shoulder harness was replaced on 21 April 1996. The inertia reel was not installed in accordance with Britten-Norman's installation standards. The reel, which was mounted vertically, was firmly attached to the door post, and the strap was turned backward. The reel should have been mounted horizontally and left free to pivot around the attachment point, and the strap should have been turned upward. Consequently, the strap was not able to stop correctly on impact and did not keep the co-pilot in place. Examination of the co-pilot's shoulder harness did not show any damage characteristic of rapid deployment and sudden stopping.

1.6.10 *Emergency Locator Transmitter*

The ELT (Artex 00-10-99, Narco Avionics, serial number 47005) was installed on 24 October 1988 on a mounting plate attached to the flooring behind the baggage hold bulkhead, at station 309.8. The ELT met regulatory requirements. Its housing was not water resistant. Its battery was due for replacement in

November 1999. The force of the impact bent the floor upward, deforming the ELT mounting plate. Consequently, the ELT was ejected from its position and landed on the floor. The ELT was on “arm” so that it would activate automatically on impact. The ELT was capable of functioning for a short time before being damaged in the salt water. Tests have shown that a short circuit occurs when the antenna connection contacts the water surface. The antenna, on the roof of the empennage, was attached to the ELT and sustained no damage. There was no switch for the ELT in the cockpit, even though, according to Britten-Norman, the pilot should have been able to turn the ELT on from the cockpit by means of a concealed switch. Functional testing of the ELT was not possible because of extensive corrosion. However, no irregularities were seen upon examination.

Modification Instruction NB-M-676, Part D, issued by Britten-Norman, recommends installing the ELT as far up the left wall of the baggage hold as possible, at station 255.25. Because an impact generally causes less deformation to the walls than to the floor, a wall mount lessens the risk that the ELT will be damaged or ejected in an accident. According to Britten-Norman, the recommended installation ensures the integrity of the control cables on the floor of the aircraft and facilitates access to the ELT.

The *Canadian Aviation Regulations Standards* (CARs Standards) give a general description of the ELT location. CARs Standard 551.104(c)(2)(v) states that “ELTs shall be located and mounted so as to minimise the probability of damage to the transmitter and antenna by fire or crushing as a result of crash impact.” The ELT installation was approved by a TC inspector.

1.6.11 Engines and Propellers

The pilot-in-command did not observe any engine irregularities before or during the flight. Examination of the wreckage showed that the engine controls were locked on a power setting of approximately 75 per cent.

1.6.11.1 Engines

The engines were maintained according to an on-condition maintenance program. Because of impact damage, examination of the engines had to be limited to the mechanical integrity of the assemblies. The two engines were functioning on impact. However, the examination could not determine how much power they were producing.

Examination of the left engine revealed the following irregularities:

- The gasket for the oil tank had been repaired with sealant.
- The rocker arms for cylinder No. 6 had been reversed at installation.
- Cylinders Nos. 2, 4, 5, and 6 showed signs of significant blow-by.
- The compression rings for pistons Nos. 1, 2, and 4 were broken.
- Two of the six cylinders showed signs of blow-by and had broken compression rings.

Blow-by and/or broken compression rings may result in high oil consumption and loss of power.

Examination of the right engine revealed the following irregularities:

- The model used for piston No. 3 was incorrect; a low-compression model had been installed instead of a high-compression one.
- Pistons Nos. 1, 2, 4, 5, and 6 showed signs of significant blow-by.
- The compression rings on pistons Nos. 1, 4, 5, and 6 were broken.
- The head of piston No. 5 was punctured.
- The wear on piston No. 6 exceeded the manufacturer's standards.
- Piston No. 6 was cracked on the bottom of the forward scallop.

Normally, these irregularities would lead to a decrease in power and engine vibrations, although no vibration or power loss was reported.

A significant increase in consumption of motor oil was noted in the aircraft logbook on 01 December 1998. Average hourly consumption by the left engine increased from 0.23 L to 0.80 L, while that of the right engine rose from 0.30 L to 0.88 L.

According to the maintenance schedule, one cylinder in each row should have been removed to allow internal examination of the engines. This examination should have been entered in the engine log. No documentation indicating that this work had been done was found in the aircraft technical records.

1.6.11.2 Propellers

Both propellers showed similar damage. The impact left two marks on the right propeller's pre-load plate, corresponding to blade angles of 12° and 18°. Because blade angle tends to decrease on impact, it may be concluded that the blade angle was 18° before the crash. A blade angle of 18° is typical of an aircraft flying at low speed with a moderate to high engine setting. The right propeller had no impact marks. Neither propeller showed any sign of pre-impact failure. The condition of the two propellers and the similarity of the damage indicate that they were producing an equivalent amount of thrust at impact.

1.6.12 Technical Records and Airworthiness

The TSB reviewed the aircraft's technical records and found the following irregularities:

- There was no technical record for the on-condition maintenance program for the engines. No technical entries were found regarding the condition of the engines or the inspection required under the program approved by TC. The engine inspection program had not been followed.

- *Airworthiness Directive* CAA 008-10-96 was entered in the technical logs in September 1998, whereas it should have been entered in October 1997.

- *Airworthiness Directive* CAA 009-10-97 was carried out in September 1998, whereas the prescribed limit was October 1997.

- *Airworthiness Directive* CAA 011-10-97 was carried out in September 1998, whereas the prescribed limit was October 1997.

- *Airworthiness Directive* CAA 009-05-95 was not carried out between September 1995 and November 1998. This directive should have been carried out after 500 hours' flying time.

- The two magnetos were replaced on the left engine; no technical entry was made in the engine log, and the serial numbers of the magnetos were not entered in the technical log.

- No action had been taken regarding the "Oil temp high" defect recorded in the aircraft logbook on 23 November 1998.

To maintain an aircraft's airworthiness, the following conditions must be met:

- Maintenance of the aircraft must be performed according to an approved maintenance program and maintenance schedules.
- Any irregularities discovered must be rectified immediately, unless they are deferred according to the company's maintenance control manual (MCM).

1.6.13 Take-off Performance

It was reported that the aircraft lifted off immediately before taxiway Delta, after a take-off roll of some 3700 feet. The manufacturer calculated that, with flaps extended 25° and a weight of 6850 pounds at take-off, the distance required for the aircraft, without any accumulation of snow or ice, to take off from a paved, dry runway was approximately 1200 feet. According to Britten-Norman, the difference between the observed ground roll and that calculated may be attributed to a combination of all or some of the following factors: tailwind component greater than reported, aircraft weight greater than 6850 pounds, snow-covered runway, snow or ice on aircraft surfaces, and decrease in engine power. In fact, the manufacturer calculated that, even at a weight of 7500 pounds, the take-off roll for a BN2A-26 would be 3000 to 3500 feet on a runway covered with 2 cm of snow and with a tailwind component greater than 8 knots, as reported at the time of the accident.

1.6.14 Flight Characteristics During a Stall

According to Britten-Norman, the aircraft's stall is smooth in all configurations. For this reason, the stall warning system, which gives a visual and an audible warning, activates well before a stall. If the recovery procedure is implemented without delay, the aircraft loses little altitude. According to reports on flight tests conducted by Britten-Norman, in case of stall, the BN2, at a weight of 6600 pounds, has never lost more than 100 feet of altitude, the change in pitch attitude has never exceeded 30°, and yaw and bank attitude have never exceeded 15°. The aircraft's stall characteristics were unchanged at a weight of 6900 pounds. During power-on stalls, the nose-up angle was high and could reach 35 to 40°. The aircraft's stall speed, at a weight of 6850 pounds and with engines on, was approximately 49 knots.

1.6.15 Operational Considerations in Case of Snow or Ice on Critical Surfaces

The certification of the BN2A-26 prohibits take-off when frost, ice, or snow has accumulated on the wings, control surfaces, propellers, stabilizers, or vertical tail surfaces. The manufacturer does not have any aerodynamic performance data for the BN2A-26 when the surfaces are contaminated. However, Britten-Norman believes that the presence of snow or ice may displace the centre of gravity to the aft limit, abnormally lessening the control forces load. Normally, the aircraft noses down slightly when the flaps are up, and force must be applied on the control column to offset this tendency. If an equivalent force is applied when the surfaces are contaminated and when the aerodynamic load on the controls is low, the aircraft will suddenly pitch up.

1.7 Meteorological Information

Atmospheric environment service (AES) weather reporting stations are located at the Baie-Comeau and Mont-Joli airports, but not at the Rimouski airport. The AES station closest to Rimouski is Mont-Joli, 14 nm to the northeast. The pilots used weather information from Baie-Comeau and Mont-Joli to plan the flight to Rimouski.

