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

AVIATION INVESTIGATION REPORT A16P0180

Loss of control and collision with terrain

de Havilland DHC-2 (Beaver), C-GEWG
Laidman Lake, British Columbia, 11 nm E
10 October 2016

Canada

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Summary

On 10 October 2016, at approximately 0820 Pacific Daylight Time, a privately operated de Havilland DHC-2 Beaver aircraft on amphibious floats (registration C-GEWG, serial number 842), departed from Vanderhoof Airport, British Columbia, for a day visual flight rules flight to Laidman Lake, British Columbia. The pilot and 4 passengers were on board. Approximately 24 minutes into the flight, the aircraft struck terrain about 11 nautical miles east of Laidman Lake. The 406 MHz emergency locator transmitter (ELT) activated on impact. The ELT's distress signal was detected by the Cospas-Sarsat satellite system, and a search-and-rescue operation was initiated by the Joint Rescue Coordination Centre Victoria. One of the passengers was able to call 911 using a cell phone. The pilot was fatally injured, and 2 passengers were seriously injured. The other 2 passengers sustained minor injuries. The aircraft was substantially damaged. There was no post-impact fire.

Le présent rapport est également disponible en français.

Factual information

History of the flight

At 1430[1] on 09 October 2016, the pilot and 4 passengers met at the pilot's place of business in Saskatoon, Saskatchewan, to go on a hunting trip to the Cariboo region of British Columbia. Their plan was to drive overnight to Vanderhoof Airport (CAU4), British Columbia, where the pilot kept his aircraft, and then fly to his recreational property on Laidman Lake, British Columbia. At approximately 1730, the group loaded a pickup truck with their personal belongings and left for the drive to Vanderhoof. The pilot drove the first leg of the trip, to Edmonton, Alberta. The group departed Edmonton at approximately 2300. The pilot slept in the back seat of the truck for approximately 5½ hours while another member of the group drove.

The group arrived in Vanderhoof at approximately 0500 on 10 October. They stopped for breakfast and then drove to the airport. Following arrival at CAU4 at around 0645, the pilot slept for 1 additional hour in the truck.

At CAU4, the group transferred their belongings from the truck to the aircraft, a de Havilland DHC-2 Beaver on amphibious floats (registration C-GEWG, serial number 842). The cargo was loaded into the aft area of the cabin, but was not weighed or secured. A small number of personal items were placed in one of the compartments of the aircraft's amphibious floats. The pilot fuelled the aircraft with 131 L of aviation fuel (AVGAS), and the pilot and passengers boarded the aircraft. The 3 rear-seat passengers fastened their lap belts, and the passenger in the right-hand front seat fastened his lap belt and shoulder harness. The pilot fastened his lap belt. Although the pilot normally used the shoulder harness, he did not fasten it before the occurrence flight.

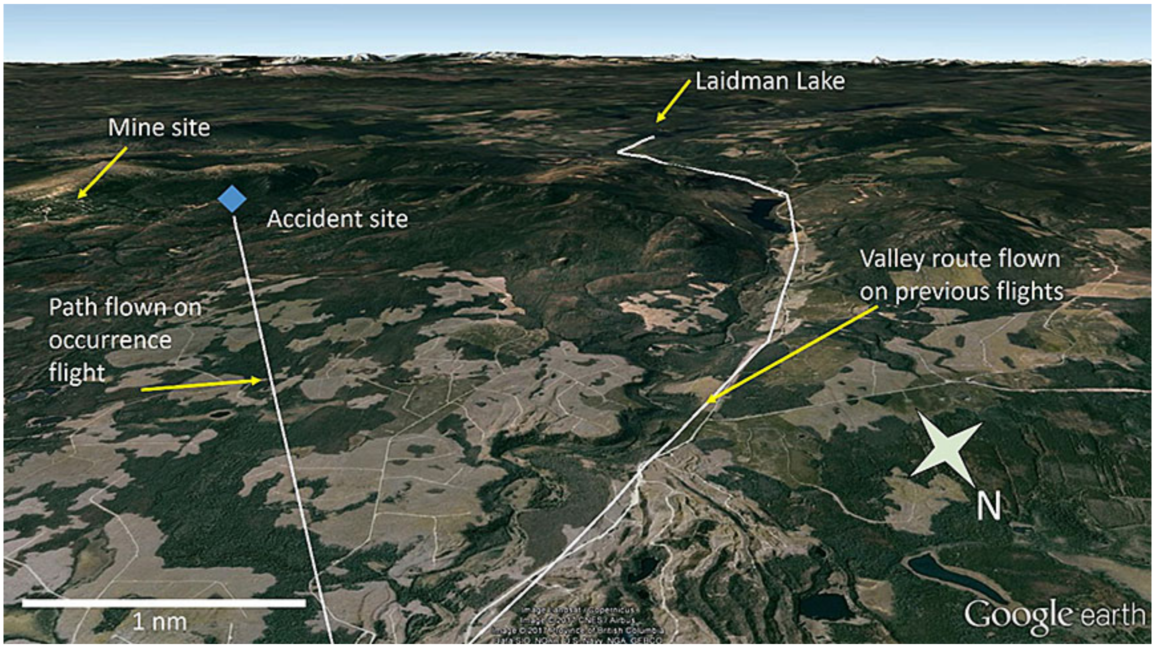
The aircraft departed CAU4 at about 0820. Shortly after takeoff, the pilot reduced the aircraft's engine power to a climb power setting and climbed to about 500 feet above ground level (AGL). The pilot made no further changes to engine power for the rest of the flight.

