Transport Canada Transports Canada

Issue 3/2024

AVIATION SAFETY LETTER

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Electronic distribution:
To subscribe to the *Aviation Safety Letter* e-Bulletin notification service, visit: canada.ca/aviation-safety-letter.

Print-on-Demand:
To purchase a Print-on-Demand (POD) version (black and white), please contact:

The Order Desk
Transport Canada
Toll-free number (North America): 1-888-830-4911
Local number: 613-991-4071
E-mail: MPS1@tc.gc.ca

Sécurité aérienne — Nouvelles est la version française de cette publication.

ISSN: 0709-8103
TP 185E

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TIPS AND TOOLS

Ensuring Safe Winter Operations: Best Practices for De/Anti-icing in Aviation

by Yvan Chabot, A/Chief, Commercial Flight Standards, Civil Aviation, Transport Canada

With winter on the horizon, the aviation community needs to remain alert to the risks of flying in snow and icing conditions. Transport Canada (TC) is providing this information to renew everyone's awareness regarding aircraft operations in icing conditions.

The Impact of Ice and Snow on Aircraft and the Importance of De-icing and Anti-icing Inspections

Research and past incidents have shown that even a thin layer of frost can disrupt airflow over an aircraft's lift and control surfaces, potentially leading to increased drag, loss of lift and impaired maneuverability. Additionally, ice can increase the aircraft's weight, interfere with control surface movement or hinder the functionality of critical sensors. Therefore, it is crucial to ensure that all critical surfaces of an aircraft are free from contamination before take-off.

Credit: Shutterstock

This can be verified by the pilot-in-command (PIC) or by trained and qualified personnel through a pre-take-off contamination inspection. The PIC must ensure that aircraft critical surfaces are free of contamination prior to take-off. If the inspection is delegated, an inspection report must be provided to the PIC, who must confirm understanding. Detailed communication guidelines should be in the operator's manual/ground icing program (GIP), as applicable.

Holdover Time Guidelines

The holdover times (HOT) for aircraft de/anti-icing fluids (ADF) are available in the Transport Canada HOT Guidelines. The HOT Guidelines indicate how long ADFs remain effective against numerous icing conditions. Since various factors may influence these times (e.g., precipitation intensity or temperature change, prevailing winds) the PIC must be aware of these factors and adjust the applicable HOT accordingly. The operators' manuals/GIP should outline these factors and procedures when using the HOT Guidelines.

Aircraft De/Anti-icing Fluid Considerations

Operators requiring a GIP must have a training component that ensures all personnel applying ADF be properly trained (e.g., use consistent application techniques, inspection procedures).

Only ADFs stored, dispensed and applied according to manufacturers' instructions should be used, as these have been tested against industry standards. It is important to also ensure that ADFs are within specifications (e.g., lowest on-wing viscosity [LOWV], highest on-wing viscosity [HOWV]) to ensure that holdover times can be safely attained and that the ADF can be used down to its Lowest Operational Use Temperature (LOUT). Using fluids not within their specifications could impact their expected performance and compromise take-off performance.

Recommended Actions for Safe Operations

Pilots, service providers and other personnel involved in de/anti-icing operations should familiarize themselves with the applicable Canadian Aviation Regulations (CARs) and Standard 622 of the General Operating and Flight Rules Standards (GOFRS)—Ground Icing Operations. They should also adhere to procedures recommended by the aircraft manufacturer and comply with all company operations manual (COM) provisions.

Guidance Documents

- Transport Canada's TP 14052—Guidelines for Aircraft Ground Icing Operations provides detailed information on application methods, fluid types and more. It is a valuable resource for ensuring safe operations in ground icing conditions.

- The holdover times for SAE-qualified de/anti-icing fluids are obtainable in the Transport Canada HOT Guidelines.

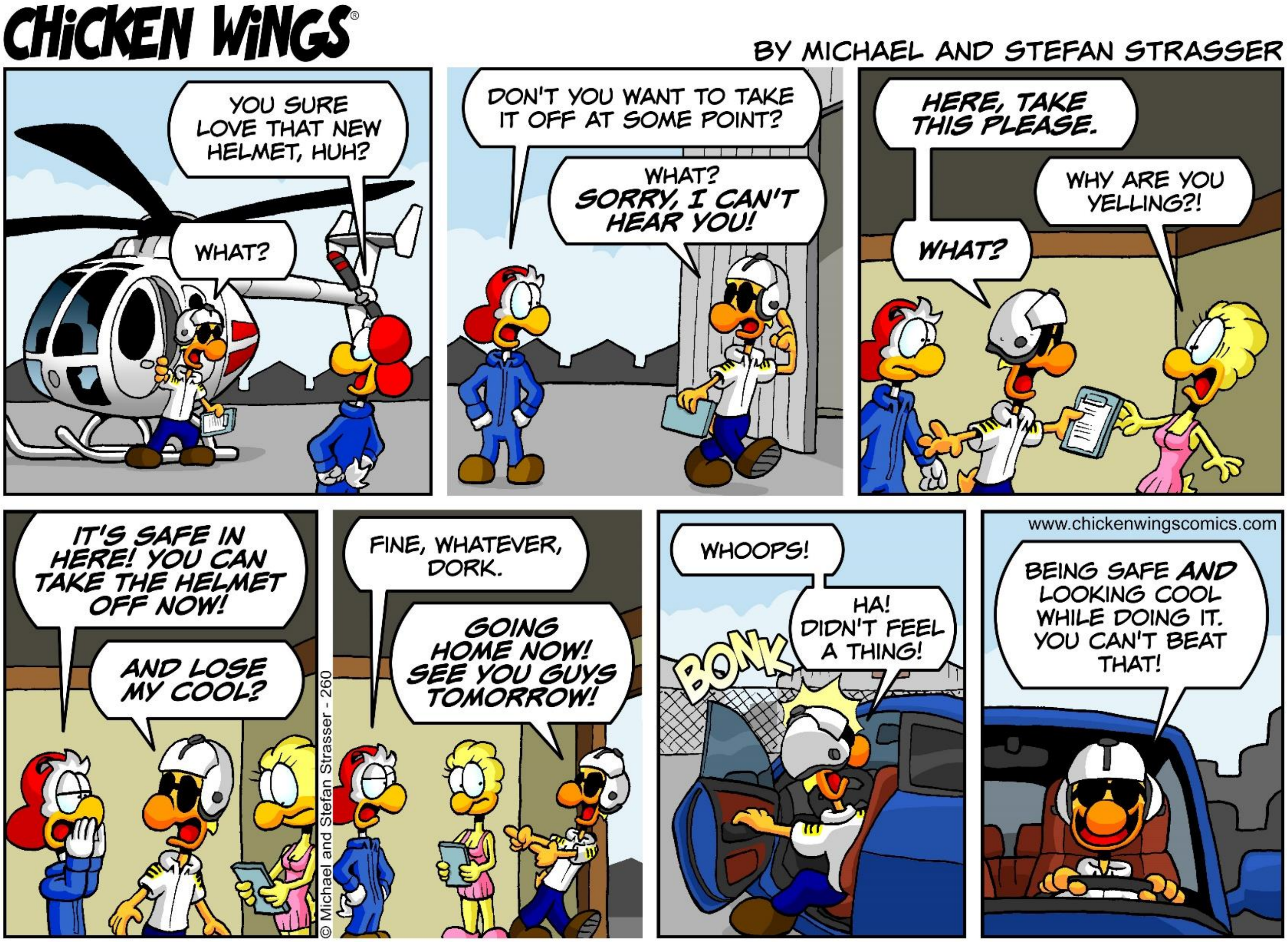
By adhering to these best practices and guidelines, pilots, operators and service providers can ensure safe and efficient operations during the winter season. Maintaining vigilance and proper procedures will help mitigate the risks associated with flying in icy conditions, ensuring the safety of all involved. △

Transport Canada's Flight Crew Recency Requirements Self-paced Study Program

The Flight Crew Recency Requirements Self-paced Study Program is no longer published in its entirety in the *Aviation Safety Letter* (ASL). With the expansion of the exam and technological advances, it was determined to be more convenient to complete the exam online. Each year, a reminder will be published in the ASL with a link to the exam to remind readers that it is available online.

It is important to note that a printable version of the exam is still available online as a PDF.

If you have any questions or comments regarding the Flight Crew Recency Requirements Self-paced Study Program, please send an e-mail to the flight crew licensing group at:
PilotLicensing-LicencesdePilote@tc.gc.ca. △



In-flight Icing

Information gathered from Skybrary

Definition

In-flight airframe icing occurs when supercooled water freezes on impact with any part of the external structure of an aircraft during flight.

Description

Although the nominal freezing point of water is 0°C, water in the atmosphere does not always freeze at that temperature and often exists as a "supercooled" liquid. If the surface temperature of an aircraft structure is below zero, then moisture within the atmosphere may turn to ice as an immediate or secondary consequence of contact.