1.7.1 Area Forecasts

The area forecast, valid on 07 December 1998 from 0600 to 1800, was issued at 0630 by the AES station in Mont-Joli. In summary, a cold front was east of Baie-Comeau and heading southwest. After the passage of the cold front, the forecast called for ceilings at 3000 feet asl and visibility reduced to 4 statute miles (sm) in rain and mist. Convection clouds were forecast, with rain showers that might reduce visibility to 1 to 3 sm. Precipitation north of the frontal wave would change to snow. Ceilings of 400 to 1200 feet were forecast for the area of precipitation. The wind was blowing out of the west at around 20 knots gusting to 30 to 35 knots.

Light to moderate rime icing was in clouds above the freezing point, which was at or near ground level. Moderate mixed icing was expected in the convection clouds. Moderate mechanical or wind shear turbulence, changing to strong at times, was forecast below 5000 feet, particularly near the cold front. Convection turbulence was also expected near convection clouds.

At 0621, the Québec FSS specialist told the pilot to expect wind shear turbulence and strong wind when the cold front passed through Baie-Comeau at about 1100.

1.7.2 Aerodrome Forecasts

The morning of the accident, the actual conditions were systematically worse than stated in the aerodrome forecasts. During the 0820 and 0912 weather briefings, the Québec FSS specialist specifically warned the pilot that the aerodrome forecasts were somewhat inaccurate and that conditions would be worse than anticipated. The pilot-in-command used the Mont-Joli forecasts to select the Mont-Joli airport as an alternate aerodrome.

The Mont-Joli aerodrome forecast, issued at 0917 and valid from 0900 to 1800, was as follows: wind 040° true at 10 knots, visibility 1 sm, light ice pellets in mist, and overcast ceiling at 300 feet. Between 0900 and 1000, a temporary fluctuation: visibility 4 sm in light freezing rain and mist, and overcast ceiling at 1500 feet. At 1000, a permanent change: wind 240° true at 12 knots, visibility more than 6 sm in mist, and overcast ceiling at 3000 feet. Between 1000 and 1100, a temporary change: visibility 1 sm in light snow, ice pellets and mist, and overcast ceiling at 1500 feet. At 1100, a permanent change: wind 280° true at 20 knots gusting to 30 knots, visibility more than 6 sm and broken ceiling at 3000 feet. Between 1600 and 1800, a temporary change: scattered clouds at 3000 feet. These forecasts were available to the crew before departure from Baie-Comeau.

After the accident, a new forecast was issued at 1121 for the Mont-Joli airport, valid from 1200 to 2400. Between 1200 and 1300, the following conditions were expected: wind 280° true at 10 knots gusting to

20 knots, visibility 0.5 sm, and moderate snow showers reducing visibility and ceiling at 200 feet.

1.7.3 Regular Weather Reports

Regular weather reports are usually prepared and issued every hour. During the morning, frequent meteorological changes required special weather observations for both airports. The following pertinent weather reports were issued at Baie-Comeau:

- Baie-Comeau, corrected at 1000: Wind calm, visibility ½ sm, moderate snow, sky obscured and vertical visibility of 1000 feet above ground level (agl), temperature 0°C, dew point 0°C, and altimeter setting 29.35 inches of mercury (inHg). Remarks: snow covering sky 8/8, snow accumulation 3 cm (after passage of the cold front at about 0830).

- Baie-Comeau, Special observation at 1029: Wind calm, visibility ¾ sm, light snow, sky obscured and vertical visibility of 1000 feet agl. Remarks: snow covering sky 8/8, recent moderate snow.

- Baie-Comeau, Special observation corrected at 1035: Wind calm, visibility 1¼ sm, light snow, overcast ceiling at 1500 feet agl. Remarks: snow covering sky 2/8, stratus 6/8, recent moderate snow.

- Baie-Comeau, 1100: Wind calm, visibility ½ sm, moderate snow, sky obscured and vertical visibility of 800 feet agl, temperature 0°C, dew point 0°C, altimeter setting of 29.35 inHg. Remarks: snow covering sky 8/8, snow accumulation 4 cm (after passage of the cold front around 0830).

The corrected special observation issued at 1035 was the last the crew received from Baie-Comeau. According to subsequent reports, 5.4 cm of snow fell between 0830 and 1300, and 1 cm fell between 1000 and 1100. Although the 1100 report indicated a temperature of 0°C , the actual temperature was -0.2°C. Conditions remained marginal until 1237 with ceilings at 200 feet agl. During the morning, equipment for measuring the wind could not be used because of the freezing rain. At 1129, based on the position of the wind sock, the observer estimated the wind to be 230° true at 7 knots. However, the cloth cone on the wind sock was covered with ice, increasing its weight.

The following pertinent weather reports were issued at Mont-Joli:

- Mont-Joli, 1000: Wind 10° true at 4 knots, visibility 1½ sm, light snow and ice pellets in mist, overcast ceiling at 400 feet agl, temperature -1°C, dew point -1°C, altimeter setting of 29.35 inHg. Remarks: stratus 8/8.

- Mont-Joli, Special observation at 1014: Wind 290° true at 5 knots, visibility ¾ sm, runway visual range 5000 feet for Runway 06, light snow, obscured sky and vertical visibility of 300 feet agl. Remarks: snow covering the sky 8/8.

The special observation issued at 1014 was the last received from Mont-Joli by the crew. The two subsequent reports indicated a visibility of ½ sm and a ceiling of 200 feet until 1156.

1.7.4 Analysis of Weather Conditions by Environment Canada

Environment Canada analyzed the area forecast, the aerodrome forecasts, and the data from the weather reports. According to Environment Canada, the most probable conditions at about 1100 near the Baie-Comeau airport are as follows: wind 230° true at 5 to 8 knots, snow showers reducing visibility to nearly ½ sm, and snow ceilings varying between 400 and 800 feet. The snow had a high water content that could result in significant icing conditions on cold objects. The reduction in visibility to ½ sm in moderate snow suggests the presence of convection clouds in the immediate area of the airport. These clouds could have generated downdrafts, causing turbulence near the ground. Moderate wind shear was probable under 3000 feet.

1.7.5 Other Information

A Cessna 310 left Air Satellite's hangar a few minutes before C-FCVK. Approximately 20 minutes later, after refuelling, the pilot of the Cessna 310 decided to brush the snow off the aircraft with a broom. The aircraft was covered with approximately 1 cm of wet snow that was sticking "a little" to the surfaces. The aircraft took off from Baie-Comeau on Runway 28 at 1039. At about 1055, the pilot of the Cessna 310 informed the crew of C-FCVK that he had observed a little rime icing on the leading edge of the wings while climbing at 4000 feet.

1.8 Aids to Navigation

Runway 10 at the Baie-Comeau airport was served by an ILS that allowed Category I approaches. The ILS decision height was 200 feet above the touchdown zone.

The Rimouski airport was served by the Mont-Joli VOR/DME (VOR / distance-measuring equipment) and by a nondirectional beacon (NDB). These navigational aids allowed circling approaches on runways 07 and 25. Because the aircraft was not equipped with a DME, only the NDB A approach was allowed. The minimum descent altitude was 640 feet asl.

The Mont-Joli airport was served by a VOR/DME, an NDB, and an ILS. The pilot could make a precision approach on Runway 06, which had a decision height of 392 feet asl (250 feet above the touchdown zone).

The BN2A-26's equipment included two NAVCOM radios. The pilots could switch between the active and standby frequencies by pushing a button. The frequencies were set for the planned flight and, in case of emergency, a return to Runway 10 at the Baie-Comeau airport. The aircraft also had a transponder, two ADFs, and a global positioning system. The flight took place below radar coverage, which starts around 6000 feet in the Baie-Comeau area.

1.9 Communications

The pilots wore communication headsets. A pushbutton on the control column was used to operate the VHF radio. All communication equipment was functioning normally. Examination of the radio communications revealed no technical irregularities in the radio equipment. Communication between the flight crew and the FSS specialist was normal and followed established rules. The co-pilot was responsible for communication with ATC. However, the pilot decided to communicate directly with the Mont-Joli FSS to establish the expected delay at the MIWAK fix.

The VHF radio transmitter-receivers were operating and set for the following frequencies:

Radio	Active Frequency	Standby Frequency
COMM No. 1	118.30 MHz (Mont-Joli FSS)	134.65 MHz (Montréal ACC)
COMM No. 2	131.95 MHz (Air Satellite)	126.70 MHz (en route)

The COMM selector on the audio panel was on COMM No. 1. The Montréal ACC frequency had not yet been activated even though, after take-off, the co-pilot had agreed to a request from the Mont-Joli FSS to contact the Montréal ACC.

