AVIATION INVESTIGATION REPORT

A98Q0192

REJECTED TAKE-OFF / RUNWAY OVERRUN

FIRST AIR / BRADLEY AIR SERVICES LIMITED

HAWKER SIDDELEY HS-748-2A   C-FBNW

IQALUIT, NUNAVUT

03 DECEMBER 1998

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Synopsis

At approximately 1536 eastern standard time, First Air flight 802, a Hawker Siddeley HS-748-2A, serial number 1759, was on a scheduled flight from Iqaluit to Igloolik, Nunavut. On board were two flight crew, one flight attendant, one loadmaster, and three passengers. During the take-off run on runway 36, at the rotation speed (V_R), the captain rotated the aircraft; however, the aircraft did not get airborne. Approximately seven seconds after V_R, the captain called for and initiated a rejected take-off. The aircraft could not be stopped on the runway, and the nose-wheel gear collapsed as the aircraft rolled through the soft ground beyond the end of the runway. The aircraft hit the localizer antenna and continued skidding approximately 700 feet. It came to rest in a ravine in a nose-down attitude, approximately 800 feet off the declared end of the runway. The flight attendant initiated an evacuation through the left, main, rear cabin door. The two pilots evacuated the aircraft through the cockpit windows and joined the passengers and the flight attendant at the rear of the aircraft. The flight attendant was slightly injured during the sudden deceleration of the aircraft. The aircraft was substantially damaged.

Ce rapport est également disponible en français.

Table of Contents

1.0 Factual Information

1.1 History of the Flight

First Air flight 802 was scheduled to depart Iqaluit at 1430 eastern standard time on 03 December 1998 for a direct flight to Igloolik.[1] The departure was delayed approximately one hour due to the change of aircraft and a delayed arrival. The ramp personnel loaded the aircraft and blew the snow off the wings and the elevators. The aircraft taxied to the active runway, and the crew requested clearance. Meanwhile, the First Air load planner was trying to get the final figures of the weight and balance. The aircraft taxied to position and waited for the final weight and balance figures. The flight service station (FSS) enquired about the delay and fixed a time limit for take-off.

After the crew received the final figures from the load planner, the aircraft was aligned with the runway centreline. The captain then started the take-off roll, which was conducted at night, with limited visual references. At 1536, the power levers were advanced to the take-off power range. By 70 knots indicated airspeed (KIAS), snow that had accumulated on the wings during taxi was observed blowing off the aircraft as it accelerated down the runway. The critical engine-failure recognition speed (V_1) was called, and rotation was initiated at the target rotation speed (V_R) of 115 KIAS, with approximately 3700 feet of runway remaining. The elevator was deflected, and the nose began to pitch up.

The captain relaxed the elevator controls somewhat—the elevator angle reduced by about 1° —when the aircraft approached what he thought was the take-off attitude. When the aircraft did not get airborne as expected, he pulled back on the controls a second time. The aircraft had reached 121 KIAS, with 2800 feet remaining during the second attempt. The aircraft did not get airborne and the captain called for a reject as the aircraft accelerated through 127 KIAS. He retarded the power levers as the aircraft reached a speed of 131 KIAS and was approximately 1750 feet from the end of the runway. The captain applied full braking, and the full-fine pitch stop lever was applied for aerodynamic braking.

When it became apparent that the aircraft would not stop on the runway, the captain steered the aircraft to the left in an attempt to avoid the localizer antenna. The aircraft was travelling at approximately 100 knots as it went off the end of the runway. As the aircraft rolled through the soft ground, the nose-wheel gear collapsed. The right wing hit the localizer antenna, and the aircraft continued skidding on its belly through heavy rocks. It came to rest in a nose-down attitude approximately 800 feet off the declared end of the runway.

1.2 Injuries to Persons

The flight attendant sustained minor injuries to her shoulder during the impact sequence.

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[1] All times are eastern standard time (coordinated universal time [UTC] minus five hours) unless otherwise noted.

1.3 Damage to Aircraft

Approximately 100 feet off the end of the runway, the nose-wheel assembly broke in overload. The nose gear separated, and the aircraft continued skidding on its belly. The aircraft subsequently struck the localizer transmitter array approximately 425 feet beyond the end of the paved runway surface, causing the right wing to separate from the fuselage. Both main landing gears collapsed as the aircraft started skidding over large rocks. The two propellers were damaged when they contacted the ground after the nose gear collapsed. The belly of the aircraft sustained severe damage as the aircraft continued skidding. All the electrical systems in the belly compartment were damaged, and the aircraft lost all its electrical power, rendering the radios unserviceable.

1.4 Other Damage

The aircraft broke through the airport perimeter fence. The localizer antenna was completely torn from its concrete attachments during the impact sequence.

1.5 Personnel Information

The captain joined First Air on 01 August 1997 and was initially employed on Hawker Siddeley HS-748-2A aircraft. He had flown a variety of aircraft, including the Dash 8, Shorts 330, and Shorts 360. He attained captain status on the HS-748 in October 1997. At the time of the accident, he had accumulated 8000 hours total flying time, including 800 hours as captain on the HS-748. The captain held an airline transport pilot licence endorsed for the HS-748, a group-1 instrument rating, and a category-1 medical certificate. The captain had successfully completed his last line check on 15 November 1998 and his last recurrent training on 16 April 1998. These flights were both very well flown and managed. The occurrence flight was his third flight of the day.

The first officer joined First Air on 14 June 1996 as a first officer on DHC-6 aircraft and, subsequently, on HS-748. He had accumulated 2143 hours total flying time, including 117 hours as a first officer on the HS-748. He held an airline transport pilot licence endorsed for the HS-748, a group-1 instrument rating, and a category-1 medical certificate. The first officer had successfully completed his last line check and last combined pilot proficiency check and instrument rating renewal flight on 14 November 1998. These flights were both well flown. The first officer was doing his line indoctrination at the time of the accident.