Considerable quantities of atmospheric water continue to exist in liquid form well below 0°C. The proportion of such supercooled water decreases as the static air temperature drops to -40°C (except in cumulonimbus [Cb] clouds, where supercooled large droplets [SLD] may exist at even lower temperatures); almost all of it is in solid form. The size of supercooled water droplets and the nature of the airflow around the aircraft surface determine the extent to which these droplets will strike the surface. The size of a droplet will also affect what happens after such impact; for example, larger droplets will often be broken up into smaller ones. Finally, since the size of a water droplet is broadly proportional to the mass of water it contains, and this mass determines the time required for the physical change of state from liquid (water) to solid (ice) to occur, larger droplets which do not break up into smaller ones will take longer to freeze because of the greater release of latent heat and may form a surface layer of liquid water before this change of state occurs.

Airframe Icing Effects

Airframe icing can lead to reduced performance, loss of lift, altered controllability and, ultimately, stall and subsequent loss of control of the aircraft. Hazards arising from the presence of ice on an airframe include:

Adverse aerodynamic effects

Ice accretion on critical parts of an airframe unprotected by a normally functioning anti-icing or de-icing system can modify the airflow pattern around airfoil surfaces, such as wings and propeller blades, leading to loss of lift, increased drag and a shift in the airfoil centre of pressure. The latter effect may alter longitudinal stability and pitch trim requirements. Longitudinal stability may also be affected by a degradation of lift generated by the horizontal stabilizer. The modified airflow pattern may significantly alter the pressure distribution around flight control surfaces such as ailerons and elevators. If the control surface is unpowered, such changes in pressure distribution can eventually lead to uncommanded control deflections, which the pilot may not be able to be overpower.

Blockage of pitot tubes and static vents

Partial or complete blockage of the air inlet to any part of a pitot static system can produce errors in the readings of pressure instruments such as altimeters, airspeed indicators and vertical speed indicators. The most likely origin of such occurrences to otherwise serviceable systems has been the non-activation of the built-in electrical heating which these tubes and plates are provided with, although in some cases, the detail design of pitot heads has made them relatively more vulnerable to ice accretion, even when functioning as certificated. It is now also recognized that the effects of high-level ice crystal icing can have what are usually transient effects on the effectiveness of normally functioning pitot probe heating.

Radio communication problems

Historically, ice forming on some types of unheated aerials has been the cause of degraded performance of radios, but this has not been encountered in the case of modern radio equipment and aerials.

Surface hazard from ice shedding

Ice shed during in-flight de-icing is not of a size which could create a hazard should it survive in frozen form until reaching the ground below. However, there has been a long history of ice falls from aircraft waste drain masts, a few of which have caused minor property damage and occasionally come close to hitting and injuring people. The drain masts involved are those from aircraft galleys or toilet compartments which are normally heated to prevent ice formation, but, for some reason, have not been operating as intended. Ice from toilet waste masts is often referred to as "blue ice." Most of these events have been recorded where there is a high density of long-haul commercial air traffic inbound to a large airport which routinely overflies a densely populated residential area as it descends below the freezing level in the vicinity of the airport.

Rime ice
Credit: Bruce Sinclair

The Airframe Ice Accretion Process

Ice accretion on an aircraft structure can be distinguished as rime icing, clear/glaze icing or a blend of the two referred to as cloudy or mixed icing:

Rime ice

Rime ice is formed when small, supercooled water droplets freeze rapidly on contact with a sub-zero surface. The rapidity of the transition to a frozen state is because the droplets are small, and the almost instant transition leads to the creation of a mixture of tiny ice particles and trapped air. The resultant ice deposit formed is rough and crystalline and opaque, and because of its crystalline structure, it is brittle. It appears white in colour when viewed from a distance: for example, from the flight deck when on a wing leading edge.

Rime ice
Credit: Bruce Sinclair

Since rime ice forms on leading edges, it can affect the aerodynamic characteristics of both wings and horizontal stabilizers, as well as restrict engine air inlets. Rime may begin to form as a rough coating of a leading edge, but if accretion continues, irregular protrusions may develop forward into the airstream, although there are structural limits to how much “horn” development can occur.

Clear ice

Clear or glaze ice is formed by larger supercooled water droplets, of which only a small portion freezes immediately. This results in runback and progressive freezing of the remaining liquid, and since the resultant frozen deposit contains relatively few air bubbles as a result, the accreted ice is transparent or translucent. If the freezing process is sufficiently slow to allow the water to spread more evenly before freezing, the resultant transparent sheet of ice may be difficult to detect. The larger the droplets and the slower the freezing process, the more transparent the ice.

Occasionally, certain temperature and droplet size combinations can lead to the formation of a “double ram’s horn” shape forward of the leading edge, with protrusions from both the upper and lower leading edge surfaces. These horns have been observed to occur in a variety of forms in a wide range of locations along a leading edge and, because clear ice has a more robust structure than rime ice, they can reach larger sizes.

Cloudy or mixed ice

This blend of the two accreted ice forms in the wide range of conditions between those which lead to mostly rime or mostly clear/glaze ice and is the most commonly encountered. Its appearance will be determined by the extent to which it has been formed from supercooled water droplets of various sizes.

Some other terms which may be encountered in connection with airframe ice accretion include:

Supercooled large droplets (SLD)

"Supercooled large droplets are defined as those with a diameter greater than 50 microns”—The World Meteorological Organisation”

“Supercooled Large Droplet....[has] a diameter greater than 50 micrometers (0.05 mm). SLD conditions include freezing drizzle drops and freezing raindrops.”2—FAA AC 91-74A, Pilot’s Guide to Flight in Icing Conditions

If a SLD is large enough, its mass will prevent the pressure wave travelling ahead of an airfoil from deflecting it. When this occurs, the droplet will impinge further aft than a typical cloud-sized droplet, possibly beyond the protected area and form clear ice.

Droplets of this size are typically found in areas of freezing rain and freezing drizzle. Weather radar is designed to detect large droplets, since they are not only an indication of potential in-flight icing but also updrafts and wind shear.

Runback ice

Runback ice forms when supercooled liquid water moves aft on the upper surface of the wing or tailplane beyond the protected area and then freezes as clear ice. Forms of ice accretion which are likely to be hazardous to continued safe flight can rapidly build up. Runback is usually attributable to the relatively large size of the SLD encountered but may also occur when a thermal ice protection system has insufficient heat to evaporate the quantity of supercooled water impinging on the surface.

Intercycle ice

Intercycle ice is that which forms between cyclic activation of a mechanical or thermal de-icing system. Accumulation of some ice when these systems are not 'on' is an essential part of their functional design. The time interval between 'on' periods is usually selectable between at least two settings. Any ice remaining after a de-icing system of this type has been selected off is sometimes referred to as residual ice.

The Adverse Aerodynamic Effects of Accreted Ice

The aerodynamic effects of accreted ice on the continued safe flight of an aircraft is a complex subject because of the many forms such ice accretion can take. In certain circumstances, very little surface roughness is required to generate significant aerodynamic effects and, as ice load accumulates, there is often no aerodynamic warning of a departure from normal performance. Stall warning systems are designed to operate in relation to the angle of attack on a clean aeroplane and cannot be relied upon to activate usefully in the case of an ice-loaded airframe.

Icing in Cloud and Precipitation

Any cloud containing liquid water can present a significant icing environment if the temperature is 0°C or less. Generally, cumuliform cloud structures will contain relatively large droplets, which can lead to very rapid ice build-up. Stratiform cloud structures usually contain much smaller droplets, although the horizontal extent of icing conditions within a stratiform cloud may be such that the accumulation in even a relatively short period of level flight can sometimes be considerable. The most significant ice accretion in any cloud can be expected to occur at temperatures below but close to 0˚C. In a stratiform cloud in temperate latitudes, the maximum ice accretion is often found near the top of the cloud, and it may be unwise for some turboprop aircraft to remain at such an altitude for extended periods.

Any drizzle or rain which is encountered at temperatures of freezing or below is likely to generate significant ice accretion in a very short period of time, even if reasonable forward visibility prevails, and such conditions should be exited by any appropriate change of flight path.

Snow, in itself, does not present an icing threat, since the water is already frozen. However, snow can be mixed with liquid water, particularly cloud droplets, and, in some circumstances, can contribute to the accumulation of hazardous frozen deposits. This phenomenon may also occur in cumulonimbus anvil clouds, where the ice crystals may be mixed with SLD to incur significant icing.

Types of In-flight Airframe Icing Accidents

There are two main origins of accidents and serious incidents involving airframe icing:

1. General aviation aircraft that are not equipped with ice protection systems but are flown in icing conditions may encounter enough icing at cruise altitudes to overwhelm the aircraft power reserve, leading to an inability to maintain altitude and/or airspeed. In mountainous terrain, this very often leads to a stall followed by a loss of control when the pilot attempts to maintain altitude over the high terrain. Alternatively, a collision with terrain may result when altitude cannot be maintained. Regardless of the type of terrain, any aircraft without airframe ice protection systems which is flown in icing conditions can quickly encounter a stall and loss of control due to the excessive drag and loss of lift which ice accretion can bring.
2. Aircraft, predominantly propeller-driven, which rely on wing and tail ice protection by de-icing, principally by pneumatic deicing boots and are operated in icing conditions which exceed the capability of the protection. In these cases, if the angle of attack increases in the presence of an abnormal ice loading either as a result of attempting to maintain a climb with limited power and a relatively high load or, more suddenly, when configuration is changed during the approach to land, a stall and loss of control can result from which recovery may not be possible at low level.