1.10 Aerodrome Information

The Baie-Comeau airport is in the municipality of Pointe-Lebel and is operated by the Regional Municipality of Manicouagan County. It is certified by TC and meets the CARs requirements. The airport has been an uncontrolled airport since TC closed the control tower in 1995; that is, the airport no longer has airport controllers to control ground traffic and local air traffic. However, a control tower is still adjacent to the terminal building. The control tower is in front of taxiway Delta, 0.5 nm from the end of Runway 10 and approximately 1.3 nm from the accident site.

The airport is served 24 hours a day by FSS specialists at the Mont-Joli FSS. The FSS specialists use a remote communications outlet (RCO) to provide flight information to aircraft flying near the Baie-Comeau airport.

When the tower was closed, all radio transmitter-receivers were removed, including the one tuned to the emergency frequency of 121.5 MHz. Consequently, the Baie-Comeau RCO could not relay the ELT signal to the Mont-Joli FSS. There are no standards or regulations requiring installation of the emergency frequency at airports served by an RCO. Shortly after the accident, Nav Canada installed the 121.5 MHz frequency at the Baie-Comeau airport.

The tower, which gives an unobstructed view of the runway and the approaches, was not occupied at the time of take-off. At about 1150, the airport manager went to the tower to try to locate the aircraft, but was not successful. The TSB investigation established that a controller would not have been able to see the aircraft after the crash, even from the roof of the control tower, because of trees obstructing the view.

The Baie-Comeau airport is 71 feet asl. Runway 10 is asphalted and is 6000 feet long by 150 feet wide. Its slope is negligible. The runway had been partly cleared immediately before the aircraft taxied onto it. A surface report was done approximately four minutes after the accident; a strip 100 feet wide had been cleared along the centre of the runway, and the runway was completely covered with an uneven layer of snow that was up to 7.6 cm deep in some areas.

1.11 Flight Recorders

The aircraft was not equipped with flight recorders, nor were any required.

1.12 Wreckage and Impact Information

The aircraft crashed into the St. Lawrence River approximately 1 nm from the end of Runway 10, 0.5 nm from the shore. The tide had been rising since 1000, and the water temperature was 1°C. Using data provided by the Canadian Hydrographic Service of Fisheries and Oceans Canada, the water depth at the accident site was estimated as follows:

Time	Water Depth (inches)

1111 (accident)	20
1200 (aircraft found)	41
1236 (first rescue)	51
1247 (second rescue)	56

From this information it can be determined that the water in the cabin was at most 50 inches deep. The damage to the wings and the stabilizer indicates that the aircraft was banked 19° to the left when it struck the surface of the water. Examination of the floor of the aircraft and the tail skid revealed that the aircraft had a nose-up angle of approximately 3° at the time of impact. The tail fin was intact; there was no sign of the deformation or distortion normally associated with a violent impact. The damage to the landing gear indicates that the aircraft was side-slipping to the left at the time of impact.

1.13 Medical Information

The crew members had valid medical certificates. The co-pilot's body was not found. Autopsies were performed on the victims.

1.14 Survival Aspects

The pilot gave a pre-flight passenger briefing. In addition, passenger information cards on the aircraft identified, by means of pictograms and text, the emergency exits, the location of the ELT, the brace posture, and the operation of the safety belts. All the occupants were seated and their seat belts were fastened. When the pilot decided to return to Baie-Comeau, the crew was not able to prepare the passengers and give the necessary safety instructions. Immediately before the aircraft nosed down toward the river, the passengers seated in the first row, behind the crew, realized the imminence of the danger and leaned forward, adopting the brace posture. Appendix B gives a chronological outline of the emergency response.

1.14.1 Evacuation of Occupants

The aircraft had three rows of two seats and a two-seat bench at the rear. The pilot, the co-pilot, and the passengers in seats 1A, 1B, 4A, and 4B survived the initial impact.

Upon impact, the floor buckled upward and the wing collapsed. This destroyed the survival space of the passengers in seats 2A, 2B, 3A, and 3B, resulting in asphyxiation due to compression and drowning. The co-pilot sustained a serious facial injury and was unconscious after the crash. The pilot and the passengers in 1A and 1B freed the co-pilot from her seat and brought her up on top of the wreckage, where they awaited assistance.

The passengers in 4A and 4B, who sustained multiple injuries, were unable to move and remained seated and secured to the rearmost seat. The tide rose, bringing water up to their waists. Because of their injuries and resulting incapacity, the survivors on top of the cabin were unable to help those passengers out of the wreckage. While the pilot and the passenger from 1A held onto the co-pilot, the passenger from 1B, lying on the roof, held the head of the passenger in 4B out of the water; he did so until water submerged the cabin between 1200 and 1215. The passenger in 4A never regained consciousness after the crash and also drowned.

Shortly after the water covered the wreckage, the survivors, who were suffering from hypothermia, could no longer hold onto the co-pilot, who was carried away by the water at about 1230.

1.14.2 Lifejackets

C-FCVK flew between Baie-Comeau and Rimouski almost exclusively, making the trip twice a day, five days a week. The flight path was almost entirely over the St. Lawrence River; it was 41 nm from Baie-Comeau to Rimouski and 35 nm from Baie-Comeau to Mont-Joli.

The BN2A-26 was capable of maintaining flight in case of engine failure and did not fly more than 50 nm from the shore. Therefore, in accordance with existing regulations, the company's management did not equip the aircraft with lifejackets. The company had lifejackets in its hangar, however.

1.14.3 ELT Signal Received by Search and Rescue Satellite

No ELT signal was received, heard, or reported during the search. The ELT on board C-FCVK could broadcast a signal on the 121.5 MHz and 243 MHz frequencies. This signal could be detected by the SARSAT (search and rescue satellite-aided tracking) and COSPAS orbital satellites, or by any aircraft or radio tuned to those frequencies. However, this model of ELT was restricted to line-of-sight range.

The SARSAT system did not report any valid events for the Baie-Comeau area. A few minutes after the aircraft was found, the Rescue Coordination Centre (RCC) in Halifax, Nova Scotia, examined the SARSAT database. Analysis of the SARSAT data revealed that an ELT signal with a very weak confidence level, 1 out of 4, was recorded by the system at 1119. The SARSAT system does not validate events with a confidence level less than

3. The recorded signal had a high intensity. According to the data, recording of the signal began at 1111 (the time of the accident) and stopped at 1115. However, the length of a recording is not precise and may differ from the actual duration of an ELT signal's reception. The signal's geographic position, as calculated by SARSAT, was 111 nm from the accident site. It cannot be definitely concluded from the SARSAT data that the signal detected came from C-FCVK's ELT.

1.14.4 Nav Canada Procedure

When aircraft need aid, the Air Traffic Services (ATS) division of Nav Canada alerts the appropriate agencies, including search-and-rescue teams, ambulances, doctors, and other emergency services.

Because the required routine contact had not been established with C-FCVK and no information indicated that the aircraft had crashed, the ACC controller in Montréal and the FSS specialist assumed that the aircraft had experienced a communication failure. They therefore followed the emergency procedures for communication failure. In accordance with Part 6, "Emergencies", in the *Air Traffic Control Manual of Operations,* the ATS separated other aircraft from C-FCVK, blindly transmitted a description of the ATC's actions and the weather conditions at the destination and alternate airports, tried to locate the aircraft, performed a communications search, and, finally, took the necessary measures at the airports concerned.

ATS activated the Baie-Comeau airport's emergency plan by declaring a Code White alert 18 minutes after take-off. The Montréal ACC informed the RCC that C-FCVK was in an uncertainty phase and transmitted information on the aircraft 39 minutes after a position report was to have been received. According to the *Air Traffic Control Manual of Operations,* the Montréal ACC should have informed the RCC after 30 minutes.

1.14.5 Baie-Comeau Airport Emergency Plan

The airport's emergency procedures manual (EPM) contains the procedures to follow in case of emergency, the responsibilities of the public and private agencies concerned, and a directory of regional agencies and resources available. Response procedures are organized by codes (Code White, Code Yellow, and Code Red). Code White, which precedes Code Yellow, is declared only when deployment of airport emergency units and the alerting of outside agencies are required. A Code White was declared 16 minutes after the crash and remained in effect almost until the aircraft was found. As soon as he was advised of the situation, 8 minutes after the crash, the airport manager began conducting his own search operation at the airport and in the surrounding area. When the wreckage was found in the St. Lawrence River, the procedure for an aerodrome within 8 km of a large body of water was followed. In the event of a crash in the water, the EPM stated that if the crash occurred in the St. Lawrence River, assistance was to be requested from helicopter companies, such as Hydro-Québec and the Canadian Coast Guard, that have float-equipped helicopters. The EPM also provided the necessary information to reach local boat operators.

