Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A18P0031

LOSS OF CONTROL AND COLLISION WITH TERRAIN

Island Express Air Inc.
Beechcraft King Air B100, C-GIAE
Abbotsford Airport, British Columbia
23 February 2018

Canada

ABOUT THIS INVESTIGATION REPORT

This report is the result of an investigation into a class 3 occurrence. For more information, see the Occurrence Classification Policy at www.tsb.gc.ca

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

Citation

Transportation Safety Board of Canada, *Air Transportation Safety Investigation Report* A18P0031 (released 14 August 2019).

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Air transportation safety investigation report A18P0031

Cat. No. TU3-10/18-0031E-PDF
ISBN: 978-0-660-32001-4

This report is available on the website of the
Transportation Safety Board of Canada at www.tsb.gc.ca

Le présent rapport est également disponible en français.

Table of contents

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Summary

On 23 February 2018, at 1204 Pacific Standard Time, an Island Express Air Inc. Beechcraft King Air B100 aircraft (registration C-GIAE, serial number BE-8), departed Runway 07 at Abbotsford Airport, British Columbia (BC), on a day instrument flight rules flight to San Bernardino International Airport, California, United States. On board were the pilot and 9 passengers. It was snowing at the time of departure. A few seconds after taking off, the pilot raised the landing gear. At that same moment, the aircraft veered to the left and struck the ground just north of Runway 07. Five passengers and the pilot were seriously injured. The other 4 passengers received minor injuries. The aircraft was destroyed by impact forces. The aircraft's emergency locator transmitter activated and was detected by the Cospas-Sarsat search and rescue satellite system.

1.0 FACTUAL INFORMATION

1.1 History of the flight

On 23 February 2018, the pilot, who was also the owner of Island Express Air Inc. (Island Express), planned to take 9 family members on a no-cost charter instrument flight rules (IFR) flight from Abbotsford Airport (CYXX), BC, to Long Beach/Daugherty Field/Airport (KLGB), California, United States, using a company Beechcraft King Air B100 (King Air).

On the day of the occurrence, the pilot arrived at the hangar at approximately 0800.[1] In the hours leading to the departure, the pilot was involved in several different operational and

1 All times are Pacific Standard Time (Coordinated Universal Time minus 8 hours).

business-related activities. These activities included a flight with the other company King Air during which a mechanical issue rendered the aircraft unserviceable. This meant that the flight to KLGB would be using the only serviceable King Air at Island Express.

The pilot delegated most of the flight planning and pre-flight duties for the occurrence flight to Island Express staff members. Due to concerns about the deteriorating weather at the airport where the flight was going to clear customs, staff members were instructed to amend the operational flight plan, and arrangements were made to clear customs at a different airport.

At approximately 1030, the passengers arrived and loaded and secured their own baggage in the rear baggage compartment of the aircraft, using the supplied cargo net. The aircraft was in the hangar, with the door closed, to protect it from contamination due to snowfall and to make it easier for passengers to board.

At 1121, the pilot called the Abbotsford air traffic control (ATC) tower to ask whether he could receive an early clearance while the aircraft was still in the hangar.[2] The pilot was concerned that, with the heavy snowfall, the aircraft would be covered in snow if the flight experienced any delay in receiving the IFR clearance. Because the pilot's flight plan was not yet in the system, the pilot told the controller he would call back in 10 to 15 minutes for his clearance.

At 1140, the pilot called ATC back and requested clearance over the phone; however, the controller was unsure if that was allowed. The pilot then told the controller that he would have the aircraft towed out and would call on the radio for the clearance. The pilot also mentioned the snow accumulation and his concern about the possibility of having to wait for a clearance in the falling snow. The controller informed the pilot that there was one aircraft inbound for landing, but that it should not significantly delay his departure.

The pilot and passengers boarded the aircraft and, at 1150, the hangar door was opened and the aircraft was towed outside. At this time, it was snowing.

At 1154, both engines were running. No de-icing[3] or anti-icing[4] fluid was applied to the aircraft. The pilot requested and read back the clearance, and at 1155 he began taxiing to Runway 07.

Shortly after this time, the flight crew of the aircraft that had just landed on Runway 07 reported that they had had the airport in sight when they were approximately 400 feet above ground level and that the braking action on landing was moderate to poor.

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2 The typical temperature in the hangar was between 18 °C and 21 °C.

3 De-icing "is a procedure by which frost, ice, or snow is removed from the critical surfaces of an aircraft in order to render them free of contamination." (Source: Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, Standard 622.11: Ground Icing Operations, section 2.0, Definitions.)

4 Anti-icing "is a precautionary procedure that provides protection against the formation of frost or ice and the accumulation of snow on treated surfaces of an aircraft for a period of time." (Source: Ibid.).

At 1159, the pilot informed the controller that the aircraft was holding short for Runway 07. While the aircraft was waiting for takeoff clearance, no contamination was observed adhering to the wings. Two minutes later, the aircraft that had just landed exited Runway 07, and the occurrence aircraft was cleared for takeoff. At 1203, the aircraft taxied onto the snow-covered Runway 07 and continued with an immediate takeoff.

Approximately 4 to 5 seconds after takeoff, the pilot selected the landing gear control to the up position. As the gear retracted, the aircraft rolled approximately 30° to the left. To correct the uncommanded left bank, the pilot applied right aileron, and the aircraft returned to a near wings-level attitude. In order to make an immediate off-field emergency landing, the pilot retarded the power levers and then applied forward pressure on the control column to land the aircraft. The aircraft struck terrain between Runway 07 and Taxiway C. The aircraft slid across the snow-covered ground for approximately 760 feet before coming to rest in a raspberry patch located on the airport property.

Once the aircraft came to rest, the pilot moved the FUEL CUTOFF & FEATHER levers to the FUEL CUTOFF & FEATHER position and ordered the passengers to evacuate the aircraft. The pilot then exited the cockpit and opened the cabin door to help all the passengers exit the aircraft. After all the occupants had exited the aircraft, airport rescue and fire fighting personnel arrived on scene, followed shortly thereafter by members of the Abbotsford fire and police departments.

1.2 Personnel information

1.2.1 General

Table 1. Personnel information

Pilot licence	Airline transport pilot licence
Medical expiry date	01 September 2018
Total flying hours	10 000+
Flight hours on type	Approximately 800
Flight hours in the last 7 days	9.5
Flight hours in the last 30 days	29.6
Flight hours in the last 90 days	108
Hours on duty prior to the occurrence	4
Hours off duty prior to the work period	13

1.2.2 Pilot-in-command

The pilot held a Canadian airline transport pilot licence - aeroplane, with a type rating on the Beechcraft King Air B100. His licence was endorsed with a Group 1 instrument rating and was valid until 01 September 2018.

The pilot began flying in 1994 and flew commercially from the early 2000s until he started Island Express in 2009. The pilot was both the accountable executive and the operations manager for the company.

It was not possible to determine whether or not the pilot met the minimum training requirements, as company training records were incomplete; however, the pilot did have experience flying single-pilot IFR and had completed training on 24 July 2017 that included the approach to a stall.

The pilot was well rested, and there is no indication that fatigue played a role in this occurrence.

1.2.3 Pilot's pre-flight planning

At Island Express, the pilot-in-command of a flight normally completed flight planning duties, including completing the operational flight plan (OFP). However, it was the occurrence pilot's practice to delegate pre-flight planning duties to other staff members.

In the hours leading up to the occurrence, the OFP was changed several times. The destination for the first leg of the flight changed from Bellingham International Airport (KBLI), Washington, U.S., to Norman Y Mineta San Jose International Airport (KSJC), California, U.S., then to Bob Hope Airport (KBUR), California, U.S., and finally to San Bernardino International Airport (KSBD) California, U.S.

Island Express staff had completed the OFP for a flight to KSJC; however, customs were not available at KSJC, so efforts then began to arrange to clear customs at KBUR. Before approval could be obtained by company staff to clear customs at KBUR, the pilot made arrangements to clear customs at KSBD, and KSBD became the new destination for the first leg of the journey to KLGB. The pilot amended the destination on the OFP by hand, scratching out "Jose" and inserting "Bernadino" [*sic*], and then, without recalculating the new fuel requirements, signed it to indicate that the plan was accepted.

As a result, the OFP did not reflect the intended routing or fuel requirements.

1.3 Aircraft information

1.3.1 General

Table 2. Aircraft information

Manufacturer	Beechcraft
Type, model and registration	King Air B100, C-GIAE
Year of manufacture	1976
Serial number	BE-8
Certificate of airworthiness/flight permit issue date	08 September 2017
Engine type (number of engines)	Garrett TPE331-6-511B (2)
Left engine	p/n 3101630-1; s/n P-27016C

Right engine	p/n 3101630-3; s/n P-20086C
Propeller type (number)	Hartzell HC-B4TN-5F (2)
Maximum allowable take-off weight	11 800 pounds (5352 kg)
Maximum allowable landing weight	11 210 pounds (5085 kg)
Recommended fuel type(s)	Jet A, Jet A-1, Jet B
Fuel type used	Jet A

The occurrence aircraft was imported from the United States in March 2017, and the Beechcraft Inspection Program (Complete) was carried out at that time. The aircraft had accumulated 10 580.4 total time airframe hours.

According to the aircraft journey log, the next scheduled maintenance for the occurrence aircraft was Airworthiness Directive (AD) CF-1981-25R6,[5,6] which was due on 20 February 2018. This recurring AD is related to a wing spar crack inspection. It had last been completed on 20 February 2017. There is no record of the AD having been completed as required before the occurrence. According to section 605.84 of the *Canadian Aviation Regulations* (CARs), “no person shall conduct a take-off or permit a take-off” unless the requirements of any airworthiness directives issued under CARs 521.427 have been complied with. Failure to comply with a required airworthiness directive renders the aircraft unairworthy.

There was no indication of a pre-existing system malfunction that may have played a role in the occurrence.

1.3.2 Stall warning system

The occurrence aircraft was equipped with a stall warning system, consisting of an indicator mounted on the left side of the glareshield, a circuit breaker, a warning horn, and a heated lift transducer vane and face plate on the leading edge of the left wing.

The lift transducer vane senses lift coefficients based on the stall angle of attack of a “clean” aircraft.[7] When aerodynamic pressure on the lift transducer vane indicates a stall is imminent, a transistor switch will actuate, and the stall warning horn will activate. However, the King Air aircraft flight manual (AFM) states that “…a buildup of ice on the

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5 Transport Canada, Airworthiness Directive (AD) CF-1981-25R6, *Raytheon Aircraft Company (formerly Beech) – Wing Main Spar* (effective date: 31 December 2001).

6 This airworthiness directive is equivalent to Federal Aviation Administration Airworthiness Directive 89-25-10.

7 The term “clean” in this context means that no frost, ice, or snow is adhering to any of the aircraft’s critical surfaces such as wings and propellers.

wing may disrupt the airflow and prevent the system from accurately indicating an incipient stall."[8]

The investigation found no indication that the stall warning system activated during the occurrence flight.