The flight attendant joined First Air in June 1998. She completed her initial training and was qualified to fly on all aircraft operated by First Air. In October 1998, she completed her recurrent training, which included crew resource management training. Line indoctrination on the HS-748 was completed in November 1998. At the time of the occurrence, she had flown eight flights on the HS-748.

1.6 Aircraft Information

The aircraft maintenance records indicate that the aircraft had been maintained in accordance with the company's maintenance control manual and applicable airworthiness standards. The investigation did not reveal any failure or system malfunction prior to the flight. The aircraft's brakes, anti-skid system, and tires functioned properly throughout the rejected take-off.

At the time of the occurrence, the outside temperature was minus 2.1 degrees Celsius. The ground personnel de-iced a company B727 parked adjacent to the HS-748 before take-off but did not de-ice the occurrence aircraft. The snow covering the wings was blown off the wings with leaf blowers. Company procedures require that all critical surfaces be de-iced when precipitation is falling and the temperature is higher than minus 2 degrees Celsius, which was the case for the occurrence flight. The crew of the HS-748 were aware of this situation but decided to not de-ice the aircraft. The snow that accumulated on the wings during the ground operations reportedly blew off during the initial stage of the take-off run. Studies have shown that icing can significantly affect the lift performance of an aircraft's wings and elevators. Following the occurrence, the company changed the temperature limit from minus 2 degrees Celsius to minus 10 degrees Celsius in order to increase the safety margin.

A pilot may decide to use water methanol to increase power and shorten take-off distances. However, document number AO.1.8 in the HS-748 aircraft flight manual requires the use of water methanol for take-offs when a runway has snow, slush, or water on its surface. Water methanol was not used for the occurrence take-off. The use of water methanol for the take-off would have shortened the take-off roll by approximately 1000 feet.

The accident aircraft is a "combi" model designed to carry passengers and cargo in the aircraft cabin. The aircraft has a maximum seating capacity of 44. Cargo/baggage stowage areas are located forward and aft of the passengers' area. The forward cargo/baggage area is located between the passenger cabin and the flight deck. A movable bulkhead separates the passenger cabin from the forward cargo/baggage area.

Shortly after the accident, the aircraft was unloaded station by station and the contents weighed by TSB investigators. The following table presents First Air's pre-flight calculations and the TSB's post-accident calculations. The weight and balance limits of First Air and Hawker Siddeley are included for comparison purposes.

Table 1 - Calculations and Limits

	Calculated by First Air		Calculated after the accident		First Air limits		Hawker Siddeley limits	
	Weight (pounds)	Index	Weight	Index	Weight	Balance	Weight	Balance
Zero-fuel weight	38 240	20.9	38 697	19.7	38 500	21.1 to 34.2	38 500	19.0 to 34.5
Ramp fuel	8100	3	8100	—	—	—	—	—
Taxi fuel	100	—	100	—	—	—	—	—
Gross take-off weight	46 240	23.9	46 697	22.7	46 500	23.7 to 35.3	46 500	21.6 to 37.2

First Air voluntarily changed the C of G limits from the original Hawker Siddley limits to represent curtailment, principally needed for movement of flight attendants from the back to the front of the aircraft during flight. Transport Canada had approved these new company limits, which are listed in the approved company operations manual.

For the occurrence take-off, the aircraft's actual gross take-off weight was 46 697 pounds, which is almost 460 pounds heavier than the weight calculated by First Air before the flight, and approximately 200 pounds over maximum gross weight. The actual C of G was at an index of 22.7, which was outside the First Air forward limit of 23.7, but within the manufacturer-specified forward limit of 21.6.

The aircraft configuration was changed at the last minute when extra baggage was loaded in the front section of the cargo compartment. The new figures were evaluated by the loadmaster and passed to the load planner. The loadmaster did not use a scale to evaluate the excess baggage loaded. This evaluation was made quickly because the aircraft was waiting on the runway, in position for take-off. Transport Canada-approved company procedures require that baggage be weighed on a scale.

This underestimation of the baggage weight explains the discrepancy in weight and C of G calculations. With a forward C of G position, aircraft performance is affected, and more back pressure must be applied on the controls to achieve the pitch-up attitude required for take-off.

Based on the ambient pressure altitude and temperature conditions, and 7½ degrees take-off flap setting, the aircraft was performance limited to a WAT (weight-altitude-temperature) weight of 45 100 pounds for single-engine climb considerations. The aircraft was estimated to be about 1600 pounds over the WAT weight published in the HS-748 Aircraft Flight Manual. A take-off planning worksheet is normally required to evaluate the engine-out performance of the aircraft when obstacles are present. The captain did not do the calculation of the WAT limit during the flight planning.

1.7 Meteorological Information

The reported weather conditions at 1500, approximately 36 minutes before the take-off, were as follows: precipitation ceiling 800 feet obscured, visibility one statute mile, light snow showers, temperature minus 2.1 degrees Celsius, dew point minus 3.0 degrees Celsius, winds from 360 degrees true at two knots, altimeter setting 29.47 inches of mercury, and stratocumulus cloud with 10/10 coverage.

1.8 Communications

When the pilot called the FSS to advise he was starting the engines, he requested instrument flight rules clearance to Igloolik. The FSS specialist issued the wind information and the altimeter setting to the pilot. The specialist did not include information on the condition of the runway, although the FSS manual of operations requires this information to be passed. A review of recorded FSS communications earlier in the day revealed that information concerning the runway condition was not included in communications with other departing aircraft.

The pilot reported for a runway 36 departure, received the air traffic control (ATC) clearance, and taxied to position on runway 36. At 1536:24, the pilot began the take-off roll; this was the last communication from the aircraft to the FSS.

At 1536:51, the monitor and control unit alarm panel in the FSS indicated an overall instrument landing system fault. The specialist found it unusual to see the entire instrument landing system show a fault, but did not take any specific action at the time. The alarm had resulted from the aircraft striking and breaking a portion of the localizer antenna.