At 1210, 10 minutes after C-FCVK was found, the Sûreté du Québec (Quebec police) informed Héli-Manicouagan of the accident and asked that a helicopter be dispatched to the site. Although none of the operator's helicopters were equipped to perform a water rescue, the company's owner sent a ski-equipped Bell

206 with a pilot and an aircraft maintenance engineer on board. Because all the pilots had gone out for lunch, the helicopter did not take off until 17 minutes after the call. Héli-Manicouagan was the only helicopter operator in the Baie-Comeau area. The TSB investigation revealed the following:

- No helicopter operators were listed in the EPM.
- A crash in the water was the only emergency situation requiring the assistance of a helicopter operator.
- The possibility of a crash in the water was not included in the Code White and Code Yellow alerts.
- As early as 1205, emergency personnel tried to locate a boat and dispatch it to the site. Because of a combination of unfortunate circumstances, the difficult access to the water, the distance to be covered in rough water, and adverse environmental conditions, the first boat arrived at the scene of the accident at 1311, 21 minutes after the survivors were evacuated by helicopter.

1.15 Tests and Research

The following tests were performed:

- to determine whether the Mont-Joli FSS or another VHF station was able to receive an ELT signal from the accident site
- to define the conditions needed for reception of an ELT signal by the Mont-Joli FSS and other VHF stations at the Baie-Comeau airport
- to assess the operation of an ELT in contact with water
- to compare the data recorded by the SARSAT satellite at the time of the accident with the test results

At the accident site, an ELT was turned on for four minutes at a time. Because the RCO was now able to relay an ELT signal, Nav Canada was asked to stop its operation during some of the tests. The results of the tests were as follows:

- The signal received by the SARSAT satellite had a confidence level of 1 and, consequently, the information was not relayed to the RCC.
- The Mont-Joli FSS did not receive the ELT signal when the 121.5 MHz frequency was not in operation at the Baie-Comeau RCO.
- The Mont-Joli FSS received the ELT signal when the 121.5 MHz frequency was in operation at the Baie-Comeau RCO.

- A VHF radio in the Baie-Comeau tower received the ELT signal.

- The ELT stopped transmitting a signal as soon as the antenna connection contacted the surface of the water.

- The ELT signal was not received at the Baie-Comeau harbour where the Canadian Coast Guard vessel was berthed.

1.16 Organizational and Management Information

1.16.1 General

Operation of C-FCVK was subject to Section 703 of the CARs, "Air Taxi Operations". At the time of the accident, Air Satellite was operating a fleet of 17 aircraft, with 10 different types, mainly single-engine and piston-powered twin-engine aircraft carrying less than 10 passengers. The company had only one BN2A-26. Air Satellite operates from its main base at Baie-Comeau and from secondary bases at Havre-Saint-Pierre, Sept-Îles, and Rimouski.

1.16.2 Management Organization and Company Operation

Air Satellite's vice-president is also the company's general manager and operations manager. She is responsible for strategic and routine management of the company. As general manager, she is the immediate superior of the maintenance manager and, as operations manager, she is the immediate superior of the chief pilot. According to the company operations manual, the operations manager must ensure that flights are conducted safely, in accordance with State rules and regulations and in accordance with the standards, practices, procedures, and specifications specified in the company operations manual.

1.16.3 Maintenance Department

Air Satellite maintained its aircraft according to a maintenance schedule approved by TC. The maintenance manager was responsible for all of the company's maintenance activities. He also performed all administrative functions relating to maintenance: chief inspector, production manager, and head of quality control. Five apprentice aircraft maintenance engineers worked under his supervision. Three of them had four to six months' experience; the other two had two years' experience. It was not possible to determine the apprentices' training because the company did not keep records on maintenance staff.

1.16.4 Flight Operations

Like many Level 3 air carriers, Air Satellite had difficulty recruiting and keeping qualified personnel, including filling the chief pilot position. In July 1998, Air Satellite's chief pilot accepted to work for another company. He accepted to act as Air Satellite's chief pilot part-time until the position was filled permanently. Air Satellite reported the situation to TC in July 1998. After this notice, as prescribed in the procedures, TC forwarded a notice to Air Satellite advising that the company had 30 days to hire a new chief pilot on a permanent basis and that, after that date, the failure to do so might result in suspension of the company operating certificate. In September 1998, a new permanent chief pilot began employment with Air Satellite.

The chief pilot was responsible for matters relating to professional standards for the flight crews under his responsibility. Among other things, he was required to develop SOPs, develop and implement all approved training programs required for the operator flight crews, and, as necessary, provide directives, instructions, and supervision to flight crews. In addition, he had to fly regularly to assess the pilots' performance. At the time of the accident, the chief pilot did not have a PPC for the BN2A-26 and, consequently, could not be a crew member on C-FCVK. He could, however, perform a training flight in visual flight rules conditions.

Air Satellite used a pilot self-dispatch system, under which the pilot had sole responsibility for the preparation, planning, and execution of a flight. The pilot had to ensure that the flight was conducted according to existing regulations and company procedures as outlined in the operations manual. In November 1998, Air Satellite's management reviewed the experience of its pilots. The company concluded that the pilots' flight times were adequate (1000 to 2000 hours) but that the pilots had little experience in IFR and winter conditions. Consequently, the management decided that each IFR flight would have to be authorized by the chief pilot or the operations manager.

1.16.5 TC Safety Overview

Company audit frequency depends on TC's previous findings. According to TC, every air carrier holding a Canadian aviation document will be audited on a periodic cycle of 6 to 36 months or in accordance with the policy document on inspection frequency. However, a carrier may be subject to additional audits, special audits, or more frequent audits if risk management indicators are identified.

1.16.5.1 Regulatory Audit of Maintenance Department

TC conducted regulatory audits of Air Satellite's maintenance department in February 1987, September 1991, May 1993, June 1995, and September 1998. During the last audit, 21 out of 31 maintenance areas were audited. Area 3.5.7, "De-Icing Procedures and Equipment", was not audited. Several of the irregularities identified by the inspectors involved updating maintenance documents but did not compromise aircraft airworthiness. However, TC also identified irregularities relating to airworthiness of some aircraft. TC noted the following:

- The maintenance procedures manual (MPM) and the MCM did not reflect the current status of the company's activities. Many audit observations revealed irregularities needing correction.
- The company did not keep its regulatory and technical publications up to date.
- No records were kept showing that maintenance personnel received training on the company's policies and procedures. The company did not follow the programs outlined in the MPM and the MCM.
- The procedures outlined in the MCM for recording and control of important maintenance events were not followed.
- The operator deferred the correction of defects essential to the airworthiness of some aircraft.
- Inspection of the company's different aircraft revealed a number of irregularities requiring immediate action by the company that had not been reported to the maintenance organization.
- Maintenance schedules were not followed. Planned inspections were not performed within the tolerances specified by the approved programs. Special inspections were not conducted in accordance with the specifications outlined in the programs.
- Airworthiness directives were not carried out at the prescribed times, and aircraft were returned to service that should not have been.

After this regulatory audit, TC's audit manager established an audit frequency of 18 months. Air Satellite drew up a corrective plan to be implemented over several months. TC accepted all proposed corrective measures. The aircraft airworthiness deficiencies have since been corrected.

1.16.5.2 Regulatory Audit of Flight Operations Department

The last two regulatory audits of Air Satellite's flight operations were conducted by TC in September 1991 and September 1998. The 1991 audit revealed a number of irregularities, all of which were corrected to TC's satisfaction. In September 1998, the inspectors found various deficiencies related to the responsibilities of the operations manager and the chief pilot. For example, the training program was incomplete, the pilot training records contained many errors and omissions, pilots acted as crew members when they did not have the required qualifications, and no training for flight monitoring personnel was planned. TC's evaluation of these irregularities did not reveal a direct link with factors compromising flight safety. TC's audit report concluded that "[Translation] There are obvious problems with respect to the operational management of Air Satellite Inc." The report identified the source of the problems as follows: "[Translation] Due to the size of the company's operations, required by the area, staff must be qualified and regularly trained. Frequent turnover in the chief pilot position has clearly been a source of the problems identified in the regulatory audit. The operations manager, who has a degree in business administration from a recognized university and is trained in aircraft maintenance, is investing considerable time, energy, and effort in the company, but cannot manage the company's operations by herself." The report recommended close supervision of Air Satellite by TC inspectors and an increase in the frequency of routine inspections and regulatory audits.