1.3.3 Ice protection systems

The occurrence aircraft was equipped with a full suite of ice protection systems[9] and the relevant switches were all found to be in the appropriate position for flight into icing conditions.

1.3.4 Weight and balance

According to the aircraft flight manual, the aircraft must be loaded so as to not exceed the weight and centre of gravity (C of G) limitations. If an aircraft is loaded above the maximum take-off weight (11 800 pounds) or the maximum landing weight (11 210 pounds), it will have overall lower performance than what would normally be expected. In particular, an overweight condition will increase take-off and landing distances, increase the stall speed, decrease the rate of climb and the cruise speed, and reduce the aircraft's range. The TSB has previously identified the risks associated with operating above the maximum allowable gross weight, and the effect that it can have on aircraft performance.[10]

In general, as the C of G moves further aft, it results in less downforce on the tail and improved aircraft performance; however, moving the C of G aft also reduces the longitudinal stability of the aircraft.[11] The aircraft flight manual states that if an aircraft is loaded beyond the aft C of G limit,

> the pilot will experience a lower level of stability…lower control forces, difficulty trimming the airplane, lower control forces for maneuvering with attendant danger of structural overload, decayed stall characteristics, and a lower level of lateral-directional damping.[12]

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[8] Beechcraft King Air B100 Pilot's Operating Handbook and FAA Approved Airplane Flight Manual (revised August 2004), p. 7-38.

[9] The suite of ice protection systems includes propeller electric de-ice, windshield anti-ice, surface (leading edge) de-ice, heated pitot tubes, heated stall warning anti-ice system, and heated fuel vents.

[10] TSB aviation investigation reports A10Q0117, A12O0154, A13A0075, A13O0125, A13W0210, A14W0181, A15O0031, and A15C0163.

[11] The Boeing Company, "The Effect of High Altitude and Center of Gravity on The Handling Characteristics of Swept-wing Commercial Airplanes," *AERO Magazine* (Issue 02, Spring 1998), at https://www.boeing.com/commercial/aeromagazine/aero_02/textonly/fo01txt.html (last accessed on 03 July 2019).

[12] Beechcraft King Air B100 Pilot's Operating Handbook and FAA Approved Airplane Flight Manual (revised August 2004), p. 10-8.

The investigation identified a number of errors on the OFP relating to weight and balance. Most notably, although the aircraft had 549 pounds of fuel in the auxiliary tanks, 0 was entered on the OFP. There were no scales in the Island Express hangar and several of the occupant weights, including those of the pilot and the passenger in the right-hand crew seat, were incorrect. In addition, the distribution of these passenger weights on the OFP did not reflect the actual seats occupied during the occurrence flight.

The OFP indicated that the aircraft was more than 600 pounds under the maximum allowable gross take-off weight of 11 800 pounds, and that the C of G was within the approved flight envelope. However, based on the actual occupant and baggage weights and fuel loading, the investigation determined that the aircraft weighed approximately 12 000 pounds. The aircraft's C of G was near the aft limit of the approved envelope.

The pre-flight inspection did not ensure that the baggage was loaded properly.

1.3.5 Rear baggage compartment

The maximum allowable weight in the rear baggage compartment is 410 pounds.[13] In addition, "all cargo shall be properly secured by a Federal Aviation Administration–approved cargo restraint system."[14] In this occurrence, the passengers loaded approximately 480 pounds of baggage in the rear baggage compartment, and the cargo stored in the rear baggage compartment was secured using a cargo net. The investigation could not identify this net as an approved cargo restraint system.

During the impact sequence, the cargo net failed to restrain the baggage stored in the rear baggage compartment. One of the cargo net attachment points on the floor of the aircraft was pulled out, and the cargo net did not remain connected to the other attachment points. Some of the baggage was projected forward into the cabin and struck passengers seated at the rear of the cabin.

The TSB has previously identified the risks associated with not ensuring that baggage is adequately secured or not adhering to the weight limitations of the baggage compartment.[15]

1.4 Meteorological information

1.4.1 General

In the hours leading up to the accident, the Abbotsford area was under a low pressure system (Appendix A) that brought with it snow and reduced visibility, and temperatures of

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13 Ibid., p. 1-10.

14 Ibid., p. 2-13.

15 TSB aviation investigation reports A01P0194, A04W0114, A06P0095, A10P0147, A10Q0117, A14A0067, A15A0045, and A16P0180.

approximately −2 °C. At the time of the occurrence, moderate mixed icing in cloud was forecast between 3000 feet and 14 000 feet above sea level (Appendix B).

1.4.2 Aviation routine weather reports

The information in Table 3 was extracted from the aviation routine weather reports (METARs) at CYXX in the hours prior to, and shortly after, the occurrence.

Table 3. METARs information for CYXX on the day of the occurrence (Source: NAV CANADA)

Time	Wind	Visibility (sm)	Snow intensity	Ceiling (feet)	Temperature	Dew point
1100	Calm	½	moderate	1000 overcast	−2 °C	−3 °C
1127	080°T at 3 knots	⅝	moderate	700 overcast	−2 °C	−3 °C
1200*	Variable at 2 knots	⅜	moderate	600 broken	−2 °C	−3 °C
1212	Calm	⅜	moderate	600 broken	−2 °C	−3 °C
1247	190°T at 8 knots	½	moderate	600 broken	−2 °C	−3 °C
1300	200°T at 5 knots	¾	light	800 broken	−1 °C	−3 °C

* The 1200 METAR information was the most current weather at the time of the occurrence.

The investigation was able to determine, using snowfall rate information from Abbotsford Airport, that the snowfall rate had increased to approximately 2 cm per hour during the half hour before the occurrence.[16] At this rate, the amount of snow estimated to have fallen on the aircraft from the time it exited the hangar until it entered the runway was about 4 to 5 mm.

The weather information for the area indicated that there may have been a layer of moist air near 0 °C above the surface level. This could have caused wet snow to form, with partially melted flakes and a higher water content than would be expected for dry snow at the −2 °C surface conditions.

1.4.3 Snowfall intensity rating

For the purposes of METARs or Special Meteorological Reports (SPECI) and automated terminal information service (ATIS) broadcasts, visibility is used to estimate snowfall intensity according to the following guidelines:

- **Light**: if visibility is ⅝ mi. or more
- **Moderate**: if alone[1] and visibility is reduced to ½ or ⅜ mi.
- **Heavy**: if alone[1] and visibility is reduced to ¼, ⅛, or 0 mi.

16 Snowfall data from Environment and Climate Change Canada and NAV CANADA.

Note (1): "Alone" means no other precipitation and/or obstruction to vision is present.[17]

For de-icing and anti-icing purposes, snowfall intensity is an important consideration in determining holdover time.[18] Instead of relying solely on visibility as an indicator of snowfall intensity, industry and regulators have established a snowfall intensity chart that takes into account lighting, temperature range, and visibility (Table 4).

Table 4. Snowfall intensities as a function of prevailing visibility (Source: Transport Canada, Transport Canada Holdover Time (HOT) Guidelines: Winter 2018-19, Table 40, p. 48)

Lighting	Temperature Range		Visibility in Snow in Statute Miles (Metres)			
	°C	°F	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1 (≤1600)	>1 to 2½ (>1600 to 4000)	>2½ to 4 (>4000 to 6400)	>4 (>6400)
	Below -1	Below 30	≤3/4 (≤1200)	>3/4 to 1½ (>1200 to 2400)	>1½ to 3 (>2400 to 4800)	>3 (>4800)
Daylight	-1 and above	30 and above	≤½ (≤800)	>½ to 1½ (>800 to 2400)	>1½ to 3 (>2400 to 4800)	>3 (>4800)
	Below -1	Below 30	≤3/8 (≤600)	>3/8 to 7/8 (>600 to 1400)	>7/8 to 2 (>1400 to 3200)	>2 (>3200)

Based on the CYXX weather information (daylight, -2 °C, and ⅜ sm), the conditions at the time of the occurrence fall into the heavy snowfall category. According to Transport Canada (TC) de-icing and anti-icing fluid guidelines,[19] no holdover guidelines exist for heavy snowfall, regardless of the type of de-icing or anti-icing fluid used, at any temperature. In other words, in heavy snowfall, de-icing and anti-icing fluid is not considered an effective way of combatting the risk of contamination during ground operations. International

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17 Environment and Climate Change Canada, *MANOBS Manual of Surface Weather Observation Standards*, Eighth Edition (February 2019), section 6.6.2.5.3: Intensity by visibility, p. 6-35.

18 Holdover time "is the estimated time that an application of de-icing/anti-icing fluid is effective in preventing frost, ice, or snow from adhering to treated surfaces. Holdover time is calculated as beginning at the start of the final application of de-icing/anti-icing fluid and as expiring when the fluid is no longer effective." (Source: Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, Standard 622.11: Ground Icing Operations, section 2.0, Definitions.)

19 Transport Canada, *Holdover Time (HOT) Guidelines Winter 2018-19* (original issue 07 August 2018).

holdover guidelines put heavy snow in the same category as ice pellets, moderate and heavy freezing rain, and small hail and hail.[20,21,22]

1.5 Aerodrome information

The elevation of CYXX is 194 feet above sea level. CYXX has 2 runways. Runway 07/25 is asphalt/concrete and measures 9597 feet long and 200 feet wide, and Runway 01/19 is asphalt and measures 5328 feet long and 200 feet wide.

To the north of Runway 07 is a parallel taxiway, Taxiway C. North of Taxiway C is a raspberry patch that is located on the airport grounds.

At 1127, the ATIS reported the runway surface condition for Runway 07 as 80% trace dry snow and 20% bare and damp. The runway surface condition information in the 1127 ATIS originated from a SNOWTAM/NOTAMJ observation at 1048.[23] The runway surface condition information had not been updated to reflect the increase in snowfall between the 1048 SNOWTAM/NOTAMJ observation and the time of the occurrence. However, just before the occurrence, ground operators reported that the Canadian runway friction index (CRFI)[24] was 0.18, that conditions were changing rapidly as the snowfall intensified, and that they were preparing to sweep the runway as the occurrence aircraft departed. A CRFI reading of 0.18 represents the lowest value TC publishes for landing distance corrections on contaminated runways.[25]

1.6 Flight recorders

The occurrence aircraft was not equipped with a cockpit voice recorder (CVR) or a flight data recorder (FDR), nor was it required to be so equipped under the regulations.

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20 Ibid.

21 Federal Aviation Administration, *FAA Holdover Time Guidelines Winter 2018-2019* (original issue 07 August 2018).

22 International Civil Aviation Organization, Document 9640, *Manual of Aircraft Ground De-icing/Anti-icing Operations*, Third Edition (2018).