Solutions

- **flight planning.** For aircraft without airframe ice protection systems, operation in icing conditions should be avoided. This can only be assured if operating in visual meteorological conditions (VMC) and flight in freezing precipitation will not occur, or in instrument meteorological conditions (IMC), when temperatures will be above freezing and flight in freezing precipitation will not occur. It is particularly important that the cruise portion be planned so as to avoid icing at high altitudes above mountainous terrain.

- **operation of ice protection systems.** Care should be taken to operate the wing and tailplane ice protection systems in accordance with the manufacturer's specification. In recent years, there have been significant changes in procedures for effective operation of pneumatic ice protection systems, and these instructions should not be ignored in favour of popular notions such as ice bridging.

- **approach and landing.** Pilots operating ice-protected aircraft should consider the effects of any residual ice which may be present during approach and landing, since it may degrade performance substantially and lead to abnormal responses to configuration changes. △

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Soar Spots: A Review of Glider Conflictions in Canada

by Nicholas van Aalst, Safety & Quality, NAV CANADA

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The author thanks the tremendous contributions of Dr. Jonathan Histon, Manager, Human Performance and the wider Safety & Quality Department at NAV CANADA for article development and subject matter expertise. Additional acknowledgement goes to Captain Ashley Gaudet of 2 Canadian Air Division, as well as Mr. David Donaldson of the Soaring Association of Canada.

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Soar Spots

During the late morning of August 12, 2022, a Boeing 767-375ER was conducting an instrument landing system approach to Hamilton, Ontario's Runway 12 when a glider rapidly filled the crew's windscreen, forcing the crew of the 767 to take evasive action, passing close enough to clearly observe the glider pilot. Fortunately, both aircraft were able to continue and make normal landings without further incident (Aviation Safety Network, 2022). This event illustrates the challenges and importance of airspace deconfliction and interactions between glider operations and other airspace users.

The Safety & Quality (S&Q) team at NAV CANADA has identified glider operations as a driver for conflicts with a heightened risk of collision within controlled airspace. Several features of glider operations contribute to this risk driver, including constraints on human performance, air traffic control operational limitations including airspace requirements, as well as the limitations on aircrew and their operational requirements. In varied and dynamic combinations of these factors, the result may render a degraded state of situational awareness and collective mental modelling leading to a mishap. Via awareness for this type of confliction, this article will provide insights into some of the pre-conditions for events, such as occurred in Hamilton, and provide readers with interest-based best practices for prevention.

Background

On August 28, 2006, a Hawker 800XP on descent near Reno, Nevada—collided with a Schleicher ASW 27 glider, as seen in Figure 1, at approximately 16 000 ft above sea level. According to the National Transportation Safety Board (NTSB) report (Charnon, 2008), "…damage sustained by the Hawker disabled one engine and other systems; however, the flight crew was able to land the airplane. The damaged glider was uncontrollable, and the glider pilot bailed out and parachuted to the ground" (p. 1). The NTSB's findings indicated that the closure rate between the aircraft rendered collision avoidance was improbable, if not impossible once the conflict became apparent. Moreover, the lack of a transponder signal from the glider led to a degraded state of air traffic control (ATC) and aircrew situational awareness, which contributed to the mishap.

Method

The S&Q department has conducted a review of probable glider confliction areas in Canada, including transponder and ATC service provision requirements. This analysis further examined operating locations, including adjacent airspace and stakeholder interactions. Moreover, the review explored limitations of "see and be seen" and "see and avoid" principles associated with visual meteorological conditions (VMC) for both visual flight rules (VFR) and instrument flight rules (IFR) aircraft.

Figure 1: Schleicher ASW 27 glider, (Münch, n.d.)

Figure 2: Hawker 800XP following a mid-air collision with glider
(National Transportation Safety Board, 2006)

From this review, three key elements of conflicts, including their relationships, were identified as summarized below, as well as in Figure 3.

1. human performance limitations
2. ATC operational limitations
3. aircrew operational limitations

Where limitations in Figure 3 overlap and interact, conflicts are more likely to occur. The following sections describe these interactions in greater detail.

Human Performance Limitations

The subject of human performance is a cross-discipline conversation requiring an understanding of situational awareness and perceptual blindness affecting mental modelling.

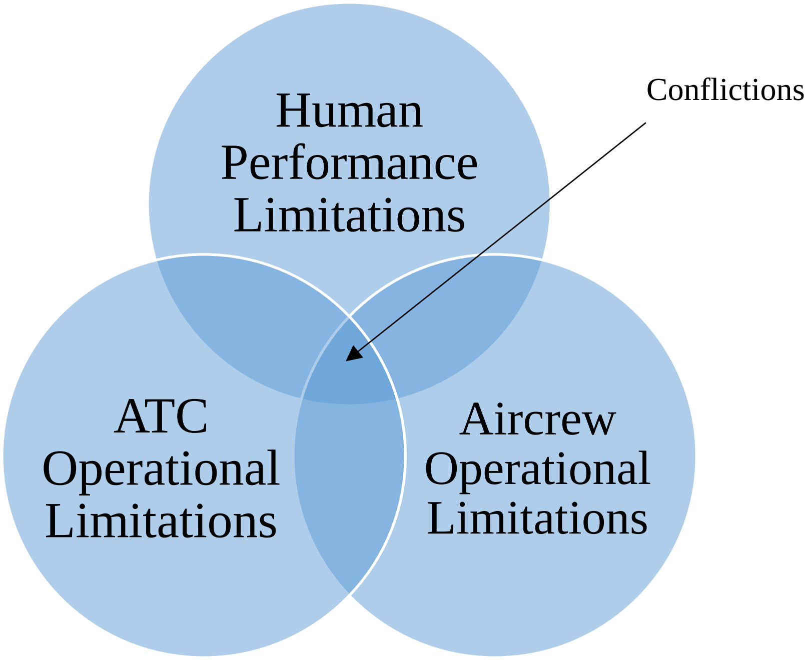

Figure 3: Risk driver relationships and interactions

Situational Awareness
Situational awareness (SA) is generally comprised of three levels: detection, understanding and prediction. First and foremost, detection requires aircrew and ATC to sense information regarding the environment. Second, aircrew and ATC must understand the meaning of the information, ultimately leading to the third level of situational awareness: the predicting of future needs.

Reflecting on the events of Reno, Nevada, and Hamilton, Ontario, what is apparent is that SA was not complete prior to the gliders being spotted. However, SA was rapidly restored, although with varied outcomes, with time being the critical factor in conflict resolution.

Perceptual Blindness
While levels of SA are built on our ability to sense the world around us, phenomenon such as perceptual blindness, also referred to as inattention blindness, involve failing to observe what may be considered obvious. Similarly, it is plausible that cognitive capture can promote a fixation upon a task, an object or even a thought, at the expense of SA.

What is apparent from stakeholders is that gliders are rarely forming a component of SA, largely due to low priming on the threat associated with gliders and a bias towards power-driven aircraft during traffic lookouts. Additionally, research indicates that inconspicuous coloration of objects may play a role in perceptual blindness. When applied to low-profile design gliders—predominantly white in colouration—the ability to visually identify gliders is reduced.

ATC Operational Limitations

ATC is often relied upon for traffic information to augment aircrew SA. Simultaneously, control instructions and clearances are provided based on known traffic with transponder-derived secondary surveillance radar and space-based surveillance data. However, under *Canadian Aviation Regulation* 605.35, gliders are permitted to operate within significant segments of Canadian domestic airspace without a transponder and altitude encoding equipment. This renders gliders as effectively invisible across vast areas of airspace, with only occasional primary radar returns being possible, which may represent any number of objects, including but not limited to birds.

Moreover, with primary radar returns not rendering altitude information and with primary radar returns being quite frequent, it may be challenging for ATC to provide relevant traffic information, particularly due to workload. To better manage workload, ATC may heavily rely upon altitudes for traffic separation, such as when aircrew adhere to standard altitudes based on flight rules and direction of flight. However, the nuance and inability of gliders to maintain constant altitudes means gliders pass through altitudes of IFR and VFR aircraft, suggesting a wide rang of altitudes where conflictions may occur.

Aircrew Operational Limitations

Having explored the concepts of human performance and limitations for ATC, operating limitations for aircrew in VMC, as well as available publications, deserves some consideration.

VMC Visual Separation

Whether operating as VFR or IFR, aircrews in VMC rely on mantras of “see and be seen,” as well as “see and avoid” for deconfliction. Of these, three elements appear:

1. a traffic lookout
2. being visible
3. resolving conflicts

Glider visibility. From the vantage point of a glider pilot, traffic lookout is counter-intuitively limited, even with the visibility afforded by canopy designs. Restrictions of visibility include the wingspan and wing position, as well as the positioning of the pilot’s seat. As gliders may operate for extended periods at high bank angles and high rates of turn, glider pilots are challenged to maintain effective lookouts in rapidly changing environments. In turn, from a third-party perspective, the ability to observe a tightly orbiting glider can be difficult, particularly with low-profile designs and the absence of anti-collision lighting.

