AVIATION OCCURRENCE REPORT

CONTROLLED FLIGHT INTO TERRAIN

AIR MANITOBA LIMITED
HAWKER SIDDELEY, HS 748 SERIES 2A C-GQTH
SANDY LAKE, ONTARIO 1 nm NW
10 NOVEMBER 1993

REPORT NUMBER A93H0023

Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

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Synopsis

The flight departed Winnipeg, Manitoba, at 1438 central standard time (CST) for Sandy Lake, Ontario. On arrival at Sandy Lake at approximately 1549 CST, the crew attempted to land but were unable to because of the low ceiling and visibility. They then diverted to St. Theresa Point, Manitoba, landing at 1630 CST. After a normal turnaround, the flight returned to Sandy Lake and landed at approximately 1745 CST. The aircraft took off from runway 29 at Sandy Lake at approximately 1805 CST and immediately entered a right turn. After turning through about 120 degrees, the aircraft descended into 100-foot trees and crashed. All seven occupants of the aircraft were fatally injured, and the aircraft was destroyed.

The Board determined that, after take-off, the crew most likely lost situational awareness and, as a result, did not detect the increasing deviation from their intended flight path. Contributing to the loss of situational awareness was the lack of AC power to some of the flight instruments; the reason for the lack of AC power could not be determined.

Ce rapport est également disponible en français.

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5.0 Appendices

1.0 Factual Information

1.1 History of the Flight

The aircraft, a Hawker Siddeley 748 Series 2A Model 234 (HS 748) owned and operated by Air Manitoba Ltd. (Air Manitoba), took off from Winnipeg at 1438 central standard time (CST)[1], 10 November 1993, on scheduled flight NAM 205/ 206 that included stops at Sandy Lake, Ontario; St. Theresa Point, Manitoba; Island Lake, Manitoba; and return to Winnipeg, Manitoba. The flight was conducted in accordance with an instrument flight rules (IFR)[2] flight plan and flight notification.

On arrival at Sandy Lake at approximately 1549, the crew attempted to land but were unable to because of the low ceiling and visibility. They then diverted to St. Theresa Point, landing at 1630. A normal turnaround was completed; the number of passengers on departure was 26, and 2,086 pounds[3] of fuel was uploaded to an estimated total of 6,700 pounds on board. The flight departed St. Theresa Point for Sandy Lake at 1720.

1 All times are CST (Coordinated Universal Time (UTC) minus six hours) unless otherwise stated.

2 See Glossary for all abbreviations and acronyms.

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

The aircraft landed at approximately 1745 at Sandy Lake, where 22 passengers deplaned while four remained on board; the aircraft was not refuelled or otherwise serviced at Sandy Lake. During the stop, both engines were shut down. On take-off from Sandy Lake, there were two pilots, a flight attendant, and four passengers on board.

The aircraft took off from runway 29 at Sandy Lake at approximately 1805 and entered a right turn. Witnesses indicate that the aircraft appeared to fly at a lower than normal height throughout the turn. After turning through approximately 120 degrees(°), the aircraft descended into 100-foot trees and crashed. The aircraft struck the ground about one nautical mile (nm) northwest of the airport. (See Appendix A).

All seven occupants of the aircraft were fatally injured in the crash. The accident occurred during the hours of darkness. The wreckage was located at position latitude 53°04'71"N, longitude 93°21'38"W, at an elevation of approximately 940 feet above sea level (asl).

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	3	4	-	7

1.3 Damage to Aircraft

The aircraft was destroyed by the impact with the trees and the ground.

1.4 Other Damage

There were trees damaged, and the fuel that was on board the aircraft spilled into the swampy area of the crash site.

1.5 Personnel Information

1.5.1 General

	Captain	First Officer
Age	52	34
Pilot Licence	ATPL	ATPL
Medical Expiry Date	01/ 02/ 94	01/ 07/ 94

Total Flying Time	16,000 hr	6,500 hr
Total on Type	4,500 hr	1,100 hr
Total Last 90 Days	247 hr	274 hr
Total on Type Last 90 Days	234 hr	215 hr
Hours on Duty Prior to Occurrence	10 hr	10 hr
Hours off Duty Prior to Work Period	15 hr	14 hr

Note: The pilots' log-books were not recovered, and flying times, except for the last 90 days, have been estimated using Air Manitoba and Transport Canada records. The captain's off-duty time was estimated from company records.

1.5.2 The Captain

1.5.2.1 General

The captain was qualified and certified for the flight. He had successfully completed a pilot proficiency check (PPC) and instrument flight check (IFC) on 21 April 1993, and he held a Group 1 instrument rating. The captain's Licence Validation Certificate (LVC) was valid with a requirement that he wear glasses.

The captain began his employment with Air Manitoba Limited (formerly Ilford Riverton Airways) in June 1981. He completed his initial check ride on the HS 748 in October 1985. He maintained proficiency on both the HS 748 and the Curtis Wright C-46. At the time of the occurrence, the captain was the Director of Flight Operations for Air Manitoba, responsible for establishment of flight operations policy, regulatory affairs, and the overall management of flight operations.

All of the pilots interviewed felt that the captain could effectively handle an emergency situation. They indicated that during an emergency he would not necessarily take control of the aircraft if the first officer was flying, as he had confidence in first officers' abilities.

The captain was considered to be an easy person to get along with, and he had the personal and professional respect of his colleagues and was easy to approach in his capacity as Director of Flight Operations. He ran this department with a very direct approach. Pilots who had flown with the captain indicated that, while flying, he was considered to be just another pilot. He was not strongly assertive and was always willing to discuss any decisions that needed to be made regarding the in-flight operation of the aircraft. He was considered a person who always got results.

1.5.2.2 Flying History

The captain's records indicate that he experienced no difficulty on the Curtis Wright C-46 aircraft but demonstrated difficulty during some HS 748 PPC and IFC rides.

The captain started flying the HS 748 when it was introduced into the company in 1985. Since then he had completed 10 check-rides on the HS 748; six of these rides were conducted by the same Transport Canada inspector, and two of these were PPC rides which he failed. Four of the rides with the Transport Canada inspector indicated the same "satisfactory with briefing (SB)" on the Transport Canada flight test checklist for item 4(c)(2), missed approach power loss. One ride with an Air Manitoba company check pilot (CCP) also indicated the same SB for 4(c)(2).

Following a PPC/ IFC ride on the HS 748 on 26 November 1992, the inspector commented on the test report, "4(c)(2) - SB - missed approach - power loss, requires review of exercise - marginal aircraft handling." A note was written below the comments: "Knowledge of aircraft is good but the pilot becomes very nervous during rides which contributes to the above comments."

The Transport Canada inspector explained the requirements of item 4(c)(2), which includes procedures during an overshoot from an instrument approach or a balked landing. The inspector recalls that the captain was consistently slow to react and, in some cases, did not know the required emergency procedure. The inspector's conclusion was that the captain had not prepared for the rides.

A review of the comments made on flight test reports shows that most of the difficulties noted were related to handling of the HS 748 aircraft. All of the captain's check rides on the C-46 were completed successfully.

1.5.3 First Officer

1.5.3.1 General

The first officer reportedly was an easygoing individual. Company captains and training pilots who had flown with him described him as an average pilot. They felt he had been improving steadily on the HS 748 aircraft; however, some of them expressed doubts as to how the first officer would react in an emergency situation. Some captains indicated that he lacked assertiveness and might be hesitant to react independently. Two captains stated that the first officer sometimes completed checklists too quickly during normal operations, and, as a result, missed items on the checklist. On more than one occasion, these captains had told the first officer to slow down while doing the checks.

Other captains stated that the first officer was assertive and spoke out when necessary, handled actual emergency situations professionally and competently, and properly performed his checklist duties.

The first officer had recently applied for the vacant Company Flight Safety Officer position. The first officer thought highly of the captain and had flown with him quite often in the recent past.

1.5.3.2 Flying History

The first officer was issued a private pilot licence (PPL) in December 1981. In March 1982, he failed the flight test for a commercial pilot licence on his first attempt; he successfully passed on his second attempt on 09 March 1982. On 15 April 1982, he failed his multi-engine flight test during the ground briefing part of the test; he successfully completed the flight test on 20 April 1982. On 03 May 1982, he failed his initial multi-engine instrument check ride; he passed a re-ride on 07 May 1982.

In 1984-1985, the first officer flew small aircraft such as the Piper Supercub, Cessna 172, and Cessna 180 in a commercial visual flight rules (VFR) operation. He renewed his instrument rating in December 1986. His rating lapsed, and in April 1989 he failed an instrument check ride; he successfully passed a re-ride on 25 April 1989. He flew for three weeks on the west coast flying a Beaver (DHC-2) on floats. He flew Cessna 206 floatplanes commercially for the summer on a VFR operation, then obtained employment with a different company flying floatplanes.

The first officer began his employment with Air Manitoba in June 1989 as a crewman on the C-46 aircraft. In April 1990, he began flying the C-46 as a first officer and earned an airline transport pilot licence (ATPL) in February 1991.

The first officer began initial training on the HS 748 in March 1992 and passed his PPC ride on the aircraft on 25 March 1992. The Transport Canada (TC) inspector who conducted the ride indicated on the ride report that the pilot needed work on altitude and airspeed control; he commented negatively on a simulated double engine failure procedure, and concluded by stating that the next ride was to be done by a DOT inspector. The first officer's HS 748 line indoctrination was completed 03 April 1992.

On 11 March 1993 the first officer failed his annual HS 748 PPC ride and had his instrument rating cancelled by the inspector. The unsatisfactory sequences were a check that was completed too slowly and an instrument holding pattern established incorrectly. On 18 March 1993, he successfully completed his last HS 748 check ride, which was valid until 01 October 1993. On 14 September 1993 he completed a PPC in the C-46 with a company check pilot; the PPC was valid until 01 April 1994. The qualification on the C-46 extended the HS 748 qualification to 01 April 1994 as per Air Navigation Order (ANO) Series II, No. 53.

A review of the comments made on flight test reports and training records showed that most of the difficulties noted were related to handling of the aircraft.

1.5.4 Flight Attendant

The flight attendant began his employment with Air Manitoba in 1984. At the time of the occurrence, he was one of two flight attendants employed full time with the company. He had recently completed a period as Acting Chief of Cabin Safety while the incumbent was on maternity leave; his performance during this period was considered by his peers and Air Manitoba management personnel as exemplary.

1.5.5 Pilot at the Controls

The types of injuries and bone fractures sustained by aircrew in accidents and the damage patterns on the control column and rudder pedals can often indicate which pilot was flying the aircraft at the time of a crash. A review of the radiology reports on the remains of this crew did not reveal any evidence to indicate who was flying the aircraft. The right control column wheel was badly damaged compared to the left wheel; however, no determination about who was flying could be made from this information.

Air Traffic Control (ATC) recordings and company interviews indicate that it was the first officer who made the radio transmissions during the departure from Winnipeg. The captain's voice has been identified on the recording of the radio transmissions between the Thompson Flight Service Station (FSS) and the flight en route from St. Theresa Point to Sandy Lake. It is common practice that the pilot not flying make the radio calls; however, based on cockpit workload, either pilot may use the radio.

The conversation recorded on the cockpit voice recorder (CVR) during the flight from St. Theresa Point to Sandy Lake indicates that the captain was flying that leg, at least the approach to Sandy Lake. If the pilots were to have equal time at the controls, it would have been likely that the first officer was flying the aircraft during the departure from Sandy Lake on the accident flight.

Although it is considered likely that the first officer was flying, without CVR information from the accident flight or eyewitness information, there is no material evidence to determine which pilot was flying the aircraft when it departed Sandy Lake.

1.5.6 Company Training on the HS 748 Aircraft

1.5.6.1 General

The initial pilot ground training on the HS 748 is a two-week course contracted outside the company. The recurrent ground training course, required annually, is two days long, and it also is contracted out. A review of the training curriculum found the ground training to be in accordance with the approved company Crew Training Manual. The pilots interviewed said the initial and recurrent ground training provided thorough coverage of the aircraft systems and procedures.

The flight training for both the initial and recurrent courses is provided by the company and is conducted by the chief pilot or a nominated training pilot. The minimum flight training required by Transport Canada, and provided by Air Manitoba, is eight hours. New pilots on type were required to complete an additional 25 hours minimum of line indoctrination under the supervision of a check pilot.

Pilots were normally upgraded on a seniority basis provided they met company capability and experience requirements, as is normal industry practice. The decision to upgrade a pilot was usually made by the chief pilot and the Director of Flight Operations, with the approval of the company president.

1.5.6.2 Simulator Training

Canadian regulations do not require that aircraft simulators be used for training; Air Manitoba did not have access to an HS 748 flight simulator. ANO Series VII, No. 2, requires that specific training items be completed in an aircraft when a simulator is not available or is not capable of accurately reproducing the characteristics of the aircraft.
Air Manitoba's training curriculum satisfied the requirements specified in ANO Series VII, No. 2.

1.5.7 Flight Crew Working Conditions

The Air Manitoba schedule was regular and usually allowed the pilots to return daily to Winnipeg. A review of the published schedules showed that the flight times did not exceed the established flight time and duty day limits.

As part of their normal duties, company pilots were required to load and unload the aircraft cargo at en route stops. The flight crews interviewed did not express concern about this work and did not feel it imposed undue hardship or caused excessive fatigue. About once a month the HS 748 pilots were scheduled to fly a freighter out of Churchill. The captain and first officer recently flew together on this flight, departing Winnipeg on 01 November and returning on 04 November 1993.

The captain flew from 01 to 05 November inclusive; he accumulated 29.3 flight hours, never exceeding 6.7 hours per day. He did not fly again until 10 November when he flew 2.7 hours prior to the crash. The captain's duties as Director of Flight Operations required that he be in the office during regular work hours when he was not flying.

In the first 10 days of November, the first officer flew seven days, being off duty on the 4th, 7th, and 8th. He accumulated 39.8 flight hours, never exceeding 6.5 hours per day. He flew 6.0 hours on 10 November prior to the crash.

The first officer was apparently happy with the flying schedule in that it was regular, reasonable, and allowed for scheduled days off.

1.5.8 Crew Resource Management Training

In December 1991, the company Flight Safety Officer invited Transport Canada System Safety personnel to provide a one-day presentation on crew resource management (CRM) training. The intent was to assess the effectiveness of CRM training and consider the possibility of implementing the program. The session was well received by the company and by those pilots who attended. There was no CRM training provided to the pilots subsequent to this session. The captain attended the course but the first officer did not; the first officer was away on flying duty at the time.