On previous trips to the recreational property, the pilot had usually flown a direct track for the majority of the route and then entered and followed a river valley that led to Laidman Lake (Figure 1). Ground elevations along that valley routing remained relatively constant at about 3100–3200 feet above sea level (ASL). Accordingly, for approximately 20 minutes after departure, the flight continued in a southwesterly direction at approximately 300–500 feet AGL. When the aircraft was about 12 nautical miles (nm) from Laidman Lake, the pilot diverted from the usual route and turned the aircraft to fly over a mining exploration site located on higher terrain east of the lake. Ground elevations in that area rise from 3200−4600 feet ASL over a distance of about 4.5 nm. The aircraft continued to

1 All times are Pacific Daylight Time (Coordinated Universal Time minus 7 hours).

fly at a constant altitude over the rising terrain for about 4 minutes until its height above the hillside had decreased to approximately 100 feet above the trees.

Figure 1. Aerial view of the general flight area from the direction of CAU4 (Source: Google Earth, with TSB annotations)



The pilot then banked the aircraft steeply to the left toward lower terrain. The aircraft rolled abruptly further to the left, then to the right and again to the left. At about 0844, the aircraft struck the trees and the ground.

The aircraft was substantially damaged on impact. The baggage stored in the aft cabin area was thrown forward by impact forces and struck the aircraft occupants. The pilot was fatally injured, and 2 passengers were seriously injured. The 2 other passengers sustained minor injuries. The 406 MHz emergency locator transmitter (ELT) activated on impact. The ELT's signal was detected by the Cospas-Sarsat satellite system, and a search and rescue operation was initiated by the Joint Rescue Coordination Centre (JRCC) Victoria. One of the passengers was able to call 911 using a cell phone, and the call was transferred to JRCC Victoria so that he could assist them in locating the accident site.

Wreckage and accident site examination

The wreckage was found in a snow-covered, uniformly forested area approximately 1.5 nm northwest of the mine site and 11 nm east of Laidman Lake. The aircraft was substantially damaged when it struck trees and the ground (Figure 2). There was no post-impact fire.

Figure 2. Photo of the accident site showing the aircraft wreckage, as viewed from the direction of flight

The aircraft entered the trees in a wings-level, slightly nose-high attitude, at an elevation of approximately 4600 feet ASL. The initial impact occurred when the aircraft's right horizontal stabilizer struck the treetops. The aircraft then continued through the trees in the direction of flight for approximately 130 feet before pitching forward and striking the ground in a steep nose-down and right-wing-low attitude. The aircraft came to rest nose down and semi-inverted (Figure 3).

Figure 3. The occurrence aircraft at the accident site

The majority of the wreckage was located near the fuselage. Both wings and both floats had separated from the fuselage, and each of these components showed impact damage resulting from contact with the trees. All of the control surfaces were accounted for, and examination of the flap system indicated that the flaps were in the up (0°) position at the time of impact. All damage to the airframe was attributable to impact forces. The fuel selector was found set to the forward tank, which contained sufficient fuel for the remainder of the flight to Laidman Lake. Damage to the engine and propeller were consistent with a high power setting at the time of the occurrence.

The aircraft's flight instruments were severely damaged. The engine tachometer, manifold pressure gauge, carburetor temperature indicator, and portable global positioning system (GPS) were removed and sent to the TSB Engineering Laboratory for further examination. The manifold pressure indicator showed damage consistent with aircraft impact at a high engine-power setting. The GPS unit did not provide usable data.

The aircraft's 406 MHz ELT activated on impact and transmitted a signal until search-and-rescue personnel arrived.