Power-driven aircraft. When discussed from the perspective of power-driven aircraft, physical obstructions limit visibility. However, a deeper challenge presents a conflict between the “heads up” monitoring of displays and effective traffic lookouts, with cockpit workload becoming increasingly predominant in modern general aviation aircraft.

Right-of-way-based deconfliction. CAR 602.19–Right of Way contains significant information regarding deconfliction. Most notable in the hierarchy is the priority of gliders, potentially rendering some measure of complacency for glider pilots, although VMC presents with shared responsibility for traffic detection and deconfliction.

Publications

A review of aeronautical publications, including applicable NOTAMs, has revealed that gliding operations are not clearly defined, nor are glider pilots required to remain confined to Class F airspace or as depicted on VFR navigation charts. This finding is not limited to VFR publications, as there is less clarity on IFR publications, including STARs and approach plates, suggesting that IFR traffic may have a degraded level of SA.

Addressing NOTAMs specifically, a published glider operations NOTAM may serve to reinforce glider pilot complacency under the assumption that NOTAMs are widely and thoroughly reviewed and understood.

A Probable Confliction Scenario

Based on the drivers in Figure 3, identifying probable confliction locations within Canada required S&Q to explore areas with a mixed requirement for ATC clearances, communication, navigation and surveillance, coupled with significant mixed flight rules and performance elements. Further review suggests that this complexity occurs more frequently within Class E airspace, where VFR aircraft operate without the element of a control service and where transponder requirements vary in accordance with the Designated Airspace Handbook. Consequently, Class E airspace is a probable driver for conflictions within controlled airspace.

As such, consider the scenario of an IFR aircrew during arrival and approach phases of flight, descending through a small area of Class E airspace on an ATC clearance, prior to transitioning into a terminal control area or control zone. During this time, this crew may face heightened cognitive workloads and competing priorities—covering distances upwards of four nautical miles per minute—transitioning between VMC and IMC through scattered or broken cumulus clouds, as depicted in Figure 4. In a multi-crew environment, workload factors for the pilot monitoring include direct controller–pilot communications and other "heads down" duties, requiring significant crew resource management skills.

Consider now the perspective of the VFR glider pilot, operating within the same segment of Class E airspace, relying upon rising air beneath a cumulus cloud through which the previously mentioned IFR aircraft, is about to pass. In this scenario, absent a requirement for communication and surveillance-related equipment, gliders are unable to contribute to the shared mental modelling of the IFR aircrew and ATC, nor are gliders fully aware of the related traffic picture. It is here that the pre-conditions for a confliction are present, and it is here that conflicts, such as previously depicted in Hamilton and Reno, potentially develop.

How You Can Stay Classy in Class E

As the prevalence of threat has presented predominantly within Class E airspace, including across airways where aircrew and ATC may not be aware of glider operations, specific locations for conflictions are vast and challenging to predict. However, during stakeholder engagement with S&Q, perhaps the most impactful moment came in the form of a philosophical quote: "…talk to the people who can kill you!", crystalizing the core concept that awareness and collaboration drive effective flight safety initiatives.

Figure 4: Glider pilot perspective under cumulus cloud (Sosinski, 2024)

Recommended Best Practices

Recalling Figure 3, prominent best practices surfaced towards the development, maintaining and recovering of situational awareness and may largely be divided by perspective.

Glider Pilots

1. Study airspace prior to flight operations and be aware of IFR and VFR traffic flows, including STARs and instrument approaches.
2. Provide frequent and accurate position reporting on enroute frequencies.
3. Develop rapports with adjacent operators and ATC units while adhering to localized agreements and best practices.

Power-driven Aircraft Pilots

1. Study publications prior to flight operations and be familiar with adjacent aerodromes and airspace that support glider operations.
2. Where practicable, monitor for traffic on the enroute frequency, and provide position reports.
3. Be deliberate and critical when conducting traffic lookouts in VMC.

Air Traffic Controllers

1. Where practicable, provide information on known and unverified traffic, including primary targets that are persistent or steady state, in areas where gliders may be present.
2. Develop a rapport with glider operators to engage and inform on operational impacts.
3. Where required, develop, verify and validate localized procedures for glider operations.

Conclusion

What S&Q's review has shown is that glider conflictions are driven by three key enablers: human, ATC, and aircrew operational limitations and requirements. Further degrading situational awareness are aircraft operating without a transponder, such as the case with many gliders in Canada. As a result, best practices towards deconfliction in advance of operations, as well as during operations, including frequent and effective communications and stakeholder engagement. These practices are crucial in preventing airborne conflictions such as those having occurred in Hamilton, and mishaps such as Reno, and may serve wider benefits to the aviation ecosystem in Canada. △

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Back into the Circuit–Changes to the TC AIM

by Uwe Goehl, Civil Aviation Safety Inspector, Transport Canada, General Flight Standards

Unless you are a balloon pilot, you have probably spent a fair amount of time flying in an aerodrome traffic circuit.

Student pilots pursuing an Ultralight Aeroplane Permit, Recreational Pilot Permit or Private Pilot Licence spend a considerable part of their training in the circuit, logging and perfecting take-offs, approaches and landings. Not only are traffic circuits flown by aircraft operating under visual flight rules (VFR), but a traffic circuit may be part of a visual approach, a contact approach or a circling approach flown by an aircraft operating under instrument flight rules (IFR). It may even be the quick, safe method used by an aircraft to return to the aerodrome following a situation during or right after take-off, such as an engine failure on a multi-engine jet in visual meteorological conditions (VMC).

Aside from balloons, all sorts of aircraft of different configurations and with different performance capabilities may fly a traffic circuit, from slow ultralight aeroplanes to much faster transport category jets. This can create challenges when these aircraft with very different performance capabilities are operating at an aerodrome at the same time. Because of this, Transport Canada’s Aeronautical Information Manual (TC AIM) had a significant update to the guidance on flying visual circuits at controlled and uncontrolled aerodromes in edition 2024-2, published on October 3, 2024.

The way pilots must operate their aircraft when flying near an aerodrome can be found in the *Canadian Aviation Regulations* (CARs) Subpart 602, Division V. CAR section 602.96 closely mirrors the International Civil Aviation Organization (ICAO) *Standards and Recommended Practices* (SARPs) published in ICAO Annex 2–Rules of the Air, section 3.2.5. In a nutshell, both the CARs and the ICAO SARPs say that the pilot-in-command must:

- observe aerodrome traffic to avoid a collision;
- conform to or avoid the flow of traffic already established by other aircraft;
- make all turns to the left, unless otherwise instructed. In Canada, that instruction may be given by ATC or published in the *Canada Flight Supplement*; and
- when practical, land into the wind.

This helps explain why traffic circuit procedures are the same in other countries (i.e., observe other traffic to avoid a collision, conform to and avoid the pattern of traffic formed by other aircraft operating at the aerodrome and make all turns to the left in a circuit, unless otherwise specified), while some procedures, such as recommended traffic circuit entries, are different.

For example, in Canada, the preferred entry at an uncontrolled aerodrome is crossing the aerodrome mid-field. In the United States, the preferred entry at a non-towered airport is at a 45-degree angle to the downwind leg.