1.6 Aircraft Information

1.6.1 Aircraft Data

Manufacturer	Hawker Siddeley Aviation
Type	HS 748 Series 2A Model 234
Year of Manufacture	1967
Serial Number	1617
Certificate of Airworthiness (Flight Permit)	Issued 09 April 1981
Total Airframe Time	29,284.3 hours
Engine Type (number)	Rolls-Royce turboprop (2)
Propeller Type (number)	Dowty Rotol variable pitch (2)
Maximum Allowable Take-off Weight	46,500 pounds
Recommended Fuel Type(s)	Jet A, Jet B, or other wide-cut fuels
Fuel Type Used	Jet B

1.6.2 Aircraft History

The aircraft was manufactured in Manchester, England, in 1967 and originally purchased by the air carrier Lan-Chile in Santiago, Chile. In 1979 it was purchased by Austin Airways Ltd., Timmins, Ontario, and registered in Canada as C-GQTH. In December 1980 the aircraft was leased to Maersk Air, Denmark, and it was returned to Canada in March 1981. In January 1984 the aircraft was leased to Ilford Riverton Airways Ltd., Winnipeg, and then sold to Northland Outdoors Canada (1983) Ltd. In 1985 Northland became Northland Air Manitoba. In February 1987 the aircraft's registration was changed to indicate Nunasi Northland Airlines on lease from Northland Air Manitoba. The aircraft was registered to Air Manitoba Ltd. in 1991 when the company name was changed.

1.6.3 Weight and Balance

A copy of the weight and balance form for the accident flight was not found. However, weight and balance were calculated using information found in the aircraft journey log-book, which was recovered from the wreckage, and estimated fuel and baggage loads.

The take-off weight, in pounds, was calculated as follows:

aircraft APS[4] weight (log-book)	- 26,967
water/ methanol (estimate)	- 400
flight attendant (standard)	- 174
catering	- 100
dry operating weight (total)	- 27,641

dry operating weight	- 27,641
fuel (estimate)	- 5,450
passengers (standard)	- 550
cargo/ baggage (estimate)	- 400
estimated take-off weight	- 34,000 pounds

C-GQTH had two designated cargo areas, one forward and one aft. The maximum cargo and baggage estimated to have been on board C-GQTH was 400 pounds. Calculations indicated that neither a forward nor an aft loading of the 400 pounds, combined with any seating arrangement of the four passengers, would cause the aircraft's balance limits (C of G) to be exceeded.

1.6.4 Flight Controls

1.6.4.1 General

The HS 748 is equipped with a manual, dual control, tab-assisted flight control system. The primary control surfaces are actuated by cables, tie rod circuits, and push rods which provide direct mechanical connection between the cockpit and the control surfaces. If the primary system fails, the aircraft can be controlled by a trim tab system. There was no autopilot installed in C-GQTH.

4 APS - aircraft prepared for service - includes aircraft empty weight, two pilots, oil, toilet fluid, spare tires, tools, crew equipment, survival gear.

The control system was extensively damaged, and continuity could not be confirmed. However, examination of all retrieved components did not reveal any pre-impact failure or malfunction, and all of the breaks in the cables were overload in nature.

1.6.4.2 Aileron Control System

A review of HS 748 aircraft accidents and incidents where aircraft control may have been, or was, linked to the cause revealed that misrigging of the ailerons can have a marked detrimental effect on controllability of the aircraft under certain conditions of flight. The most evident effect is aileron lock, where the ailerons deflect toward their limits. If not overcome by control forces, aileron lock, with large aileron deflection angles, generates high roll rates and has led to aircraft crashes. An engineering study of the aileron rigging of C-GQTH was conducted to determine how the system was rigged and to evaluate if misrigging could have contributed to this occurrence.

Based on examination and analysis of recovered control parts and on comparison with other HS 748 aircraft, it was concluded that the ailerons were probably rigged in accordance with specifications.

The probability of aileron lock occurring increases with the magnitude of aileron control input, airspeed (aerodynamic loads), and the degree of misrigging of the aileron system. During the accident flight there was no observed violent departure from smooth flight, the maximum airspeed during the climb was probably less than 130 knots, and the ailerons of C-GQTH were probably rigged within specifications. Based on this study and considering the probable flight profile, it is highly unlikely that aileron lock occurred on the accident flight.

Witness marks on the aileron hinge points were considered to be reliable evidence and suggested that, at impact, the aileron controls were positioned for a left roll.

The control wheel rotates 88° to give full aileron deflection of 18.5°, and the rotation and deflection are linear. A specific aileron deflection angle at a constant airspeed produces a specific aircraft rate of roll; as airspeed increases, so does the rate of roll. On the HS 748, an aileron deflection of 1.8° will produce approximate roll rates, on a well-trimmed aircraft, of 1.4° per second at 100 knots indicated airspeed (KIAS) and 1.8° per second at 135 KIAS. Aileron deflection of 1.8° equates to a wheel deflection of 8.6°.

1.6.4.3 Gust Locks

The flight controls incorporate internal mechanical gust locks controlled from the cockpit. With the gust locks engaged, the flight controls are held in a neutral position. It is not possible to engage the gust locks with the propellers at a power setting required for flight, nor can power be advanced on both engines simultaneously if the gust locks are in place.

The gust locks were intact after the crash, and their examination at the site and in the laboratory revealed that they were not engaged at the time of impact.

1.6.4.4 Flaps

The Fowler type flaps are electrically operated, powered by a reversible electrical motor, and controlled by a lever on the starboard side of the centre console. The flaps may be set to any one of five pre-set positions. The drive train comprises a gearbox, torque shafts, and cables. As a protection against asymmetry, the torque shafts are duplicated. The secondary shaft is chain driven from the primary. Failure of any single torque tube or cable will not affect normal flap operation. There are other electrical and mechanical devices to protect against various flap faults.

At the accident site, the centre console was located with the flap selector lever still attached; the lever was in the full forward position (UP). The track for the flap lever had been distorted by impact forces, and the lever itself was bent forward, showing that it had been pushed or struck from behind during the crash. From the evidence, the position of the flap lever just prior to impact could not be determined.

Examinations of the flap-up cables, scroll pulleys, and witness marks on the flap tracks indicate that the flaps were up at the time of impact, with no flap asymmetry. The components of the flap signalling unit assembly were found in positions that indicated the flaps were fully retracted.

1.6.5 Electrical System

1.6.5.1 General

The primary electrical system of the aircraft is supplied at 28 volts direct current (DC) by two 9-kilowatt engine-driven generators, one on each accessory gearbox. The aircraft is equipped with four batteries fitted primarily for emergency use. The batteries are also used to supply power for engine starting if ground power is not available.

Three-phase, 115-volt, 400-hertz (Hz) alternating current (AC) is distributed through the No. 1 and No. 2 AC buses, which are powered by a static inverter system.

Two alternators provide 115-volt AC power to the anti- and de-icing equipment.

There had been numerous modifications to this aircraft's electrical system, and accurate circuit diagrams are not available.

1.6.5.2 DC Power System

Light bulb analyses showed that the following lamps were on at the time of impact: two emergency panel illumination lamps; the right low-fuel-pressure warning lamp; the radar altimeter illumination lamps and the decision height lamp; and the left navigation light. Witnesses saw aircraft landing lights, wing inspection lights, and interior lights on before and during the flight; various recovered DC fuse links were melted; the outside air temperature gauge was indicating at or just below 0° and the flaps and landing lights were retracted. All of the above operate on 28 VDC and, because of the power source of each, provide conclusive evidence that there was 28 VDC power on the left, right, and centre busbars throughout the accident flight.

1.6.5.3 Inverter System

Originally the aircraft was equipped with two Bendix rotary inverters that supplied 115V, 3-phase, 400-Hz power to the No. 1 and No. 2 AC buses. In July 1989, each of these inverters was replaced with two static inverters, model PC-17A, and one phase converter, model PH-3Φ-400. The PH-3Φ-400 converts the two PC-17As into a 115 VAC, line-to-line, 400-Hz, Delta, 3-phase power source and allows each inverter to operate individually, although the loads may be unbalanced. The phase converter synthesizes a third phase of 115 VAC by forcing a phase difference between the two PC-17A inverters. The PC-17A inverters are transistorized static power sources that operate from 28 VDC airplane power and deliver 115 and 26 VAC at 400 Hz. On C-GQTH, the 26 VAC output was not used because the original No. 1 and No. 2 115/ 26V autotransformers supplied the 26 VAC power requirements. The outputs from each pair of inverters are identified as the red and blue phases, and are fed through 10 ampere fuses to a transfer relay and then to the No. 1 and No. 2 AC busbars mounted on the left distribution panel. Henceforth, each pair of inverters will be referred to as one inverter, No. 1 or No. 2.

The inverters are selected on or off by two switches on the cockpit overhead panel. Air Manitoba procedure was to select the switches on at the start of a series of flights and leave them on until the end of the last flight for that crew. A transfer switch for each inverter enables, through a transfer relay, the transfer of all electrical services from a failed or de-selected inverter to the operating inverter. Either inverter is capable of supplying the total AC electrical power requirements of the aircraft. Single voltmeter and frequency gauges display the output from one inverter at a time, whichever one is selected to display.

Normally the No. 1 inverter supplies 115 VAC to the No. 1 AC bus which powers the following:

- flight data recorder (from red phase);
- cockpit voice recorder (from blue phase);
- CL2 compass system including the left and right directional gyros (from 3 phases);
- left horizon indicator;
- left engine oil pressure and temperature gauges;
- left fuel contents gauge;
- left de-icing cycle switch motor;
- No. 1 static sensing unit;
- No. 1 voltmeter inverter;
- left windscreen heating control;
- left engine firewall control unit; and
- left stall warning.

Normally the No. 2 inverter supplies 115 VAC to the No. 2 AC bus which powers the following:

- right horizon indicator;
- right engine oil pressure and temperature gauges;
- right fuel contents gauge;
- right de-icing cycle switch motor;
- No. 2 static sensing unit;
- No. 2 voltmeter inverter;
- right windscreen heating control;
- right stall warning;
- right engine firewall control;
- navigation radio supplies; and
- cabin temperature control.

Turning off, or failure of, the No. 1 or No. 2 inverter, including partial failure, will cause the following:

- the associated magnetic indicator will indicate OFF;
- the associated inverter fail light[5] will illuminate;
- the failure flag of the left (No. 1) or right (No. 2) horizon indicator will come into view;
- the left (No. 1) or right (No. 2) oil pressure gauge will read zero;
- the left (No. 1) or right (No. 2) oil temperature gauge will indicate minus 30; and,
- the left (No. 1) or right (No. 2) fuel gauge will indicate the reading when failure occurred.

Turning off, or failure of, the No. 1 inverter will cause, in addition to the above, the flight data recorder (FDR) fail light[6] to

5 There were two inverter power failure warning lights (amber coloured), one for each inverter. They were mounted one on each side of the emergency panel directly in front of each pilot. These lights cannot be dimmed by the crew.

6 The FDR failure warning light was red and was located on the inside of the doorway between the cockpit and the cabin.

illuminate, the CVR to test as unserviceable (there are no other CVR fail indications), and, if the directional gyro rotors are not turning from inertia, the gyro compass cards to remain on the heading when failure occurred. The cards could be manually adjusted but would not necessarily turn when the aircraft turned.

The inverter system incorporates a magnetic indicator for each AC bus. The indicator is spring loaded to display OFF when the bus is not powered and magnetically rotated to display ON when it is powered. The magnetic indicator for the No. 1 AC bus was recovered in a damaged condition; the damage shows that the indicator was displaying ON at the time it was damaged. This would, in the absence of other evidence, indicate that the No. 1 AC bus was powered, either by the No. 1 inverter or by the No. 2 inverter with the No. 1 transfer switch activated. *There was no other evidence found that indicated the No. 1 AC bus was powered at any time after the aircraft shut down after landing at Sandy Lake.* Evidence, as follows, indicates that the No. 1 AC bus was not powered:

- neither the FDR nor the CVR operated; and

- the CL2 compass system was not powered. (Refer to section 1.6.10.2 for detail about the compass system). This was determined from the following facts: the master indicator was found on approximately the same heading (between 350° and 358°) as the heading of the aircraft when it was parked in front of the terminal (356.5° from the FDR); a directional gyro rotor assembly was found and it did not exhibit any rotational damage and its windings were not burnt; and a compass face was found with the compass rose captured by impact damage on a heading of 280°. Runway heading is 290°, and it is believed that the compass was set to runway heading by one of the pilots before take-off, a normal procedure.

The No. 1 transfer relay was found at the crash site; however, it was so badly damaged that a determination regarding its state or serviceability prior to the accident could not be made.

The evidence showing that the No. 1 AC bus was not powered outweighs the evidence of the magnetic indicator. It was, therefore, concluded that the No. 1 AC bus was not powered. However, it could not be determined why the indicator would be showing ON if the bus was not powered.

One oil pressure gauge instrument was found. There is an arc-shaped smear mark on the dial face starting just below the 20 psi graduation and continuing to the 10 psi graduation. A review of the aircraft log-book for the previous month showed that the normal operating oil pressure range for the right engine was 22 to 24 psi, and for the left was 21 to 22 psi. After analysis of the mark and the design of the instrument, it was concluded that the mark was made by the oil pressure pointer during the crash. The gauge pointer is spring loaded and indicates below the zero mark when there is no AC power to the instrument. The mark, then, is an indication that the gauge was indicating oil pressure and, therefore, was powered at the time of impact. As the oil pressure gauges are AC powered, and as there was no power coming from the No. 1 AC bus, the mark on the dial is an indication that the No. 2 AC bus was powered. This is the only evidence found regarding the state of the No. 2 AC bus.

Functional testing of the inverters was not possible given the extent of impact damage. All of the in-line fuses tested serviceable. Examination of the recovered active components did not reveal any pre-impact failures that may have contributed to the failure of any inverter. There was no arcing or heat damage noted on the circuit boards or any of the other components. The two 200-ampere fuses (F179 and F180) that supplied DC power to the inverter system were still attached to a section of the centre busbar, and they both tested serviceable. The four 50-ampere fuses that powered individual inverters were recovered; however, they were damaged to the extent that their serviceability at impact could not be determined.

1.6.5.4 Other Electrical Determinations

The examination of the recovered electrical components and wiring, and review of the documentation relative to the electrical system revealed, in addition to that discussed above, the following:

- the serviceability, prior to impact, of the four inverters in the No. 1 and No. 2 AC systems could not be determined;
- the output voltage of the No. 1 inverter supplying the red phase was operating at 122 V nine days prior to the accident; the specified tolerance is 115 V +5%,-7% (maximum 120.75 V, minimum 107 V);
- the No. 1 and No. 2 phase converters were not installed in accordance with the approved wiring diagram;
- the No. 1 under-voltage phase sequence unit was serviceable prior to the accident;
- the No. 2 inverter transfer relay was unserviceable prior to the accident. It is unlikely that the crew would have been aware of this condition;
- C-GQTH did not have the under-voltage protection system installed;
- the fuse and circuit breaker index for C-GQTH was not kept up-to-date as various wiring changes took place; and
- the complete lack of identification on wires that were added to the airplane during modifications made examination of the various electrical systems difficult.

1.6.6 Hydraulic System

The hydraulic system is powered by two engine-driven pumps, one on each engine, and operates the following services: landing gear retraction and lowering; nose-wheel steering; and wheel brakes.

On examination after the accident, the main landing gear actuators were found extended, the uplocks were closed, and the uplock mechanism of one main gear had fractured, all of which indicate that the landing gear was locked up at the time of impact. That the landing gear was up is evidence that the hydraulic system was operable when the aircraft took off.