Within three minutes of the registered take-off time, the specialist thought the flight had departed, and a communication search was initiated, with calls to the Montréal Area Control Centre and the First Air / Bradley dispatcher at Iqaluit; neither agency was in contact with the aircraft. The specialist then instructed an airport security worker to proceed onto the runway and initiate a search. The aircraft was found off the end of the runway about 13 minutes after the recorded take-off time.

1.9 Aerodrome Information

Iqaluit Airport is a certified airport served by a single asphalt-surface runway, 8600 feet long by 200 feet wide, designated 18/36. The field is 110 feet above sea level. The airport manager is responsible for ensuring that essential maintenance services, contracted to a private company, are provided both winter and summer. The superintendent of airport field maintenance, hired by the company, is responsible for carrying out the maintenance activities, such as snow and ice removal operations.

The Iqaluit Snow Removal Plan, dated 08 July 1996, details the policies, norms, guidelines, and responsibilities pertaining to snow and ice removal from traffic areas at Iqaluit Airport. It provides direction to the services involved in winter operations to ensure that airport surfaces are kept safe. According to the *Canada Flight*

Supplement, snow removal operations at Iqaluit Airport may vary from day to day to accommodate flight schedules. The runway is checked twice every day: once before the first scheduled flight of the day and again in the afternoon. A Notice to Airmen (NOTAM) must be issued as soon as any section of the airport movement area is closed.

The Snow Removal Plan specifies that runway surface condition (RSC) reports will be issued each time there is a major change in the RSC, each time the runway is cleared after spreading sand or de-icing products, each time the runway has been cleared of snow, after an accident or incident involving aircraft on the runway, and in response to a reasonable request by an air carrier or pilot. A friction index report, using a decelerometer-equipped vehicle, is provided only when the runway is covered by ice, compacted snow, or powder snow less than 2.5 centimetres deep, or when de-icing products or sand have been spread onto an ice-covered runway. Decelerometer readings are not provided (because they are not valid) when the runway is covered by powder snow more than 2.5 centimetres deep, water, or slush. A decelerometer reading, termed a Canadian runway friction index (CRFI), of 0.40 would indicate good braking action whereas a reading of 0.25 or below would indicate poor-to-nil braking action. Charts published in the *Canada Flight Supplement* equate the CRFI reading with recommended landing distances and RSC for use by aircrew.

On the day of the accident, three NOTAMs were issued concerning the RSC. The first RSC report was sent out at 0945: runway 18/36 was 90% covered with a trace of loose snow and a 10% trace of compacted snow, temperature was minus three degrees Celsius, and the CRFI was 0.41. Another RSC report was issued at 1445: runway 18/36 was 90% covered with loose snow, and the CFRI was 0.40. A post-accident RSC report was completed by airport field maintenance staff at 1605: runway 18/36 was 100% covered with a trace of loose snow, the temperature was minus two degrees Celsius, and the CFRI was 0.21.

Between 0945 and 1505, snow-clearing operations were conducted between flights. Light snow was falling throughout the period, but the centre 100 feet of runway was reportedly kept clear, and the RSC had not changed from the 0945 reading. No snow clearing or RSC reading was done after 1505 (roughly 30 minutes before the take-off) because of traffic. Photos of the runway, taken within an hour after the accident, show that the runway was covered with snow and that snow was compacted where vehicles had been. The RSC report after the accident did not mention compacted snow.

1.10 Flight Recorders

1.10.1 General

The flight recorders were analyzed at the TSB Engineering Laboratory. The cockpit voice recorder was an Allied Signal solid-state voice recorder. The recorder was in good condition, and the data were recovered. The cockpit voice recorder recorded the last 30 minutes of audio from the pilot, copilot, and cockpit area microphone channels. The internal communications were of good quality on the radio channels, indicating the use of hot microphones. The recording began while the aircraft was on the ramp at Iqaluit, approximately 19 minutes before engine start, and ended during the impact sequence.

The flight data recorder was an Allied Signal solid-state flight recorder. The recording contained approximately 26 hours of data, including the rejected take-off and nine previous flights. The recorder was in good condition, and the data were recovered. The quality of the accident data was good.

1.10.2 Pre–Take-Off Segment

The flight controls were checked for full and free movement five seconds before commencing the take-off roll. The flight data recorder indicated full movement of the elevator surfaces.

1.10.3 Take-Off Roll and Reject

The initial portion of the take-off roll was uneventful, with the captain performing the take-off. All engine parameters and annunciator lights were normal and remained stable throughout the take-off roll, which lasted 38 seconds. The acceleration rate was consistent with the loose snow-covered runway surface conditions that existed during the accident take-off.

At the dispatched gross take-off weight (46 240 pounds) and with take-off flaps at 7.5 degrees, the operations manual indicates V_1 and V_R target speeds of 109 KIAS and 115 KIAS, respectively. The V_1 decision speed was called through approximately 103 KIAS (call led by about 6 knots). At V_1, the aircraft was estimated to be approximately 4800 feet from the end of the runway (including the 200-foot overrun). Approximately 6.1 seconds after V_1, rotation was called, and aircraft rotation was initiated at the target speed of 115 KIAS, with approximately 3700 feet of runway remaining. The elevator was deflected, and the nose began to pitch up. The aircraft had reached 121 KIAS, with 2800 feet remaining, when it initially reached 7.6 degrees nose up. At the start of the rotation, the elevator and pitch rates were about 1 degree per second. The nose pitched down to 6.7 degrees as the pilot relaxed the back pressure. The elevator was deflected nose up a second time to a maximum of approximately 7.0 degrees, at an increased elevator rate of about 2 degrees per second (see tables 2 and 3). Following the second nose-up elevator input, the nose began to respond, pitching up more rapidly (2 degrees per second). The elevator was then deflected nose-down (control inputs checked) from 7.0 degrees to 5.8 degrees, at a rate of 0.6 degrees per second. The maximum pitch-up attitude subsequently attained was 8.3 degrees, with speed increasing through 126 KIAS (11 knots above V_R). This was followed again by a reduction in pitch attitude to 6.6 degrees. From elevator/pitch data, the pitch response mirrored the elevator inputs during the two rotation attempts, with pitch attitude decreasing as control inputs were checked.