23 NOTAMJ and SNOWTAM are types of NOTAM used to notify users of the presence or removal of hazardous conditions due to snow, ice, slush or standing water associated with snow and braking action of runway surfaces in accordance with published reporting requirements. (Source: NAV CANADA, "NOTAMJ/SNOWTAM," at https://ais.navcanada.ca/ACS/help/snowiz/howto_adv_user.htm [last accessed on 03 July 2019])

24 CRFI is a measure of the decelerating forces acting on a vehicle when brakes are applied. The index numbers range from one to zero. A value of one represents the theoretical maximum decelerating capability of the vehicle on a dry surface and zero represents low braking coefficients of friction.

25 Transport Canada, *Transport Canada Aeronautical Information Manual* (TC AIM), AIR – Airmanship (11 October 2018), section 1.6.6, Table 4.

1.6.1 TSB recommendation on mandatory installation of lightweight flight recording systems

On 13 October 2016, a privately operated Cessna Citation 500 crashed shortly after takeoff. There were no survivors. The aircraft was not equipped with a CVR or FDR. As a result of that accident, the TSB issued Recommendation A18-01, which calls for the mandatory installation of lightweight flight recording systems by commercial operators and private operators not currently required to carry these systems.[26] TC's September 2018 response to this recommendation indicated that efforts would be made to work with industry to promote the voluntary installation of FDRs and lightweight data recorders. However, TC did not provide a timeline for the proposed actions. Therefore, the response to Recommendation A18-01 is assessed as Satisfactory in Part.[27]

1.7 Wreckage and impact information

1.7.1 Wreckage examination

The impact point was between Runway 07 and Taxiway C. The terrain at the initial point of collision was flat and not frozen at the time of the occurrence; however, it was covered by approximately 3 cm of snow. After the initial collision with terrain, the aircraft skidded about 760 feet across the ground and Taxiway C before it came to rest in a raspberry patch about 800 feet left of the runway centreline and about 7500 feet from the runway threshold (Figure 1). The left wing broke off, just outboard of the left engine nacelle during the impact sequence.

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26 TSB Aviation Investigation Report A16P0186.

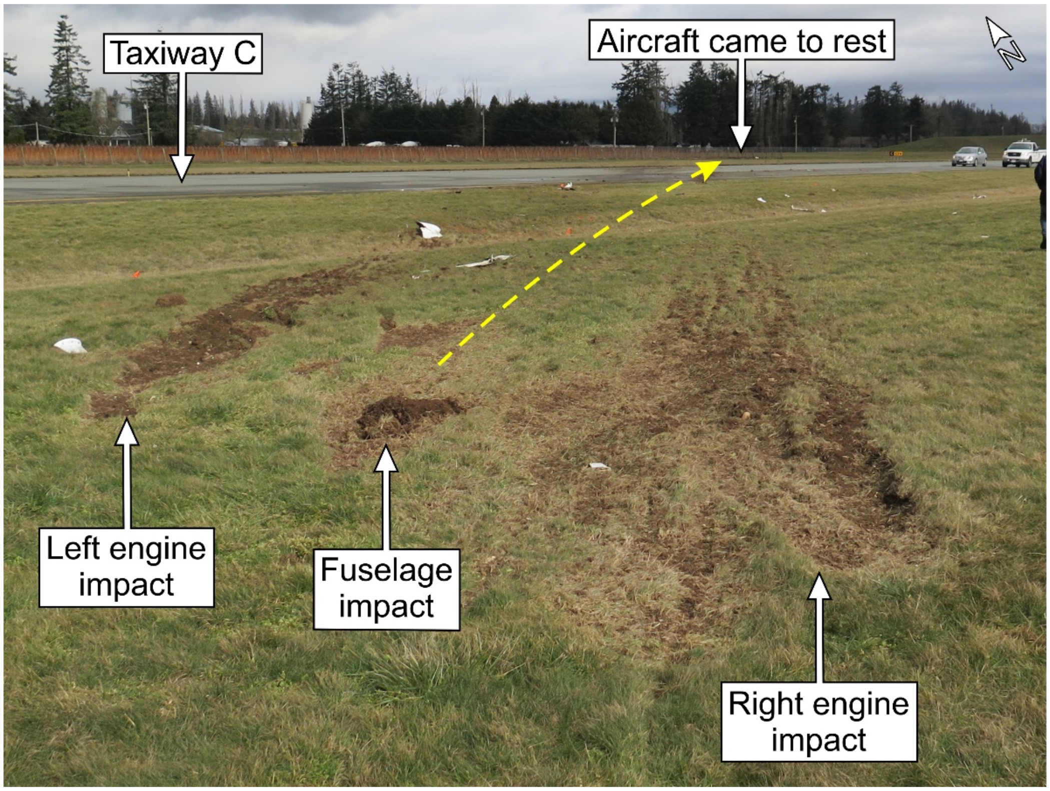
27 A **Satisfactory in Part** rating is assigned if the planned action or the action taken will reduce but not substantially reduce or eliminate the deficiency, and meaningful progress has been made since the recommendation was issued. The TSB will follow up with the respondent as to options that could further mitigate the risks associated with the deficiency. The TSB will reassess the deficiency on an annual basis or when otherwise warranted.

Figure 1. Occurrence aircraft where it came to rest (Source: Transport Canada)

Examination of the initial point of collision on the terrain showed 3 distinguishable ground scars (Figure 2). The 2 long ground scars consistent with impact by the bottoms of the engine nacelles were on each side of a ground scar consistent with impact by the bottom of the fuselage. The maximum depth of this ground scar was estimated to be greater than 1 inch (2.5 cm). Crushing to the bottom of the fuselage and both engine nacelles, as well as the absence of signs of interaction between the right wingtip and the ground, indicated the aircraft had been nearly level in pitch and roll when it collided with the terrain. Signs of vertical shear on both sides of the fuselage were consistent with a large upward impact force transmitted from the wing spars when the bottoms of the engine nacelles struck the ground.

Performance calculations carried out at the TSB Engineering Laboratory determined that the vertical descent velocity of the aircraft at the time of the crash (at the beginning of the impact) was estimated to be at least 20 fps.

Figure 2. The aircraft's initial point of collision with terrain and the direction of travel (photograph taken 27 February 2018) (Source: TSB)



Representatives from Textron Aviation, Hartzell Propeller Inc., and Honeywell Aerospace participated in an examination of the aircraft wreckage at the TSB's regional facility in Richmond, BC.

During the wreckage examination, the propellers were removed and examined by the TSB with the assistance of the propeller manufacturer's representative. No pre-existing condition that would have interfered with the normal operation was identified in either propeller. Blade damage and scuff marks on the cylinder in the hub of the propeller mechanism suggested that the power level on both propellers was near idle at the time of impact, consistent with the pilot reducing power before touchdown.

Both engines were removed and shipped to Honeywell Aerospace in Phoenix, Arizona, for a teardown and examination with a TSB investigator in attendance. The engine teardown and examination determined that the damage to both engines was indicative of engine rotation and operation at the time of impact with the ground. Functional testing of the engine control system, propeller governors, and the fuel controls identified no anomalies that would have interfered with normal operation of the engines.

Due to impact damage, it was not possible to determine the integrity of the stall warning system with certainty. However, the stall warning heat-tested serviceable when electrical power was applied to the circuit during post-crash examinations.

An analysis of fuel samples from both engine fuel pump filter bowls identified no anomalies.

The occurrence aircraft's Garmin Aera 696 global positioning system (GPS) was sent to the TSB Engineering Laboratory in Ottawa, Ontario, and all available data was successfully extracted.

1.8 Injuries

All occupants were transported to the hospital following the occurrence. In general, the occupants, particularly the adults, all experienced varying degrees of jackknife injuries. Jackknifing typically occurs when a person is subject to impact forces but restrained only at the hip by a lap belt; the upper and lower body then fold together like a jackknife. In this situation, injuries typically occur when the person strikes a surface.

Both occupants of the crew seats received serious head injuries (i.e., facial fractures and lacerations) and compression injuries (i.e., spinal fractures). The passenger seated in the right-hand crew seat was rendered unconscious and had to be carried out of the aircraft.

The passengers seated in the cabin received a variety of injuries, in addition to jackknifing, resulting from the impact sequence. Two of the adult passengers seated in the cabin had compression injuries and spinal fractures. Otherwise, the injuries received by the adults and children seated in the cabin were the result of being hit by loose articles, detached seats, and other passengers.

1.9 Survival aspects

1.9.1 Crew shoulder harnesses

A safety belt is defined in CARs 101.01(1) as "a personal restraint system consisting of either a lap strap or a lap strap combined with a shoulder harness." CARs 605.27(3) states that at least 1 pilot must wear a safety belt at all times, and CARs 605.27(1)(a) states that all flight crew are required to wear a safety belt during takeoffs and landings.

CARs 605.24 indicates that small airplanes manufactured before 18 July 1978 are not required to be equipped with a shoulder harness restraint system. Although the occurrence aircraft was manufactured in 1976, the pilot seats were equipped with shoulder harnesses. With the exception of CARs 705.29(1), which applies only to operators governed by CARs Subpart 705, the CARs do not specifically direct if, and when, installed shoulder harnesses must be worn. However, according to TC, the wearing of a shoulder harness, when it is installed, is mandatory to meet safety belt requirements.

In this occurrence, the pilot and the passenger seated in the right-hand crew seat were not wearing the available shoulder harnesses. As a result, they sustained serious head injuries during the impact sequence.

1.9.2 Passenger seats

Some of the passenger seats became detached from the aircraft floor during the impact sequence. As a result, all of the passenger seats were examined. No seats occupied by passengers with a body weight of less than 75 pounds were damaged during the crash. However, seats occupied by passengers with a body weight of 75 pounds and greater were all damaged by the impact forces during the crash.

The seats had to meet the certification requirements under Technical Standard Order (TSO)-39a, which was in effect when the aircraft was manufactured. Under TSO-39a or its later version, a seat in Category II (normal or utility) aircraft would have to meet a minimum 7.0*g* inertia load requirement in downward direction from a standard passenger with a body weight of 190 pounds plus the weight of the seat. Because the impact forces experienced by each passenger ranged from 8.5*g* to 14.3*g*, the seats in this occurrence performed as expected given the vertical impact forces experienced.

1.9.3 Emergency locator transmitter

The occurrence aircraft was equipped with an Artex 406 MHz automatic fixed emergency locator transmitter (ELT). The ELT activated upon impact, and transmitted a distress signal that was detected by the Cospas-Sarsat search and rescue satellite system.

1.10 Tests and research

1.10.1 Performance analysis

The investigation analyzed information from NAV CANADA secondary surveillance radar in the vicinity of CYXX, GPS data from the Garmin Aera 696 installed on the aircraft, and airport surveillance closed-circuit television (CCTV) cameras. The radar and GPS data made it possible to obtain information about the aircraft's flight profile. The CCTV information was helpful in establishing how long the aircraft was exposed to snow prior to takeoff.