1.6.7 Fuel System

The fuel capacity of the aircraft is approximately 12,240 pounds. The fuel is carried in two integral wing tanks each with a usable fuel capacity of 720 Imperial gallons. There are two electrically operated boost pumps in each tank that feed fuel to the engine driven pumps. During all phases of flight, all boost pumps are normally selected ON. With no boost pumps operating, the engines will continue to operate; however, there is a risk of cavitation of the engine driven fuel pumps when operating with the boost pumps off, and this risk increases with an increase in altitude and/ or engine power. The four boost pumps were found to be operable.

Individual fuel systems feed each engine; however, the two systems are interconnected by a crossfeed line. Crossfeed can be selected to allow both engines to be supplied from one tank to balance fuel, or to supply fuel from both tanks to a single operating engine in an emergency.

There was no evidence found to indicate that the fuel delivery system was not operating normally. Fuel samples from the tanks used for fuelling the aircraft at St. Theresa Point, and from the aircraft's left fuel collector tank, were tested and found to be acceptable and uncontaminated. Based on the amount of fuel spread around the crash site, and on the fuel load and consumption history, it is also concluded that the aircraft did not run out of fuel.

The right low-fuel-pressure warning lamp was found, and analysis showed that it was illuminated at impact. Wiring that was the same as that which connected various fuel system components and lights was found near the start of the wreckage trail. Before electrical power was disabled, the right wing of the aircraft had broken up as the aircraft passed through the trees. The breaking of the wires could have activated the illumination circuit, or the loss of fuel as the wing was breaking up could have resulted in the loss of fuel pressure and, thus, the illumination of the low-pressure warning lamp.

1.6.8 Air Conditioning System

The air conditioning system provides ventilation, cabin pressurization, and temperature control. The system incorporates a manual dump valve to cater for unpressurized flight and for ventilation and pressure equalization during an emergency and on landing. Two spill valves, which operate manually or automatically, regulate mass air flow to the cabin from the supercharger. Air Manitoba crews manually close the spill valves.

Pressurization of the cabin is initiated as soon as convenient after take-off. Pressurization requires manual action to close the dump valve lever located outboard of the first officer's right ankle, and to operate the spill valve switches located adjacent to the first officer's right hand to close the two spill valves.

1.6.9 Powerplants and Propellers

1.6.9.1 General

The HS 748 aircraft is powered by two Rolls-Royce Dart gas turbine engines, each driving a four-bladed variable pitch propeller. A water/ methanol injection system is fitted to each engine to boost engine power for take-off if required. The propeller has a pitch range from zero to fully feathered, and its control system incorporates automatic controls and indicator and warning lights. The propeller has two fine pitch stops (FPS), ground and flight. The ground FPS is fixed at a propeller angle of 0° for use on the ground when starting the engine and during initial acceleration, and to provide drag during landing. The flight FPS is a mechanical removable stop, at a position corresponding to 18° blade angle, to prevent the propeller from achieving ground fine pitch when airborne.

1.6.9.2 Powerplants

After the accident the engines were examined at Rolls-Royce, Montreal, and at the TSB Engineering Branch. The severity of the impact limited the engine examination to the mechanical integrity of the assemblies. In summary, there was no indication of any pre-impact failure of either engine.

The impeller drive shafts of both engines had failed in torsional overload, but there was comparatively little compressor and turbine blade damage, and not much rubbing between rotating and stationary components. Very little evidence was discovered during the investigation that would assist in the calculation of engine speed at impact.

Both engines were running at impact; however, the power level could not be determined from examination of the engines.

1.6.9.3 Propellers

The propellers were examined at Dowty Aerospace Canada, Ajax, Ontario. The propeller units could not be completely disassembled because of the damage. The propeller assemblies were damaged and the blades were severely damaged, bent, and twisted. Impact marks were made on the transfer sleeve of each propeller during the crash--the right propeller blades struck trees before striking the ground, while the left propeller blades probably struck only the ground. The impact marks on the transfer sleeves equate to blade angles of 31° on the right propeller and 33° on the left propeller. Using information supplied by the manufacturer, and assuming an engine speed of between climb power of 14,200 rpm and take-off power of 15,000 rpm, blade angles of 31° and 33° equate to true airspeeds of 170 and 190 knots respectively.

The condition and the similarity of the damage patterns of the two propellers indicate that both propellers were developing significant and similar thrust at the time of impact.

1.6.10 Flight Instruments

1.6.10.1 Attitude Indicators

The aircraft was equipped with two AC-powered gyro horizon (attitude) indicators, an AIM model 500-ECF on the left and an AIM model 251-ECFR on the right. The left side was powered by the No. 1 AC bus and the right side was powered by the No. 2 AC bus. Each indicator is equipped with a warning flag designed to appear on the instrument face if there is no electrical power to the instrument. Neither of the horizon indicators, nor any parts of them, were located after the crash.

The aircraft was also equipped with two DC-powered turn and slip indicators, one on each instrument panel. Both instruments were powered by the centre bus.

ANO Series II, No. 18, the *Additional Bank and Pitch Indicator Order*, enacted in 1972, requires that large (more than 12,500 pounds take-off weight), turbo-jet aircraft have a third bank and pitch indicator system powered from a source independent of the electrical generating system. There is no regulatory requirement that large, turbo-prop aircraft be so equipped, and C-GQTH was not equipped with a standby artificial horizon.

Tests conducted on six non-installed AIM horizon indicators showed that it was not possible to predict the final orientation of the instrument after power was removed or after caging and uncaging a non-powered instrument. During observation of the AIM horizon indicators on an in-service HS 748, power was removed from the instruments; however, the warning flag on one instrument did not come into view until the instrument glass had been tapped several times. Jet Electronics, the manufacturers, have no history of problems with the flags not properly indicating failure. A Service Advisory, entitled *500 Series Attitude Indicator Flag Adjustment*, was issued in January 1978 by AIM for the 500 series horizons. There was no explanation of why the advisory was issued, but it is assumed that it addressed the problem of warning flags not properly indicating the status of the instrument. It could not be determined if the adjustment of the model 500 horizon of C-GQTH had been made.

1.6.10.2 Compasses

There were two CL2-type gyrosyn compasses installed, one for each crew member; this was the original system installed by the manufacturer. Both were large instruments and easily read. Only one compass could be slaved at a time, controlled by a switch located on the left side panel left of the captain's seat. In accordance with the aircraft checklist, it was usual for the aircraft to be operated with the slaving function selected to the left compass. The other compass would operate as a directional gyro which would have to be set manually periodically.

The gyrosyn compass system for both compasses was powered by the No. 1 AC bus. If that power source was lost, and no transfer was effected, both compasses would cease to function, and neither compass card would necessarily move when the aircraft turned.

A master indicator was positioned behind the left seat at head level and was originally designed for a navigator. It was synchronized with the gyro unit and provided azimuth monitoring for ancillary equipment.

The aircraft was equipped with a standby magnetic compass.

1.6.10.3 Radio Altimeter

The aircraft was equipped with a radio altimeter (radalt) with direct scale reading of altitude from 0 to 2,500 feet. Air Manitoba SOPs direct that, before departure, the bug be set to 400 feet or the above-ground circling altitude, whichever is higher; and, en route, the bug be set to 1,500 feet when cruising above the radio altimeter's operating range, or 100 feet below the indicated radio height. The decision height light on the radalt will be illuminated while the aircraft is below the selected height. At the time of the crash, the decision height (DH) light on the radalt was illuminated, as was the instrument light itself, and the radalt was set to 2,100 feet. The setting mechanism is geared, and it is highly unlikely that the setting would have changed during impact. That the radalt was reset is a further indication that normal cockpit activities were performed, at least until 400 feet. It is not known why the radalt was set to 2,100 feet.

1.6.10.4 Altimeters

The aircraft was equipped with two altimeters, one on each instrument panel. The left was a servo-altimeter that required 28 VDC power to operate; the right altimeter was mechanical and was provided with a vibrator, which operated on 28 VDC, to avoid errors due to frictional drag.

1.6.11 Ice and Rain Protection

Two 200-volt, 3-phase, variable frequency alternators, one mounted on each engine accessory gearbox, supply power when required for anti-icing or de-icing the following: cockpit windscreens and direct vision windows; propellers and spinners; and engine and oil cooler intakes. Failure of one alternator will still allow use of all anti- or de-icing equipment, but some rearrangement or reduction in loads may be required. Airframe de-icing is provided by inflatable rubber boots bonded to the leading edges of the tailplane, the vertical fin, and the wings outboard of the nacelles.

1.6.12 Global Positioning System (GPS)

A GPS (Garmin 100) was installed in C-GQTH, but was not integrated with any part of the aircraft's navigation system. GPS information, including way points, tracks, headings, distances, times, ground speed, etc., was displayed visually on the unit.

The Garmin 100 GPS installation did not meet the requirements of the Technical Standard Order (TSO) for IFR GPS receivers (TSO C-129); therefore, the GPS could not be approved for use as the primary IFR flight guidance.

The GPS unit was recovered intact at the crash site; however, because its internal battery had become disconnected, it yielded no information.

1.6.13 Ground Proximity Warning System (GPWS)

A GPWS operates without any pilot input and provides audible and visible warning to the pilots if their aircraft approaches terrain more closely than permitted by the limits entered into the system computer. One of the warning modes activates if the aircraft begins to descend after take-off; for an HS 748, the GPWS is programmed to provide a warning if the aircraft begins a descent before a radio altitude of 700 feet is reached. GPWS has prevented many accidents where, until the warning was sounded, the pilots had been unaware that the aircraft was in danger because of its proximity to the ground or water.

C-GQTH was not equipped with a GPWS, but it had been so equipped in the past. ANO Series II, No. 22, requires that large, turbo-jet aircraft be equipped with a GPWS; there is no regulatory requirement that large, turbo-prop aircraft be so equipped.

The GPWS installation for this aircraft would require 115 VAC and 28 VDC power, the AC power being supplied by the No. 1 AC bus.

1.6.14 Minimum Equipment List (MEL)

Air Manitoba operated the HS 748 aircraft in accordance with the Air Manitoba HS 748 Minimum Equipment List. The MEL is dated 01 June 1990 and was approved by Transport Canada 14 September 1990. The MEL allows certain deviations from aircraft instrument and system requirements to permit continued or uninterrupted operation of the aircraft as long as the equipment that remains operating can provide continued safe operations.

Following are some requirements extracted from the MEL regarding aircraft operation:

1. Item 23-10 Cockpit Voice Recorder

Where a cockpit voice recorder becomes inoperative but the flight data recorder is operative, the aeroplane may be flown on such flights as are necessary to complete a planned itinerary but shall not depart a maintenance base where repairs or replacements can be made.

2. Item 24-13 Main Inverters (No. 1 and No. 2)

One may be inoperative provided: a) the aircraft is operated in daylight VMC [visual meteorological conditions] conditions only....

There is no mention of the inverter transfer switch in the MEL under section 24.

3. Item 24-14 Main Inverter Failure Warning Lights

One may be inoperative provided: a) that prior to each flight the associated inverter is energized to check for correct voltage and frequency to determine that it is operating normally....

4. Item 31-2 Flight Data Recorder

Where a flight data recorder becomes inoperative but the cockpit voice recorder is operative, the aeroplane may be flown on such flights as are necessary to complete a planned itinerary but shall not depart a maintenance base where repairs or replacements can be made.

5. Item 34-1 Horizontal Indicators

One may be inoperative provided: a) flight is made in day VMC; and b) the third self-contained gyro horizon is operative. (C-GQTH did not have the third gyro installed.)

6. Item 34-3 Directional Gyro Systems

One directional gyro may be inoperative provided: a) flight is made in daylight VMC conditions...

1.6.15 Aircraft Checklists - Applicable to C-GQTH

INITIAL PRE-START - This check is completed prior to the Pre-Start check. According to Air Manitoba Standard Operating Procedures, the initial check is to be completed in accordance with the HS 748 normal checklist and need only be completed on the first flight of the day.

The Initial Pre-Start check includes, amongst other items, FDR/ CVR FUNCTION CHECK ... DONE, INVERTERS ... ALL ON, EMERGENCY LIGHTS ... TESTED, and FLIGHT INSTRUMENTS ... CHECKED/ SET.

AFTER START - This check includes, amongst other items, INVERTERS ... ON, FLIGHT DATA RECORDER ... SET, and COMPASS & RMI ... (set heading).

TAXI - This check includes GYROS ... CHECKED. This would include checking the horizon indicators and the directional gyros.

LINE UP - This check includes COMPASSES CHECKED. This would mean ensuring that the compasses indicate runway heading or close to it.

1.6.16 Aircraft Performance

Aircraft take-off performance for the accident flight was calculated using the following conditions: zero headwind; temperature minus 5° Celsius; altimeter setting 29.75 inches, pressure altitude 1,000 feet asl; and a hard, dry, prepared runway surface 3,500 feet long. The temperature was the average temperature from the three nearest weather reporting stations, and the altimeter setting the lowest reported from the same stations. Although the runway is gravel surfaced, the surface was frozen and hard-packed, similar to a hard, dry, prepared surface.

The chart below indicates the maximum allowable take-off weight, in pounds, for the above conditions. As can be seen from the chart, there were a number of options available to the flight crew for their departure from Sandy Lake. Using an estimated take-off weight of 34,000 pounds, the aircraft, at take-off, would have had a margin of safety at all three approved flap settings. The most common practice of company pilots for departure from Sandy Lake was to use 15 flap.

Flaps 7 1/ 2		Flaps 15		Flaps 22 1/ 2
Wet	Dry	Wet	Dry	Wet *
40,400 (R)	37,700 (R)	42,900 (R)	39,200 (R)	42,100 (W)

Wet - power enhanced by water/ methanol
Dry - normal take-off power
* - All take-offs with a 22 1/ 2 flap setting require the use of water/ methanol.
R - Runway limited, balanced field length

W - Weight, altitude, and temperature (WAT) limited

There is a cost associated with the use of water/ methanol, and operators will use it only if required for increased take-off performance.

In summary, the aircraft was capable of departing Sandy Lake at a maximum operating weight between 37,700 and 42,900 pounds depending on the flap configuration and whether water/ methanol was used.

The aircraft manufacturer computed that, with the flaps set at 15 and for the conditions and aircraft weight at the time of take-off, the take-off distance on a dry paved runway required for the aircraft to reach 35 feet above the runway was 2,093 feet, with a ground run of 1,826 feet. To adjust for a gravel runway, the ground run was then multiplied by a factor of 1.15 to give a ground run of 2,100 feet.

At the time of take-off, the surface of the runway was very hard packed snow and ice and was smooth; there was no gravel at the surface. The TSB concluded, therefore, that the actual take-off run would have been closer to 1,826 feet than 2,100 feet.

On 12 March 1971, Hawker Siddeley Aviation issued a Notice to Operators entitled *Operations From Unpaved Surfaces,* which pertained to HS 748 aircraft, Series 1, 2, and 2A. The notice discusses rolling start techniques to prevent propeller damage when taking off from gravel runways. This technique is assumed in the Flight Manual take-off distances, and was, therefore, used in calculating the take-off run in this occurrence.