Weather

Weather data was obtained from the Environment and Climate Change Canada weather-reporting station at Ootsa Lake, British Columbia, and from an automated station 1.5 nm from the occurrence location. At the time of the occurrence, there were high cirrus clouds, the temperature was −5 °C, and winds were light and variable from the northwest. The altimeter setting was 30.09 inches of mercury, there was no precipitation, and flight visibility was unlimited.

Pilot information

Records indicate that the pilot was certified and qualified for the flight in accordance with existing regulations. He had held a private pilot licence since 15 January 2016 and had accumulated approximately 280 hours of flying experience. The majority of that flight time (211 hours) had been acquired in a single-engine 4-seat Cessna 182E. The pilot had completed 7.1 hours of float training and was issued an endorsement for a seaplane rating on 20 June 2016.

The pilot had purchased the occurrence aircraft in May 2016. He had accumulated 23.1 hours of flight time on the aircraft, of which 5.7 hours had been flown while the aircraft was configured with amphibious float landing gear. The pilot's amphibious float training on the occurrence aircraft had included takeoffs, landings, emergency procedures, slow flight, and stalls.

The TSB examined the pilot's sleep-wake history to determine whether any of the 6 risk factors[2] known to increase the probability of fatigue-related performance may have played a role in the occurrence.

On each of the 2 nights prior to the night before the occurrence, the pilot had obtained 5 to 6 hours of sleep at home. That duration was consistent with his normal routine of going to sleep at 2200 and waking up at 0300 local time. On the night preceding the occurrence, during travel by road to Vanderhoof, he obtained 6 to 7 hours of sleep, which was also consistent with his normal sleep routine. However, it is likely that the quality of that sleep was adversely affected by noise and motion during travel.

The investigation determined that there were no medical conditions affecting the pilot's ability to operate the aircraft at the time of the occurrence.

Aircraft information

General

The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The aircraft was not equipped with a stall warning system.

Weight and balance

The aircraft's empty weight at the time of the occurrence was 4036 pounds. According to the aircraft type certificate, the maximum allowable gross weight of the DHC-2 Beaver when configured with floats is 5090 pounds, which provides a useful load capacity of 1054 pounds.

The investigation determined that the aircraft was carrying 495 pounds of cargo and 209 pounds of fuel, and that the combined weight of its occupants was 1032 pounds. Its resulting total weight was 5772 pounds, with a centre of gravity (C of G) 9.2 inches aft of the datum (Figure 4), which placed the aircraft 682 pounds over its maximum allowable gross weight, with a C of G 3.1 inches beyond the aft limit.

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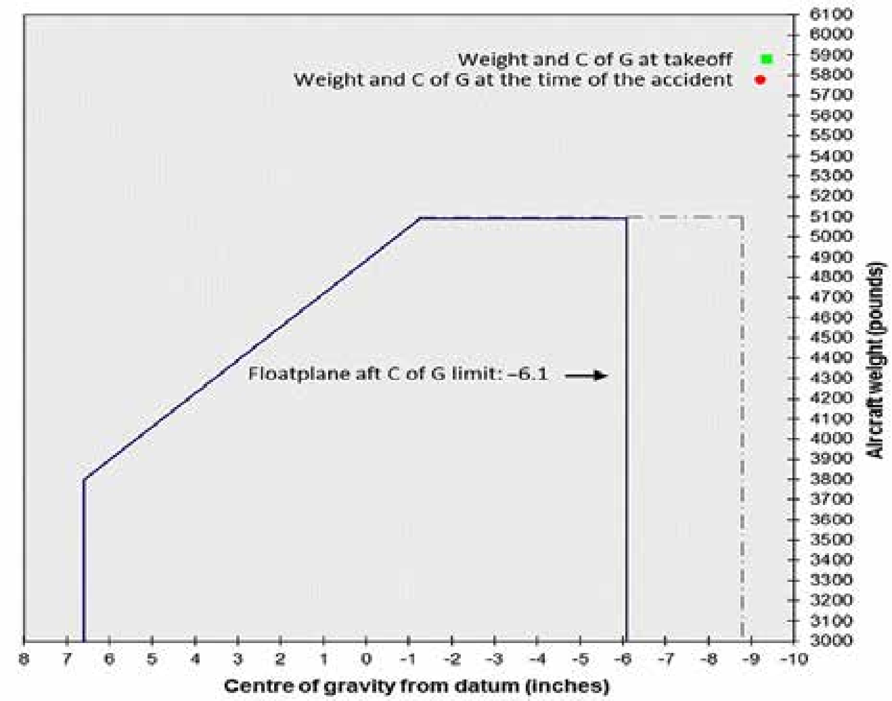
2 The 6 risk factors are acute sleep disruption; chronic sleep disruption; continuous wakefulness; circadian rhythm effects; sleep disorders; and medical and psychological conditions, illnesses or drugs.