After this audit, Air Satellite drew up a corrective plan to be implemented over several months. TC accepted all the proposed corrective measures. After the accident, while a TC inspector was on his way to Baie-Comeau to suspend the company operating certificate, Air Satellite surrendered the certificate voluntarily and stopped its operations for 15 days. This time allowed the management to support the investigation, supervise company personnel, and take the corrective actions required by TC, including PDM training for company pilots.

1.17 Additional Information

1.17.1 De-icing Regulations

No person shall take off or attempt to take off in an aircraft that has frost, ice, or snow adhering to any of its critical surfaces. In addition, the Air Satellite operations manual states that, where conditions are such that frost, ice, or snow may reasonably be expected to adhere to the aircraft, no person shall take off or attempt to take off in an aircraft unless the aircraft has been inspected immediately before take-off to determine whether any frost, ice, or snow is adhering to any of its critical surfaces. The risks associated with icing are known and documented in many publications and letters that TC sends to pilots.

1.17.2 Aerodynamic Effects of Icing

Experimental data indicate that the formation of frost, ice, or snow of a thickness and roughness comparable to that of medium or coarse sandpaper on a wing's leading edge and upper surface can reduce a wing's lift by up to 30 per cent and increase drag by 40 per cent. The lift loss comes largely from contamination of the leading edge. Consequently, aerodynamic stall of a contaminated wing may occur before the stall warning system activates.

1.17.3 Air Satellite's Procedure in Case of Contamination of Critical Surfaces

Section 3.3, "Contamination of Critical Surfaces", of the company operations manual reiterates the requirements of the CARs:

> [Translation]
>
> Frost or snow adhering to any lift or control surface must be completely removed before take-off.
>
> If it is impossible to clean the aircraft before departure, the only solution is to delay the flight until acceptable conditions prevail.
>
> No pilot shall begin or continue a flight into known or expected icing conditions if the accumulation of frost on the aircraft may compromise the flight safety. At all times, the pilot-in-command assumes full responsibility for deciding whether or not to undertake a flight in icing conditions.

Air Satellite's pilots could remove surface contamination by placing the aircraft in the hangar, applying hot water to the contaminated surfaces, using de-icing liquid from a portable tank kept in the company's office in the terminal building, or by using a broom.

1.17.4 Stall

The symptoms of an impending stall include sluggish control surfaces (loss of effectiveness), airframe vibration, and activation of the stall warning system. Pilots must decrease the angle of incidence and minimize the loss of altitude. To do so, they must apply full throttle and take an attitude close to cruising attitude. Extending the flaps improves lift by increasing part of the wing's camber and decreases the stall speed. However, while increasing lift, the flaps increase drag. To maintain the same flight regime, pilots must increase engine thrust to compensate for the increased drag.

1.17.5 Air Satellite's SOP Manual

Air Satellite had an SOP manual for the Embraer 110, the Cessna 402, the Cessna 310, and the BN2A. According to the BN2A SOP manual, the pilot-in-command was responsible for performing all tasks, making standard announcements, and assuming all responsibilities. The SOP manual did not assign any specific responsibilities to the co-pilot.

1.17.6 ELT Model 406

In 1979, an ELT model that transmits on the 406 MHz frequency was put into service. The digital signal is received by a geostationary satellite that partially processes it and relays the information to a ground station. Although TC does not specify a particular model to be installed, this model offers significant advantages in comparison with the 121.5/243-MHz model:

- global coverage;
- almost instantaneous reception and relay of the ELT signal;
- more specific identification of the ELT's geographic position;
- complementary information from the coded digital message, such as the device's country of origin, the aircraft's registration, and the derived position of a navigation system on board the aircraft;
- elimination of false signals.

2.0 Analysis

2.1 General

No irregularities were noted during the flight or during previous flights. Examination of the wreckage and the individual components did not reveal any indication of a structural defect, control malfunction, or loss of power that could have caused the accident.

2.2 Flight Planning

2.2.1 Weather Conditions

2.2.1.1 Turbulence and Wind Shear

The area forecast in effect at the time of the accident and the 0618 briefing from the FSS specialist indicated moderate to strong wind shear turbulence below 5000 feet asl associated with the passage of the cold front through Baie-Comeau at about 1100. Consequently, the information received by the pilot-in-command should have made the crew aware that sudden changes of attitude and significant variations in speed could occur during the flight to Rimouski.

2.2.1.2 Type of Precipitation While the Aircraft was Outside

The ambient temperature was near the freezing point (-0.2°C), creating wet snow. Environment Canada reported that the snow had a high water content, and a pilot observed wet snow on his aircraft at about 1030. The 1000 and 1100 weather observations indicated moderate snow, whereas those of 1029 and 1035 reported light snow. Between 1000 and 1100, 1 cm of new snow fell. The aircraft took off nine minutes later, during moderate snow. Therefore, it may be concluded that more than 1 cm of snow fell while the aircraft was outside and that snow accumulated on the aircraft's surfaces.

2.2.1.3 Crew's Decision Not to Remove Snow From Aircraft

The upper surface of the wings, cabin, stabilizer, and elevator were more than six feet above the ground. Therefore, the pilot-in-command could not inspect the horizontal surfaces without a stairway. The pilot-in-command could only inspect the upper surface of the aircraft's horizontal surfaces when he refuelled the aircraft during a lull in the weather (the weather observations indicated light snow), 40 minutes before take-off. Based on this observation and the fact that snow was not adhering to the windshield while taxiing, the pilot-in-command concluded that the surfaces were not contaminated; he relied on obsolete or insufficiently representative information. Because the crew could not see the aircraft's surfaces from the cockpit, the pilot-in-command should have asked another staff member to assist him by inspecting the surfaces.

It seems that the surface contamination training did not assist the pilot-in-command in identifying the weather conditions conducive to aircraft surface contamination.

2.2.1.4 Weather Conditions in Rimouski and Mont-Joli at Take-off

Given the proximity of the weather station, it was reasonable to think that weather conditions at the Rimouski airport were fairly similar to those observed at the Mont-Joli airport. The 1014 observation from Mont-Joli and the 0917 Mont-Joli aerodrome forecast would have led the pilot-in-command to expect the ceiling at Rimouski to change from 300 feet agl to 3000 feet agl after 1100 and visibility to increase from ¾ sm to 6 sm. Consequently, the decision to undertake the flight with a view to completing an approach was in accordance with regulations, because the Rimouski airport was not subject to an approach ban. The decision to select Mont-Joli as the alternate airport was consistent with the relative weather requirements. However, examination of the Mont-Joli weather observations should have confirmed the warnings from the Québec FSS specialist regarding the unreliability of the Mont-Joli aerodrome forecast.

Because the flight was to last 30 minutes, the available information led the crew to believe that, in all probability, the ceiling and the visibility would be below the approach minimums in Rimouski and the alternate airport in Mont-Joli. The lowest minimum descent altitude at which the crew could descend, if they had not established the necessary visual references, was 640 feet asl. The likelihood of seeing the runway at the end of the approach was therefore rather poor. Because the crew could expect not to land at their destination 30 minutes later, and the flight had been delayed five hours because of the weather, the decision to take off for Rimouski in such conditions, although consistent with regulations, was marginal.

2.2.2 Aircraft Load

As permitted by regulations, the pilot-in-command used the approved standard summer weights to calculate the aircraft's weight and balance. However, the actual weight of each occupant exceeded the average weight used. Consequently, the total weight of the occupants was underestimated. Given the winter weather conditions, use of the standard winter weights, although not mandatory, would have been appropriate. Moreover, to determine the weight of the occupants more accurately, the true weight of the occupants and their carry-on bags should have been used.

The pilot-in-command asked the flight monitoring attendant to enter 500 pounds of fuel on the weight and balance form. However, once he arrived at the fuelling pit, the pilot-in-command refuelled to full tanks (780 pounds), as indicated in the flight plan filed one hour before. The pilot-in-command signed the weight and balance form without amending the fuel weight. According to the form, the sum of the standard summer weights for the occupants, the weight of the passengers' luggage, the weight of the fuel, and the empty weight of the aircraft were within the prescribed limits for take-off and for landing at Rimouski. The pilot-in-command should have known that the weight of the aircraft at the time of the final load report exceeded the allowable take-off weight, because he knew that there were 280 pounds of fuel more than expected. In addition, he should have known that the weight of the aircraft would have exceeded the allowable weight for landing at Rimouski. Although the difference between the weight registered and the actual weight of each of the elements seems negligible, the total discrepancy probably contributed to a decrease in performance; when the aircraft took off, it was overweight by more than 200 pounds.