1.7 Meteorological Information

1.7.1 Weather Forecasts

There is no Atmospheric Environment Service (AES) weather reporting station at Sandy Lake.

There are three AES weather reporting stations surrounding Sandy Lake, the closest being Island Lake (YIV), 67 nm to the northwest; Big Trout Lake (YTL) is 132 nm northeast, and Red Lake (YRL) is 122 nm south.

The Island Lake forecast valid 10 November from 1100 to 2300 CST was as follows: 2,000 feet scattered cloud, ceiling 5,000 feet overcast, visibility 6 miles or greater in light snow, variable to ceiling 1,000 feet obscured, visibility 1½ miles in light snow and fog. A slight improvement was expected after 2300 CST. This forecast was available to the crew prior to their departure from Winnipeg.

The Island Lake forecast valid from 1700 CST 10 November to 0500 CST 11 November was as follows: ceiling 1,000 feet overcast, visibility 6 miles or greater in light snow, with occasional ceiling 2,000 feet broken, visibility 6 miles or greater. The crew would not have received this forecast prior to departing Winnipeg.

1.7.2 Weather Reports

Relevant weather reports for the three stations were as follows:

Island Lake - 1400 CST - partially obscured, estimated ceiling 1,100 feet overcast, visibility 1 mile in light snow, temperature minus 6° Celsius (C), dew point minus 7°C, wind 220°T at 6 knots, and altimeter setting 29.76.

Island Lake - 1600 CST - partially obscured, estimated ceiling 1,100 feet overcast, visibility 8 miles in light snow, temperature minus 4°C, dew point minus 6°C, wind 260°T at 5 knots, and altimeter setting 29.74.

Island Lake - regular special 1800 CST - measured ceiling 900 feet overcast, 10 miles visibility in light snow, temperature minus 4°C, dew point minus 6°C, and wind 310°T at 8 knots, altimeter setting 29.76.

Big Trout Lake - regular observation 0000Z (1800 CST) - 1,600 feet scattered, estimated ceiling 2,200 feet overcast, 3,100 feet overcast, 4 miles visibility in light snow, temperature minus 7°C, dew point minus 9°C, winds 220°T at 7 knots, altimeter setting 29.77.

Big Trout Lake - special observation 0011Z (1811 CST) - estimated ceiling 1,100 feet overcast, 2.5 miles visibility in light snow, temperature minus 7°C, dew point minus 8°C, wind 220°T at 8 knots, altimeter setting 29.77.

Red Lake - regular observation 0000Z (1800 CST) - measured ceiling 1,100 feet overcast, visibility 3 miles in light snow, temperature minus 5°C, dew point minus 7°C, winds 190°T at 6 knots, altimeter setting 29.81.

Red Lake - special observation 0010Z (1810 CST) - precipitation ceiling 700 feet obscured, 1/2 mile visibility in snow, wind 190°T at 6 knots; remarks: snow covering 10/10 of the sky.

After the accident, AES provided a summary of weather conditions at the time of the accident (aftercast). The summary indicates that the Sandy Lake area was under the influence of a weak low or frontal wave, with broken to overcast cloud layers 3,000 to 6,000 feet asl with some embedded convective cloud topped between 7,000 and 8,000 feet asl. There was a possibility of moderate to severe icing in the cloud, which could have existed in the vicinity of Sandy Lake at the time of the occurrence. The visibility was generally better than 5 miles but at times as low as 1/2 mile in snow.

A Beech 99 aircraft landed at Sandy Lake and had just shut down at the terminal as C-GQTH was taxiing for take-off. The crew of the Beech 99 indicated that, during the flight from Deer Lake at 3,500 feet asl, the aircraft had picked up some ice during the climb and descent through the cloud. The approach to Sandy Lake was visual below about 1,000 feet above ground level (agl), with about 3 to 5 miles visibility in very light snow. This same crew departed Sandy Lake about 15 minutes after the accident to search for the crash site. They indicated that the ceiling was about 1,700 feet asl (700 feet agl) overcast, and that it was snowing very lightly at that time.

Another pilot, who departed runway 29 in a Piper Navajo only minutes before C-GQTH, indicated that the ceiling was about 2,000 to 2,200 feet asl (1,000 to 1,200 feet agl), and the visibility was greater than 5 miles in very light snow. He stated that it was a very dark night and that, when the aircraft broke out of the cloud in the climb around 8,000 feet asl, there was less than 1/4 inch of ice on the wings.

1.8 Aids to Navigation

A non-directional beacon (NDB), identifier ZSF, is located on the Sandy Lake Airport property, north of the centrepoint of the runway, and serves as an approach aid.

Air Manitoba has authorization from TC to use the NDB 29 approach at Sandy Lake. The chart is labelled "Company Use Only," and is not for public use without TC approval. The minimum descent height for both the NDB straight-in and circling approaches to runway 29 is 1,740 feet asl, 803 feet above airport reference elevation. There is no approved approach to runway 11.

Published departure procedures for runway 29 require a visual climb to 1,200 feet agl before proceeding on course.

1.9 Communications

On departure from Winnipeg, C-GQTH, as Air Manitoba Flight 205, was in radio contact with Winnipeg Departure Control and Winnipeg Centre. At St. Theresa Point the flight number changed from 205 to 206, and Flight 206 communicated with Thompson FSS on departure from St. Theresa Point destined for Sandy Lake. Taped communications between the crew and the ATC units and the FSS indicate nothing out of the ordinary.

1.10 Aerodrome Information

Sandy Lake Airport is a public use airport located at Sandy Lake, Ontario, a community of about 1,600 people. The airport is identified as CZSJ, is certified, and is operated and maintained by the Ontario government. The airport reference elevation is 937 feet asl. It has one runway, 11/29, which is gravel surfaced, 3,500 feet long and 100 feet wide. At the time of the occurrence the runway was smooth, hard-packed, and frozen. The tower for the NDB is located on the airport north of the runway and extends to 1,066 feet asl.

Low intensity runway edge lights and threshold and runway end lights are available for both runways and can be activated by aircraft radio control of aerodrome lighting (ARCAL). The lights are activated for 15 minutes by keying a microphone five times in five seconds on frequency 122.8 megahertz (MHz).

Runway 29 heads directly away from the main community of Sandy Lake. There are scattered houses along the shore of the river to the right of the airport.

1.11 Flight Recorders

1.11.1 General

The aircraft was fitted with an FDR and a CVR. Both recorders were recovered from the wreckage intact and in good condition. It was determined that neither recorder functioned after shutdown of the aircraft at the end of the flight into Sandy Lake; however, a functional analysis of both recorders revealed they were capable of recording at the time of the accident.

Recorder information from the previous flight revealed that both recorders powered up prior to engine start. A synchronization of the FDR and CVR indicated that the recorders powered down at essentially the same time. The CVR revealed that the recorders stopped at the time the engines were spooling down.

It was determined that neither recorder came on-line for the accident flight because of the lack of 115-volt 400-Hz power at the recorders. The source of 115-volt AC power for the recorders is the No. 1 AC bus, powered either by the No. 1 inverter or the No. 2 inverter if transferred.

1.11.2 Flight Data Recorder

1.11.2.1 General

The FDR is a Sundstrand (980-4100-FWUS) digital universal flight data recorder (UFDR). It records five parameters, including pressure altitude, indicated airspeed, magnetic heading, vertical acceleration, and temperature. The recorder contained the previous 25 hours of data recorded prior to the accident flight.

In 1991, Transport Canada issued Air Manitoba an exemption to Section 2 of the *Flight Data Recorder Order* (ANO Series II, No. 13). This exemption authorized the company to operate four HS 748 aircraft using installed and functioning five-parameter foil recorders pursuant to subsection 5.9(2) of the Aeronautics Act. Approval from Transport Canada to install and operate the universal recorder in C-GQTH had not been requested. A universal recorder provides more accurate data which is easier to analyze.

1.11.2.2 FDR Data

The FDR readout regarding the flights from Winnipeg to Sandy Lake and St. Theresa Point, and from St. Theresa Point to Sandy Lake was analyzed to provide information on the conduct of these flights.

Analysis of the applicable FDR data required that some assumptions and interpretations be made, especially for the approaches to Sandy Lake. The only authorized instrument approach to Sandy Lake is the non-directional beacon approach to runway 29 (NDB RWY 29). This approach requires that the Island Lake altimeter setting be used, so in calculating heights agl, the altimeter setting from Island Lake at 1600 CST, 29.74, was used. The FDR does not record the track flown, only headings. The track over the ground would be affected by the wind, and interpretations were made to convert the headings to tracks and make the tracks relative, in general, to the position of the airport. It appears that the pilots made two approach attempts to runway 29 and two attempts to see the runway environment approaching runway 11 from the west. The reference elevation of the Sandy Lake Airport is 937 feet asl.

The aircraft approached the airport from the south en route from Winnipeg and descended to about 1,600 feet asl before reaching the airport; the aircraft turned right and passed over the airport at this height on a heading of about 135°. The aircraft then turned right to a heading of about 152°, climbed to about 2,200 feet, and turned left to about 310°, the approximate inbound track of the NDB approach to runway 29. A further turn to 300° was made, and the aircraft began descending.

The aircraft turned to 292°, descended to about 1,300 feet asl, and held this altitude for 26 seconds. The aircraft then commenced a climbing right turn to 2,450 feet on a heading of about 330°.

The aircraft turned left to a heading of about 110° and descended to approximately 1,400 feet asl as it passed over the airport. The aircraft then climbed to about 2,000 feet asl on a heading of 148°, turned left towards the inbound track to runway 29, and climbed to about 2,150 feet asl. The aircraft began to descend and rolled out on a heading of about 300°. The aircraft descended to about 1,200 feet asl on heading 300° and held that altitude for 38 seconds, during which time the aircraft turned left to 282°. The approach was then discontinued.

The minimum safe altitude within 25 nm of the Sandy Lake NDB, as published on the approach plate, was 2,700 feet asl, and the minimum descent altitude (MDA) for the published approach to runway 29 was 1,740 feet asl, 803 feet above the airport elevation; there was no published approach for runway 11. The estimated tracks flown were not always coincident with the tracks on the approach plate. It is concluded that the crew did not see the runway because the aircraft was in cloud, or they saw the runway but not clearly enough to allow them to land.

The crew then flew to St. Theresa Point and conducted a straight-in approach to runway 22 and landed. After the turnaround, the aircraft took off from runway 22. During the climb, the aircraft heading gradually changed from 220° to 237°. After a brief reduction in climb (at flap retraction altitude), the aircraft continued the climb and turned left toward Sandy Lake. The aircraft flew straight in to runway 11, descending en route, and landed off the first approach. The CVR tape indicates that the ground was reported to be visible from the cockpit just after a verbal call by a crew member at 450 feet.

The NDB could have provided the crew with enough information to allow them to follow the paths that they did. However, it would be most unlikely for the crew to descend to altitudes as much as 1,300 feet below the minimum safe altitude within 25 miles of the NDB, and 540 feet below the MDA for runway 29, without being sure of their position. In the Sandy Lake area, the GPS could provide this information; the NDB could not. Based on the tracks and altitudes flown, and on the information from the CVR, it is concluded that the crew were using the GPS as the primary navigation aid while the aircraft was in instrument meteorological conditions.

1.11.3 Cockpit Voice Recorder (CVR)

The CVR is a Fairchild A100, and it contained approximately 32 minutes of audio recording for the flight from St. Theresa Point to Sandy Lake, the last flight prior to the accident. The only channel recording was that of the cockpit area microphone (CAM). The tape contained some of the intra-cockpit communications between the crew. The two radio channels and the cockpit interphone did not record because they were not properly connected to the CVR. However, the CAM channel was noisy, with much of the voice communications masked by engine and aerodynamic noise. Filtering of the audio signal allowed the transcription of some of the communications during the start, taxi, approach, and landing. The CVR data did not reveal anything unusual regarding the aircraft, and the engines sounded normal during the flight.

The transcript of the CVR recording made on the approach to Sandy Lake during the flight previous to the accident flight contains conversation between the two pilots. The first officer, identified by his voice, is stating steering, distance, speed, and height information, presumably to assist the captain, who is flying the aircraft. There is no distance measuring equipment associated with the airport, and there is no approved approach to runway 11. Based on the flight profile and the crew's discussions, it is concluded that the crew were using the GPS for navigation during the approach.

1.12 Wreckage and Impact Information

During the crash, the aircraft travelled through the trees for about 200 feet, then struck the ground and travelled for another 400 feet before coming to rest. The initial track through the trees was about 050° magnetic (M), changing to about 060°M for the last 500 feet through the trees and on the ground. The aircraft entered the trees at a right bank angle of approximately 50°, which steepened to 80° to 90° before the aircraft struck the ground. The descent angle was approximately 25° when the aircraft entered the trees, and it did not change appreciably before the aircraft struck the ground.

The aircraft started to break up on initial contact with the trees, and the entire crash trail was strewn with wreckage. The fuselage, from the area of the wing trailing edge to the empennage, was relatively intact and was the furthest major piece of wreckage from the initial tree strike.

An inventory of the wreckage revealed that all of the primary control surfaces, fuselage doors, and cabin emergency overwing exits were accounted for. All of the right and left propeller blades (four on each propeller) were discovered either close to, or still attached to, their respective engines.

1.13 Medical Information

The captain's LVC was valid with a requirement to wear glasses. It could not be determined if the captain was wearing his glasses at the time of the accident. According to the pilot's wife and his peers, the captain always wore his glasses while flying.

The first officer held a valid Category 1 medical, with no limitations. His LVC indicated that an electrocardiogram (ECG) was required on the next medical.

Autopsies and toxicological tests were conducted on the remains of the captain and first officer. There was no indication of any pre-existing conditions which could have affected their performance.

1.14 Fire

Witnesses generally agreed that there was no fire coming from the aircraft while it was in flight; however, one witness saw something "like sparks from a fire coming from the right engine, but no banging." Another witness said the right engine was on fire; "it was a small flame, and it was not smoking."

There was no evidence found at the crash site or during examination of the wreckage and engines that would indicate there was an in-flight fire of any kind.

During the on-site investigation, it was discovered that there had been a small post-crash fire in the right engine nacelle area which caused little damage. There was a larger post-crash fire in the area of the left engine nacelle on the left wing which caused some burning and melting of the wing metal. The fire did not spread more than a few feet in any direction, and it is believed the fire was of short duration. Soot was found in the snow around the area, suggesting that this was a fast-burning, fuel-fed fire. The fires self-extinguished.

1.15 Survival Aspects

1.15.1 Emergency Response

There were no emergency response services available at the Sandy Lake Airport, nor were they required for the airport certification standard; however, a number of members of the community witnessed the occurrence and began to respond immediately. A large contingent of the community, on foot and snowmobile, assisted the First Nations and Band Constables in mounting a search for the crash site and survivors. The local nursing station was instructed to prepare for casualties and air traffic control was advised of the occurrence.