Figure 4. Weight and centre of gravity of the occurrence aircraft



Survival aspects

General

Impact forces during the occurrence were focused primarily on the right side of the aircraft, resulting in more extensive damage to that side. The right float and right forward cabin sustained the most substantial damage. The engine, forward floor, and right-hand instrument panel were crushed inward, significantly reducing the occupiable volume of the front passenger side of the cabin. Although there was significant damage to the left forward cabin area, the occupiable volume of the pilot's side was not reduced. The pilot's seat had broken free of the aircraft's floor structure during the impact, fatally injuring the pilot, while the front passenger seat remained attached to the floor.

The 2 front seats were individual high-back seats composed of fibreglass and metal. At the time of the aircraft's manufacture, safety restraint belts on this type of seat consisted of lap belts that were attached directly to the seat. In 1994, the aircraft's 2 front seats were retrofitted with lap belts and shoulder harnesses in accordance with U.S. Federal Aviation Administration (FAA) Supplemental Type Certificate (STC) SA711GL. The modifications consisted of replacing the existing lap belts and adding a single-belt shoulder restraint at each front-seat position. STC SA711GL retained the aircraft manufacturer's original design, which incorporated lap-belt mounting to the seat. The additional shoulder harness extended from a structurally mounted inertia reel and was attached at the lap-belt buckle. When the shoulder harness was used, this design allowed partial load transfer to the aircraft structure.

Both front-seat restraint systems were removed from the aircraft for examination by the TSB Engineering Laboratory. Examination of the pilot's shoulder harness revealed that the inertia reel was not functioning correctly at the time of the occurrence. A component failure within the reel prevented the unit's locking mechanism from engaging. It could not be determined whether the pilot had been aware of this defect or whether it had influenced his decision not to use the shoulder harness during the occurrence flight.

Examination of the front passenger-seat restraint system found that it had functioned properly and that its webbing strength met the manufacturer's rating. During the occurrence, the shoulder harness inertia reel had broken off from the airframe following an overload failure of its mounting bolt.

The investigation determined that the rear seats had partially detached from the aircraft structure during the occurrence. The damage to the seats was consistent with the forward shift of the unsecured cabin baggage during the occurrence. The rear-seat passengers sustained injuries caused by the unsecured baggage in addition to aircraft impact forces.

Other TSB investigations[3] have identified unsecured baggage as either a contributing factor or a risk finding. In its investigation into a July 2010 occurrence involving the loss of control and collision with terrain of a DHC-2 Beaver aircraft at La Grande Rivière Airport, Quebec,[4] the TSB found that during the impact, the unsecured baggage shifted forward, causing the rear triple seat to pivot forward and propel the 3 rear-seat passengers up against the pilot and front-seat passenger.

Emergency locator transmitter

In 2016, following its investigation into the May 2013 controlled flight into terrain occurrence involving a helicopter at Moosonee, Ontario,[5] the TSB found that more than half of all Canadian-registered aircraft that require an ELT are being operated with a 121.5 MHz ELT signal that is not detectable by Cospas-Sarsat.[6] It further concluded that if Canadian regulations are not amended to reflect the standards of the International Civil Aviation Organization, it is highly likely that non–406 MHz ELTs will continue to be used on Canadian-registered aircraft and foreign aircraft flying in Canada. As a result, flight crews and passengers will continue to be exposed to potentially life-threatening delays in search-and-rescue service following an occurrence. Therefore, the Board recommended that

> the Department of Transport require all Canadian-registered aircraft and foreign aircraft operating in Canada that require installation of an ELT to be

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3 TSB aviation investigation reports A07W0003, A09C0167 and A10Q0117.

4 TSB Aviation Investigation Report A10Q0117.

5 TSB Aviation Investigation Report A13H0001.

6 Cospas-Sarsat is an international satellite-based monitoring system that detects distress signals from emergency locator beacons on aircraft or vessels within Canada's search-and-rescue area of responsibility.

> equipped with a 406 MHz ELT in accordance with International Civil Aviation Organization standards.
>
> **TSB Recommendation A16-01**

The aircraft was equipped with a 406 MHz ELT capable of broadcasting signals on 406 MHz and 121.5 MHz. When activated, the ELT transmits a continuous homing signal on 121.5 MHz and an alert-message signal to the Cospas-Sarsat satellite system every 50 seconds on 406 MHz.