However, previous flight data indicated that, with elevator deflections similar to the occurrence take-off but with higher elevator rates, the nose continued to rotate (beyond 8 degrees), and the aircraft lifted off. On the occurrence take-off, the aircraft did not lift off the runway. The slight dip in a pressure altitude, typical of lift-off (in ground effect) as noted on previous take-offs, was not apparent. Table 2 outlines the maximum elevator deflections applied, the elevator rates, and the maximum pitch attitudes attained during the accident flight and during three previous flights.

Table 2 - Maximum Elevator Deflection / Rate and Pitch Attitude on Rotation

Flight	Maximum elevator deflection (degrees)	Maximum elevator rate (degrees/second)	Maximum pitch attitude (degrees)	Aircraft take-off weight (pounds)
Accident flight	7	2.2	8.3	46 697
Flight 2	4.1	2.9	11.5	44 871
Flight 5	6.2	3.5	9.5	45 660
Flight 9	6.5	2	10	46 405

The HS-748 operations manual states that the captain, at V_1, should rotate the aircraft smoothly to 10 degrees pitch up until the aircraft gets airborne. The captain applied the usual back pressure on the control column, but the aircraft did not seem to respond to his actions by rotating normally and getting airborne. Table 3 outlines the key events and the corresponding time, speed, and runway distance information.

Table 3 - Matrix of Key Events

UTC (hrmn:sec)	Time to V_1 (seconds)	Event	Elevator deflection (degrees)	Pitch attitude (degrees)	Speed (KIAS)	Distance travelled (feet)	Distance remaining (feet)
2036:29.0	-36.6	Start take-off	-8.3	1	0	0	8600
2036:48.8	-16.8	70-knot call	-8.2	1.6	68	1300	7300
2037:05.6	0	V_1- call	-3.9	1.9	103 (target 109)	3800	4800
2037:11.7	6.1	Elevator deflection begins	2	3.2	115 (target 115)	4900	3700
2037:13.2	7.6	Elevator goes above +4°	4	3.7	116	5200	3400
2037:14.7	9.1	Peak elevator (initial)	5.2	5.2	119	5500	3100
2037:16.1	10.5	Peak pitch (initial) attitude	4.6	7.6	121	5800	2800
2037:16.2	10.6	Increased control pressure	4.6	7.6	121	5850	2750
2037:16.7	11.1	Elevator goes above +5.5°	5.5	7.6	122	5900	2700
2037:17.2	11.6	Peak elevator (final)	7	7.1	124	6050	2550
2037:18.8	13.2	Peak pitch attitude (final)	5.7	8.3	126	6400	2200
2037:19.2	13.6	Rejected take-off initiated (column checked forward)	5.6	7.3	127	6500	2100
2037:20.8	15.2	Power reduction (maximum speed)	3	3.3	131	6850	1750
2037:23.5	17.9	Maximum deceleration	-8.1	1.1	127	7400	1200
2037:24.5	18.9	Rejected take-off called	-8.3	1.4	123	7600	1000
2037:30.0	24.4	Runway departure	-8.4	0.4	96	8600	0
2037:30.7	25.1	Impact sounds / Gear collapse	-8.3	-3.6	94	8700	-100

1.11 Fire

A large amount of fuel was spilled when the right wing separated from the fuselage during the impact with the localizer antenna. However, crash switches were activated and, during the impact sequence, the engines shut down and the fire extinguishers discharged automatically, preventing a fire.

1.12 Survival Aspects

1.12.1 Aircraft Configuration

There are five designated emergency exits and two flight deck windows on the HS-748-2A.[2] The aft passenger door and the aft baggage door are the primary emergency exits. The passengers' door opens out and aft, locking against the outside fuselage by means of a gust lock. The baggage door operates in the same manner except it opens out and forward. Neither door has a window. Two over-wing exit windows, one on each side of the aircraft, are designated as secondary or alternate exits. The fifth exit, the crew/freight door, is in the forward baggage area on the port side of the aircraft. However, this door is an alternate exit only, because it is close to the propellers and unsupervised. On flight 802, the starboard over-wing exit was not accessible because of the aircraft configuration.

1.12.2 Emergency Evacuation

When the captain called the reject, the first officer (F/O) did not call and advise the ATC facility. Further, a message was not sent over the public address (P/A) system to advise the flight attendant and passengers to brace. Immediately after the aircraft came to a stop, the flight attendant, who had no communication with the front crew, evacuated the passengers through the aft passenger door.

The HS-748 overrun list and the emergency checklist call for the following:

- HP COCKS........................OFF Captain
- BOOST PUMPS.................OFF Captain
- FIRE EXTINGUISHERS.... OFF Captain
- CABIN P/A........................BRACE F/O

[2] In addition to the five emergency exits, two sliding windows in the flight deck could be used in an emergency. However, these windows are very small and difficult to access and therefore not considered suitable emergency exits for passengers. A third cargo door, comprising a large portion of the aft port side of the fuselage, slides forward along the fuselage when opened but is not an emergency exit. Neither the flight deck windows nor the aft port cargo door are shown on the aircraft safety features card in accordance with Canadian Aviation Regulation 704.44.

– ATC.....................................BROADCAST F/O

– BATTERIES........................ OFF F/O

When the captain rejected the take-off, he did not identify the emergency or refer to the emergency checklist. He did not call for the overrun drill, and none of the above items were called out loud or completed. Afterward, the captain did not call for emergency evacuation.

According to the manufacturer, BAE Systems, closure of the mechanically operated HP cocks only prevents fuel from entering the engines, whereas closing the electrically operated LP cocks shuts off the lines upstream of the nacelles. Thus, in the event of disrupted fuel components within the nacelle itself (e.g. the fuel heater), selecting the HP cocks to OFF will not prevent leakage of fuel. If the aircraft finishes in a nose down attitude due to gear collapse, all the fuel in the affected wing will be free to drain away. Moreover, the LP cocks are not connected to the crash switch circuit and, therefore, will not close automatically in the event of its activation. Clearly, this can prevent a significantly increased fire hazard following an overrun.