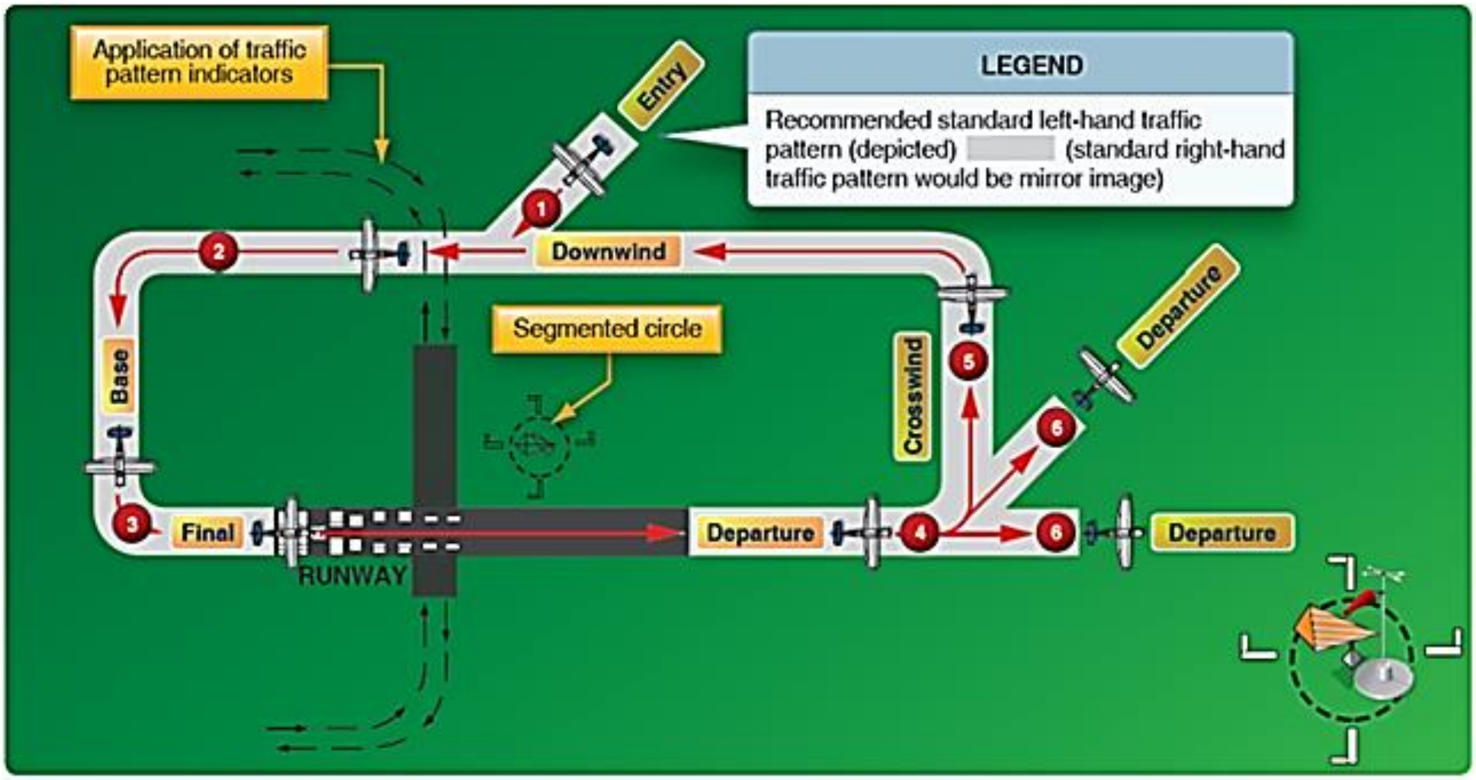

Diagram 1: Recommended standard left-hand traffic pattern at U.S. non-towered airports with entry on a 45° angle to the downwind leg

Some countries chart the specific lateral track and altitude to be followed, depending on aircraft performance, for each aerodrome.

While some elements of the traffic circuit are identical, these examples also underscore why it is important for a pilot to thoroughly familiarize themselves with differences before flying in another country.

What’s changed and what hasn’t?

Here is the good news. It is very likely, whether you are an aeroplane, glider, rotorcraft or balloon pilot, that you are already flying a traffic circuit as described in the updated edition of the TC AIM. We haven’t changed the recommended traffic circuit entry procedures. We expect pilots to comply with the regulations, and we encourage pilots to operate in accordance with published guidance information. In this case, though, the recommendations in the TC AIM were lagging with respect to industry-accepted procedures and airline standard operating procedures (SOPs), so the objective was to bring the TC AIM into alignment with the way many aircraft already, and legally, fly traffic circuits. The new guidance is better harmonized with recommended aerodrome circuit procedures in other countries, such as Australia and the United States. However, if you are a light general aviation aeroplane pilot, you may not have been aware that jets and turboprops typically conduct wider circuits at 1 500 ft above ground level (AGL). This makes sense because they operate at higher speeds and have greater turning radii, so they cannot conform to the flow of traffic formed by slower single- and multi-engine aeroplanes.

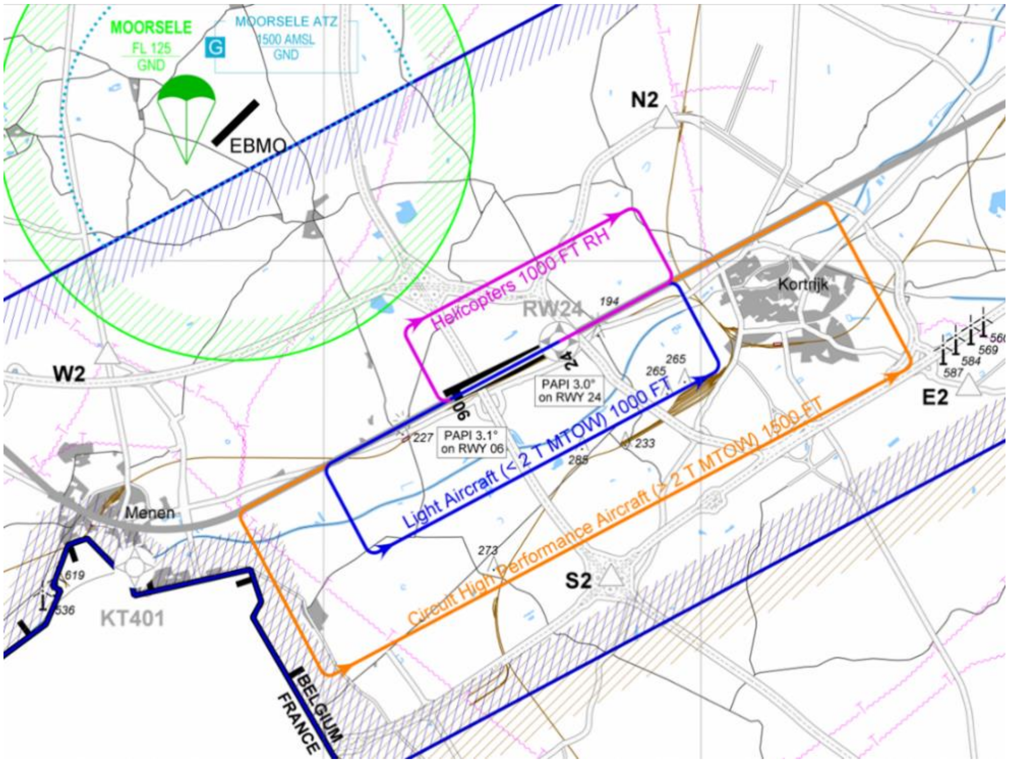

Diagram 2: Charted lateral and vertical traffic circuit paths for helicopters, light aircraft and high-performance aircraft at Flanders Airport, Belgium

If you are a jet pilot, you may be unfamiliar with the modified circuits flown by glider pilots. Most pilots know that gliders have the right of way over powered aircraft (they cannot maintain altitude, and a successful go-around is very improbable). But did you know that aircraft towing gliders may follow what looks like an erratic departure track to keep their glider within gliding distance of a safe landing spot, and that this is legal?

If you are a glider pilot, do you know what to expect from slow, low performing ultralight aeroplanes operating in the circuit?

If you are a powered paraglider pilot flying a low, tight-traffic circuit at 20 mph, are you aware that you may be sharing the circuit with gyroplanes and helicopters?

Rotorcraft pilots: there are several recommendations for you to fly the circuit depending on your performance capabilities. Of course, helicopter pilots may choose to avoid the flow of traffic in the circuit(s), opting to arrive or depart directly from the helipad at the aerodrome. But do you know what to expect from a balloon operating at an aerodrome? Also, for helicopter pilots: the TC AIM has an update on helicopter operations at aerodromes in RAC 4.5.3.

Finally, for balloon pilots: do you know where and how other aircraft in the airspace around you manoeuvre near an aerodrome?

It is important for pilots to have good situational awareness and to know what to expect from each other. The objective is to ensure safety for everyone while providing fair aerodrome access to all legitimate airspace users, regardless of the size or performance capabilities of their aircraft.

Traffic circuits can get busy and increase pilot workload, especially at uncontrolled aerodromes. A few other suggestions in the TC AIM can help minimize surprises and keep everyone safe:

- Keep a good look-out.
- Make yourself visible. Turn on your anti-collision (beacon/strobe) lights and landing lights. It will make it easier for other pilots to see you.
- If you have a transponder, always use it, including the altitude encoding function. Even if you are not in transponder airspace, you will be visible to aircraft using Aircraft Collision Avoidance Systems (ACAS).
- Communicate, communicate, communicate! Speak clearly and concisely using the recommended terminology. See NAV CANADA's Phraseology Guides.

Note: Read more about United States non-towered airport flight operations. △

Note: Uwe is a qualified aeroplane, balloon, glider, gyroplane, RPAS and ultralight aeroplane pilot. Prior to joining Transport Canada, if he wasn't doing a visual circuit in an Airbus A320 or a gyroplane, he would do be doing them in a sailplane, weight shift control aircraft, or in his powered paraglider.

RECENTLY RELEASED TSB REPORTS

TSB Report A18P0031—Loss of control and collision with terrain

History of the flight

On February 23, 2018, the pilot planned to take nine passengers on a charter under instrument flight rules (IFR) flight from Abbotsford Airport, BC (CYXX) to Long Beach/Daugherty Field/Airport, California, United States (KLGB) using a company Beechcraft King Air B100 (King Air).

On the day of the occurrence, the pilot arrived at the hangar at approximately 0800. In the hours leading to the departure, the pilot was involved in several different operational and business-related activities.

The pilot delegated most of the flight planning and pre-flight duties for the occurrence flight to the company 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. 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 or anti-icing 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 ft above ground level and that the braking action on landing was moderate to poor.

At 1159, the pilot informed the controller that the aircraft was holding short for Runway 07. While the aircraft was waiting for take-off 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 take-off. At 1203, the aircraft taxied onto the snow-covered Runway 07 and continued with an immediate take-off.

Approximately four to five seconds after take-off, 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 ft before coming to rest in a raspberry patch located on the airport property.

Personnel information

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 September 1, 2018.

Pilot's pre-flight planning

In the company, 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.

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

Aircraft information

General

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.