Following the occurrence, the aircraft's ELT transmitted a 406 MHz alert message that included the aircraft's registration, location, and emergency contact details. The message was received by the Cospas-Sarsat satellite system, then relayed to JRCC Victoria at 0904. The JRCC attempted to reach the pilot's emergency contacts, but was unsuccessful.

At 0925, the JRCC initiated a search based on the coordinates transmitted by the ELT.

At 0927, the JRCC received a telephone call from the British Columbia Ambulance Service, which was in contact with one of the aircraft passengers. The call was transferred to JRCC Victoria, and the passenger was able to give a general description of the area in which the accident had occurred, but was unable to provide searchers with an exact location. The passenger remained in contact with the JRCC until the arrival of search-and-rescue personnel.

At 1157, JRCC aircraft were able to locate the passengers and wreckage using the coordinates provided by the alert message transmitted on 406 MHz and the homing signal transmitted on 121.5 MHz.

DHC-2 stall characteristics

General

In 1947, the DHC-2 Beaver was certified in accordance with the *British Civil Airworthiness Requirements* and its stall characteristics were found to be acceptable. At the time of certification, there was no requirement to include a stall warning system in the aircraft design.

The airspeed at which a stall occurs is related to the load factor of the manoeuvre performed. The load factor is defined as the ratio of the load acting on the wings to its gross weight, and represents a measure of the stress (or load) on the structure of the aircraft. By convention, the load factor is expressed in *g* (the unit of measure for vertical acceleration forces) because of the perceived acceleration due to gravity felt by an occupant in an aircraft. In straight and level flight, lift is equal to weight, and the load factor is 1 *g*. However, in a banked, level turn, greater lift is required. It can be achievedby, among other things, increasing the angle of attack (by pulling back on the elevator control), which increases the load factor. As the load factor increases with bank angle, there is a corresponding increase in the stall speed at which the stall occurs.

The DHC-2 Beaver flight manual indicates that when the aircraft is configured with flaps up, an unaccelerated aerodynamic stall will occur at an indicated airspeed of 60 mph. It goes on to state that, during the stall, "If yaw is permitted, the aircraft has a tendency to roll. Prompt corrective action must be initiated to prevent the roll from developing."[7]

A series of flight tests were conducted on the DHC-2 Beaver in 1995 by Aeronautical Testing Service Inc. (ATS).[8] The tests evaluated the stall characteristics, stall warning, and controllability of the stall in a variety of weight and balance configurations that were not specifically required by the original *British Civil Airworthiness Requirements*. The flight test report[9] identified that with a forward C of G, the Beaver's stall characteristics were acceptable. However, with an aft C of G and with power on, stall characteristics were found to be unacceptable in wings-level, turning, and accelerated stalls.

When an aircraft is manoeuvred with an aft C of G, there is more pitch-up authority than with a forward C of G. This condition permits a higher rate of pitch-up acceleration with the flight controls, which can result in a more severe stall than would occur in an aircraft with a forward C of G position.

Outstanding TSB safety concern

In 2012, the TSB conducted an investigation[10] into an occurrence involving a DHC-2 at Lillabelle Lake, Ontario. On arrival, a landing had been attempted across the narrow width of the lake, because the winds favoured this direction. The pilot was unable to land the aircraft in the distance available and executed a go-around. Shortly after full power application, the aircraft rolled quickly to the left and struck the water in a partially inverted attitude. It came to rest on the muddy lake bottom, partially suspended by the undamaged floats. The passenger in the front seat was able to exit the aircraft and was subsequently rescued. The pilot and rear-seat passenger were unable to exit and drowned.

During the investigation, the TSB found that, if a pilot does not recognize buffeting or misinterprets it as turbulence while at a low airspeed or high angle of attack, there is a risk that the warning of an impending stall will be unrecognized. A stall warning system providing visual, aural, or tactile warning can give pilots a clear and compelling warning of an impending stall.

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7 de Havilland Inc., *DHC-2 Beaver Flight Manual* (31 March 1956), Revision dated 28 July 2002, Section 4.11: Flight Characteristics, paragraph 4.11.5.

8 Aeronautical Testing Service Inc., based in Washington, D.C., United States, is an aeronautical consulting and manufacturing company involved primarily in the engineering, development, and manufacture of modifications for general aviation aircraft.

9 Aeronautical Testing Service Inc., Flight Test Report, Canadian de Havilland DHC-2 MK1, r/n C-FJOM, s/n 1024, TIA No. ST15969SE-A, 25 May 1995.