The Emergency and Abnormal Procedures Checklist in the *HS-748 Operations Manual* was reviewed, and the overrun drill and emergency evacuation drill were compared. The overrun drill does not mention “FLAPS 27”. When following the emergency evacuation drill, the flaps are selected at 27 degrees and used as slides to descend from the tops of the wings to facilitate passenger evacuation. The flaps were not lowered to 27 degrees before the evacuation; they remained in the 7-degree position. All the passengers and the flight attendant evacuated the aircraft by the air-stairs.

1.12.3 Emergency and Survival Equipment

The accident aircraft was equipped with the required emergency and survival equipment, such as flashlights, fire extinguishers, protective breathing equipment, first-aid kit, fire axe, emergency locator transmitters, and survival gear. In addition, company procedures required that each flight attendant have a personal flashlight readily available at all times. The aircraft did not have a megaphone, nor was one required by regulations.

1.12.4 Emergency Lighting

This aircraft has two types of emergency lighting: fixed emergency lighting in the cabin ceiling and aisle path lighting. In the aircraft ceiling, six lighting panels with four light bulbs in each panel run the length of the cabin. The fourth bulb, the emergency light, lights automatically in the event of a crash and is activated by an inertia switch on the front spar web. The HS-748-2A is also equipped with the intervalve system of aisle path emergency lighting. The system is a set of dual lights just below every third aisle seat on the starboard side. A strobe light is beside each exit. Each unit has a self-contained battery pack that is automatically activated by a total loss of aircraft power if the emergency light switch in the flight deck is armed. The lights will last for approximately 20 minutes.

The ceiling emergency lights and the intervalve system can be manually activated using an emergency light switch in the flight attendant control panel. Although the switch has two possible positions, on and armed, it is witnessed wired in the armed position to ensure that the system activates automatically in an emergency. However, should the automatic system fail, the emergency lights can be turned on by breaking the witness wire and moving the emergency switch to the on position. The emergency lighting is designed to activate when vertical acceleration exceeds 3 g. The maximum vertical acceleration recorded on the flight data recorder for the occurrence flight was 2.4 g, which was not sufficient to activate the emergency lighting. The flight attendant could not find the emergency light switch on the flight attendant control panel in the dark. The light switch was not visible, and no requirement to that effect is listed in the certification standards for transport-category aircraft.

1.12.5 Crew Preparedness Issues

According to the *First Air Flight Attendant Manual*, a rejected take-off is an abnormal situation for which flight attendants are advised to maintain a high-alert awareness of their surroundings. They are advised to remain seated, with their seat belts and shoulder harnesses securely fastened while the aircraft is still moving. The flight attendant did not shout the "brace" command to the passengers. Once the aircraft has stopped or turned off the runway, flight attendants are to remain seated and assess conditions while awaiting the captain's instructions. If they notice an emergency situation developing at that time, they are to assess the situation further, getting out of their seats only if necessary. If, in their estimation, the situation is an emergency, they are to advise the flight deck immediately.

1.12.6 Aircraft Evacuation Decision Making, Passenger and Crew Evacuation

When the aircraft came to a complete stop, the flight attendant released her seat belt, stood up, and assessed the situation. Given the obvious need to evacuate, she did not wait for a command from the flight deck; she immediately initiated the prescribed emergency evacuation procedures.

Neither the ceiling emergency lights nor the intervalve aisle path lighting system activated. In accordance with the operator's evacuation procedures, the flight attendant attempted to activate both systems manually by turning the emergency light switch to the on position. Although she knew the location of the switch, she was unable to find it in the dark. The flight attendant could have used her personal flashlight or the onboard emergency flashlight to find the emergency light switch. However, given the time required to do so and the risks inherent in delaying an evacuation, she chose not to.

The flight attendant's next objective was to open the primary exit, the aft passenger door. This area of the aircraft was very dark. To find the door handle, she used her flashlight. At that point, the flight attendant noticed that the stowed air-stairs had dislodged on impact and were partially blocking the exit door. Nevertheless, she was able to access the handle and open the door. Initially the gust lock did not engage. A second attempt was made. This time the door locked against the aircraft fuselage in the fully-open position.

The flight attendant was able to push the air-stairs out the door to make a walkway to the ground. She shouted the appropriate commands for the passengers to exit the aircraft, counted them as they departed, and then exited herself. The flight attendant did not take any emergency/survival equipment from the aircraft.

The captain and the first officer were already outside the aircraft when the flight attendant opened the aft passenger door. The cargo in the forward baggage compartment shifted on impact, blocking access to the port over-wing exit and the crew/freight door. The flight crew evacuated through the sliding windows in the cockpit.

1.12.7 Emergency Rescue Services

No firefighting or emergency response service was stationed at the airport. The municipal fire department assumes responsibility for emergency response service to the Iqaluit Airport and ensures a response within 20 minutes of notification. The fire department is staffed with paid and voluntary personnel. All personnel were provided with a three-day course in aircraft firefighting theory that emphasized safety aspects and what not to do, but were not provided with hands-on practice. The available firefighting equipment included two front-line pumpers, capable of dispersing foam to fight fuel-fed fires, and one mini-pumper.

The municipal fire chief arrived at the airport ahead of the rest of the fire trucks. He was advised by radio that an aircraft had crashed and that it was 20 feet outside the airport perimeter fence, to the right of the airport. The fire chief was unsure as to the exact location of the accident because the specialist did not clearly describe whether the accident was at the approach or departure end of runway 18. The fire chief thought the accident may have occurred at the south end of the airport. When he did not see any sign of activity or other vehicles on the south side of the airport, he quickly arrived back at the airport terminal building. On the way back to the airport, he instructed his vehicles to proceed to the site at the north end of the runway. There is no perimeter road or other access to this part of the airport except via the runway.