The investigation determined that liftoff occurred between 100 and 110 knots indicated airspeed (KIAS). The published rotation speed specified in the aircraft flight manual for a normal takeoff (i.e., with flaps at 0 degrees) is 97 knots KIAS, making the estimated liftoff speed consistent with the rotation speed in the aircraft flight manual. The airspeed peaked at about 110 KIAS approximately 10 seconds after the aircraft became airborne. The airspeed then decreased until the aircraft struck the ground at about 100 knots KIAS. Assuming that deceleration was constant, the aircraft skidded for approximately 8 to 9 seconds before coming to a full stop.

The investigation determined that the aircraft took off approximately 3300 feet down the runway, and the airborne portion of the flight was approximately 3500 feet. Approximately 2800 feet of runway remained beyond the impact point.

According to the aircraft flight manual, the aircraft should achieve rotation airspeed in about 1700 feet.[28] An analysis of the available information suggests that a gradual application of power, combined with the increased rolling resistance on the contaminated runway, resulted in a longer takeoff roll. Once the aircraft lifted off, the aircraft's acceleration decreased for the remainder of the flight.

The last valid altitude point was from radar about 8 seconds before impact. Impact analysis conducted by the TSB estimated the vertical speed at impact was 1200 feet per minute. The vertical speed and airspeed at impact yield a final flight path angle of −6.8°. The radar, GPS, and impact trajectory provided a complete height profile for the flight. The peak climb rate was about 1000 feet per minute, and fell to zero within 5 seconds of takeoff as the altitude reached maximum height. The maximum height was about 100 feet above the runway; however, the aircraft may have been as low as 75 feet given the accuracy of Mode S transponder altitude.[29] Altitude then decreased until the impact (Appendix C).

1.10.2 Cold temperatures and snow contamination

The aircraft's exterior surface is primarily aluminum, which has a high thermal conductivity and therefore cools quickly. Some aircraft surfaces will quickly cool to 0 °C when exiting warm hangars into sub-zero air, generally within a few minutes. Although the fuel tanks in the wings may have contained warm fuel, it has been established that warm fuel in the wings will not prevent all aircraft surfaces from reaching freezing levels.[30] In addition, several locations on the aircraft (e.g., leading edges, wingtips, ailerons, flaps, empennage) do not contain fuel and, therefore, would cool at different rates than parts of the aircraft that contain fuel.

Cooling tests were conducted at the TSB Engineering Laboratory with an exemplar aircraft component of typical lightweight aluminum, taken from indoor temperatures at 20 °C to outdoors at −5 °C (Appendix D). The initial cooling was rapid, as much as 10 °C per minute. As the temperature of the component dropped, the cooling rate slowed, and the component reached a temperature of 0 °C after about 7 minutes of exposure.

In the cooling tests, the first snowflakes that fell on the warm component melted into small water drops about 1 to 2 mm in size. As the surface quickly cooled, the melt rate decreased, and a mixture of water drops and partially melted flakes was observed (Appendix D, Figure D1). As the surface reached 0 °C, ice crystals began to grow from the water drops (Appendix D, Figure D2). As snowfall continued, the falling flakes bonded with the partially melted and re-frozen precipitation layer, creating a very rough surface that protruded up to

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28 At maximum take-off weight, on a bare, dry, level runway, with take-off power set when the brakes are released.

29 Mode S transponder altitude is given in 25-foot increments.

30 APS Aviation Inc., TP 13482E, *Evaluation of Warm Fuel as an Alternative Approach to Deicing* (October 1999), pp. viii−ix.

3 mm and was difficult to see on the white paint (Appendix D, Figure D3). The contamination layer was resistant to attempts to disturb it with airflow or rapid acceleration, suggesting that it would remain bonded to the surface during a takeoff. Some of the contamination seen on the wreckage after the crash demonstrated this melt/refreeze process, and likely existed to some extent before the crash (Appendix D, Figure D4).

The cooling tests produced results consistent with previous research, as well as the 1989 crash of the Air Ontario Fokker F-28 at Dryden, Ontario. In the Dryden accident, it was estimated that a precipitation layer of wet snow totally froze in 2 to 4 minutes, and that partial freezing would have occurred sooner.[31] Although the Dryden aircraft was cold-soaked from having just landed after a previous flight, the conditions were otherwise comparable to the occurrence flight.

1.10.3 TSB laboratory reports

The TSB completed the following laboratory reports in support of this investigation:

- LP094/2018 – Flight Path Analysis
- LP096/2018 – Structural/Impact Analysis
- LP112/2018 – Analysis of Engine and Flight Instruments

1.11 Organizational and management information

1.11.1 General

Island Express Air Inc. is a locally owned and operated air carrier providing scheduled service to Abbotsford, Vancouver, Victoria, and Nanaimo, and charter service to destinations around BC and the United States. At the time of the occurrence, the company operated a fleet of aircraft under CARs Subpart 703 (Air Taxi) and Subpart 702 (Aerial Work), certified for day and night visual flight rules (VFR) as well as IFR. The company has grown from 1 aircraft to 10 since it began service in 2009. At the time of the accident, the company's fleet of aircraft consisted of the following:

- 1 x Piper PA-28 Cherokee Warrior
- 1 x Piper PA-32 Cherokee Six
- 3 x Piper PA-31 Navajo
- 3 x Piper PA-31 Chieftain
- 2 x Beechcraft B100 King Air

Island Express did not have a safety management system (SMS) in place, nor was this required by regulation.

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[31] M. M. Oleskiw, National Research Council of Canada report NRC-32124, Freezing Precipitation on Lifting Surfaces (September 1991), in the Technical Appendices of the *Commission of Inquiry into the Air Ontario Crash at Dryden, Ontario – Final Report* (1992).

1.11.2 Transport Canada surveillance history

On 07 February 2018, Island Express received a letter from TC concerning the company's ability to conduct aerial work and air-taxi operations in compliance with the CARs. The letter was issued following a December 2017 program validation inspection and stated that TC was considering suspending the company's operating certificate. According to the letter, TC's oversight activity "revealed wide-ranging deficiencies in Island Express's equipment, personnel training, and operational processes, which have resulted in significant non-compliant activity."[32] The letter stated the following additional concerns:

- Flight crew operating aircraft that were not airworthy
- Aircraft defects not being recorded and/or recorded but not rectified in the aircraft journey logs
- Failure to maintain a quality assurance program that ensures that its maintenance control system and maintenance schedules continue to be effective and comply with the CARs
- Permitting persons who have not fulfilled the Island Express–approved training program for charter and scheduled flights to act as flight crew members[33]

Island Express was given an opportunity to respond to these concerns; however, on 21 February 2018, Island Express was issued a Notice of Suspension, effective 28 March 2018. The notice was issued under paragraph 7.1(1)(c) of the *Aeronautics Act,* which is used when a suspension is deemed to be in the public interest due to safety. In the letter, TC indicated that

> while the stated actions address the grounds for suspension, they do not constitute a demonstration that Island Express is capable of exercising operational control resulting in compliant and safe operations as required by Canadian Aviation Regulation (CAR) 703.07.[34]

The letter identified a number of concerns to demonstrate the grounds for issuing a public-interest Notice of Suspension, including:

- Significant non-compliant activity, some resulting in fines
- Since initial certification in 2009, 11 formal surveillance activities that resulted in 3 instances of enhanced monitoring
- 47 findings of alleged non-compliances related to technical dispatch and flight crew member qualifications

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32 Transport Canada, letter from Operations, Pacific Region to Island Express Air Inc., 07 February 2018.

33 Ibid.

34 Transport Canada, letter from Operations, Civil Aviation, to Island Express Air Inc., 21 February 2018.

- Concerns which illustrated an inability to conduct operations in compliance with the CARs[35]

In the weeks before the flight, TC informed the pilot that he could not use the company King Air for the flight with his family because he did not have a private operator registration document, as required by CARs 604.03(1). In response, the pilot indicated that he would conduct the flight as a charter flight like any other Island Express passenger flight carried out under CARs Subpart 703.[36]

Following the occurrence, on 28 February 2018, Island Express was issued a Notice of Suspension under subsection 7(1) of the *Aeronautics Act*, which is used to issue suspensions when there is an immediate threat to aviation safety. In the rationale, TC cited the concerns raised in the 21 February 2018 Notice of Suspension, as well as other alleged non-compliances associated with the pilot's flight carried out just prior to the occurrence flight. The immediate Notice of Suspension also stated that the OFP did not meet the requirements of CARs 703.18[37] and the pilot self-dispatched in a manner that was not in accordance with section 2.3 of the Island Express company operations manual, which states that an OFP shall be completed for every flight.

There has been a change of ownership at Island Express since the accident, along with a new accountable executive, a new operations manager, and a new person responsible for maintenance.

On 26 June 2018, Island Express's operating certificate was reinstated after the company underwent a recertification process by TC.

1.12 Additional information

1.12.1 Icing

1.12.1.1 General

The occurrence aircraft is certified for icing conditions in accordance with the standard contained in Appendix C to Chapter 525 of the *Airworthiness Manual*.[38] However, according to the aircraft flight manual, some icing conditions could exceed the capabilities of the

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35 Ibid.

36 Flights conducted under CARs Subpart 703 are subject to more regulations than private flights.

37 Subsection 703.18(1) of the CARs states, "No air operator shall permit a person to commence a flight unless an operational flight plan that meets the *Commercial Air Service Standards* has been prepared in accordance with the procedures specified in the air operator's company operations manual."

38 This appendix is identical to the U.S. *Federal Aviation Regulations* (FAR), Part 25, Appendix C.

aircraft's ice protection equipment and/or create unacceptable performance and controllability.[39]

1.12.1.2 De-icing capabilities at Island Express Air Inc.

At the time of the occurrence, Type 1 de-icing fluid was available at Island Express.

1.12.1.3 Ground icing

Snow and ice adhering to the aircraft can have a profound impact on aircraft performance. For that reason, CARs 602.11 states that "no person shall conduct or attempt to conduct a take-off in an aircraft that has frost, ice or snow adhering to any of its critical surfaces"[40] - a condition known as ground icing. The CARs also state that "where conditions are such that frost, ice or snow may reasonably be expected to adhere to the aircraft,"[41] and the aircraft is not operated under Subpart 5 of Part VII or subject to an operator's established aircraft inspection program,[42] it must be inspected "immediately prior to take-off to determine whether any frost, ice or snow is adhering to any of its critical surfaces."[43]

Standard 622.11 of the CARs, Ground Icing Operations, identifies 2 types of inspections: a critical surface inspection and a pre-takeoff contamination inspection.

The critical surface inspection is a pre-flight external inspection and is mandatory when ground icing conditions are present. In situations where holdover time is being used as a decision-making criterion, if the holdover time has been exceeded, takeoff can occur only if a pre-takeoff contamination inspection is completed or the aircraft is de-iced or anti-iced again.