10 TSB Aviation Investigation Report A12O0071.

A large number of DHC-2 Beaver aircraft without a stall warning system installed continue to operate in Canada. See Appendix A for a list of TSB investigations of stall-related accidents involving DHC-2 aircraft without a stall warning sytem installed.

Stalls during critical phases of flight often have severe consequences. Therefore, the Board is concerned that the aerodynamic buffeting alone of DHC-2 aircraft may provide insufficient warning to pilots of an impending stall.

Previous TSB recommendation

In its investigation into an August 2015 occurrence[11] involving the loss of control and collision with the ground of a DHC-2 in Tadoussac, Quebec, the TSB found that the pilot involved had regularly conducted stall exercises under controlled conditions as an instructor. He was also aware of the DHC-2's more abrupt stall characteristics during steep turns. However, despite his experience, he was not able to detect the impending stall before control of the aircraft was lost.

To reduce the risk of losing control of the aircraft, the pilot must have an immediate, clear indication of an impending stall: immediate because it is urgent, and clear to prevent any possibility of mistaking the impending stall for another type of event. The aural and sometimes visual signal of an impending aerodynamic stall emitted by stall warning systems means they are one of the last lines of defence against accidental stalls.

In 2014, Transport Canada and the aircraft type certificate holder, Viking Air Limited, recommended that stall warning systems be installed; however, only 4 such systems have been installed on Canadian-registered DHC-2s. There are currently 382 DHC-2s registered in Canada, 223 of which are used in commercial operations.

Level of risk is determined by the probability and severity of adverse consequences. Given the number of DHC-2s without a stall warning system in commercial operations, combined with the fact that low-altitude manoeuvres are an integral part of bush flying, it is reasonable to conclude that a stall at low altitude is likely to occur again. Given the catastrophic consequences of stalls at low altitude, this type of accident carries a high level of risk.

Until, at a minimum, commercially operated DHC-2s registered in Canada are required to be equipped with a stall warning system, pilots and passengers who travel on these aircraft will remain exposed to an elevated risk of injury or death as a result of a stall at low altitude.

Therefore, the Board recommended that

> the Department of Transport require all commercially operated DHC-2 aircraft in Canada to be equipped with a stall warning system.
>
> **TSB Recommendation A17-01**

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[11] TSB Aviation Investigation Report A15Q0120.

While this recommendation would not apply to the privately operated aircraft involved in this occurrence, this accident underscores once again the potential benefits of having a stall warning system installed.

Spatial orientation and optical illusions

Cues for maintaining control of aircraft in visual flight

In visual flight, the primary reference pilots use to monitor aircraft attitude is the relationship between the horizon (line formed where the ground meets the sky) and some portion of the aircraft (such as the top of the instrument panel). As the aircraft assumes a more nose-up attitude to climb or for slower flight, the horizon line will move lower in the windscreen and less ground will be visible over the instrument panel.

In addition to flying by reference to the horizon, pilots also monitor the aircraft's instruments (which provide information on the aircraft's altitude, rate of climb, airspeed, power setting, etc.) to confirm that what is observed outside is consistent with the instrument readings and to ensure that the aircraft power setting and attitude are providing the desired aircraft performance. As the aircraft assumes a more nose-up attitude, if engine power is not changed, airspeed will decrease and the aircraft will transition to the slow flight speed range. Further attempts to maintain altitude by increasing the nose-up attitude of the aircraft will result in a further decrease in airspeed, and could lead to an aerodynamic stall.[12]

The horizon moving lower in the windscreen and less of the ground being visible over the instrument panel are the primary visual cues used by pilots to recognize an increasing nose-up attitude. When these observations are combined with decreasing airspeed and difficulty maintaining altitude without increasing power, the pilot should be prompted to lower the nose to increase airspeed, thereby increasing the margin of safety.

Cues relevant to judging speed, altitude, and time to collision with terrain

A number of external visual cues are relevant to judging speed, altitude and time to collision with terrain. These include:

- perceived size and depth of small- and large-scale terrain features, which allow pilots to judge their height above ground and time to collision with terrain (e.g., smaller-sized trees with small gaps between them appear farther away)
- optical flow,[13] which is also used to estimate the height above ground, speed, and time to collision with terrain, especially when positional cues are reduced or lacking. Closer objects move more rapidly in the optical flow field compared to the relatively

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12 Transport Canada, TP 1102, *Flight Training Manual – Aeroplane*, 4th edition (2004), pp. 73–74.

13 Optical flow is a phenomenon whereby the rate at which objects appear to flow outward from a central point decreases with increased height above the surface.

slow angular velocities of more distant objects and terrain.[14,15] Increased optical flow can provide an indication of increasing speed or decreasing altitude.