The momentary confusion as to the location of the accident did not significantly delay the response, but had the potential to do so. The FSS does not use an airport map with a superimposed grid system to describe locations for response vehicles. This type of map is, however, available and is included in the current airport emergency response manual. The International Civil Aviation Organization recommends:

> A grid map of the aerodrome and its immediate vicinity should be provided for the use of the aerodrome services concerned. Information concerning topography, access roads and location of water supplies should be indicated. This map should be conspicuously posted in the rescue and fire fighting vehicles and such other supporting vehicles required to respond to an aircraft accident or incident. Copies should also be distributed to public protective agencies as desirable.[3]

A survey of three Ontario airports and one Quebec airport revealed that their emergency response plans contained airport grid maps and that response agencies have access to the airport emergency response plans. The airport grid map is, in those cases, not available to the operators of the emergency response vehicles and is not used when relaying the location of the accident site. Terminology familiar to operators working on the airport, such as runway/taxiway designators or other known reference points, is not always understood by

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[3] *International Standards and Recommended Practices*, Annex 14: Aerodromes, Volume 1: Aerodrome Design and Operations, Attachment A: Guidance Material, supplementary paragraph 16.1.4, 2nd edition, 1995.

drivers of emergency response vehicles and could be ambiguous to anyone. For example, during an exercise, one fire truck proceeded to the opposite end of the runway after receiving instructions from the FSS.

1.13 Tests and Research

1.13.1 Aircraft Performance Analysis

The TSB Engineering Laboratory conducted a detailed aircraft performance analysis to evaluate those factors that potentially contributed to the rejected take-off accident. The aircraft's performance during the rejected take-off was compared to its performance on three take-offs that were successful earlier on the day of the accident and that used the same configuration. To assess wing performance during the rejected take-off, it was necessary to establish a baseline of performance for the aircraft under non-ice conditions.

The following conclusions have been extracted from TSB Engineering Report *LP 135/98—Flight Data and Voice Recorder Analysis*:[4]

- The maximum pitch attitude eventually attained was less than that observed on previous flights despite more elevator input being applied.

- The performance analysis suggested that the aircraft was under-rotated as a result of a forward C of G loading and that the generated lift never exceeded the aircraft's weight during the take-off attempt.

- Although atmospheric conditions were conducive to contamination and the aircraft was not de-iced, it could not be determined if contamination was present or if it degraded the aircraft performance during the attempted take-off.

- The performance analysis indicated that, during the initial rotation attempt, the aircraft had not reached sufficient pitch attitude to achieve flight, and the pitch attitude was not maintained.

- The pitching moment resulting from the additional elevator input was essentially negated by the pitching moment from wing lift, due to the forward C of G position and the relatively slow rate of elevator input.

- After the additional elevator inputs were applied, pitch attitude and speeds were approaching the conditions required for flight.

1.13.2 Rejected Take-off Decision Making, Certification Criteria

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

The HS-748 was issued a type certificate, number A-87, in accordance with the *Canadian Aviation Regulations*. As part of this certification, the manufacturer must demonstrate to Transport Canada the performance data that are included in the Transport Canada-approved aircraft flight manual.

In the context of a field-length-limited take-off, V_1 is the maximum speed at which the rejected take-off manoeuvre can be initiated and the airplane stopped within the remaining field length. According to the definition of V_1 in the United States *Federal Aviation Regulations*, the pilot must recognize the engine failure and take initial stopping action to reject the take-off by V_1. If the pilot's stopping action is initiated at a speed higher than the field-length-limited V_1, insufficient runway will remain to stop the aircraft on the runway.

The balanced field length was calculated by the crew to have been 5250 feet, based on the aircraft flight manual supplement and the temperature and weight of the aircraft that day and considering that no water methanol was used. Given that the runway length is 8600 feet at Iqaluit and that the manufacturer's recommended aircraft configuration and power settings were used, there should have been enough runway to accelerate to V_1, reject, and stop on the runway.

According to the manufacturer, assuming the calculated aircraft weight and existing weather conditions, the gross ground run to the point of rotation for a dry runway should have been 4232 feet. The gross braking distance following abort of the take-off (including the delays for power reduction and brake application) from the V_1 speed of 109 KIAS should have been approximately 1918 feet. The effect of continuing the ground roll to 131 KIAS with all wheels on the ground would have significantly increased the braking distance. For the occurrence take-off, the acceleration to the target V_R of 115 KIAS was about 15% slower than the acceleration based on take-off data in the aircraft flight manual.

1.13.3 Rejected Take-off Training Issues

In 1989, in reaction to take-off accidents resulting from improper rejected take-off decisions and procedures, a joint Federal Aviation Administration (FAA) / industry team studied what actions might be taken to improve take-off safety. The team studied approximately 3000 rejected take-offs that occurred between 1959 and 1990. The FAA published the team's findings in April 1993 in a publication entitled *Take-off Safety Training Aid* and in a flight crew briefing video entitled *Rejected Take-off and the Go/No-Go Decision*. The training video emphasizes the need to adhere to the V_1 decision-making concept and highlights the inevitability of an overrun if a rejected take-off is initiated after V_1. In its discussion of rejected take-off situations, *Take-off Safety Training Aid* states that a take-off should not be rejected once the aircraft has passed V_1 unless the pilot has reason to conclude that the airplane is unsafe to fly. The study concluded that in most overrun accidents, the pilots, using visual cues, did not accurately assess the amount of runway remaining or the aircraft's ability to stop. The FAA/industry analysis of the 74 rejected take-off occurrences that resulted in overruns indicates that a number of these rejected take-offs involved crew uncertainty about the ability of the airplane to fly, as well as unidentifiable loud bangs, vibrations, and other characteristics that were later assessed as indications of engine stall or engine failure.

First Air pilots receive training in rejected take-off scenarios during annual recurrent flying training. The training is designed to provide the crew with experience in decision making before and after V_1. However, this training is not conducted in a simulator; it is conducted on the actual aircraft. Because no simulator exists for this type of aircraft, it is very hard to simulate a rejected take-off, at V_1 and gross weight, in different scenarios such as with an extreme C of G position. These simulations could easily be reproduced on modern simulators, giving the pilots a realistic feel of the aircraft.