The pre-takeoff contamination inspection does not require a tactile examination when the manufacturer has identified representative aircraft surfaces that can be reliably observed during day and night operations to judge whether critical surfaces are contaminated or not.[44] Of note, the manufacturer has not identified a "representative aircraft surface" that can be used, in lieu of a tactile inspection, to visually carry out the pre-takeoff contamination inspection.

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39 Beechcraft King Air B100 Pilot's Operating Handbook and FAA Approved Airplane Flight Manual (revised August 2004), p. 2-14.

40 *Canadian Aviation Regulations*, section 602.11. This provision states that "critical surfaces" are the wings, control surfaces, rotors, propellers, horizontal stabilizers, vertical stabilizers or any other stabilizing surface of an aircraft and, in the case of an aircraft that has rear-mounted engines, includes the upper surface of its fuselage.

41 Ibid.

42 In accordance with the *Canadian Aviation Regulations*, Part VI: General operating and flight rules.

43 Ibid.

44 *Canadian Aviation Regulations*, Standard 622.11: Ground Icing Operations, paragraph 7.1.1.3.

If snow and ice are not removed before takeoff, they can alter the airfoil contours of the wing to the point where the lift qualities of the airfoil contours will be seriously impaired, due to increased drag and in some cases weight.[45,46] This can create control problems, reduce the angle of attack at which the aircraft stalls, decrease rate of climb and speed performance, and increase stall speeds.[47] Even almost imperceptible amounts of ice can cause performance penalties comparable to much larger, easily visible, ice accumulations.[48] Therefore, pilots relying solely on a visual inspection may not fully appreciate the risk that exists. It is nearly impossible to determine by visual inspection alone if a wing is wet or has a thin film of ice.[49] This concern is echoed in the Island Express company operations manual, which cites the TC *Aeronautical Information Manual* (AIM)[50] and states that "misconceptions exist regarding the effect on performance of frost, snow or ice accumulation on aircraft."[51] According to TC's Technical Publication (TP) 10643,

> test data indicates that during takeoff, frost, ice or snow formations having a thickness and surface roughness similar to medium or coarse sandpaper, on the leading edge and upper surface of a wing, can reduce wing lift by as much as 30% and increase drag by 40%.[52]

Similarly, other studies have determined that as little as 1/16 inch of icing can increase stall speed by around 20%.[53] For these reasons, ground icing presents a significant risk, particularly during the takeoff phase when the aircraft is operating extremely close to its stall speed, and there is much less altitude for recovery should a stall occur shortly after takeoff.

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45 Beechcraft King Air B100 Pilot's Operating Handbook and FAA Approved Airplane Flight Manual (revised August 2004), p. 8-11.

46 H. H. Hurt, Jr., NAVWEPS OD-ROT-80, *Aerodynamics for Naval Aviators*, Chapter 6: Application of Aerodynamics to Specific Problems of Flying, p. 373.

47 Federal Aviation Administration Advisory Circular (AC) 91-74B: Pilot Guide: Flight in Icing Conditions (effective 08 October 2015).

48 National Transportation Safety Board, Safety Alert SA-006: Aircraft Ground Icing (revised December 2015).

49 Ibid.

50 Transport Canada, TP 14371E, *Transport Canada Aeronautical Information Manual* (TC AIM) AIR – Airmanship (11 October 2018), section 2.12.1.

51 Island Express Air Inc., *Company Operations Manual* (15 February 2016), p. 3-29.

52 Transport Canada, TP 10643E, *When in Doubt…Small and Large Aircraft – Aircraft Critical Surface Contamination Training for Aircrew and Groundcrew*, 7th edition (December 2004), pp. 15–16.

53 P. R. Veillette, "Recovering from ice-induced stalls in turboprops," *Business and Commercial Aviation*, 21 December 2007.

1.12.1.4 Environmental conditions associated with icing

According to the aircraft flight manual, potential icing conditions exist whenever visible moisture is present and the outside air temperature is at or below 5 °C.[54]

In-flight icing research has identified that severe icing is most likely to occur in conditions of high liquid water content (e.g., freezing drizzle or freezing rain; mixing icing conditions; or heavy snow) and temperatures below freezing. Any time that water droplets are visible, it is an indication of high liquid water content.[55] According to the National Aeronautics and Space Administration (NASA),

> "snowfall at near-freezing temperatures, roughly -2°C to +2°C, is likely to have very high moisture content, and can stick to your airframe. It is unlikely to "blow off" during the takeoff roll."[56]

Initially the ice forms as a thin, rough layer and it will continue to build up, taking on a new shape that can significantly degrade the aerodynamics of the airframe.[57]

The Island Express company operations manual states that wet snow with the ambient temperature around 0 °C is critical from a ground icing standpoint.[58]

1.12.1.5 Impact of icing on aircraft performance

Although icing will increase drag, the increase in drag will not be significant during the initial stages of the takeoff roll. As a result, the effects of ground icing may not be noticeable on the aircraft's initial acceleration, unless the accumulation of ice has significantly increased the aircraft's weight. However, as the aircraft accelerates, even virtually imperceptible amounts of ice on a wing's upper surface can significantly reduce performance and make it difficult to rotate and climb away safely.[59]

If the aircraft is able to get airborne, it may initially benefit from the effects of ground effect and gain a small amount of altitude. This is because a wing in ground effect will have a lower coefficient of drag and a higher coefficient of lift for any angle of attack, because the

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54 Beechcraft King Air B100 Pilot's Operating Handbook and FAA Approved Airplane Flight Manual (revised August 2004), p. 2-13.

55 Federal Aviation Administration Advisory Circular (AC) 91-74B: Pilot Guide: Flight in Icing Conditions (effective 08 October 2015).

56 National Aeronautics and Space Administration, "A Pilot's Guide to Ground Icing," section "Anticipating Contamination," at https://aircrafticing.grc.nasa.gov/2_1_0_0.html (last accessed 03 July 2019).

57 T. P. Ratvasky, B. P. Barnhart, and S. Lee, NASA/TM—2008-215453, AIAA–2008–6204, Current Methods for Modeling and Simulating Icing Effects on Aircraft Performance, Stability and Control (December 2008).

58 Island Express Air Inc., *Company Operations Manual*, p. 3-31.

59 National Transportation Safety Board, Safety Alert SA-006: Aircraft Ground Icing (revised December 2015).

wing is considerably more efficient.[60] However, the benefits of ground effect vanish when the aircraft's height is approximately equal to its wingspan.[61] If the wing is contaminated, increased drag will adversely impact the aircraft's ability to continue the initial climb normally. If the pilot is unaware of the contamination, they may not realize how close the aircraft's angle of attack is to the stall point. In addition, stall characteristics with icing can differ significantly from stall characteristics without icing. The aircraft flight manual states that unusual roll response or uncommanded roll control movements are warnings of an impending stall.

The Island Express standard operating procedures state that if an unusual roll response or uncommanded roll control movement is observed, the pilot is to reduce the angle of attack.[62]

1.12.1.6 Aircraft exiting hangars in falling snow

Although a hangar can be used to protect an aircraft from environmental conditions such as snow and/or freezing precipitation, there are some important considerations for pilots and air operators when bringing an aircraft out of a hangar into falling snow. The aircraft flight manual states that a plane that has been stored in a hangar should be treated with anti-icing solution, because snow falling on a relatively warm surface in ambient temperatures that are below freezing will tend to melt and then refreeze.[63] If precipitation is present, a warm aircraft should be allowed sufficient time for the skin temperature to drop below freezing before it is removed from the hangar.[64,65] The temperature is typically caused to drop by opening the hangar doors and cold-soaking the aircraft some time before subjecting the aircraft to direct precipitation.

1.12.1.7 TSB recommendation related to contamination on takeoff

On 13 December 2017, an Avions de Transport Régional ATR 42-320 aircraft (registration C-GWEA, serial number 240), operated by West Wind Aviation LP (West Wind) as flight 282, conducted an instrument flight rules flight from Prince Albert (Glass Field) Airport (CYPA), Saskatchewan, to Fond-du-Lac Airport (CZFD), Saskatchewan.[66] During the descent, the aircraft encountered icing conditions, and the crew activated the de-icing and

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60 E. Cui and X. Zhang, "Ground Effect Aerodynamics," in: R. Blockley and W. Shyy (eds), *Encyclopedia of Aerospace Engineering* (John Wiley and Sons, Ltd., 2010), Chapter 18, pp. 245–256.

61 The occurrence aircraft's wingspan is approximately 46 feet.

62 Island Express Air Inc., *Standard Operating Procedures, King Air B100* (15 October 2014), p. 51

63 Beechcraft King Air B100 Pilot's Operating Handbook and FAA Approved Airplane Flight Manual (revised August 2004), p. 8-11.

64 Transport Canada, TP 14052 E, *Guidelines for Aircraft Ground Icing Operations*, Third Edition (June 2018)

65 Transport Canada, TP 10643 E, *When in Doubt…Small and Large Aircraft – Aircraft Critical Surface Contamination Training for Aircrew and Groundcrew*, Seventh edition (December 2004), pp. 15–16.

66 TSB Air Transportation Occurrence A17C0146. At July 2019, the investigation was ongoing.

anti-icing systems. When the de-icing and anti-icing systems were turned off 9 minutes later, while the aircraft was on final approach, residual ice remained on portions of the aircraft.

After landing at CZFD and before departing for the next leg of the flight, one of the pilots conducted a pre-flight inspection of the aircraft and told the other pilot that the aircraft had ice on it. West Wind had some de-icing equipment in the terminal building at CZFD; however, the aircraft was not de-iced before takeoff, and it crashed shortly thereafter. Nine passengers and 1 crew member received serious injuries, and the remaining 13 passengers and 2 crew members received minor injuries. One of the passengers who had received serious injuries died 12 days after the accident.

As part of this investigation, the TSB conducted a large-scale survey of pilots at 83 Canadian operators that fly out of many of Canada's remote northern airports. The survey revealed that in the absence of adverse consequences, taking off with contamination on critical surfaces is a practice that has become normalized. The Fond-du-Lac occurrence and the pilot survey revealed that some of the current defences used by the Canadian air transportation system to prevent aircraft from taking off with frost, ice, or snow adhering to any critical surface are less than adequate.

Accidents related to contaminated aircraft will continue to occur until the industry and the regulator approach the issue as systemic and take action to eliminate underlying factors that can negatively affect pilot compliance. Therefore, the Board recommended that:

> the Department of Transport and air operators take action to increase compliance with *Canadian Aviation Regulations* subsection 602.11(2) and reduce the likelihood of aircraft taking off with contaminated critical surfaces.
>
> **TSB Recommendation A18-03**

At the time of report writing, TC's response to Recommendation A18-03 was being assessed.