- dense vegetation on hills, which can help disguise an upsloping terrain and lead to an underestimation of the slope,[16] making it more challenging to judge the time available to avoid approaching terrain.

Spatial orientation and optical illusions in mountainous terrain

In mountainous areas with rising terrain, the pilot's ability to make accurate judgments regarding the aircraft's attitude, altitude, and speed can be diminished; the horizon provided by the rising terrain is unlikely to represent the true horizon because the upsloping terrain often blocks reference to the actual horizon. Consequently, when approaching rising terrain, pilots may try to maintain a constant angle between the portion of the aircraft used as a reference point and the rising terrain by pitching the nose of the aircraft up. Reference to the aircraft instruments would be required to recognize the performance effects of the increased nose-up attitude.

If aircraft instruments are not consulted, the pilot will have more difficulty recognizing the performance effects associated with the nose-up attitude using external visual cues due to the additional illusions that result from being closer than usual to terrain.

When the terrain is snow-covered, the lack of features to provide scale may make it more difficult for the pilot to estimate height and distance. In diffuse light conditions, pilots may overestimate their altitude because the lack of contrast between the trees and the surrounding environment can give the impression that the trees are shorter than they actually are. Similarly, a snow-covered ridge may become less visible against a background of uniformly lit mountainous terrain.[17,18]

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14 J. M. Loomis, R. Klatzky, R. G. Golledge et al., "Nonvisual navigation by blind and sighted: Assessment of path integration ability," *Journal of Experimental Psychology*, Vol. 122, No. 1 (1993), pp. 73–91.

15 H. J. Sun, J. L. Campos, M. Young et al., "The contribution of static visual cues, nonvisual cues, and optic flow in distance estimation," *Perception*, Vol. 33 (2004), pp. 49–65.

16 F. H. Previc, "Chapter 7: Spatial disorientation in aviation: Historical background, concepts, and terminology," in: F. H. Previc and W. R. Ercoline (eds.), *Spatial disorientation in aviation (Vol. 203, Progress in astronautics and aeronautics)* (Reston, VA: American Institute of Aeronautics and Astronautics: 2004).

17 K. K. Gillingham and F. H. Previc, AL-TR-1993-0022, *Spatial orientation in flight* (Armstrong Laboratory, Brooks Air Force Base, TX: 1993).

18 Civil Aviation Authority of New Zealand, CAA Safety Publication, *Mountain Flying* (Wellington, New Zealand: March 2012).

TSB laboratory reports

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

- LP003/2017 – Safety Belt Restraint System Analysis
- LP015/2017 – Instrument Analysis
- LP246/2016 – GPS Data Recovery

Analysis

The examination of the aircraft did not reveal any engine or aircraft system failures or malfunctions. Therefore, this analysis will focus on pilot fatigue, optical illusions created by rising terrain, aerodynamic stall and the effects of aircraft loading on performance, and survivability.

Pilot fatigue

The TSB conducted a fatigue analysis to determine what role, if any, fatigue may have played in this occurrence. One of the 6 fatigue risk factors examined was found to have played a role in this occurrence: on the night prior to the occurrence, the pilot experienced mild acute sleep disruption. Although the pilot obtained his usual amount of sleep the night before the occurrence, it was likely of poor quality as it was obtained in the back of a truck en route to the Vanderhoof airport.

Although the pilot had obtained quality sleep at home the day before leaving Saskatoon, the investigation could not determine whether the quality of sleep obtained in the truck, the day before the occurrence, had been compromised to a degree that the pilot may have been in a fatigued state at the time of the occurrence. The decision to travel all night before undertaking the flight likely reduced the possibility of the pilot obtaining quality sleep, increasing the likelihood of impaired decision making due to acute fatigue.

If pilots do not obtain quality sleep during the rest period prior to flying, there is a risk that they will operate an aircraft while fatigued, which could degrade pilot performance.

Optical illusions

The prevailing conditions at the time of the occurrence were conducive to optical illusions associated with low-altitude flight over rising terrain. The lack of features to provide scale in the snow-covered terrain, together with the minimal contrast among the dense trees given the diffuse light conditions, likely disguised the upsloping terrain and the actual horizon.

These visual characteristics would have made it challenging to judge the distance of the aircraft from the rising terrain and may have led the pilot to underestimate the increasing slope and overestimate the time available to complete a successful turn away from it.

As the slope steepened, the perceived horizon would have moved upward in the windscreen, and the pilot may have pitched the aircraft up to maintain a constant angle between the pilot's reference point on the aircraft and the rising terrain. The increased nose-up attitude would have resulted in a reduction of airspeed, bringing the aircraft into the slow-flight speed regime. As the aircraft approaches an aerodynamic stall condition in this speed regime, coordinated flight is more difficult to maintain.