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

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

Weight and balance

The investigation identified a number of errors on the OFP relating to weight and balance. Most notably, although the aircraft had 549 lbs of fuel in the auxiliary tanks, 0 was entered on the OFP. There were no scales in the company 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 lbs under the maximum allowable gross take-off weight of 11 800 lbs, 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 lbs. 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.

Rear baggage compartment

The maximum allowable weight in the rear baggage compartment is 410 lbs. In addition, “all cargo shall be properly secured by a Federal Aviation Administration–approved cargo restraint system.” In this occurrence, the passengers loaded approximately 480 lbs 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.

Meteorological information

General

In the hours leading up to the accident, the Abbotsford area was under a low pressure system that brought snow and reduced visibility with it and temperatures of approximately -2°C. At the time of the occurrence, moderate mixed icing in cloud was forecast between 3 000 ft and 14 000 ft above sea level.

Aviation routine weather reports

The information in Table 1 was extracted from the aviation routine weather reports (METARs) at CYXX in the hours prior to, and shortly after, the occurrence.

Time	Wind	Visibility (sm)	Snow intensity	Ceiling (ft)	Temperature	Dew point
1100	Calm	½	moderate	1 000 overcast	-2°C	-3°C
1127	080°T at 3 kt	⅝	moderate	700 overcast	-2°C	-3°C
1200*	Variable at 2 kt	⅜	moderate	600 broken	-2°C	-3°C
1212	Calm	⅜	moderate	600 broken	-2°C	-3°C
1247	190°T at 8 kt	½	moderate	600 broken	-2°C	-3°C
1300	200°T at 5 kt	¾	light	800 broken	-1°C	-3°C

Table 1: METARs information for CYXX on the day of the occurrence (Source: NAV CANADA)

* *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. 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.

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.

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

For de-icing and anti-icing purposes, snowfall intensity is an important consideration in determining holdover time.[2] Instead of relying solely on visibility as an indicator of snowfall intensity, industry and regulators have established a snowfall intensity chart that takes lighting, temperature range and visibility into account (Table 2).

Lighting	Temperature Range		Visibility in Snow in Statute Miles (Metres)			
	ºC	ºF	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	≤¾ (≤1200)	>¾ 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	≤⅜ (≤600)	>⅜ to ⅞ (>600 to 1400)	>⅞ to 2 (>1400 to 3200)	>2 (>3200)

Table 2. Snowfall intensities as a function of prevailing visibility

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[1] 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.

[2] 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.)

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

Aerodrome information

The elevation of CYXX is 194 ft above sea level. CYXX has two runways. Runway 07/25 is asphalt/concrete and measures 9 597 ft long and 200 ft wide, and Runway 01/19 is asphalt and measures 5 328 ft long and 200 ft 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. 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) 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.

Wreckage and impact information

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 ft across the ground and Taxiway C before it came to rest in a raspberry patch about 800 ft left of the runway centreline and about 7 500 ft from the runway threshold (Figure 1). The left wing broke off, just outboard of the left engine nacelle during the impact sequence.

Examination of the initial point of collision on the terrain showed three distinguishable ground scars (Figure 2). The two 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.

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

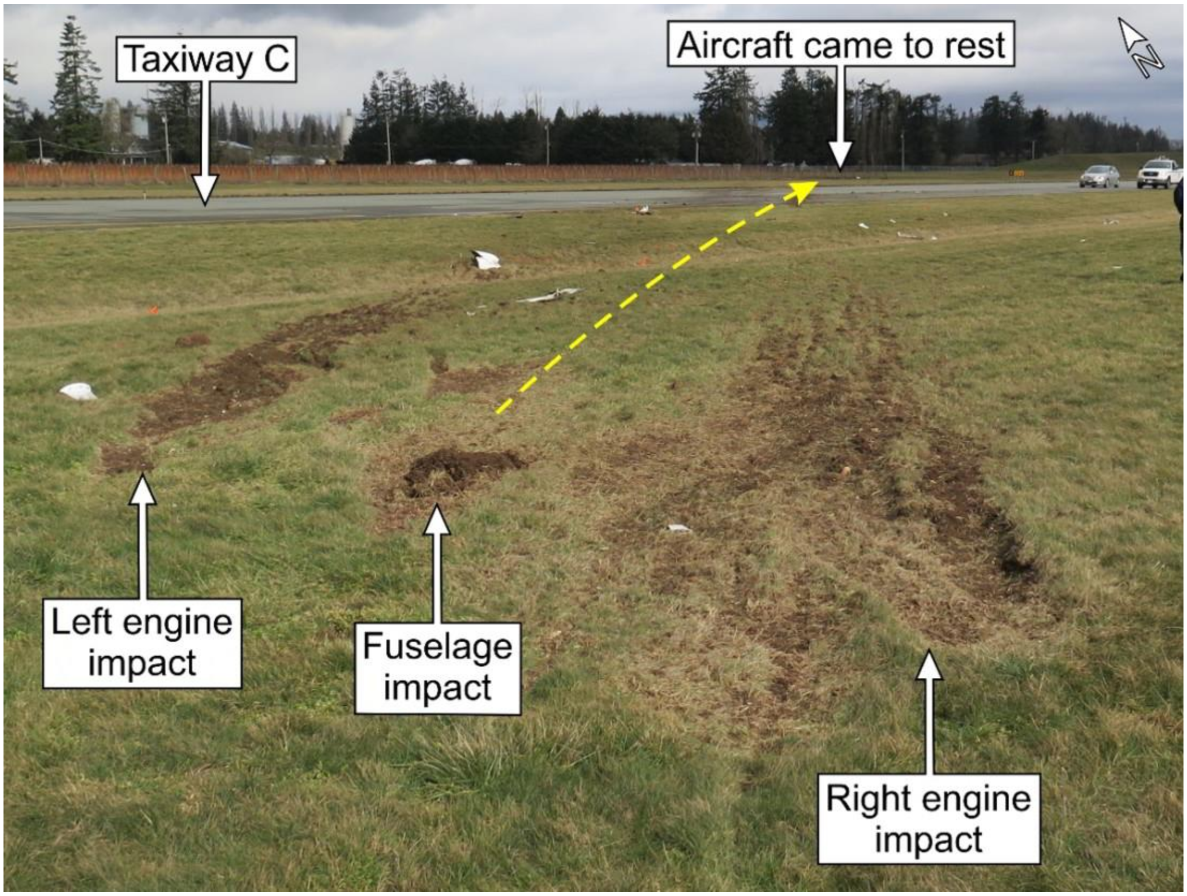

Figure 2: The aircraft's initial point of collision with terrain and the direction of travel (photograph taken February 27, 2018) (Source: TSB)

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.

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 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.

Tests and research

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 take-off.

The investigation determined that lift-off occurred between 100 and 110 kt indicated airspeed (KIAS). The published rotation speed specified in the aircraft flight manual for a normal take-off (i.e., with flaps at 0 degrees) is 97 kt KIAS, making the estimated lift-off 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 kt KIAS. Assuming that deceleration was constant, the aircraft skidded for approximately eight to nine seconds before coming to a full stop.

The investigation determined that the aircraft took off approximately 3 300 ft down the runway, and the airborne portion of the flight was approximately 3 500 ft. Approximately 2 800 ft of runway remained beyond the impact point.

According to the aircraft flight manual, the aircraft should achieve rotation airspeed in about 1 700 ft. 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 take-off 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 eight seconds before impact. Impact analysis conducted by the TSB estimated the vertical speed at impact was 1 200 ft 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 1 000 ft per minute and fell to zero within five seconds of take-off as the altitude reached maximum height. The maximum height was about 100 ft above the runway; however, the aircraft may have been as low as 75 ft given the accuracy of Mode S transponder altitude.[3] Altitude then decreased until the impact (Figure 3).