1.12.2 Continuation bias

To make decisions effectively, a pilot needs an accurate understanding of the situation and an appreciation of the implications of the situation, then to formulate a plan and contingencies, and to implement the best course of action. Equally important is a pilot's ability to recognize changes in the situation and to reinitiate the decision-making process to ensure that changes are accounted for and plans modified accordingly. If the potential implications of the situation are not adequately considered during the decision-making process, there is an increased risk that the decision and its associated action will result in an adverse outcome that leads to an undesired aircraft state.

A number of different factors can adversely impact a pilot's decision-making process. For example, increased workload can adversely impact a pilot's ability to perceive and evaluate cues from the environment and may result in attentional narrowing.[67] In many cases, this attentional narrowing can lead to confirmation bias, which causes people to seek out cues that support the desired course of action, to the possible exclusion of critical cues that may support an alternate, less desirable hypothesis.[68,69] The danger this presents is that potentially serious outcomes may not be given the appropriate level of consideration when attempting to determine the best possible course of action.

One specific form of confirmation bias is (plan) continuation bias, or plan continuation error.[70] Continuation bias is best described as "the unconscious cognitive bias to continue with the original plan in spite of changing conditions"[71] or "a deep-rooted tendency of individuals to continue their original plan of action even when changing circumstances require a new plan."[72] Once a plan is made and committed to, it becomes increasingly difficult for stimuli or conditions in the environment to be recognized as necessitating a change to the plan. Often, as workload increases, the stimuli or conditions will appear obvious to people external to the situation; however, it can be very difficult for a pilot caught up in the plan to recognize the saliency of the cues and the need to alter the plan.[73]

When continuation bias interferes with the pilot's ability to detect important cues, or if the pilot fails to recognize the implications of those cues, breakdowns in situational awareness (SA) occur.[74,75] These breakdowns in SA can result in non-optimal decisions being made, which could compromise safety.

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67 CRM Standing Group, *Crew Resource Management*, Royal Aeronautical Society (London, United Kingdom, 1999).

68 C. D. Wickens and J. G. Hollands, *Engineering Psychology and Human Performance*, 3rd edition (CRC Press, 1999), Chapter 11: Attention, time-sharing and workload.

69 M. Martinussen and D. R. Hunter, *Aviation Psychology and Human Factors* (CRC Press, 2009), pp. 64–65.

70 J. Orasanu, L. Martin, and J. Davison, "Cognitive and contextual factors in aviation accidents: decision errors," in: E. Salas and G. A. Klein (eds.), *Linking Expertise and Naturalistic Decision Making* (Lawrence Erlbaum Associates, Inc., 2001), pp. 209–225.

71 See for example the definition in EUROCONTROL SKYbrary, "Continuation Bias" available at: http://www.skybrary.aero/index.php/Continuation_Bias (last accessed 03 July 2019).

72 B. Berman and R. K. Dismukes, "Pressing the approach," *Aviation Safety World*, Flight Safety Foundation, Volume 1, Issue 6 (December 2006), pp. 28–33.

73 E. Muthard and C. Wickens, "Factors that mediate flight plan monitoring and errors in plan revision: Planning under automated and high workload conditions," presented at the 12th International Symposium on Aviation Psychology, Dayton, Ohio, 14–17 April 2003.

74 J. Goh and D. A. Wiegmann, "Visual flight rules flight into instrument meteorological conditions: An empirical investigation of the possible causes," *International Journal of Aviation Psychology*, Volume 11, Issue 4 (2001), pp. 357–359.

75 J. Orasanu, L. Martin, and J. Davison, "Cognitive and contextual factors in aviation accidents: decision errors," in: E. Salas and G. A. Klein (eds.), *Linking Expertise and Naturalistic Decision Making* (Lawrence Erlbaum Associates, Inc., 2001), pp. 209–225.

In a NASA and Ames Research Center review of 37 accidents investigated by the U.S. National Transportation Safety Board, it was determined that almost 75% of the tactical decision errors involved in the 37 accidents were related to decisions to continue on the original plan of action despite the presence of cues suggesting an alternative course of action.[76] Dekker (2006) suggests that continuation bias occurs when the cues used to formulate the initial plan are considered to be very strong. For example, if the plan seems like a great plan, based on the information available at the time, subsequent cues that indicate otherwise may not be viewed in an equal light, in terms of decision making.[77]

Therefore, it is important to realize that continuation bias can occur, and it is important for pilots to remain cognizant of the risks of not carefully analyzing changes in the situation, and considering the implications of those changes, to determine whether or not a more appropriate revised course of action is appropriate. As workload increases, particularly in a single-pilot scenario, less and less mental capacity is available to process these changes, and to consider the potential impact that they may have on the original plan.

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76 J. Orasanu, L. Martin, and J. Davison, NASA Ames Research Center, "Errors in Aviation Decision Making: Bad Decisions or Bad Luck?", presented at the Fourth Conference on Naturalistic Decision Making, Warrington, Virginia, 29–31 May, 1998.

77 S. Dekker, *The Field Guide to Understanding Human Error* (CRC Press, 2006).

2.0 ANALYSIS

Nothing was found to indicate that any type of pre-existing, or in-flight, system malfunction played a role in this occurrence. As a result, the analysis will focus on the operational aspects of the flight leading up to the accident. In particular, the analysis will focus on the conditions leading to an aerodynamic stall on takeoff, the role that ground icing played in the occurrence, pilot decision making, flight planning and aircraft loading considerations, and snowfall intensity reporting.

2.1 Aerodynamic stall on takeoff

As the aircraft took off from the runway and the landing gear was retracted, the aircraft immediately banked to the left. Although this left bank was initially perceived as a power loss on the left-hand engine, nothing was found to support this theory. Based on a performance analysis, it is evident that the aircraft did not gain much altitude or airspeed on takeoff. When the aircraft took off, its indicated airspeed reached a peak of approximately 110 knots, and then began to decrease. This relatively low speed went undetected as the pilot's attention was primarily outside for the departure, in low visibility conditions.

Based on the combination of environmental conditions and the aircraft's flight profile, it is likely that the aircraft experienced an aerodynamic stall, as a result of icing and reduced airspeed during the initial climb, once the aircraft lost the benefits of ground effect. The combination of a warm aircraft surface (i.e., the wings) being exposed to 14 minutes of heavy (wet) snow, in below-freezing temperatures, created a situation that produced conditions highly conducive to ground icing. The fact that the aircraft was above the maximum allowable take-off weight exacerbated the situation by increasing the aircraft's stall speed.

As the aircraft climbed out of ground effect on takeoff, it experienced an aerodynamic stall as a result of wing contamination. Pushing the control column forward and landing straight ahead following the unexpected left bank reduced the aircraft's angle of attack and likely resulted in a partial recovery from the aerodynamic stall before impact.

2.2 Ground icing

The occurrence aircraft, which had been sitting in a warm hangar, was exposed to heavy snow in below-freezing temperatures for approximately 14 minutes. This created an ideal situation for ground icing to occur.

As the surface temperature of the aircraft reached 0 °C, the liquid water portion of the precipitation layer on the wing would have begun to freeze into ice. The precipitation layer would then include ice from frozen water droplets and partially melted snowflakes. New snowflakes would continue to bond to the existing layer. The resulting surface, from the 4 to

5 mm of wet snow that fell on the aircraft, would be very rough and would cause very high aerodynamic degradation.

No contamination was observed on the aircraft's wings before takeoff. However, there may not have been obvious signs that the wings were contaminated, because it is difficult to visually detect whether a wing is wet or has a thin film of ice adhering to the surface, under visible water droplets.

Although no de-icing fluid had been applied to the occurrence aircraft, the conditions present on that day exceeded the capabilities of all types of de-icing or anti-icing fluid in heavy snow. The occurrence aircraft exited a warm hangar and was exposed to 14 minutes of heavy snow in below-freezing conditions. This resulted in a condition highly conducive to severe ground icing.

2.3 Pilot decision making

In this occurrence, the pilot was motivated to complete this flight with his family, and even though there were a number of indications that a different course of action may have been warranted, the pilot elected to continue with the original plan. On the morning of the occurrence, the telephone conversations with Abbotsford air traffic control indicated that the pilot was concerned about the heavy snow and the potential implications of any delays getting airborne. Having recognized these issues, the pilot did not alter the plan even though the aircraft had spent 14 minutes in heavy snow at temperatures that presented a significant risk of ground icing. The pilot's decision making was affected by continuation bias, which resulted in the pilot attempting a takeoff with an aircraft contaminated with ice and snow adhering to its critical surfaces.

2.4 Flight planning and pre-flight duties

On the morning of the occurrence, the pilot was involved in several different operational and business-related activities that diverted his focus away from duties necessary to ensure that the occurrence flight was conducted safely and in accordance with the *Canadian Aviation Regulations*. The operational flight plan did not reflect the intended routing, fuel requirements, or weight and balance.

In addition, because the passengers loaded all the baggage without supervision, the weight of the baggage had not been confirmed and had not been properly secured. A thorough pre-flight inspection to ensure proper aircraft loading was not completed. The journey log was not subject to a careful review, and therefore it was not identified that the aircraft was not airworthy at the time of the occurrence as a result of an incomplete airworthiness directive.

As seen in this occurrence, if pilots do not ensure that flight planning is accurate and that pre-flight duties are completed, there is an increased risk of operational or technical errors that could jeopardize safety.

2.5 Aircraft loading

In this occurrence, the aircraft had a full fuel load, 9 passengers on board, and approximately 480 pounds of baggage in the rear baggage compartment. Although the weight and balance indicated on the operational flight plan showed the aircraft to be within the aircraft's weight and balance and centre-of-gravity limits, the investigation determined that the weight and balance information did not accurately reflect the aircraft's true loading. A thorough review of the aircraft's fuel and the weight of the occupants determined that the aircraft was approximately 200 pounds above the maximum allowable gross take-off weight. In addition, the aircraft's aft centre of gravity was near its aft limit and may have made the aircraft more difficult to control as it approached aerodynamic stall. The combination of operating above the maximum allowable gross weight, near its aft centre of gravity limit, would have increased the aircraft stall speed and contributed to the instability of the aircraft during the takeoff.

The 480 pounds of baggage in the rear baggage compartment was 70 pounds above the maximum allowable weight for the compartment. The baggage was not weighed before it was loaded on board, and it was loaded by the passengers. The baggage was secured by a cargo net that came with the aircraft when it was imported into Canada. It could not be determined whether the cargo net was an approved cargo net. During the impact sequence, the cargo restraint system used to secure the baggage in the rear baggage compartment failed, causing some of the baggage to injure passengers seated in the rear of the aircraft cabin.

This occurrence highlights the importance of ensuring that baggage compartments are not loaded beyond their capacity, because it may lead to the failure of cargo restraining devices, such as cargo nets. If cargo is not loaded within prescribed weight limits and properly secured, there is a risk that the cargo will shift or come free in an accident, potentially injuring aircraft occupants.