Within 30 minutes of being advised of the occurrence, the Rescue Coordination Centre in Edmonton, Alberta, had position information from the search and rescue satellite (SARSAT) system which had received the signal from the aircraft's emergency locator transmitter (ELT). The Ontario Air Ambulance service dispatched an air ambulance aircraft to Sandy Lake to await possible medical evacuation requirements. The Ontario Provincial

Police (OPP) activated their Emergency Response Team and additional constables were flown into the area.

The first rescuers arrived at the crash site within two hours of the occurrence; they found that all persons on board had died. The bodies of the victims were transported from the site the following day by OPP helicopter.

1.15.2 Crew Seats and Harnesses

The captain and first officer were found separated from their seats on impact. The flight attendant was found in the rear section of the fuselage, held in his seat by the secured lap belt.

The lap belt anchor points in both flight deck crew seats had started to tear out in overload, suggesting that the seats were occupied and the lap belts done up at impact. Both flight deck crew seats were equipped with shoulder harnesses. Examination of the harnesses indicated that it was probable that the shoulder harnesses were not secured to the lap buckle at impact.

1.16 Tests and Research - Flight Path Calculations (Reference LP 148/93)

As there was no information from the FDR for the accident flight, the flight path and aircraft behaviour were estimated using information gathered during the investigation.

A normal departure for this flight would be to climb straight ahead, retract the landing gear when safely airborne, retract the landing lights[7], continue climb to 400 feet and retract the flaps, continue climb to the turn altitude (normally 500 feet agl or greater), and turn 20° to the right en route to Island Lake.

Certain assumptions were necessary to derive the most probable flight profile. The primary assumption was that the aircraft reached 400 feet agl; this was based on witness descriptions and the fact that, at impact, the flaps were up and the landing lights were retracted and off. Flap retraction is normally accomplished after the aircraft reaches 400 feet above runway elevation. Pilot interviews indicated that some pilots retract the lights once 400 feet is reached while others retract the lights after the landing gear is selected up. Other assumptions were that the aircraft did not "S" turn--that is, it followed a smooth path--and that the rate of heading change increased progressively.

Wreckage analysis, historical performance data from the FDR, witness information, known data points (crash position[8], impact speed, and bank and descent angles through the trees), aircraft performance information, mathematical calculations, computer estimations, and animated computer graphics were then used to determine the most probable flight profile of the aircraft from lift-off to the crash site.

The generated theoretical flight profile revealed that, in order to get to the crash site at the speed and angles as determined through analysis of the wreckage and tree-cuts, *the aircraft had to lift off approximately 1,800 feet from the threshold of the runway and begin turning to the right within five seconds after lift-off.* The duration of the flight from lift-off was determined to be approximately 31 seconds.

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7 Some pilots stated that it was normal to climb to 400 feet agl before retracting the landing lights.

8 The position of the crash site with respect to the threshold of runway 29 was measured with a GPS in a helicopter and with a hand-held GPS. Although the measurements were nearly the same, averages were used to determine the bearing and distance used in the following calculations. There is, therefore, the possibility that the calculations are in error by a few percentage points, but not enough to affect the general conclusions.

The theoretical profile revealed that the aircraft was likely in a right bank of approximately 35° and rolling at the rate of 1.5° per second when flap retraction altitude (400 feet above runway elevation) was reached, and the aircraft probably reached about 450 feet prior to starting to descend. In the final seconds of the flight, the aircraft was probably descending at approximately 7,500 feet per minute.

1.17 Additional Information

1.17.1 Aircraft Contamination

Examination of the wreckage revealed no evidence that the aircraft was contaminated with ice or snow at the time of the crash. The temperature, from the time of the crash until the wreckage was examined, was below zero. Two pilots who looked at the wings of C-GQTH prior to its departure stated that there was no ice visible on the leading edges of the wings. According to a third pilot, when C-GQTH taxied out its wings were well lit by what he assumed to be the aircraft's wing inspection lights, and he noticed a trace amount of snow or ice on the right wing. The pilots of the aircraft that searched for the crash site indicated that icing of their aircraft did not occur while they were on the ground or airborne. Although there was icing in cloud forecast, there is no evidence that aircraft on the ground at Sandy Lake would have iced up because of precipitation, fog, or condensation.

1.17.2 Air Manitoba

1.17.2.1 Organizational and Management Information

A review of the management organization and the manner in which it operates was conducted to determine if there was any link to the accident.

General

At the time of the accident Air Manitoba operated a fleet of six aircraft, including five HS 748 aircraft. The Company had been providing scheduled and charter service with HS 748 under ANO VII, Series No. 2, since 1985. The Company employed 100 persons and operated from a hangar and maintenance facility located at Winnipeg International Airport.

Air Manitoba is a class three carrier that evolved through acquisitions and mergers with smaller carriers. Small carriers usually operate from a main base with offices, maintenance facilities, and support staff. However, operations and maintenance activities when away from the main base are often conducted in relatively austere and difficult environments with little support. This requires that a person, pilot or maintainer, have the ingenuity and initiative to get the job done.

Senior Management

At the time of the accident, Air Manitoba was a privately owned company with about 70 full-time employees. The company had a Board of Directors, a President/ CEO, and, reporting to the CEO, a Vice President of Finance and Administration, a Director of Flight Operations, a Director of Maintenance, and a Director of Commercial Services. There was a company Flight Safety Officer who had direct access to the CEO on flight safety matters. The V/ P Finance and Administration and the Flight Safety Officer positions were vacant; the incumbents had recently left the company for employment elsewhere.

The President/ CEO came to Air Manitoba in 1990 from Air Ontario, where he had been V/ P Maintenance. He indicated that he had reasonable latitude to make decisions and that he had a good relationship with his Board. He was responsible for the financial health of the company and, as such, was responsible for the major financial and marketing decisions. Departments within the company did not have their own budgets, but did have spending authority for minor items.

Flight Operations

Director of Flight Operations (DFO) - The captain of the accident aircraft was also the DFO and had been with the company and its predecessors for many years. He had flown the HS 748 since its introduction by the Company in 1985. He was responsible for the overall management of flight operations, the establishment of operations policy, and regulatory affairs. His department was considered to be efficient.

Chief Pilot - The Chief Pilot had been with the company for eight years and had held that position since 1988. He was responsible for the supervision of all flying activities, which included training, standards, and scheduling of all pilots. He was also responsible for the survey of new routes and any required limitations. He was experienced on the HS 748 and considered by Transport Canada to be well qualified for his position. Company personnel and other pilots described him as a capable manager.

No conflicts between the flight operations department and other departments in the company were identified, but there was concern expressed by some pilots that maintenance was not always as supportive as it could be.

Interviews revealed that it would not be uncommon for some captains to conduct a flight, or series of flights, with equipment unserviceabilities which, in their opinion, would not greatly affect the airworthiness of the aircraft yet would be in contradiction of the MEL.

Company Flight Safety Officer

In 1990, the company established a permanent position for a Flight Safety Officer (FSO). The FSO reported directly to the CEO on matters of flight safety and acted as secretary to the Flight Safety Committee (the committee is chaired by the CEO and comprised mostly management staff). Regular meetings of the committee were held and minutes were kept. The FSO position was vacant at the time of the occurrence because the incumbent had resigned two weeks previously to accept employment elsewhere. The flight safety program was deemed effective and worthwhile by those persons interviewed.

Cabin Safety

The Chief of Cabin Safety was responsible for cabin safety issues in the company and reported to the DFO. The Cabin Safety section had two full-time staff and a small complement of part-time flight attendants. TC considered the section to be well run and administered by qualified personnel; company flight attendants interviewed held the same view.

Maintenance Department

The Air Manitoba maintenance department was an approved maintenance organization (AMO), managed by a director who reported to the President of the company. The department had TC authority to carry out all levels of inspection and maintenance on its aircraft.

Director of Maintenance (DOM) - The DOM had been with Air Manitoba and its predecessors since 1975 and had moved up from a line aircraft maintenance engineer (AME) to the position of DOM. His primary experience had been with piston aircraft until the introduction of the HS 748 in 1985.

Quality Assurance Manager (QAM) - The QAM joined the company as an apprentice mechanic in 1984 and progressed through various positions to his appointment as QAM in June 1992. As QAM, his primary responsibility was to ensure the quality and regulatory compliance of aircraft maintenance. From interviews, it was determined that he was often directly involved in daily maintenance activities, particularly those which were complex, such as control rigging and engine changes. These maintenance activities apparently took precedence over his quality assurance responsibilities and, as duties other than those related to the quality assurance system were not approved in the Maintenance Control Manual (MCM) for the QAM, participation in maintenance activities would not have been in accordance with the MCM.

Maintenance Resources - Both the DOM and the QAM indicated shortly after the accident that there were adequate spare parts, time, and manpower to allow for proper maintenance and servicing of company aircraft. Interviews with line maintenance personnel revealed that they were often required to work well beyond their normal day to repair aircraft for the next morning's flight. They also indicated that apprentice mechanics were regularly working unsupervised during weekend shifts. During subsequent interviews with the DOM and QAM, they indicated also that, at the time of the accident, staffing levels were low, and that there were insufficient numbers of parts and time to allow timely aircraft repair.

1.17.2.2 Operations

Air Manitoba operations are governed by ANO Series VII, No. 2, which deals with air carriers using large airplanes (airplanes with a maximum certified take-off weight in excess of 12,500 pounds).
Air Manitoba's Operating Certificate (Number 1066) authorizes domestic and non-scheduled international service between points in Canada, between points in Canada and abroad, and between points abroad with HS 748, Curtis C-46, and Cessna 208 aircraft. The main base of operations is Winnipeg, Manitoba, and there is an active approved sub-base at Churchill, Manitoba. Approved sub-bases at Gillam and Thompson, Manitoba, are inactive.

1.17.2.3 Maintenance

The maintenance records for aircraft C-GQTH were reviewed for the period January 1989 to the occurrence date. Details of the review are contained in a report prepared by the TSB Engineering Branch, LP 078/ 94 - Maintenance Records, HS 748, C-GQTH, which is available on request from the TSB. The following has been condensed from LP 078/ 94.

The review showed that Air Manitoba maintenance practices were, in many cases, not in accordance with requirements as specified in Air Regulations and Air Navigation Orders that pertain to Air Manitoba's operations. Some of the determinations from the review are as follows:

A. The MCM did not conform to the requirements of the *Airworthiness Manual* in that the MCM did not, at all times, accurately reflect the approved maintenance program.

B. Maintenance Program - Some items on the Out-of-Phase list[9] either were described in error or had been approved by TC without consideration for the content of the Air Manitoba maintenance program, or knowledge of the company's recurring defect history. For example, horizon indicators were to be overhauled on condition[10]; however, there were no repetitive inspections or tests in place to determine the condition of these items. Interviews revealed that most of the Air Manitoba maintenance personnel were not familiar with the term "on condition" nor were they aware of any required inspections.

C. Aircraft Components - Time Between Overhaul (TBO) - The records review did not identify any example of calendar- or hour-limited components having exceeded the specified time in service. The serial number of the installed CVR was not the same as the serial number on the TBO list, and a maintenance release tag for the CVR was not found; the TBO status of the CVR is not known.

D. Defects and Rectification Control - In most cases, the aircraft journey log-books indicate that flight crews were appropriately entering defects. However, many defects were recorded numerous times and reflected that the rectifications were inadequate. There were no deferred defects on C-GQTH at the time of the occurrence.

E. Minimum Equipment List (MEL) - It was observed that some items had been incorrectly deferred or deferred without reference to the MEL.

F. Maintenance System Anomalies - Many anomalies were identified. Some examples are as follows:

9 An Out-of-Phase List is a list of maintenance items which require action at times other than at scheduled inspections.

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

- The installation of the static inverters was completed in July 1989; however, the company did not have installation drawings, nor was the maintenance program modified to include the required repetitive checks for these inverters.

- The drawings for the installation of the CVR and current FDR systems were not found in Air Manitoba records. They were later obtained from the previous operator of C-GQTH and from Transport Canada, Ontario Region.

- At the time of the crash, although four CVR recording channels were required by regulation, only one channel of the CVR was capable of recording. The daily inspection of the CVR required "observing the needle pulse as each channel is tested," and the CVR was routinely signed out as being serviceable. This deficiency was identified in June 1990 by a Transport Canada inspector who issued a Notice of Inspection form. The rectification by Air Manitoba was replacement of the control head and the notation "Test function 'S.'"

- Proper certification of maintenance functions was not always completed. In some cases the aircraft was not certified as "released for return to service" after the completion of minor maintenance checks.

G. General Observations - Following are some examples of evidence gathered during the records review.

- A number of inverter-related problems were recorded after the installation in July 1989 of the static inverters.

- Often when there was a problem with the compass system, there was also a problem with the inverter system.

- Since 1989, three horizon instruments had been replaced in the No. 1 position and seven replaced in the No. 2 position. For some of the replacements, there was no certification in the journey log-book.

- Since March 1991, four turn and slip indicators had been changed in the No. 1 position and six in the No. 2 position.

- There were numerous certification tags showing that serviceable parts were removed from one aircraft and installed on another within the fleet. There were also tags indicating that parts had been removed from aircraft C-GQPE, an HS 748 flown into Canada from the Bahamas on a flight permit; this aircraft had not been subjected to an import procedure or issued with a Canadian Certificate of Airworthiness (C of A), and was not in service. There was no component history on, or attached to, the tags relating to aircraft C-GQPE, as is required by Section 575.217 of the *Airworthiness Manual*.

- At the time of the crash, the No. 1 engine was 2.6 hours overdue for a hot section inspection. There was no evidence found that this inspection was scheduled to be accomplished. Otherwise, the engines and propellers of C-GQTH were maintained as required.

H. Maintenance Evaluation

Following is a condensation of the major evidence with regard to the Air Manitoba maintenance program. Some immediate analysis of the evidence is made to explain its significance.

1. The review of technical records for C-GQTH identified a significant number of discrepancies which formed the basis for an assessment that the aircraft had not been maintained in accordance with the company approved Maintenance Control Manual.

2. The practice of removing parts from one aircraft to install on another indicates the possibility of a parts availability problem.

3. Records show there were instances where a particular defect and its rectification were repeatedly entered in the journey log-book. The repetition indicates there could be a lack of knowledge on the part of the persons performing the rectifications, insufficient spare parts, insufficient resources to troubleshoot effectively, or any combination thereof.

4. The extent of the discrepancies noted and the potential airworthiness implications are considered to reflect negatively on the effectiveness of the audit and surveillance process conducted by Transport Canada. TC inspectors had access to the same records.

5. The maintenance system had not, in all cases, been amended to reflect changes in requirements resulting from modifications to the aircraft, such as the conversion of the AC power system from rotary to static inverters.

6. Airworthiness of C-GQTH

- ANO, Series II, No. 4 - Order Respecting Conditions And Procedures For Keeping A Certificate of Airworthiness states the following:

3. Every certificate of airworthiness issued in respect of an aircraft is issued on condition that

(a) the aircraft will be maintained in accordance with a maintenance program that meets the aircraft standards of airworthiness established by the Minister pursuant to section 211 of the *Air Regulations*, and

(b) an entry will be made in the Aircraft Journey Log of the aircraft by an authorized person, certifying that the aircraft is

(i) airworthy, or
(ii) released for return to service,

whichever is applicable, at the times and in accordance with the procedures set out therefor in the *Airworthiness Manual* or in the *Engineering and Inspection Manual*.