2.2.3 Pre-flight Check

2.2.3.1 Engines and Electrical System

The pre-flight inspection would not have detected the internal irregularities in the engines and the electrical system (excessive wear of alternator brushes). The significant increase in oil consumption indicated that some of the engine's internal components were defective, but the pilot-in-command was not qualified to diagnose the deficiencies. No operational irregularities had been reported before the flight.

2.2.3.2 Co-pilot's Shoulder Harness

The co-pilot's shoulder harness did not function correctly because it was not installed properly. This could have been detected by pulling rapidly on the diagonal strap to ensure that it would stop. It seems unlikely that no pilot, maintenance personnel, or TC inspector had performed this simple check since the belt's installation in 1996. Consequently, it is possible that the company's staff and TC's inspectors had incorrectly assessed the importance of proper shoulder harness installation and the consequences of an improper installation in an accident.

2.2.3.3 Stall Warning System

The lift sensor for the stall warning system is in the leading edge of the left wing, six feet from the ground. It was therefore possible to detect that a screw was missing. However, confirmation that the audible and visual alarms were working suggested, incorrectly, that the system was functioning properly. Even if the lift sensor had been attached properly, the alarm would not have activated, because the aircraft stalled approximately 20 knots over the stall speed.

2.3 The Flight

2.3.1 Taxiing

The aircraft had to wait in the manoeuvring area for clearance to use taxiway Delta. Normally, from taxiway Delta, the aircraft should have turned right onto the runway to taxi to the threshold of Runway 10. For undetermined reasons, once the aircraft reached the runway, it turned left and backtracked onto Runway 28 before turning around. It is possible that the crew were distracted or that the aircraft rolled onto taxiway Delta before receiving clearance and then had to backtrack onto Runway 28 to let the snow removal equipment go by.

2.3.2 Choice of Take-off Runway

When the Mont-Joli FSS informed the crew that departure from Runway 28 would probably lead to a wait at the MIWAK waypoint fix, the pilot-in-command agreed to take off from Runway 10. He chose to continue waiting on the ground and take off with a tailwind rather than risk in-flight icing in the holding pattern at the MIWAK fix. When the expected wait at the MIWAK fix was cancelled and Runway 28 was again available, the pilot-in-command still chose, for undetermined reasons, to take off from Runway 10, despite the advantages of taking off from Runway 28. It would have made sense to take off from Runway 28: taking off with a headwind would have allowed the shortest ground roll, the slowest ground speed, a more open angle of climb, and, because the threshold of Runway 28 is 3000 feet closer to taxiway Delta, less surface contamination. The take-off on Runway 10 was conducive to snow accumulation on the critical surfaces, degrading the aircraft's performance.

2.3.3 Take-off Roll and Flight

The take-off roll was approximately three times longer than it should have been. According to Britten-Norman, the take-off roll was longer than the distance required by a BN2A-26 weighing 500 pounds more than C-FCVK, on a runway covered with nearly 7.6 cm of snow, and a tailwind component exceeding 8 knots. The degree of contamination of the aircraft is the only variable that was not factored into the calculation. Consequently, contamination of the critical surfaces must have been an important factor in increasing the take-off roll and affecting the aircraft performances. Because the aircraft did not show any adverse effects related to contamination after rotation, until suddenly pitching up at just over 500 feet asl, it is unlikely that enough snow accumulated on the critical surfaces during the climb of about 60 seconds to cause a stall above 70 knots.

As during his training flights, the pilot-in-command did not follow the checklist sequence and reduced power before retracting the flaps. The change in sequence decreased thrust without reducing drag. If the pilot had not reduced power before retracting the flaps, the aircraft would have been operating with full thrust and a higher speed at the time of the sudden pitch-up.

Airspeed decreased by more than 25 knots and lateral stability was affected at approximately the same time as the flaps were retracted and the aircraft entered the cloud base. The rapid decrease in speed indicates that the aircraft climbed into a wind shear area. The flaps were retracted just before the aircraft pitched up, so, when the aircraft entered the wind shear area, the pilot-in-command was probably pulling on the control column to compensate for the aircraft's natural tendency to nose down. The combination of wind shear and flap setting would then have amplified the rate at which the nose rotated upward and contributed to the rapid loss of speed. The pilot-in-command probably did not realize that the aircraft was crossing a wind shear area. However, even if he had realized it, he was not familiar with the recommended recovery procedure.

The pilot's immediate challenge was to recognize the aircraft's attitude and speed. Because the aircraft was set to climbing power, it was imperative to increase thrust by applying full throttle, take the attitude corresponding to the maximum angle of attack, and keep the aircraft straight and level to avoid stalling.

After the aircraft pitched up, the pilot-in-command lowered the aircraft's nose, maintained power, extended the flaps after the aircraft's speed decreased to 70 knots, and initiated a left turn, during which the aircraft stalled. The pilot-in-command appears to have considered the situation serious enough to turn back for a visual flight rules approach on the closest runway (Runway 28) in conditions that required constant monitoring of the flight instruments, instead of following the plan established during the pre-flight briefing. Although extending the flaps increased lift, it also increased drag and probably decreased airspeed. The combined effects of contamination of the critical surfaces and the turn increased the stall speed. The stall may thus be attributed to a combination of all these factors, which eliminated the difference between the aircraft's speed and the stall speed.

2.3.4 Stall and Impact

The general instability of the aircraft at 70 knots is characteristic of an aircraft approaching stall speed. The fact that the left wing dropped first and that the nose pitched down corresponds to a loss of control after a stall in a level or descending turn.

The stall must have occurred about 500 feet asl because it happened very soon after the start of the turn. According to Britten-Norman, the aircraft could lose at most 100 feet, in normal conditions, if the stall recovery procedure was begun immediately. It is possible that the element of surprise kept the pilot from immediately lowering the nose of the aircraft and delayed stall recovery.

Examination of the damage and the slightly nose-up attitude of the aircraft indicate that the aircraft was no longer in a stall. In theory, a stall recovery can be made in about 100 feet of altitude. In the circumstances, however, there was likely insufficient altitude available to recover from the stall before striking the water.

2.4 Survival Aspects

2.4.1 Emergency Message and Distress Signal

Because there were no witnesses to the accident and no emergency messages or signals, Nav Canada could not know that the aircraft had crashed into the St. Lawrence River. The crew did not send an emergency message in flight and no ELT signal was recognized and confirmed, delaying implementation of emergency procedures. If Nav Canada had been made aware of C-FCVK's situation as soon as it crashed, analysis of the information available at that time would likely have allowed identification of the area where the accident occurred.

2.4.1.1 Emergency Message and Communications

When the aircraft became unstable, the pilot-in-command assessed that continuing would compromise the flight. When he decided to return to the Baie-Comeau airport, he informed the co-pilot of his intentions. The co-pilot, whose main responsibility was to conduct air-ground communications, should have informed the Mont-Joli FSS at that time. This responsibility, although hers, could have been shared with the pilot-in-command. If the aircraft was in distress, the pilot-in-command could have contacted ATC directly to explain the situation. In fact, the pilot-in-command did contact ATC directly, a few minutes before the accident, to obtain details regarding the expected delays at the MIWAK waypoint fix. However, the crew did not transmit an emergency message. A number of factors, including the following, might have contributed to the co-pilot and the pilot-in-command not communicating their intentions on the air-ground frequency:

- The time and the circumstances probably did not allow the crew to contact ATC.
- The origin of the problem was linked to the manoeuvrability of the aircraft rather than to an aircraft system. Consequently, the co-pilot might not have had the same impression of urgency as the pilot-in-command.
- The crew's little experience in CRM was not favourable for good coordination.
- The pilot-in-command might have focused all his attention on maintaining control of the aircraft.
- The co-pilot's role was not clearly defined in the company's SOPs.
- The pilot-in-command and the co-pilot had not received training in effective communications; this training is not mandatory.

2.4.1.2 ELT Operational Condition

The SARSAT system recorded a low-reliability event at the exact time of the crash. Nevertheless, it cannot be concluded with certainty that the signal received was from C-FCVK. Tests demonstrated that a signal can be recorded without being validated if its duration is insufficient for an acceptable level of reliability. Given that no ELT irregularities were reported before the accident, that examination by the TSB did not reveal any defects other than those caused by corrosion, and that its battery was not due for replacement until a year later, it is reasonable to believe that the ELT was functioning before the flight. Therefore, it may be concluded that the ELT, which was switched to "arm", activated on impact. The emergency signal probably stopped when the ELT was ejected from its mounting plate on impact and/or when a short circuit occurred due to contact with the salt water.