2.6 Snowfall intensity reporting and anti-icing

According to the aviation weather report current at the time of the occurrence, the aircraft departed in moderate snowfall. However, according to internationally recognized de-icing and anti-icing fluid holdover guidelines, which were developed based on a more comprehensive understanding of the risks associated with ground icing, the snowfall intensity would be considered heavy snow. For the purposes of calculating holdover time, heavy snow is treated in the same manner as ice pellets, moderate and heavy freezing rain, small hail, and hail. For these weather conditions, the holdover time is 0 minutes, regardless of the anti-icing fluid type. In other words, anti-icing fluid is considered to no longer be effective in heavy snow conditions as soon as it is applied. This highlights the severity of heavy snowfall conditions from a ground icing standpoint.

As a result of the difference in meaning of snowfall intensity between aviation weather reports and holdover time guidelines, it is highly likely that pilots will continue to underestimate the significance of the ground icing risk. If pilots rely only on the snowfall intensity reported in aviation routine weather reports or automated terminal information service broadcasts, they will not correctly determine de-icing and anti-icing holdover times, increasing the risk of aircraft accidents.

3.0 FINDINGS

3.1 Findings as to causes and contributing factors

1. The occurrence aircraft exited a warm hangar and was exposed to 14 minutes of heavy snow in below-freezing conditions. This resulted in a condition highly conducive to severe ground icing.

2. As the aircraft climbed out of ground effect on takeoff, it experienced an aerodynamic stall as a result of wing contamination.

3. The pilot's decision making was affected by continuation bias, which resulted in the pilot attempting a takeoff with an aircraft contaminated with ice and snow adhering to its critical surfaces.

4. The pilot and the passenger seated in the right-hand crew seat were not wearing the available shoulder harnesses. As a result, they sustained serious head injuries during the impact sequence.

5. During the impact sequence, the cargo restraint system used to secure the baggage in the rear baggage compartment failed, causing some of the baggage to injure passengers seated in the rear of the aircraft cabin.

3.2 Findings as to risk

1. If pilots do not ensure that flight planning is accurate and that pre-flight duties are completed, there is an increased risk of operational or technical errors that could jeopardize safety.

2. If pilots rely only on the snowfall intensity reported in aviation routine weather reports or automated terminal information service broadcasts, they will not correctly determine de-icing and anti-icing holdover times, increasing the risk of aircraft accidents.

3. If cargo is not loaded within prescribed weight limits and properly secured, there is a risk that the cargo will shift or come free in an accident, potentially injuring aircraft occupants.

3.3 Other findings

1. The aircraft was not airworthy at the time of the occurrence as a result of an incomplete airworthiness directive.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 Island Express Air Inc.

Immediately after the accident, Island Express voluntarily suspended operations, and Transport Canada suspended its operating certificates until the company underwent recertification. The company subsequently took the following safety action:

- Performed a complete overhaul of company publications to include detailed de-icing information and a practical winter operations course
- Enhanced the company's training program, including training for instructors
- Increased the minimum pilot training times for all aircraft
- Introduced electronic flight books and new flight planning software
- Introduced new operational flight plan and technical dispatch procedures to ensure aircraft are dispatched safely
- Hired additional administration and maintenance personnel to help reduce workload on company personnel
- Implemented a new flight crew schedule to combat pilot fatigue
- Initiated a non-punitive reporting system that will be the basis for a functioning safety management system that is still in development

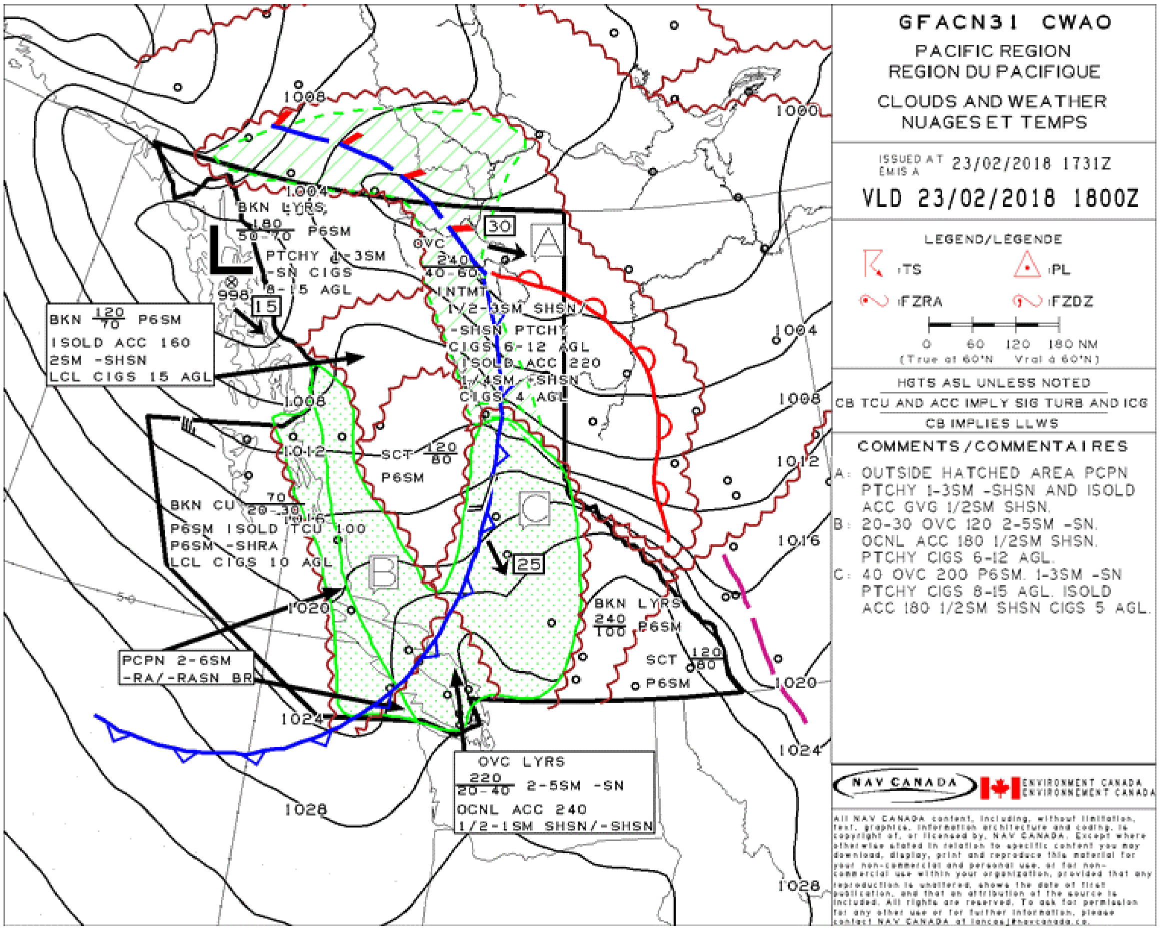
4.1.2 Transport Canada

Transport Canada completed 3 initial pilot proficiency check rides on Island Express flight crews to validate the completeness and effectiveness of its training programs. This included conducting a monitor ride on a company-approved check pilot.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 03 July 2019. It was officially released on 14 August 2019.

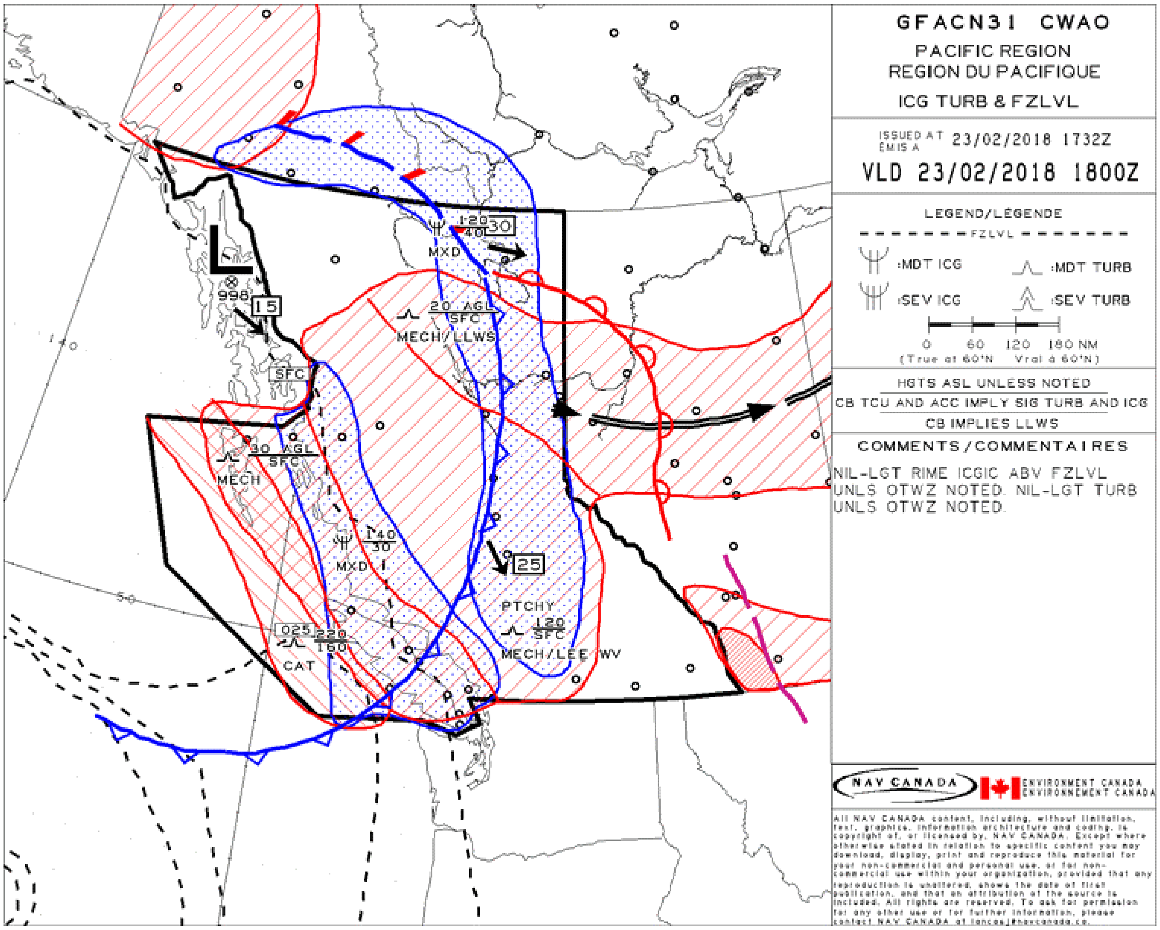
APPENDICES

Appendix A – Graphical area Clouds and Weather forecast valid on 23 February 2018 at 1800 UTC