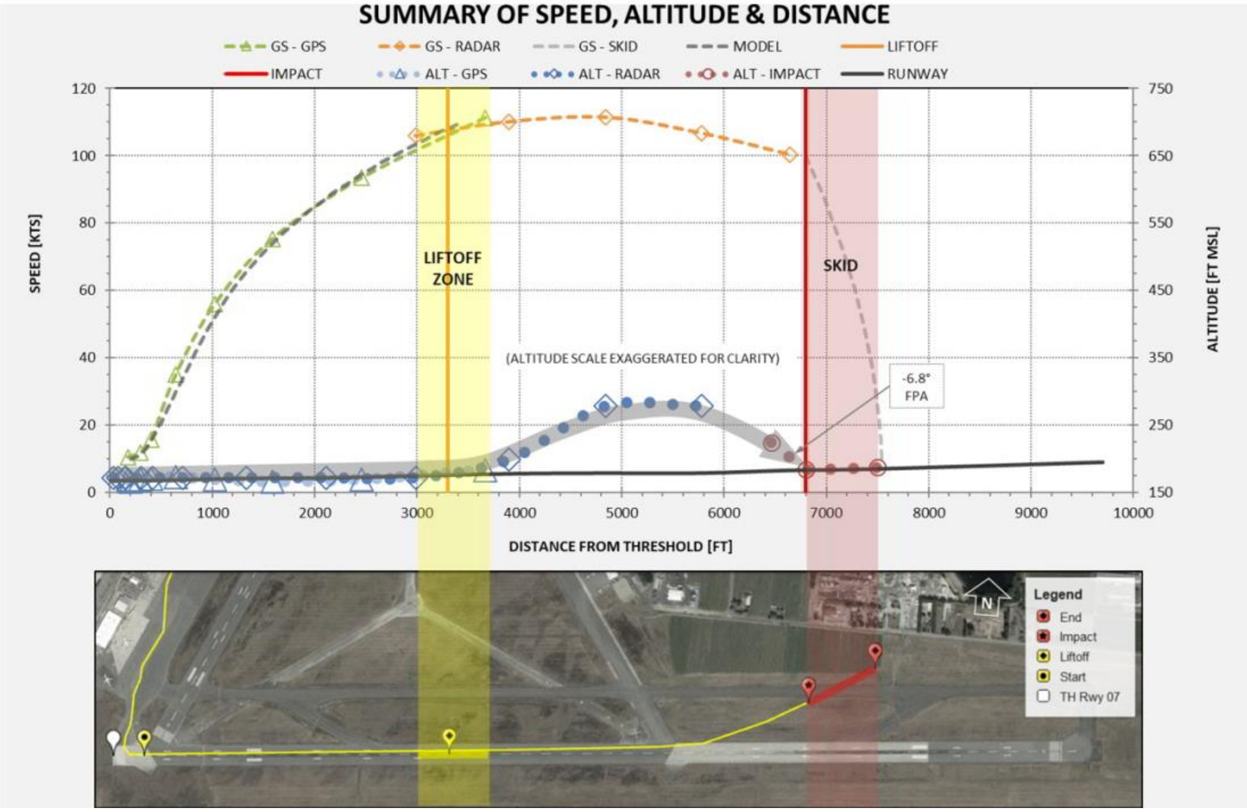

Figure 3: Reconstruction of the path taken by the occurrence aircraft
Note: The "Model" line represents the predicted runway performance based on the aircraft flight manual, aircraft loading and environmental considerations. (Source: TSB)

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. 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. 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 seven minutes of exposure.

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[3] Mode S transponder altitude is given in 25-ft increments.

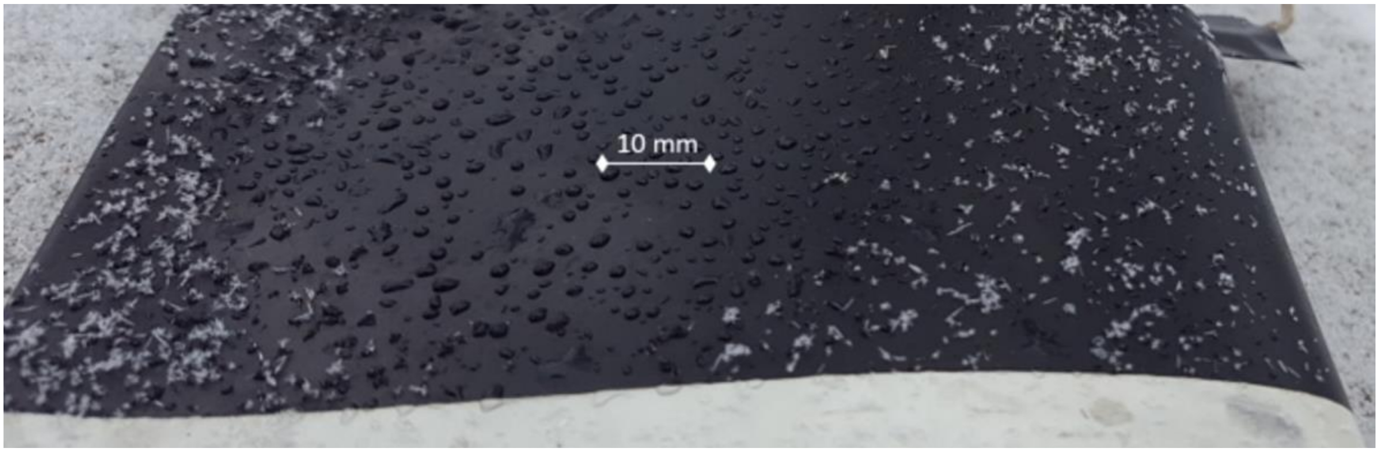

Figure 4: Cooling test showing melted flakes and ice crystals

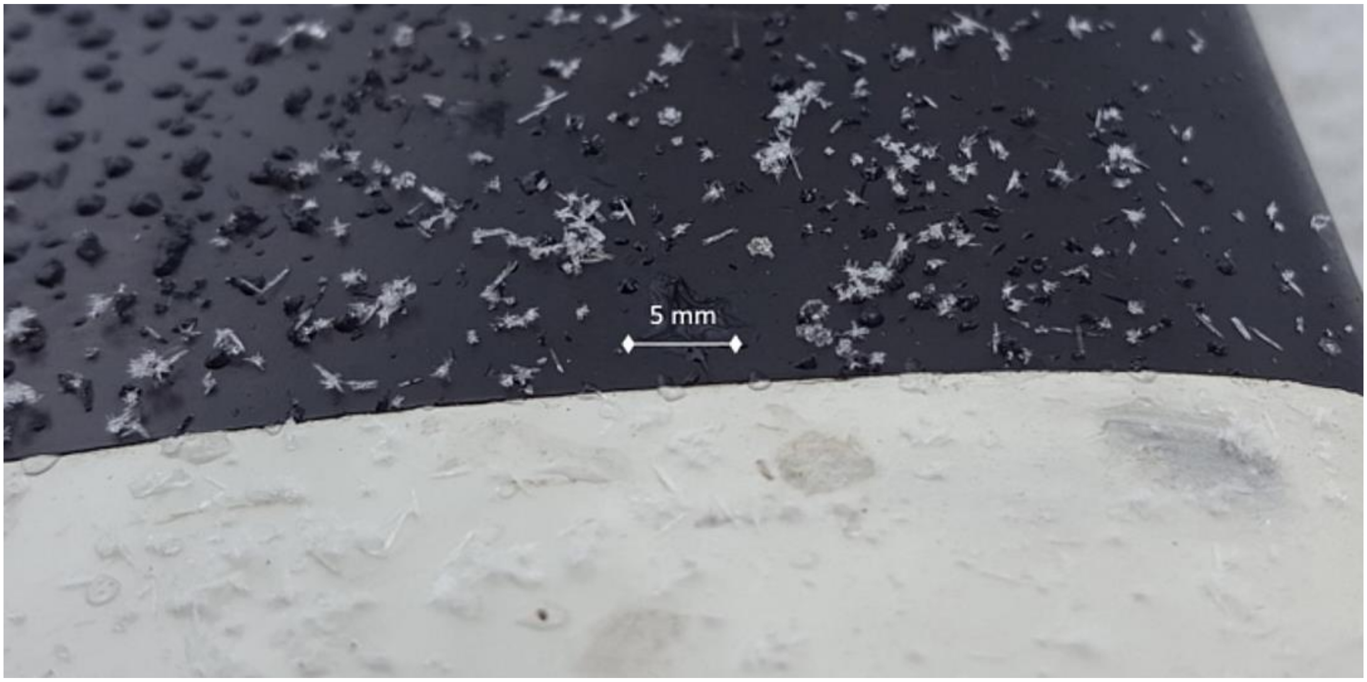

Figure 5: Cooling test (close-up)

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 (Figure 4). As the surface reached 0°C, ice crystals began to grow from the water drops (Figure 5).

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 3 mm and was difficult to see on the white paint (Figure 6). 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 take-off. 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 (Figure 7).