2.4.2 Installation of ELT

Britten-Norman believed that the rear wall was less likely to sustain deformation after an accident. Therefore, the wall mount was the best way to ensure that the ELT could emit a signal after a crash. The impact seriously damaged the floor of the aircraft, whereas the rear wall sustained little damage. The wall mount would have greatly increased the likelihood that the ELT would remain out of the water, attached to its support, and capable of emitting an emergency signal. The ELT had not been installed according to the instructions specified in *Modification Instruction* NB-M-767, Part D, issued by Britten-Norman. It is TC's position that the installation did not meet regulatory requirements; however, despite regular inspections, this fact was not noted or otherwise commented on by TC inspectors. The TSB also concluded that the installation did not comply with the regulations.

2.4.3 Stations Capable of Receiving ELT Signal From Accident Site

It was reported that the Mont-Joli FSS was the only ground station in the crash area that was listening to the 121.5 MHz emergency frequency. Because of the range-of-sight limitations (distance and obstacles) of VHF frequencies, this station could not receive the ELT signal from C-FCVK. The tower at the Baie-Comeau airport was within range of the ELT. However, there was no transmitter-receiver tuned to the 121.5 MHz emergency frequency at the airport because there was no regulatory requirement to that effect. Aircraft categories, type of flight, and density of traffic around the airport are not factors considered in the decision to equip an RCO with an emergency frequency. When TC closed the tower in 1995, the RCO was equipped with frequencies useful for operation of the airport only. The Mont-Joli FSS, which offered an alerting service to aircraft under its control, could not receive an ELT signal transmitting from the vicinity of the Baie-Comeau airport.

According to tests conducted by the TSB, if the Baie-Comeau RCO had had the 121.5 MHz frequency, the Mont-Joli FSS would have known, when the ELT activated, that C-FCVK was in distress rather than experiencing a communication failure. Consequently, it is probable that the rescue time would have been reduced.

The ELT signal was too short for the SARSAT system to validate it and determine the location of C-FCVK.

2.4.4 Lifejackets

The regulations do not provide for emergencies requiring an immediate water landing or events leading to an unexpected water landing. According to the regulations, an aircraft on a regular flight conducted almost entirely over the water, as with Flight ASJ501, is not required to have lifejackets on board. Because the river is approximately 35 nm wide between Baie-Comeau and Rimouski, C-FCVK was never more than 18 nm from the shore when flying between the two airports.

There were two groups of survivors: the passengers in 4A and 4B, who were trapped in the cabin, and the four occupants seated at the front, who were found on top of the cabin. The passengers in 4A and 4B were seriously injured. Even if they had been wearing lifejackets, they would not have been able to evacuate the cabin before the tide submerged the wreckage. Three of the survivors who were found outside the cabin could partially move. It took all their energy to hold onto the unconscious co-pilot for nearly 1 hour 20 minutes, in extremely difficult conditions. Out of strength and suffering from hypothermia, they were unable to hold onto the co-pilot when the tide submerged the cabin, about 10 minutes before help arrived. In those circumstances, it is reasonable to think that if the co-pilot had worn a lifejacket, it would have been easier for the survivors to hold onto her. The availability of lifejackets on board an aircraft increases the occupants' chances of survival in case of an emergency water landing.

2.4.5 Baie-Comeau Airport Emergency Plan

The emergency response before the aircraft was found suggests that all agencies concerned thought that the aircraft had probably crashed. The ground search began 22 minutes after take-off, even though the Code White that had been in effect for 3 minutes required these agencies only to be on standby. It seems that the assistance of a helicopter was not requested until the aircraft was found because this procedure was described only in the section "crash landings in water" in the airport's emergency plan. Because the company, Héli-Manicouagan, was not advised of the situation earlier, there were no pilots available at the company's base when the company was informed of the crash. Consequently, the Héli-Manicouagan helicopter took off 27 minutes after being informed of the accident, 17 minutes after the Sûreté du Québec asked Héli-Manicouagan to go to the accident site. The emergency response time was longer than it could have been.

2.4.6 Nav Canada Procedures

The Montréal ACC informed the RCC 9 minutes after the time lapse stipulated in the operations manual. The Hercules and the Griffon dispatched by the Halifax RCC arrived at the scene 59 minutes and 86 minutes, respectively, after the rescue. It may therefore be concluded that the survival of the occupants would not have been affected had the RCC been informed when the Code White was declared, 21 minutes earlier, or at the time stipulated in the operations manual.

2.5 *Flight Crew*

2.5.1 *Pilot-in-Command*

The pilot-in-command met the statutory requirements for a commercial pilot's licence, but his difficulty qualifying for his IFR rating, his reluctance to follow procedures and checklists, his previous attitude in icing and IFR conditions, and the fact that a TC inspector had described him as a rather weak pilot indicate that he had difficulty flying.

2.5.2 *Co-pilot*

Because the co-pilot was a flight instructor, it can be assumed that she knew the recommended procedures in case of sudden pitch-up of the aircraft and wind shear. However, for undetermined reasons, she did not take any action during those critical moments. It is probable that the following factors contributed to inhibiting the co-pilot:

- The pilot-in-command did not clearly communicate his concern or ask for assistance.
- The SOPs did not clearly define her responsibilities as co-pilot on the BN2A.
- The lack of flight instruments on the right side of the instrument panel: it was difficult to read and interpret the flight instruments in front of the pilot-in-command.
- Neither of the crew members had been trained in effective crew coordination.

2.6 Company Management

TC indicated that the company had experienced some problems at the operations management level. To solve this problem, Air Satellite had hired a production manager shortly before the accident. This person was not yet performing the duties of production manager at the time of the crash, but Air Satellite had implemented the remedial plan it had proposed to TC.

2.6.1 Maintenance

The deficiencies identified after the accident, including the defective lift sensor of the stall warning system, the incorrect shoulder harness installation, and the condition of the engines and the alternators, showed that C-FCVK's certificate of airworthiness did not meet the regulatory requirements. If the procedures outlined in the inspection program and the maintenance manuals had been followed, the aircraft's deficiencies would have been identified and corrected. The fact that the aircraft took off with several deficiencies and that many maintenance irregularities were noted indicates a lack of supervision by the company. It seems that it was not possible for the maintenance manager to assume all the responsibilities associated with his various management positions.

2.6.2 Operations

The crew was composed of two pilots who had little experience in adverse conditions; consequently, they had difficulty making effective decisions before and during the flight. In the circumstances, it would have been reasonable for the company's management to designate a pilot-in-command and a co-pilot with shared flying experience who could form a more experienced team.

Although Air Satellite uses a pilot self-dispatch system, the existing conditions and both pilots' lack of experience in those conditions and in IFR would have justified close operational control. In addition, the pilot's limited experience as pilot-in-command on a twin-engine, commanding a crew, and flying in IFR and winter conditions fully justified close supervision of his flights.

The inexperienced crew decided to take off in difficult conditions, with a snow-covered, overloaded aircraft, for an airport at which the weather conditions offered little chance of landing. One can therefore conclude that the management supervision was inadequate.

2.7 *Transport Canada Regulatory Control*

High turnover of flight personnel and the repeated changes in the position of company chief pilot were a risk indicator easily identifiable by TC's main inspector. This indicator would normally decrease the time between regulatory audits to less than 36 months. If TC had complied with its established audit standards, the many deficiencies in training and operations might have been identified well before the accident.

TC approved Air Satellite's recovery plan, even though the audit report indicated that the carrier's management was inadequate. This approval suggests that TC deemed that the deficiencies were minor and did not compromise flight safety. However, the fact that TC was en route to suspend the company's operating certificate after the accident suggests that TC reassessed the deficiencies identified previously and decided that they did jeopardize aviation safety. Therefore, it seems that TC had underestimated the company's problems.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The aircraft took off with contaminated surfaces, without an inspection by the pilot-in-command. This contamination contributed to reducing the aircraft's performance and to the subsequent stall.

2. At take-off, the aircraft was more than 200 pounds over the maximum allowable take-off weight. This added weight contributed to reducing the aircraft's performance.

3. During the initial climbout, the pilot-in-command did not follow the recommended procedure when he entered an area of wind shear. Consequently, the aircraft lost more speed, contributing to the stall.

4. Insufficient altitude was available for the pilot to recover from the stall and avoid striking the water.

5. The co-pilot's shoulder harness was not installed properly. The co-pilot received serious head injuries because she was not restrained.

3.2 Findings as to Risk

1. The crew's lack of experience in the existing conditions was not conducive to effective decision making during the pre-flight planning and the flight.

2. The stall warning system was defective and, in other circumstances, could not have alerted the crew of an impending stall.