5. Notwithstanding anything in this Order, a certificate of airworthiness issued in respect of an aircraft is not in force at any time when either of the conditions

set out in paragraph 3(a) or (b) fails to be satisfied in respect of that aircraft.

- C-GQTH was certified as "release for return to service" on the evening of 09 November 1993.

- There were no deficiencies recorded in the journey log-book on 10 November when the aircraft returned to Winnipeg from the morning flight, and no maintenance certifications were required for the second flight out of Winnipeg in the afternoon.

- The maintenance history of the aircraft showed no record of the completion of some airworthiness directives and service bulletins classified as mandatory by the issuer and required by the approved maintenance program.

- C-GQTH had not been maintained in accordance with the approved maintenance program as required by ANO Series II, No. 4, and the approved maintenance program itself did not meet the requirements of the *Airworthiness Manual*. In view of the above, the Certificate of Airworthiness of C-GQTH appears not to have been in force at the time of the accident.

1.17.3 Transport Canada and Air Manitoba

TC inspectors had a good working relationship with Air Manitoba personnel and, in general, problems identified by TC were rectified satisfactorily, although not always readily. The TC inspectors assigned to Air Manitoba, from both operations and maintenance, had been working with the company for many years and were very familiar with company operations.

TC inspectors conducted a full audit of Air Manitoba in June 1993. The audit conclusions were that Air Manitoba Ltd. had excelled in operational and maintenance record keeping, that maintenance control was satisfactory, and that the company was complying with the regulations necessary for aviation safety.

The maintenance summary indicated that, "The Company is approved for the maintenance of aeronautical products and holds the following ratings: Aircraft; Avionics; Structures; and Non-Destructive Testing."

In January 1994, in light of some telephone calls received from Air Manitoba personnel and the crash two months earlier, TC inspectors assessed that Air Manitoba's risk indicators had risen to an unacceptable level and ordered a special inspection of the company. The inspection, conducted 17-19 January 1994 by TC inspectors, identified serious maintenance deficiencies which resulted in the suspension of Air Manitoba's Approved Maintenance Certificate and the subsequent suspension of their Operating Certificate.[11]

The fact that the special inspection of January 1994 identified serious maintenance deficiencies reflects a significant contrast from the earlier audit report. Evidence from the TSB investigation indicates that there were significant deficiencies present during the June audit, which were not identified during that audit, and which were still present at the time of the accident. It is not feasible for auditors to examine every aspect of an operation when conducting an audit; however, it is thought that, during the Company audit of June 1993, some of the deficiencies were present and discernible on inspection.

Flight test results for commercial pilots, whether the flight test was conducted by the company or by TC, are

11 While maintenance deficiencies were alleged by TC, Air Manitoba disputed the majority of the alleged deficiencies, and this issue was referred by Air Manitoba to the Civil Aviation Tribunal. Also, at no time were the certificates of airworthiness of the HS 748 aircraft suspended or cancelled.

retained by the companies for which they work and by TC. However, there is no procedure in place whereby pilots are trend monitored to ensure they do not have continued difficulty, and no special attention is paid to a pilot who experiences repeated difficulty during proficiency tests.

1.17.4 Controlled Flight into Terrain

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

Between 1976 and 1992, there were 59 accidents in Canada in which fixed-wing aircraft flying under IFR collided with terrain without having first experienced an in-flight loss of control; twenty-one (36%) of these were multi-engine aircraft. Twenty-seven (46%) of the 59 accidents resulted in at least one fatality, almost four times the normal accident fatality rate. Seventy-six passengers lost their lives in 18 (86%) of the accidents involving multi-engine aircraft.

The 59 accident aircraft were equipped and certified for IFR flight and all of the pilots were qualified for flight in instrument meteorological conditions (IMC). Fifty-one per cent of the pilots involved held an ATPL, and there were two flight crew members in 41% of the accidents. Twenty-seven (46%) of the 59 accidents occurred at night. Meteorological conditions were cited as significant factors in 31 (53%) of the accidents; almost half of these resulted in fatalities, with 61 passengers and 24 crew receiving fatal injuries. In more than half of the accidents, the aircraft collided with level terrain.

Various factors have been identified in CFIT accidents; generally they include some combination of perception limitations, attention/ timing/ task management, non-compliance, procedural errors, deficient intra-cockpit interactions, and loss of situational awareness.

1.17.5 Situational Awareness

Evidence from eye-witnesses indicated that the aircraft followed a smooth and gradual turn after lift-off. Physical evidence suggests that recovery action, if any, may have been initiated only immediately prior to impact. This flight profile is consistent with a loss of situational awareness on the part of the flight crew.

A fundamental element in making correct decisions when flying an aircraft is maintaining adequate knowledge of what is happening around you, that is, situational awareness. Situational awareness is the starting point in the decision-making process; appropriate action or correct decisions cannot be expected unless the information the decisions are based upon is reasonably complete and accurate. In general, breakdowns in situational awareness are caused by faulty acquisition and processing of this information, be it accurate or not. Typically, these breakdowns occur under situations of task saturation, distraction, channelized attention, misorientation (unrecognized disorientation), or any combination of these.

1.17.6 Misorientation (Unrecognized Disorientation)

Disorientation may go unrecognized, particularly when the flight crew is preoccupied or distracted during flight in instrument meteorological conditions. Gradual and smooth changes in aircraft attitude can easily go undetected by the senses. Sensory cues, such as aircraft feel and sound, may not be sufficient to alert the crew to their actual condition. These diminished indicators of orientation can give pilots a false sense of security in that the aircraft may not be doing what the pilot believes it to be doing. For instance, the aircraft may be rolling at a rate below that which can be sensed by the pilot's vestibular system. The threshold of detection of angular velocity in roll varies but is in the range of 0.2 to 8.0° per second.[12]

TSB occurrence profile calculations showed that at 60 feet agl, the angular velocity of the aircraft was 1.4° per second; by 430 feet agl, the roll rate had increased to 1.8° per second. The roll rates could easily have been imperceptible to the pilots, resulting in their misorientation, and the average wheel rotation of 8.6° to produce those roll rates could have gone unnoticed.

12 John Ernsting and Peter King, *Aviation Medicine*, 2nd ed. (London: Butterworths, 1988)

2.0 Analysis

2.1 General

Examination of the wreckage and a detailed examination of individual components yielded no evidence that the aircraft suffered a structural failure, difficulty with the flight controls, abnormal flap condition, loss of engine power, or in-flight fire. Witness statements and wreckage examination indicate that the aircraft's flying surfaces were not contaminated prior to departure.

Wreckage examination and analysis showed that, at impact, the flaps were up, the landing gear was retracted, the landing lights were retracted and off, and the cabin pressurization dump valve was closed. Engine and propeller analysis indicated that the engines were producing considerable power at impact, and propeller blade angle analysis showed that the aircraft struck the trees or ground at a speed of approximately 180 knots true airspeed (KTAS).

The only technical anomalies discovered during the investigation were that the FDR, the CVR, and the gyro compass system were not powered at any time after the aircraft was shut down on landing at Sandy Lake. It was concluded from this information that the No. 1 AC bus was not powered at any time during the flight. It can be concluded, therefore, that no services that were powered by this bus were operating. Analysis of the oil pressure dial mark indicated that the No. 2 AC bus was powered; however, there was no corroborating evidence found.

2.2 The Flight

The normal departure for this flight would have been to climb straight ahead, retract the landing gear when safely airborne, retract the landing lights (perhaps after reaching 400 feet), continue climb to 400 feet and retract the flaps, continue climb to the turn altitude (normally 500 feet agl or greater), and turn 20° to the right en route to Island Lake. From lift-off to 500 feet agl would take about 30 seconds. The dump valve being closed, the landing lights retracted, and the flaps up indicates that the pilot making the decisions to perform these duties and the pilot making the selections believed that the flight path, at that time, was normal[13]. However, as it has been shown that the aircraft had to have been in a turn to the right within seconds of lift-off, it is evident that the pilots thought the aircraft was climbing straight ahead as per a normal departure even though the aircraft was turning. The inoperative gyro compasses would, if manually set, be indicating runway heading while the aircraft was turning, which would reinforce the pilots' belief that the aircraft was flying straight ahead.

For the aircraft to be in a turn to the right immediately after take-off, either the pilot flying was following an erroneous horizon indicator, or he was flying without adequate reference to the available flight instruments. As previously discussed, the change in bank angle may have been below the threshold of detection of the pilots' vestibular senses; in the absence of adequate instrument or external references, a turn can go unnoticed. After leaving the runway environment, the only outside visual reference available to the crew would have been the lights from the houses along the shore to the right of the runway, which, alone, probably would not have provided adequate attitude reference. The lights of the main community would not have been visible until the aircraft was well into the turn. However, as pilots normally transition to instrument flight immediately on becoming airborne at night, especially when they know that the aircraft will enter cloud soon after take-off, the pilots probably would not have been looking outside the aircraft. If the pilots had seen the lights of the community, they would have appeared high in the windscreen because of the steep bank angle of the aircraft, which would have been confusing or added to an already confusing situation. Given the attitude of the aircraft, the pilots

13 Depending on who was flying, the captain could have been the pilot making the decisions and selections, or the co-pilot could have been calling for the selection with the captain actually making the selection (except for the dump valve).

would probably have had insufficient time to recover.

2.3 Possible Scenarios

2.3.1 General

The following scenarios are based on all of the evidence, although incomplete, and are theoretical. They describe what could have happened and do not necessarily represent what did happen. However, the aircraft did take off without power to, at least, the No. 1 AC bus, and the TSB felt it was necessary to discuss the possibilities to ensure that all of the evidence was considered.

It is *improbable* that the crew could have had an AC power failure, or indications of a failure, and not become aware of any fail indications prior to taking off. It is *equally improbable* that this crew would have taken off with the knowledge that the AC system was not operating as required by the MEL and by safe operating practices. The following discussions are based on there being only four possible scenarios with regard to the AC power and the crew's awareness: there was no power from the No. 1 AC bus; there was no power from either AC bus; and, the crew were aware or were not aware of that condition.

In the following discussions where indications from instruments or lights are discussed, it is on the assumption that they operated as they were designed to operate, unless stated otherwise.

2.3.2 Number 1 AC Bus Not Powered

There was a loss of power from the No. 1 AC bus. With this loss of power, the following flight instruments should have been available: all of those on the right instrument panel, except the gyro compass; the altimeters; the standby compass; and the turn and slip indicators.

The loss of power from the No. 1 AC bus could have been the result of a failure, or the No. 1 inverter could have been intentionally turned off sometime between shutdown and normal aircraft start and not turned on again. Whatever the case, the following would have been evident: the No. 1 magnetic indicator would have been displaying OFF; the left side instruments, which include the horizon indicator, gyro compass, engine oil pressure and temperature gauge, and fuel contents gauge, would not have been operating; and the No. 1 AC bus fail light and the FDR fail light would have been illuminated. As the right gyro compass is also powered by the No. 1 AC bus, it would not have been operating either. The voltmeter and frequency gauges would not have indicated the required inverter output had the No. 1 AC system been checked.

Checks that flight crew are required to perform prior to every flight, if completed, would have revealed all of the noted conditions and failure indications. For the crew to be unaware of the failure indications, they could not have completed the required checks; in addition, either the illumination of the No. 1 AC warning light did not register with the crew or the warning light was unserviceable.

Therefore, the pilots either did not complete all elements of the required checks, or they accepted that they would be without the left instruments, the flight recorders, and the right gyro compass during the flight.

Through the manual transfer system, the services of a failed inverter may be transferred to the serviceable inverter. If the crew were aware of the No. 1 AC failure and performed this transfer, it must be concluded that the transfer did not work because power was never restored to the recorders; it was not possible to determine whether the relay was functional prior to the occurrence. It would be unusual for the crew not to notice that the transfer system had also failed, as the fail indications would have remained the same after the transfer attempt.

2.3.3 Both AC Buses Not Powered

With loss of power to both AC buses, the following flight instruments should have been available: the altimeters; the standby compass; and the turn and slip indicators.

If both AC buses were not powered, the cockpit indications would have been as for the No. 1 AC bus not being powered plus the following: the No. 2 magnetic indicator would have been displaying OFF; the right side instruments, which include the horizon indicator, engine oil pressure and temperature gauge, and fuel contents gauge, would not have been operating; and the No. 2 AC bus fail light would have been illuminated. The voltmeter and frequency gauges would not have indicated the required inverter output had the No. 2 AC system been checked.

Failure of Both AC Buses

The likelihood of simultaneous failure of both inverter systems is remote. As well, because of the number of cockpit indications, it is likely that the pilots would have seen and acknowledged that neither inverter system was operating; however, the possibility exists that they could have missed all of the indications.

Both Inverters Turned Off

There is the possibility that the crew turned off both inverters after shutdown at Sandy Lake and forgot to turn them back on. It is unlikely that the crew would not have been aware of all the AC fail indications during start-up and taxi unless they had made a deliberate decision to delay turning the inverters on until just prior to taking off, perhaps to allow the batteries to more easily become charged. However, the crew would then have had to take off, not having completed the required checks that would have reminded them that the AC buses were not powered, and unaware of the failure indications that would have been evident.

As has been shown, the crew performed normal after take-off duties until at least flap retraction. However, it is difficult to conceive that the crew could fly an aircraft to at least 400 feet agl, without any external or internal attitude references, and still perform normal duties, presumably unaware there was anything wrong with the aircraft or its flight path.

Because of the darkness, the low overcast condition, and the lack of flight instruments, it is concluded that the crew would likely not have taken off knowing that they were without any AC power.

2.4 Minimum Equipment List

The MEL allows an aircraft to depart with only one serviceable inverter if the aircraft is away from a maintenance base; however, the weather must allow visual flight and it must be daylight. The MEL does not allow an aircraft to depart with both the FDR and the CVR unserviceable.

Assuming that one or more of the above failure indications were evident and recognized by the flight crew while the aircraft was still on the ground, then, according to the approved MEL, the problem(s) should have been rectified before the flight could continue.

2.5 Decision Making

The following is based on the crew being aware that the No. 1 AC bus was not powered and that the left flight instruments were not operating. This is the only plausible scenario requiring a decision to take off with a failure. There were a number of factors which the crew could have considered prior to making the decision to proceed with the flight.

Some factors that could have influenced the crew to take off are as follows: flight completion is the objective of any airline; the flight was two hours behind schedule; there were no maintenance facilities in Sandy Lake and maintenance personnel and equipment would have had to be flown in; the crew and passengers possibly would have had to remain in Sandy Lake overnight (and, although sleeping arrangements could have been made, there were no accommodations readily available); there were 15 to 20 passengers waiting in Island Lake; and there were company economic and scheduling considerations. Considerations regarding the aircraft itself that would have mitigated the seriousness of the loss of the left flight instruments and recorders were that the aircraft was equipped with a GPS (powered by 28 VDC) that would provide heading, track, distance, and time information; and there was no immediate flight safety reason for having serviceable flight recorders. As well, the crew would have had the standby magnetic compass, the altimeters, the turn and slip indicators, and all the right side flight instruments except the gyro compass.