In this occurrence, based on the back pressure that he had applied and the nighttime visual cues, the pilot concluded that the aircraft was unsafe to fly. He felt that he had achieved the required pitch for take-off and that the aircraft should have therefore lifted off.

2.0 Analysis

2.1 General

The aircraft was maintained in accordance with the manufacturer's specifications and the applicable regulations. The aircraft systems were operated as designed and did not contribute to the overrun or adversely affect the evacuation of the aircraft.

Other than the slower than predicted acceleration during the take-off run, and the aircraft not getting airborne as anticipated by the crew, the performance of the aircraft matched the performance predicted by the manufacturer.

Although the front-end crew did not call "brace" and "evacuate" on the public address system, the evacuation of the aircraft went well. No one used an over-wing emergency exit; therefore, the fact that the flaps were not lowered at the 27-degree position did not affect the evacuation. The flight attendant, with the exception of not shouting the "brace" command and not activating the emergency lights, reacted to the rejected take-off and subsequent evacuation in accordance with established procedures. She only had a very short time to realize that the aircraft was going off the end of the runway.

2.2 Aircraft De-icing

Although it was company procedure to de-ice critical surfaces in these weather conditions, the crew decided not to de-ice the aircraft. Instead, the ground personnel blew the snow off the wings with leaf blowers. While the snow that accumulated on the wings before take-off reportedly blew off during the initial stage of the take-off run, the possibility that some ice or snow contamination remained could not be ruled out. However, this possibility must be considered in the context of the performance data available from the flight data recorder.

2.3 Use of Water Methanol

Water methanol was not used for the occurrence take-off. Use of water methanol would have reduced the normal take-off distance by up to 1000 feet. Because the rejected take-off was not initiated as prescribed in operational manuals, the consequences of using water methanol could not be determined with certainty.

2.4 Influences on the Decision to Reject

The captain thought that he had provided sufficient control back pressure and that the aircraft had achieved appropriate pitch attitude for take-off. Consequently, when the aircraft did not take off as expected, he concluded that the aircraft was not performing properly, and he rejected the take-off. However, the flight data recorder data indicate that the aircraft did not attain sufficient pitch attitude. The captain's inability to accurately assess the pitch attitude was probably influenced by the heavier-than-normal elevator control forces and the limited nighttime visual references.

Although First Air pilots are trained in take-off and rejected take-off scenarios during their annual recurrent training, no simulator exists for this type of aircraft. Consequently, they did not receive practical training with the C of G at the forward limit that existed for the occurrence take-off.

2.5 Performance Issues

2.5.1 General

The distance used for the aircraft to accelerate to the target V_R of 115 KIAS was around 15% longer than predicted, probably due to the loose snow on the runway. In addition the braking action was not ideal, as revealed by the post-accident CRFI reading of 0.21 and the slippery runway conditions reported by the crew.

Following his decision to reject, the captain retarded the power levers as the aircraft reached a speed of 131 KIAS and was approximately 1750 feet from the end of the runway. Although the data from the flight data recorder confirmed that the full-fine pitch stop lever was applied for aerodynamic braking and that maximum wheel braking was applied, the aircraft had surpassed V_1 when the reject was initiated. Even under ideal conditions from the planned V_R of 115 KIAS, 1900 feet would have been required to stop the aircraft. Consequently, at the point when the reject was initiated, at 131 KIAS, there was not sufficient runway remaining on which to stop the aircraft. The poor braking action would have further lengthened the stopping distance.

2.5.2 Aircraft Load Control Factors

Overall control of the weight and balance of an aircraft relies on everyone involved in the process adhering to established and proven procedures. The extra baggage loaded onto this flight, without the baggage being weighed, suggests a lack of appreciation, by the persons involved, of the critical nature of their role in ensuring that the aircraft weight and balance always remain within limits. The effect of the excess baggage was not evaluated in accordance with company and Transport Canada procedures. The aircraft was, in fact, almost 200 pounds over its maximum take-off weight, and the C of G was forward of the First Air forward limit.

The performance degradation caused by an additional 200 pounds to an aircraft like the HS-748 at maximum gross weight can be viewed as negligible. However, the load-control discrepancies noted for this flight probably resulted in the aircraft being over its maximum design zero-fuel weight and its maximum design take-off weight. The aircraft was also approximately 1600 pounds over the WAT limit. However, this condition was not a contributing factor in the accident.

A forward C of G loading condition typically requires greater elevator control forces for take-off rotation. Flight crews become familiar with the typical column forces and displacements experienced on take-offs in a variety of C of G and weight configurations. With elevator trim typically set to the neutral take-off position for the HS-748, variable loads in day-to-day operations would result in variable column forces and displacements experienced on rotation. Although the trim position could not be determined from the recorders, it was reportedly found in the neutral position after the accident. The C of G positions on the previously reviewed flights were not as far forward as on the accident flight, and the pilot-flying likely did not frequently encounter a take-off weight near the maximum permissible with the C of G outside the operator's forward limit. During the initial rotation attempt, the nose stopped rotating when the pilot-flying checked forward on the control column, and the aircraft, in fact, started to pitch down. At this point, the aircraft had not reached sufficient pitch attitude to achieve flight, and the pitch attitude was not maintained as the aircraft continued to accelerate. There is a general reluctance to apply control inputs much beyond the normal amounts expected, both in terms of displacement and force.

The pitch control system on the HS-748 is such that control column forces increase progressively with more elevator deflection. On the accident flight, an additional 1.8 degrees of elevator deflection was applied, over the typical amounts characteristic of previous flights, at a higher rate, when the pilot felt that the aircraft was not lifting off during the initial rotation. After pulling the additional amount (maximum elevator deflection applied was approximately 30% of full nose-up elevator travel) and accelerating 11 knots above V_R, the aircraft still did not lift off, and the take-off was rejected. The elevator performance (elevator/pitch rates) appeared consistent with previous flights, indicating no significant elevator performance degradation. During the second rotation attempt, the nose stopped rotating again and began to drop when the elevator input was checked, mirroring the elevator inputs. During the accident take-off, the amount of force applied to the controls did not result in the aircraft reaching the 10-degree pitch-up attitude required for a normal take-off. However, the elevator control could have been moved much further aft.