3. The crew did not transmit an emergency message after the pilot-in-command decided to return to Baie-Comeau for landing. This lack of a message delayed the rescue operation.

4. The emergency signal was not received by the Mont-Joli Flight Service Station because the Baie-Comeau remote communications outlet (RCO) was not equipped with the 121.5 MHz emergency frequency. The RCO was not required to be equipped with the emergency frequency.

5. The emergency locator transmitter (ELT) was not installed in accordance with Britten-Norman's instructions. The ELT's installation on the floor of the aircraft increased the risk of damage.

6. Transport Canada did not comply with its established audit standards for regulatory audits of the operator, thus increasing the risk that training and operational deficiencies would not be identified.

7. The emergency signal probably ceased after the ELT was ejected from its mounting plate and the antenna connection contacted the water. The ejection contributed to reducing the signal and prevented the SARSAT (search and rescue satellite-aided tracking) system from validating the

signal.

8. One of the occupants might have had a greater chance of survival had lifejackets been on-board the aircraft. Existing regulations did not require lifejackets to be carried on board.

9. The aircraft had numerous mechanical deficiencies that should have been detected by Air Satellite's staff.

10. According to the Baie-Comeau airport emergency plan, a helicopter could be used only after confirmation of a crash in water. The emergency response time was therefore longer than it could have been.

11. The configuration of the instrument panel made it difficult to read and interpret the flight instruments from the co-pilot's seat.

12. Air Satellite's manual of standard operating procedures did not promote effective crew coordination.

13. The pilot-in-command and the co-pilot had not taken courses in crew resource management or pilot decision making. These courses would have promoted effective crew coordination but were not required under existing regulations.

14. The high turnover of flight personnel and the repeated changes in the position of company chief pilot did not allow adequate supervision of operations.

4.0 Safety Action

4.1 Action Taken

The TSB's report underlines the fact that some aircraft that are certified for single-pilot operations do not have instrumentation at the co-pilot seat. When flying from the co-pilot position, the aircraft must therefore be flown without the benefit of a full instrument panel. To correct this deficiency in the regulations, Transport Canada (TC) has issued a notice of proposed amendment to the *Canadian Aviation Regulations* (CARs). This deficiency, identified by the TSB, will be eliminated when the amendment is incorporated into the CARs.

The report uses data observed by the weather specialists and states that, during the morning, the equipment for measuring the wind could not be used because of the freezing rain. Based on the position of the wind sock, an observer estimated the wind to be 230° true at 7 knots. However, the cloth cone on the wind sock was covered with ice, increasing its weight. Moreover, information gathered during the investigation indicates that the wind speed might have been much higher than that observed. To correct this deficiency in the regulations, TC issued a notice of proposed amendment to the CARs. This deficiency, identified by the TSB, will be eliminated when the amendment is incorporated into the CARs.

On 25 July 2002, the TSB issued Aviation Safety Advisory A010052-1 to TC concerning the problems with the improper installation of the emergency locator transmitter (ELT). C-FCVK's ELT had been installed directly on the aircraft metal covering. This installation offered less rigidity and was thus not in accordance with the aircraft manufacturer's instructions. Furthermore, the ELT was mounted to a plate that was attached to the flooring behind a bulkhead, making access difficult. Finally, its sensitive axis was 12°, which is 2° more than the 10° maximum limit prescribed by the ELT manufacturer. Following this advisory, TC may wish to consider reviewing the CARs to add more precise installation criteria to ensure that this regulation cannot have multiple interpretations.

Air Satellite has implemented some measures since the accident. These measures include improved flight supervision and hiring a licensed aircraft maintenance engineer and a safety officer. The company has also ensured that crews will receive pilot decision-making training.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 13 August 2002.

Appendix A: Weights Used for the Flight and Weights Estimated by the TSB

	Weights used by pilot (pounds)	Weights estimated by TSB (pounds)
Empty Weight of Aircraft	4136	4136
Occupants	1552	1717
Luggage	180	180
Fuel	500	780
Take-off Weight	6368	6813
Fuel Consumption	80	80
Landing Weight	6288	6743

Maximum take-off weight: 6600 pounds

Maximum landing weight: 6300 pounds

Appendix B: Chronological Outline of Emergency Response

Time elapsed after take-off at 1109	Event
About 2 minutes	The aircraft crashed into the river.
3 minutes	The Montréal Area Control Centre (ACC), the Mont-Joli Flight Service Station (FSS), and some aircraft in flight tried to contact Flight ASJ501. A communications search was then undertaken by various agencies.
10 minutes	The Mont-Joli FSS informed the Baie-Comeau airport that Air Traffic Services (ATS) had lost contact with Flight ASJ501 after take-off.
18 minutes	The Mont-Joli FSS, which thought that Flight ASJ501 had experienced a communication failure, declared a Code White alert. Code White is used to deploy the personnel of the airports concerned and to put outside agencies on alert. The Baie-Comeau airport emergency coordination centre became operational.
22 minutes	One airport maintenance attendant at the Baie-Comeau airport went to the apron with a direction finder to see if he could receive an emergency locator transmitter (ELT) signal. A second airport maintenance attendant searched the runway.
24 minutes	Pointe-Lebel firefighters and various police departments were put on standby.
26 minutes	The emergency coordination centre asked that a search be conducted on Garnier Street, which runs along the river just east of Runway 10.
38 minutes	The Baie-Comeau airport manager expanded the ground search southwest of the runway.
41 minutes	The Baie-Comeau airport manager tried to locate the aircraft from the control tower.
42 minutes	The Rescue Coordination Centre (RCC) in Halifax, Nova Scotia, was notified.
45 minutes	The Canadian Coast Guard (CCG) was notified. The CCG had a vessel, the *Pearks*, berthed at the Baie-Comeau harbour.
47 minutes	The Halifax RCC dispatched a Hercules from Canadian Forces Base (CFB) Trenton, Ontario, to the area to begin the search.

Time elapsed after take-off at 1109	Event
48 minutes	The CCG decided to dispatch the *Pearks* to search for the aircraft.

50 minutes	The Mont-Joli FSS declared the aircraft missing and moved onto Code Yellow and the alerting phase. All stakeholders were informed.
51 minutes	A citizen reported seeing C-FCVK in the river.
61 minutes	The Sûreté du Québec (Quebec police) asked Héli-Manicouagan, a commercial operator based in Baie-Comeau, to dispatch a helicopter to the site of the accident.
65 minutes	The Halifax RCC dispatched a helicopter from CFB Bagotville to the scene to rescue the victims.
78 minutes	A ski-equipped Bell 206 helicopter left the Héli-Manicouagan base for the accident scene with a pilot and an aircraft maintenance engineer on board.
98 minutes	The Bell 206, which was not equipped with floats or a winch, hovered over the wreckage. The aircraft maintenance engineer helped a survivor aboard. The survivor was then brought to emergency personnel on shore.
100 minutes	The Bell 206 returned to the scene and rescued the other two survivors.
121 minutes	The first boat arrived at the scene.
159 minutes	The Hercules arrived at the scene.
186 minutes	The Griffon helicopter arrived at the scene.

Appendix C: List of Laboratory Reports

The following TSB Engineering Laboratory reports were completed:

LP 145/98	Wreckage Analysis
LP 2/99	ELT Analysis
LP 51/99	Stall Warning Analysis

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

Appendix D: Glossary

ACC	area control centre
ADF	automatic direction-finder
AES	atmospheric environment service
agl	above ground level
A.I.P. Canada	*Aeronautical Information Publication*
asl	above sea level
ATC	air traffic control
ATS	Air Traffic Services
CARs	*Canadian Aviation Regulations*
CCG	Canadian Coast Guard
CFB	Canadian Forces Base
CRM	crew resource management
cm	centimetre(s)
DME	distance-measuring equipment
ELT	emergency locator transmitter
EPM	emergency procedures manual
FSS	flight service station
IFR	instrument flight rules
ILS	instrument landing system
inHg	inches of mercury
L	litre(s)
LL	low lead
MCM	maintenance control manual
MHz	megahertz
MPM	maintenance procedures manual
NDB	nondirectional beacon
nm	nautical mile(s)
PDM	pilot decision making
PPC	pilot proficiency check
RCC	Rescue Coordination Centre
RCO	remote communications outlet
SARSAT	search and rescue satellite-aided tracking
SB	satisfactory with briefing
sm	statute mile(s)
SOP	standard operating procedure
TC	Transport Canada
TSB	Transportation Safety Board of Canada
VHF	very high frequency
VOR	VHF omnidirectional radio range
°	degree(s)
°C	degree(s) Celsius