Factors that could have influenced a decision to not take off are as follows: the aircraft would have lost the redundancy of its AC power sources and flight instruments, the flight could not have been conducted in accordance with safety standards set by the air regulations and company policy, and only the co-pilot would have been able to fly and easily monitor the flight. The captain could have monitored as well, but he would have had to do this monitoring cross cockpit.

2.6 *Standby Attitude Indicator*

The aircraft was not equipped with a standby attitude indicator; large, turbo-prop aircraft are not required to be so equipped. A standby attitude indicator provides useful information in situations where the main horizon indicators are inoperative or are providing inaccurate or conflicting information.

2.7 *Ground Proximity Warning System*

The aircraft was not equipped with a functional GPWS; large, turbo-prop aircraft are not required to be so equipped. A GPWS, if installed and operable, would have activated as the aircraft started to descend from its peak altitude reached. However, in this case, because the GPWS, if installed, would have been powered by the No. 1 AC bus, it would not have provided a warning.

2.8 *CL2 Compass*

Assuming that the crew members were aware of the failure of the services provided by the left inverter and had decided to proceed with the flight, extra vigilance would have been required during their taxi and runway line-up checks to establish what serviceable instruments they had available to them.

The taxi checklist requires that the gyros be checked during taxi to confirm they are tracking properly, and the runway line-up checklist requires that the compass be checked to ensure that it agrees with the runway heading. These checklists are normally called out by the pilot in the right seat during the taxi and line-up.

The compass on the right side is normally not slaved and acts as a gyro compass only; as such, it precesses over time. Although it might not be unusual for the crew to see erroneous headings, it would have been unusual for them to see a 70° heading error as they lined up on the runway. The set knob on each directional gyro allows the pilot to manually turn the compass card to the desired heading; however, it is unlikely that the flight crew would have set an instrument they knew to be inoperative.

2.9 *Disorientation*

2.9.1 *Vestibular Sensing*

Given that gradual changes in aircraft attitude can easily go undetected by the senses, the angular velocity in roll as the aircraft was banking into the turn was probably below the pilots' threshold of detection, and the flight crew may not have been aware that the aircraft was banking and turning. If the captain or the first officer became aware of the aircraft attitude once the aircraft was at a steep bank angle in the turn, it would have been very difficult for them to orient themselves to their situation and recover in the altitude remaining.

Flight path reconstruction and evidence from eye witnesses suggest that the flight path was constant and indicate that recovery action was not attempted or was attempted too late. (There is some evidence that the ailerons were set for a left roll at the time of impact.)

2.9.2 *Loss of Situational Awareness*

If the crew took off with the knowledge that the No. 1 AC bus was not powered, both crew members might have been involved in trying to resolve the problem during the climb. However, they should have been keenly aware that they did not have any flight instruments on the left side and would have been attentive to the remaining instruments. If they did not become aware until after reaching V_1 during the take-off that either the No. 1 AC system or both AC systems were not operating, they may both have become involved in problem solving. As they continued, as well, to perform their normal after take-off activities, they may have been distracted from their primary task of ensuring that the aircraft remained in the proper flight attitude.

During the flight, the directional gyro would have remained fixed on the last heading that was set, re-enforcing the pilots' belief that the aircraft was climbing straight ahead. If the right side instruments were operating properly, then the first officer must not have adequately cross-checked the attitude instruments available to him, and the captain must not have ensured that the aircraft was on the desired flight path. If there was no AC power at all to the flight instruments, perhaps the horizon indicator(s) remained upright enough that the pilot flying followed the horizon indicator's guidance, unaware that the guidance was not accurate. Because of the very dark night, there would have been few outside visual cues to help the crew establish their flight attitude.

The flight profile and completion of the normal after take-off checks suggest that the crew were never aware that they had a problem with respect to aircraft attitude, at least until too late to effect a recovery from the steeply-banked, nose-down attitude.

2.10 Air Manitoba and Regulations

Both maintenance and operations personnel indicated, by their actions and through interviews, a willingness to deviate from regulations and safe operating practices.

Many of the discrepancies regarding the maintenance of Air Manitoba aircraft relate to the availability of spare parts and the non-completion of airworthiness directives, aircraft modifications, and service bulletins. All of these issues and items have a related dollar cost. It was further shown that some maintenance practices did not meet the requirements of the regulations, established to ensure a good standard of safety. There is no evidence that these deviations from accepted practice were made in ignorance of the regulations; therefore, it can reasonably be concluded that the motivation for the deviations was to increase the availability of aircraft for service and reduce the impact of maintenance on the cost of operations.

The evidence is that some captains would accept for flight, aircraft that did not meet airworthiness standards. The flight crew of the accident aircraft deviated from regulations in that they used the GPS as a primary navigation aid, and they flew the aircraft to well below minimum altitudes, while in instrument meteorological conditions, using the GPS for position information. Although the GPS is an accurate and fairly reliable system, its use in aircraft is regulated as regards the type of installation and the way the GPS can be used in order to ensure it can be safely used. Because the captain was the DFO, the highest ranking pilot on the staff of the company, his actions may have been seen by the first officer as acceptable company practice.

2.11 Flight Crew Performance

Training and flight test records indicate that both the captain and the first officer experienced some difficulty handling the HS 748 aircraft during check rides; however, both were considered to be professional and capable pilots by their peers.

From the conflicting information regarding their performance, it could not be determined whether the captain and first officer did indeed have some difficulty adapting to the HS 748 or were merely experiencing reduced performance during check rides because of the stress of a test environment.

2.12 Crew Resource Management Training

The flight crew had not received comprehensive CRM training, although the captain had attended the one-day session provided by Transport Canada.

Without the benefit of a cockpit voice recorder, it is not possible to determine how the crew interacted during the accident flight, and the quality of the CVR tape recorded during the flight prior to the occurrence is too poor to make any determinations in that respect. However, if the flight crew departed Sandy Lake knowing that several flight instruments were not functioning, they made a conscious decision to do so. CRM methods are designed to improve the quality of this type of decision making; pilots using CRM methods of evaluation and risk assessment might have made a different decision.

2.13 Returning to Land at Sandy Lake

The possibility was explored that the crew recognized that they had a problem at some point after take-off and decided to return immediately to Sandy Lake for a landing.

If the crew recognized a flight instrument problem and elected to return to Sandy Lake, it is unlikely that the crew would have performed all of the standard after take-off functions, as indicated by the evidence. It is possible that the crew recognized a problem after they retracted the flaps. If this was the case, then the crew could have experienced difficulty orienting themselves to their situation in sufficient time to recover from the descent.

2.14 Summary

It is concluded that the crew would likely not have commenced the flight if they had been aware that neither AC system was working.

The aircraft was on the ground in Sandy Lake for about 20 minutes. This was time to turn the aircraft around for the next flight, but, it would seem, hardly enough time to allow the crew to discuss and attempt to resolve the problem with the No. 1 AC system and then to discuss how they were going to cope with the lack of flight instruments. As well, had they been aware of the problem, they would likely have been careful in conducting their ground checks to ensure that they did have enough instruments for a safe flight. Because of the short time spent on the ground, particularly after engine start, it could be concluded that the crew did not carry out extraordinary procedures commensurate with a known problem and took off unaware that anything was amiss. If they took off unaware that there was no power from either one or both AC buses, they did not perform all elements of the required after start, taxi, and before take-off checks.

Based on the number of failure indications presented or available to the crew, and because flight crews normally complete required checks, a more likely scenario is that the crew were aware, prior to take-off, that the AC system was not operating properly. If they previously had been faced with this type of problem, which would not be unusual considering the number of hours that each pilot had flown, then problem solving and resolution could have been accomplished quickly. If the crew took off knowing that the No. 1 AC bus was not powered, they deviated from safe operating practices. A decision to take-off with the failure would be consistent with the Company's attitudes which supported deviating from aviation safety standards.

In conclusion, it was not possible to determine the exact state of the aircraft or what the pilots' awareness of that state was.

Because the inadvertent turn after take-off was likely below the crew's sensory threshold, it is likely the crew did not recognize their disorientation until too late in the flight to allow recovery. Loss of situational awareness such as this, ending with a collision with the ground, is typical of a controlled flight into terrain accident.

3.0 Conclusions

3.1 Findings

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

2. There was no evidence that physiological factors affected the flight crew's performance.

3. The weight and centre of gravity of the aircraft were within prescribed limits.

4. C-GQTH was not maintained in accordance with regulatory requirements intended to ensure the safe operation of an aircraft.

5. The CVR was installed so that only the cockpit area microphone (CAM) recorded to the CVR tape. The other three channels did not record because of inadequacies in the installation of the recorder.

6. The GPS installation in C-GQTH was not approved as a primary navigation aid. Indications are that the flight crew used the GPS as a primary navigational aid during the approaches to Sandy Lake, and at times descended below published minimum altitudes while in instrument meteorological conditions.

7. There was no evidence found of any airframe failure, or flight control or engine malfunction.

8. Power was never supplied to the No. 1 AC bus after the aircraft was shut down in Sandy Lake; the reason for this could not be determined.

9. Physical evidence showed that the FDR, CVR, and both gyro compasses were not operating when the aircraft took off from Sandy Lake.

10. Completion of the required pre-departure checks should have alerted the flight crew to some, if not all, of the fail indications.

11. The MEL prohibits dispatch of an aircraft, at night and in the weather conditions that existed at Sandy Lake at the time of the occurrence, with only one serviceable inverter, or only one horizon indicator, or only one directional gyro compass.

12. The MEL prohibits dispatch of an aircraft with both flight recorders inoperative.

13. At the time of the occurrence, the base of the cloud was between 700 and 1,200 feet agl, the visibility was three to five miles in very light snow, and it was dark.

14. The propeller blade angles at impact correspond to an aircraft true airspeed of approximately 180 knots.

15. Witness marks found at the aileron/ wing hinge points suggest that the ailerons, at impact, were positioned to induce a left roll.

16. The flight crew seats were occupied and the lap belts were probably done up at impact; the shoulder harnesses probably were not done up.

17. To crash in the attitude and place that it did, the aircraft had to lift off approximately 1,800 feet from the threshold of the runway and begin turning to the right within a few seconds after lift-off.

18. The crew likely lost situational awareness after take-off in a gradually steepening spiral turn downwards with a high rate of increase in airspeed.

19. Prevailing company attitudes supported deviating from safe operating practices to achieve overall commercial objectives.

20. Transport Canada inspectors' audit and surveillance of Air Manitoba, prior to the accident, did not uncover serious maintenance discrepancies that were present.

21. There are no procedures in place that require pilot flight test results to be monitored, by TC or companies, to identify pilots who experience repeated difficulty during flight tests.

22. C-GQTH was not equipped with a standby attitude indicator, nor is there a regulatory requirement that large turbo-prop aircraft be so equipped.

23. C-GQTH was not equipped with a GPWS, nor is there a regulatory requirement that large turbo-prop aircraft be so equipped.

3.2 Causes

After take-off, the crew most likely lost situational awareness and, as a result, did not detect the increasing deviation from their intended flight path. Contributing to the loss of situational awareness was the lack of AC power to some of the flight instruments; the reason for the lack of AC power could not be determined.

4.0 Safety Action

4.1 Action Taken

4.1.1 Transport Canada (TC) Special Inspection

In January 1994, TC conducted a special inspection of Air Manitoba's Flight Operations and Maintenance departments. The findings of this inspection, primarily with respect to maintenance shortcomings, resulted in removal of the company's maintenance certificate and suspension of its operating certificate. The company subsequently contracted its HS 748 maintenance to another carrier and regained its operating certificate.

4.1.2 Flight Recorders

Flight recorder information is often invaluable in the investigation of occurrences and it most certainly would have assisted in determining the events leading to this accident. In the past, the Board has made recommendations concerning deficiencies on the retrieval and quality of recorded data and on the lengthy process required to update flight recorder legislation. Notwithstanding the emphasis that the Board has put on the importance of flight recorders for investigation and accident prevention processes, there has not been any significant progress in addressing these flight recorder deficiencies. Therefore, the Board recommended that:

> The Department of Transport immediately verify through field audit that all existing FDR and CVR installations meet current regulatory requirements, and make public its findings;
> (A94-01, issued January 1994)

> The Department of Transport revise its approval and monitoring process to ensure that all future FDR and CVR installations continue to meet regulatory requirements;
> (A94-02, issued January 1994)

> The Departments of Justice and Transport promulgate the new Orders on flight recorders without further delay; and
> (A94-03, issued January 1994)

> The Department of Transport streamline its processes to facilitate the timely Canadian implementation of updated flight recorder requirements.
> (A94-04, issued January 1994)

In response to these recommendations, TC has undertaken a program to review operator compliance with existing recorder requirements in order to identify areas of the monitoring and approval processes that need revision. In addition, TC stated its intention in April 1994 to issue two interim circulars to facilitate industry adjustment to the new recorder regulation expected to come into law in early 1995.

With respect to streamlining the recorder legislation process, TC stated that a new regulatory structure will have regulations which incorporate standards by reference in order to facilitate amendment in a timely way. TC's new approach to use standards to keep pace with changing requirements in aviation, and in particular flight recorder technology, is an important improvement in the regulatory process. Also, TC has reached consensus with industry to harmonize with the U.S. Federal Aviation Regulations (FAR) in finalizing the draft Canadian regulations.

The new regulation will state which aircraft will require FDRs and CVRs; the standards section will list parameters, operational requirements, and other technical specifications.

The Department of Justice has advised that it is prepared to carry out its regulatory functions as quickly as possible to ensure the regulations proposed by TC can be promulgated with the least possible delay.

4.1.3 Static Inverter Installation

Anomalies were found in the static inverter installation which had replaced the original rotary inverter system of the occurrence aircraft. Given that other Canadian operators may also be operating HS 748s with similar electrical system discrepancies, a TSB Aviation Safety Advisory was forwarded to TC. The Advisory concerned the requirement to verify that the inverter systems of all Canadian HS 748 aircraft conform to the applicable installation drawings.

4.1.4 Undervoltage Protection

Significant importance has been afforded the issue of undervoltage protection for the HS 748 aircraft. It was determined that Service Bulletins (SB) 24/ 60 and 24/ 97 are considered to be mandatory. A TSB Aviation Safety Advisory forwarded to TC addressed the need to confirm that all Canadian HS 748 aircraft meet the current electrical system requirements for undervoltage protection.

4.1.5 Accidents Involving Controlled Flight into Terrain

The circumstances of this occurrence are typical of a Controlled Flight into Terrain (CFIT) accident. CFIT occurrences are those in which an aircraft, under the control of the crew, is flown into terrain (or water) with no prior awareness on the part of the crew of the impending disaster. The Board notes with concern that, over the 11-year period from 01 January 1984 to 31 December 1994, 68 commercially operated aircraft (not including those conducting low-level special operations) were involved in CFIT accidents. In view of the frequency and severity of such accidents, the Board is currently conducting a study of CFIT accidents to identify related systemic deficiencies.