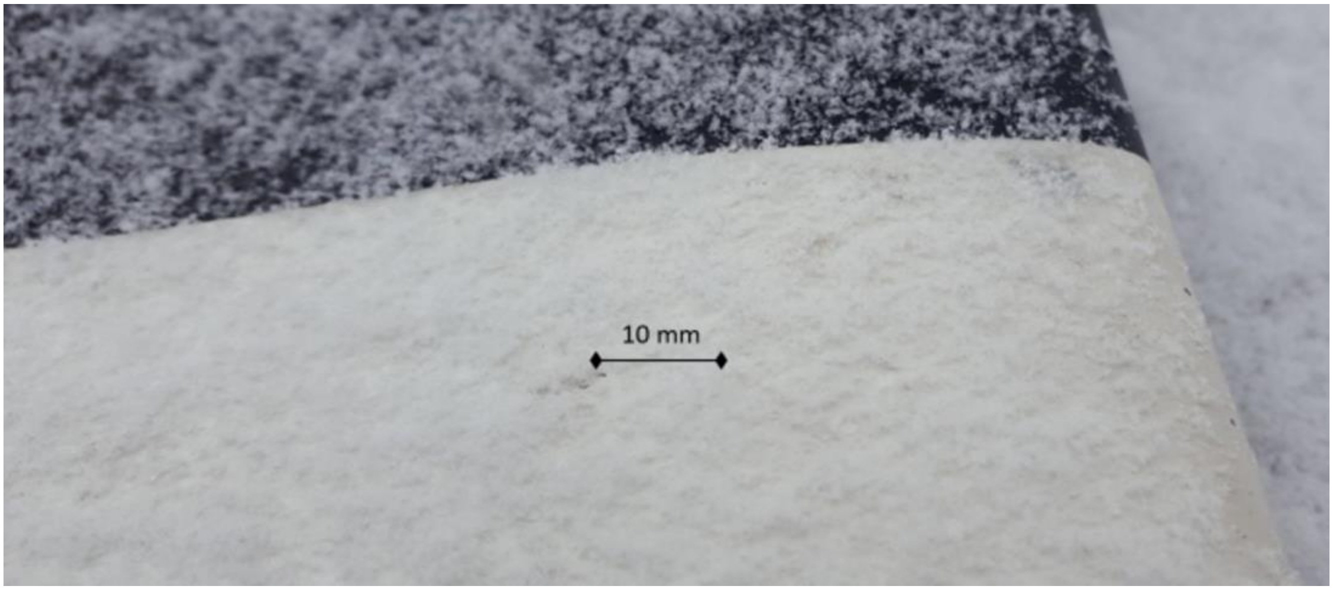

Figure 6: Cooling test after additional snowfall

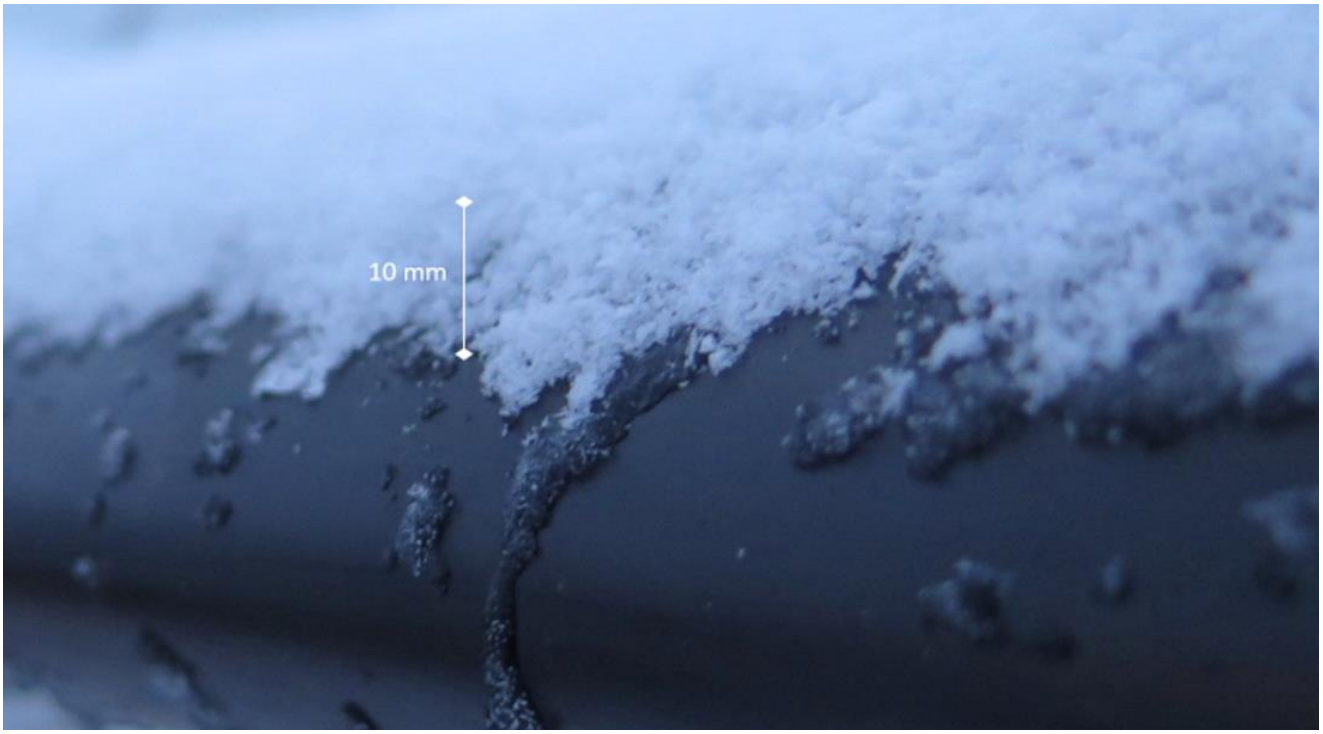

Figure 7: Occurrence wreckage demonstrating the melt/re-freeze process approximately 8 hours after the occurrence

De-icing capabilities at Island Express Air Inc.

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

Ground icing

Snow and ice adhering to the aircraft can have a profound impact on aircraft performance. For that reason, *Canadian Aviation Regulations* (CARs) 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"[4] —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," and the aircraft is not operated under Subpart 5 of Part VII or subject to an operator's established aircraft inspection program, 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."

Standard 622.11 of the CARs, Ground Icing Operations, identifies two types of inspections: a critical surface inspection and a pre-take-off 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, take-off can occur only if a pre-take-off contamination inspection is completed or the aircraft is de-iced or anti-iced again.

The pre-take-off 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. 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-take-off contamination inspection.

If snow and ice are not removed before take-off, 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. 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. Even almost imperceptible amounts of ice can cause performance penalties comparable to much larger, easily visible ice accumulations. 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. This concern is echoed in the TC *Aeronautical Information Manual* (TC AIM) and states that "misconceptions exist regarding the effect on performance of frost, snow or ice accumulation on aircraft." According to TC's Technical Publication (TP) 10643, "test data indicates that during take-off, 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%."

Similarly, other studies have determined that as little as 1/16 inch of icing can increase stall speed by around 20%. For these reasons, ground icing presents a significant risk, particularly during the take-off phase when the aircraft

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[4] *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.

is operating extremely close to its stall speed, and there is much less altitude for recovery should a stall occur shortly after take-off.

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.

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. 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 take-off roll."

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.

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 take-off 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.

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 wing is considerably more efficient. However, the benefits of ground effect vanish when the aircraft's height is approximately equal to its wingspan.[5] 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.

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 re-freeze. 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. The

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[5] The occurrence aircraft's wingspan is approximately 46 ft.

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.

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 that plans are 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. 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. 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. Continuation bias is best described as “the unconscious cognitive bias to continue with the original plan in spite of changing conditions” or “a deep-rooted tendency of individuals to continue their original plan of action even when changing circumstances require a new plan.” 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.

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. These breakdowns in SA can result in non-optimal decisions being made, which could compromise safety.

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. 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.

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.

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.

Aerodynamic stall on take-off

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 take-off. When the aircraft took off, its indicated airspeed reached a peak of approximately 110 kt, 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 take-off, 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.

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 take-off. 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.

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 ATC 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 take-off with an aircraft contaminated with ice and snow adhering to its critical surfaces.

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 CARs. 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.

Aircraft loading

In this occurrence, the aircraft had a full fuel load, nine passengers on board, and approximately 480 lbs 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 lbs 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 take-off.

The 480 lbs of baggage in the rear baggage compartment was 70 lbs 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.

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 zero 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.

Findings

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 take-off, 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 take-off 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.

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.

Other findings

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

Submission of *Aviation Safety Letter* (ASL) articles

Do you have an aviation safety topic you are passionate about? Do you want to share your expert knowledge with others? If so, we would love to hear from you!

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General information and guidance

The ASL's primary objective is to promote aviation safety. It includes articles that address aviation safety from all perspectives, such as safety insight derived from accidents and incidents, as well as safety information tailored to the needs of all holders of a valid Canadian pilot licence or permit, to all holders of a valid Canadian aircraft maintenance engineer (AME) licence and to other interested individuals within the aviation community.

If you are interested in writing an article, please send it by e-mail to TC.ASL-SAN.TC@tc.gc.ca in your preferred language. Please note that all articles will be edited and translated by the Transport Canada Civil Aviation (TCCA) Aviation Terminology Standardization Division and will be coordinated by the ASL team.

Photos

In order to captivate our readers' interest, we recommend that you include one or two photos (i.e., photo, illustration, chart or graphic) for each article, if possible. Please send us your photos as an e-mail attachment (preferably as a jpeg).

We look forward to receiving your articles. △

Civil Aviation Documents Issued Recently

Civil Aviation Safety Alerts (CASAs)

Document Nº	Issue number	Subject
CASA 2024-10	Issue 01 2024-10-10	Reported Incidents of GPS/GNSS Interference
CASA 2024-08	Issue 01 2024-07-18	Defects on the Tension-Torsion strap assemblies
CASA 2024-07	Issue 01 2024-07-10	Mitigation of Flight Deck Fires Originating from Lithium Batteries that are Not Part of the Aeroplane Type Design

Advisory Circulars (ACs)

Document Nº	Issue number	Subject
AC 521-010	Issue 01 2024-08-02	Airworthiness Directives
AC 700-024	Issue 04 2024-07-02	Required Navigation Performance Authorization Required Approach (RNP AR APCH): Special Authorization/Specific Approval and Guidance
AC 700-047	Issue 05 2024-06-28	Flight Crew Member Fatigue Management–Prescriptive Regulations
AC 571-024	Issue 06 2024-06-13	Documentation Required for the Installation of Parts onto Canadian Registered Aircraft
AC 903-001	Issue 02 2024-06-03	Remotely Piloted Aircraft Systems Operational Risk Assessment