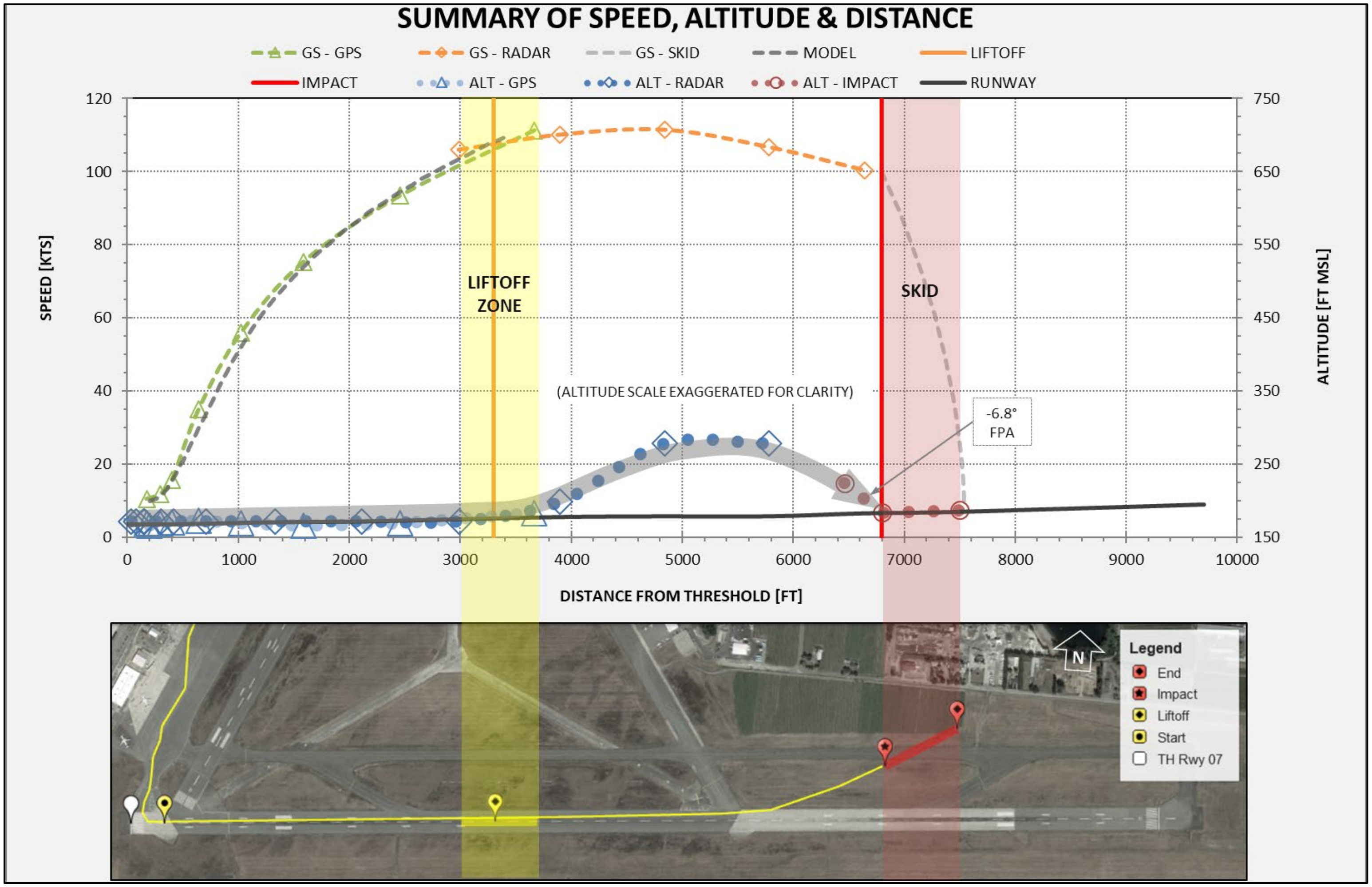
Source: NAV CANADA

Appendix B – Graphical area Icing, Turbulence and Freezing level forecast valid on 23 February 2018 at 1800 UTC



Source: NAV CANADA

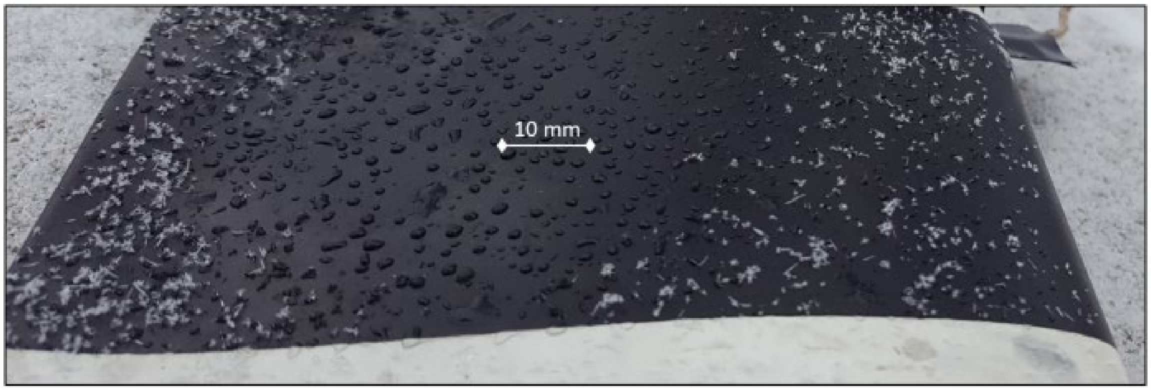
Appendix C – Reconstruction of the path taken by the occurrence aircraft



Note: The "Model" line represents the predicted runway performance based on the aircraft flight manual, aircraft loading, and environmental considerations. (Source: TSB)

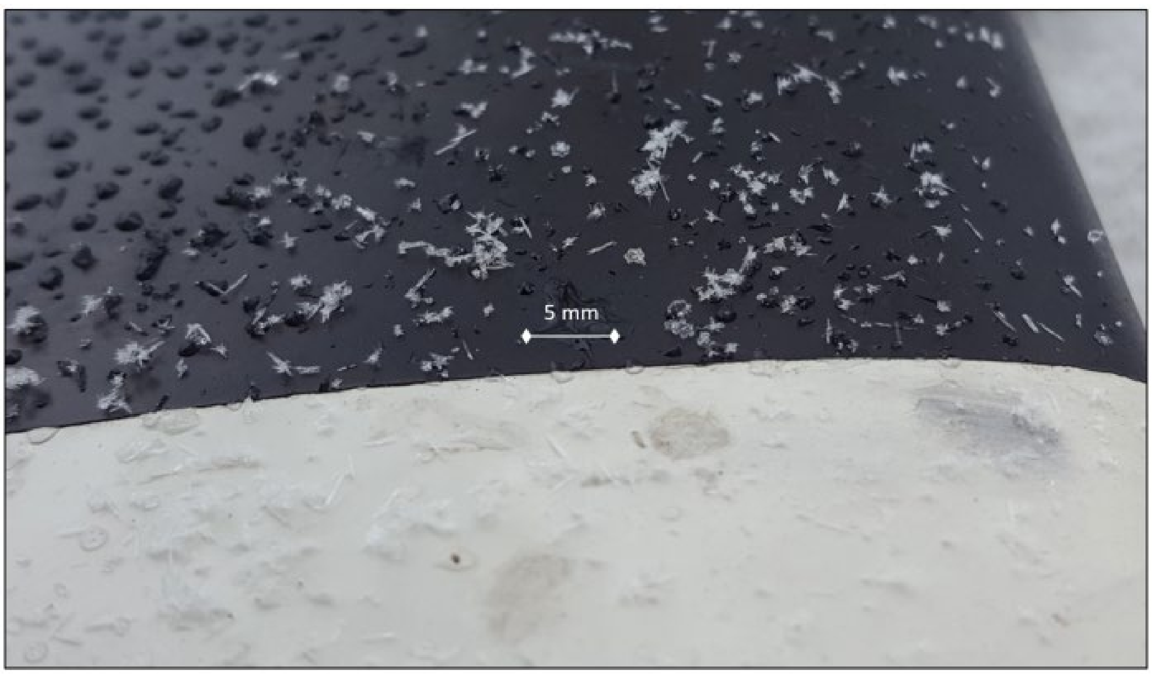
Appendix D – Cooling test

Figure D1. Cooling test showing melted flakes and ice crystals



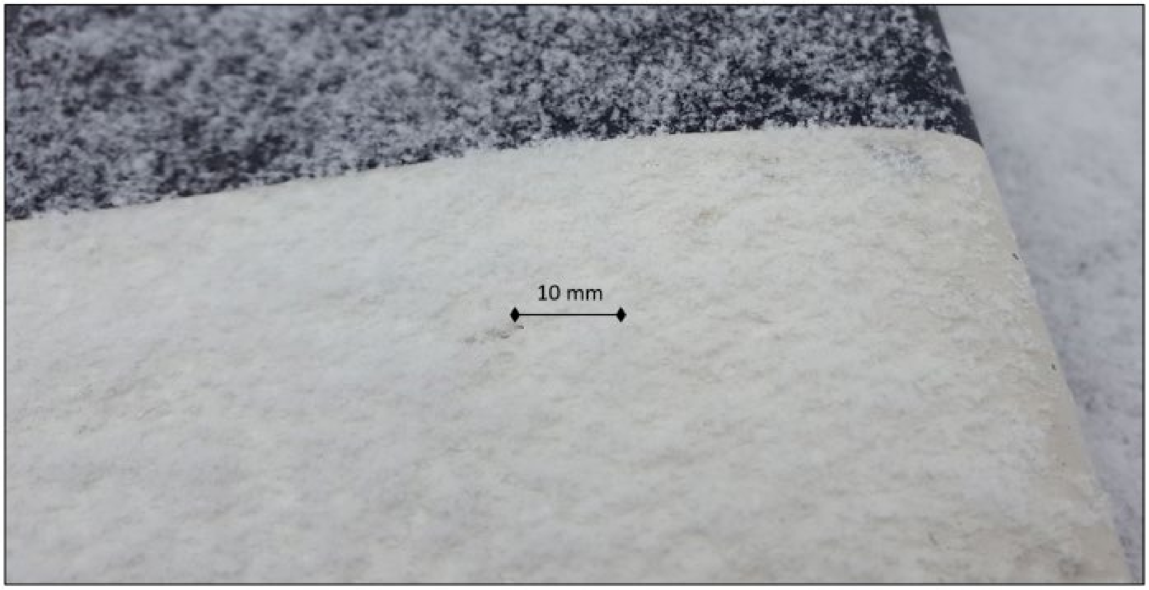
(Source: TSB)

Figure D2. Cooling test (close-up)



(Source: TSB)

Figure D3. Cooling test after additional snowfall



(Source: TSB)

Figure D4. Occurrence wreckage demonstrating the melt/refreeze process approximately 8 hours after the occurrence

(Source: TSB)