2.6 Emergency Response

The response to the occurrence by the emergency response service, airport authorities, and company personnel was not well coordinated. Initially, there was a delay because the FSS specialist was uncertain of the aircraft's location and because he had not received a radio call advising him of the rejected take-off. Subsequently, although grid maps of the airport were available, the FSS, fire trucks, and intervening teams did not use these maps for orientation, which contributed to a further delay in reaching the aircraft. Most airport emergency response plans use a grid map to facilitate a rapid, orderly response to a crash site. The emergency response time is critical in a crash, but was not critical in this accident.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The captain rejected the take-off at a speed well above the engine-failure recognition speed (V_1) with insufficient runway remaining to stop before the end of the runway.

2. The far-forward position of the centre of gravity contributed to the pilot not rotating the aircraft to the normal take-off attitude.

3. The aircraft never achieved the required pitch for take-off. The captain's inability to accurately assess the pitch attitude was probably influenced by the heavier than normal elevator control forces and the limited nighttime visual references.

4. The loadmaster did not follow the company- and Transport Canada-approved procedures to evaluate the excess baggage added to the aircraft, which led to a discrepancy of 450 pounds and a C of G position further forward than expected.

5. The performance analysis suggested that the aircraft was under-rotated as a result of a forward C of G loading and the generated lift never exceeded the aircraft's weight during the take-off attempt.

3.2 Findings as to Risk

1. The aircraft was approximately 200 pounds over maximum gross take-off weight.

2. The aircraft accelerated more slowly than normal, probably because of the snow on the runway.

3. Although atmospheric conditions were conducive to contamination and the aircraft was not de-iced, it could not be determined if contamination was present or if it degraded the aircraft performance during the attempted take-off.

4. Water methanol was not used for the occurrence take-off. Use of water methanol may have reduced the consequences of the rejected take-off.

5. The captain did not call for the overrun drill, and none of the items on the checklist were covered by the crew.

6. The co-pilot did not follow the emergency checklist and call air traffic control to advise of the rejected take-off or call over the public address system to advise the passengers to brace.

7. The aircraft lost all its electrical systems during the impact with the large rocks, rendering the radios unserviceable.

8. No HS-748 simulator exists that could be used to train pilots on the various take-off and rejected take-off scenarios.

9. There was confusion regarding the aircraft's location. The flight service station, fire trucks, and intervening teams were not using an available grid map for orientation.

10. There is a risk associated with not de-icing aircraft before take-off in weather conditions such as those on the day of the accident.

11. There is a risk associated with not calculating the WAT limit and performance of an aircraft during an engine-out procedure in an environment with obstacles.

3.3 Other Findings

1. The aircraft's brakes, anti-skid system, and tires functioned properly throughout the rejected take-off.

4.0 Safety Action

4.1 Action Taken

4.1.1 First Air

First Air has changed the definition of "dry snow"[5] in its de-icing manual. According to the revised manual: "Any time there are precipitations prior to taxi or take-off, and the temperature is warmer than minus 10 degrees Celsius, the critical surfaces of the aircraft must be de-iced with the approved de-icing fluid."

In December 1998, after the accident, First Air audited all the weight and balance documents and found discrepancies. All cargo agents received additional training based on the audit's findings. A computerized weight and balance system has been developed and is being implemented.

First Air, after being advised of the comments of the manufacturer with regard to the item "LP COCKS", is currently evaluating, in coordination with Transport Canada, the feasibility of modifying the HS 748 Overrun Emergency Checklist to include the item: "LP COCKS - OFF".

4.1.2 Government of Nunavut

Following the accident, the Government of Nunavut re-opened the airport fire station and hired a fire chief and three firefighters. One new Oshkosh T3000 fire truck was purchased and delivered at Iqaluit. A second truck was repaired to enter service in the summer of 1999.

4.1.3 Transportation Safety Board

The TSB sent a Safety Advisory Letter to Transport Canada advising that grid maps were not always used during emergency response. Grid maps are a reliable and efficient tool to minimize emergency response time when guiding emergency vehicles to a crash site. The advisory letter suggested that Transport Canada review the requirement for airport operators and applicable agencies to use grid maps to guide all emergency vehicles during an emergency response.

On 14 August 2000, Transport Canada notified the TSB that it had received the Aviation Safety Advisory dealing with the use of grid maps during emergency response to crashes. In response to the advisory, Transport Canada, Civil Aviation, Aerodrome Safety has just completed the drafting of a new Airport Emergency Planning requirement, both a regulation and a standard, that will address the issue raised by the subject

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[5] Snow with limited water content normally flies into a "cloud" when kicked and dissipates rapidly. Outside temperature is generally below -2°C (28°F). Dry snow can become wet if exposed to bright sun or radiant heat. (Reference: Ground Icing Operations Program—First Air, Weather Phenomena, chapter 5, page 5.)

advisory. This new section, which will replace the existing Emergency Response section, will impart more direction on the development and use of grid maps, as well as provide a list of all parties provided with them.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 25 September 2001.

Appendix A—Glossary

AIP	*Aeronautical Information Publication*
ATC	air traffic control
C of G	centre of gravity
CRFI	Canadian runway friction index
FAA	Federal Aviation Administration
F/O	first officer
FSS	flight service station
g	the force of gravity
hr	hour
KIAS	knots indicated airspeed
mn	minute
NOTAM	Notice to Airmen
P/A	public address
RSC	runway surface condition
sec	second
TSB	Transportation Safety Board of Canada
V_1	critical engine-failure recognition speed
V_R	rotation speed
UTC	coordinated universal time
°	degrees
°C	degrees Celsius
°F	degrees Fahrenheit