4.1.6 Regulatory Audits and Surveillance

Analysis and information from this investigation and 18 others led to the identification of shortcomings in the regulatory overview process of air carriers. In particular, it was found that TC's audits sometimes lacked depth, and that the verification of corrective action following the audits was sometimes inadequate. Therefore, the Board recommended that:

> The Department of Transport amend the *Manual of Regulatory Audits* (MRA) to provide for more in-depth audits of those air carriers demonstrating an adverse trend in its risk management indicators;
>
> (A94-23, issued December 1994)

> The Department of Transport ensure that its inspectors involved in the audit process are able to apply risk management methods in identifying carriers warranting increased audit attention;
>
> (A94-24, issued December 1994)

> The Department of Transport develop, as a priority, a system to track audit follow-up actions; and
>
> (A94-25, issued December 1994)

> The Department of Transport implement both short and long term actions to place greater emphasis on verification of required audit follow-up action and on enforcement action in cases of non-compliance.
>
> (A94-26, issued December 1994)

In response to these recommendations, TC has indicated that both Recommendations A94-23 and A94-24 will be taken into consideration during amendments to the MRA. Also, TC will ensure that the Audit Procedures training program for inspectors takes into account Recommendation A94-24 so that risk management methods are clearly understood and applied.

With respect to Recommendations A94-25 and A94-26, TC replied that the MRA will be reviewed to ensure clear policy direction is given to ensure effective audit follow-up systems are in place. Furthermore, an enhanced National Aviation Company Information System (NACIS) should be operational by September 1995 to track audit follow-up on a national basis. In the interim, a policy directive will be issued to regions to require a review of respective regional follow-up systems.

4.2 Action Required

4.2.1 Global Positioning System (GPS)

The GPS installation in C-GQTH was used in instrument meteorological conditions (IMC) as a primary navigation aid during the approaches to Sandy Lake. The GPS installation was not approved for such use. The TSB has identified other occurrences in which pilots have misused GPS while conducting IFR flights, or in which pilots on VFR flights have continued flight into adverse weather while using GPS and encountered conditions with which the pilot and/ or aircraft could not cope. Evidence suggests that both recreational pilots (seeking an inexpensive navigational system) and commercial, passenger-carrying operators are employing GPS in order to get into airports without approved instrument approaches. It is doubtful that these locally improvised GPS approaches take into account the obstruction clearance criteria used in the design of approved approaches, including the acquisition of valid local altimeter settings.

While the Board is concerned over the misuse of GPS, it recognizes the potential of this equipment and what it could offer to the Canadian aviation community. The potential benefits of GPS have been widely publicized; the safety implications of improvising in the use of GPS in a non-regulated environment have received less publicity. The benefits may be tempting pilots and operators to accept risks that would normally be unacceptable without GPS. Therefore, to reduce the potential for GPS-related occurrences resulting from the use of unapproved equipment, inadequate understanding of the system, or lack of approved approaches, the Board recommends that:

> The Department of Transport expedite the implementation of approved GPS standards and procedures for use in Canadian airspace; and
>
> A95-07

> The Department of Transport initiate a national safety awareness program addressing the operating limitations and safe use of GPS in remote operations.
>
> A95-08

4.2.2 Flight Instruments - Large Turbo-Prop Aircraft

Large turbo-prop aircraft, some capable of seating more than 50 passengers, are in wide use in Canada because of their suitability for commuter operations, and for flights into remote or smaller airports. A significant proportion of all passengers transported annually by Canadian air carriers are in such turbo-prop aircraft.

Many of these turbo-prop aircraft have a passenger-carrying capacity equivalent to that of mid-sized turbo-jet aircraft. Yet, unlike their turbo-jet counterparts, turbo-prop aircraft are not required to have either a standby attitude indicator or a Ground Proximity Warning System (GPWS). TC is currently revising the Canadian Aviation Regulations respecting the use of aircraft in a commercial air service through an advisory committee process. The regulatory committee will focus, in part, on maximizing the compatibility of the Canadian regulatory system with that of other regulatory authorities such as the Federal Aviation Administration (FAA) in the U.S.

4.2.2.1 Standby Attitude Indicators

The attitude indicator or artificial horizon is the pilot's primary reference for instrument flying at night, in low visibility, or in cloud. A standby attitude indicator provides a means to cross-check and validate information supplied by the primary attitude indicators and also serves as an independently powered backup system should the primary instruments fail.

In the United States, an independently powered standby attitude indicator has been a requirement on all turbine-powered large aircraft since October 1994[14]--with no distinction made between turbo-jet and turbo-prop aircraft. The Board believes that the need for a

14 Federal Aviation Regulation (FAR) 14, CFR Part 121

standby attitude indicator on an aircraft should not be related to the method of aircraft propulsion; rather, the role of the aircraft and its passenger-carrying capacity are better indicators of the need for added safety precautions. Given the increased safety margin provided by a standby attitude indicator in the event of failure of the primary attitude indicator, the Board recommends that:

> The Department of Transport require the installation of an independently powered standby attitude indicator on all turbine-powered, IFR- approved commuter and airline aircraft capable of carrying 10 or more passengers.

A95-09

4.2.2.2 *Ground Proximity Warning Systems (GPWS)*

Within the global aviation community, GPWS has been recognized for its potential to prevent CFIT accidents. In Canada, GPWS has shown its effectiveness on at least two occasions. In 1987, the crew of a Boeing 737 carrying 96 people were warned of the aircraft's proximity to the ground on two separate occasions by GPWS while on approach at Prince George, British Columbia (A87P4128). Similarly, in 1990, the pilots of a Dash-8 on approach into Charlo, New Brunswick, were warned by their GPWS of inadequate ground clearance caused by a 1,000-foot altimeter error. There were 32 souls on board this Dash-8 aircraft (A90A0256). (Of note, the installation of the GPWS on this turbo-prop aircraft was not required by regulations).

In an effort to reduce CFIT accidents in commercial operations, the FAA in the United States made GPWS mandatory on all turbine-powered (i.e. both turbo-jet and turbo-prop) aircraft capable of carrying 10 or more passengers, effective 20 April 1994[15]. It is understood that similar measures are not being contemplated at this time for Canadian-registered turbo-prop aircraft.

As previously stated, over the preceding 11 years, 68 commercially operated aircraft were involved in CFIT accidents; 13 of these were turbo-prop aircraft. The Board believes that the increased level of safety provided by GPWS should not be related to an aircraft's type of propulsion. Rather, GPWS installation should be based on the role of the aircraft and its passenger-carrying capacity. The Board commends the initiative of some operators to install GPWS in their aircraft--even though it is not required by Canadian regulations. However, most turbo-prop aircraft, some carrying dozens of passengers, continue to operate without the added safety protection of GPWS. Therefore, the Board recommends that:

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

A95-10

15 Federal Aviation Regulation (FAR) 14, CFR Part 135

4.3 Safety Concern

4.3.1 Monitoring of Pilot Flying Performance

In occurrence investigations, the flying history and records of the involved aircrew are routinely reviewed in detail. Analysis of recurring shortcomings in a pilot's flying performance may provide insight into the factors contributing to an occurrence, especially if the circumstances of the occurrence are similar to those in which the pilot had previously shown weaknesses.

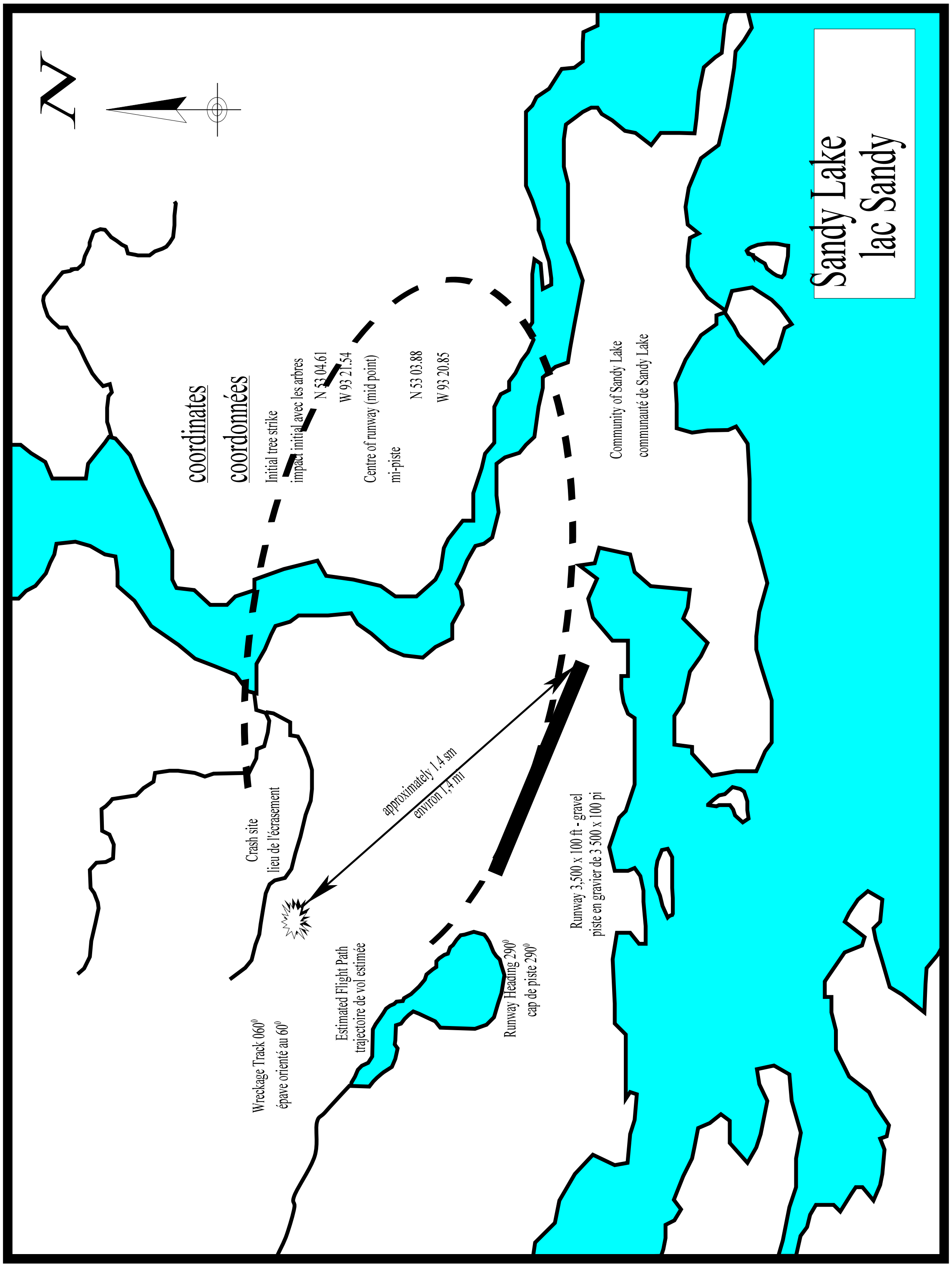
There are no requirements for company check pilots and air carrier inspectors to look for adverse trends in a pilot's performance on flight tests. Indeed, it is understood that TC discourages such practice with a view to maintaining objectivity in testing. Nor is there a tracking system within TC to identify individuals repeatedly experiencing particular difficulties during flight tests.

A pilot can achieve an overall satisfactory rating on a flying proficiency check even though a critical sequence on the test may have been performed marginally. The overall pass on the test suggests that the pilot is competent to handle all the challenges associated with the flying privileges of his/ her licence. However, this may not be the case, in that the pilot may have a history of problems in that specific aspect of flying.

The Board found no link between the flight crew's performance and this accident. Nevertheless, the Board is concerned that, without a formal procedure in place to review past flight test results, pilots with fundamental weaknesses in flying performance may be permitted to continue flight operations. Therefore, the TSB will continue, through its investigations, to analyze any correlation between aircrews experiencing repeated flying performance difficulties, the circumstances of the occurrences in which they are involved, and the flight test standards as established by Transport Canada.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Gerald E. Bennett, Zita Brunet, the Hon. Wilfred R. DuPont and Hugh MacNeil, authorized the release of this report on 14 March 1995.

Appendix A - Crash Site and Surroundings



Appendix B - Sandy Lake Approach Procedure

Appendix C - List of Supporting Reports

The following TSB Engineering Branch Laboratory Reports were completed:

LP 148/93 - Flight Recorders Report, HS 748, C-GQTH;
LP 181/93 - Aileron Control System Analysis, HS 748, C-GQTH;
LP 177/93 - Electrical System/Components, HS 748, C-GQTH;
LP 078/94 - Maintenance Records, HS 748, C-GQTH;
LP 174/93 - Technical Investigation Group HS 748-2A, C-GQTH;
LP 175/93 - Powerplants Examination, HS 748, C-GQTH; and
LP 176/93 - Structural Components Examination, HS 748, C-GQTH.

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

Appendix D - Glossary

AC	alternating current
AES	Atmospheric Environment Service
agl	above ground level
AME	aircraft maintenance engineer
AMO	Approved Maintenance Organization
ANO	Air Navigation Order
ARCAL	aircraft radio control of aerodrome lighting
asl	above sea level
ATC	air traffic control
ATPL	Airline Transport Pilot Licence
CAM	cockpit area microphone
CCP	company check pilot
CFIT	Controlled Flight Into Terrain
C of A	Certificate of Airworthiness
C of G	centre of gravity
CRM	crew resource management
CST	central standard time
CVR	cockpit voice recorder
DC	direct current
DFO	Director of Flight Operations
DH	decision height
DOM	Director of Maintenance
ELT	emergency locator transmitter
FAA	Federal Aviation Administration
FAR	U.S. Federal Aviation Regulations
FDR	flight data recorder
FPS	fine pitch stop
FSO	Flight Safety Officer
FSS	Flight Service Station
g	G load factor
GPS	global positioning system
GPWS	Ground Proximity Warning System
hr	hour(s)
IFC	instrument flight check
IFR	instrument flight rules
IMC	instrument meteorological conditions
KIAS	knots indicated airspeed
KTAS	knots true airspeed
LVC	Licence Validation Certificate
MCM	Maintenance Control Manual
MDA	minimum descent altitude
MEL	minimum equipment list
MHz	megahertz
MRA	Manual of Regulatory Audits
NACIS	National Aviation Company Information System
NDB	non-directional beacon
nm	nautical miles
OPP	Ontario Provincial Police
PPC	pilot proficiency check
PPL	private pilot licence
psi	pounds per square inch
QAM	Quality Assurance Manager
rpm	revolutions per minute
SARSAT	search and rescue satellite
SB	satisfactory with briefing
TAS	true airspeed

TBO	time between overhaul
TC	Transport Canada
TSB	Transportation Safety Board of Canada
TSO	Technical Standard Order
TSO	time since overhaul
UFDR	Universal Flight Data Recorder
UTC	Coordinated Universal Time
VFR	visual flight rules
VMC	visual meteorological conditions
V/ P	Vice President
WAT	weight, altitude, and temperature
'	minute(s)
"	second(s)
°	degree(s)
°C	degrees Celsius
°M	degrees magnetic
°T	degrees true