The increased optical flow resulting from flight closer to terrain as the pilot approached the first mountain ridge would have provided the illusion of increasing speed. Without periodic reference to the aircraft's instruments, the pilot may not have detected the decreasing airspeed resulting from the increased nose-up attitude.

There was no indication that the pilot recognized that an aerodynamic stall and a loss of control were imminent. In the moments before impact, power was not increased and the flaps were left in the 0° setting—indications that, at least until the initiation of the attempt to turn away from the mountain ridge, the pilot was unaware that the aircraft was approaching the stall speed.

As the aircraft approached the mountain ridge, the high overcast ceiling and uniform snow-covered vegetation were conducive to optical illusions associated with flight in mountainous terrain. These illusions likely contributed to the pilot's misjudgment of the proximity of the terrain, inadvertent adoption of an increasingly nose-up attitude, and non-detection of the declining airspeed before banking the aircraft to turn away from the hillside.

Aerodynamic stall

Aircraft handling

The pilot commenced a turn away from the hillside, suggesting that the pilot recognized that the aircraft was low and slow over the rising terrain and would be incapable of climbing over it. As the angle of bank increased during the turn, the stall speed also increased and the aircraft entered an accelerated stall.

Weight and balance

The pilot did not weigh or secure the cargo and did not calculate the aircraft's weight or centre of gravity before departure. At the time of the accident, the aircraft was 682 pounds over its maximum weight and its centre of gravity was 3.1 inches beyond the aft limit. The aircraft's out-of-limit weight-and-balance condition increased its stall speed and degraded its climb performance, stability, and slow-flight characteristics. As a result, its condition, combined with the aircraft's low altitude, likely prevented the pilot from regaining control of the aircraft before collision with the terrain.

Stall warning

Given that the aircraft was not equipped with a stall warning system, the stall occurred without aural or visual warning. It is reasonable to conclude that the absence of a stall warning system deprived the pilot of the last line of defence against an aerodynamic stall and the subsequent loss of control of the aircraft.

Survivability

Cargo securement

When the aircraft struck the ground, the unsecured cargo shifted forward, hitting the passengers and the pilot. As a result, the rear seats were damaged and partially detached from the aircraft structure.

The forward shifting of the unsecured cargo and the partial detachment of the rear seats during the impact resulted in injuries to the passengers. If cargo is not secured, there is a risk that it will shift forward during an impact or turbulence and injure passengers or crew.

Occupant restraint system

Although the pilot's normal practice was to wear both the lap belt and the shoulder harness while flying, he was not wearing the shoulder harness during the occurrence flight. Examination of the pilot's shoulder harness revealed that the inertia reel was not functioning correctly at the time of the occurrence. The investigation could not determine whether the pilot had been aware of this defect or whether it had influenced his decision not to use the shoulder harness during the occurrence flight.

The design of the shoulder harness is such that, when it is not used, the portion of load normally transferred to the aircraft structure remains in the area of the lap-belt-attachment points.

During the impact sequence, the load imposed on the pilot's lap-belt-attachment points was transferred to the seat-attachment points, which then failed in overload. As a result, the seat moved forward during the impact and the pilot was fatally injured.

Emergency locator transmitter

Although one of the passengers was able to call 911 and give search-and-rescue personnel a general description of where the aircraft had crashed, the passenger was not able to provide searchers with an exact location. Because the aircraft was equipped with a 406 MHz emergency locator transmitter that transmitted an alert message to the Cospas-Sarsat satellite system in combination with the homing signal transmitted on 121.5 MHz, the Joint Rescue Coordination Centre aircraft was able to locate the wreckage and occupants in a timely manner.

Findings

Findings as to causes and contributing factors

1. As the aircraft approached the mountain ridge, the high overcast ceiling and uniform snow-covered vegetation were conducive to optical illusions associated with flight in mountainous terrain. These illusions likely contributed to the pilot's misjudgment of the proximity of the terrain, inadvertent adoption of an increasingly nose-up attitude, and non-detection of the declining airspeed before banking the aircraft to turn away from the hillside.

2. As the angle of bank increased during the turn, the stall speed also increased and the aircraft entered an accelerated stall.

3. The aircraft's out-of-limit weight-and-balance condition increased its stall speed and degraded its climb performance, stability, and slow-flight characteristics. As a result, its condition, combined with the aircraft's low altitude, likely prevented the pilot from regaining control of the aircraft before the collision with the terrain.

4. The absence of a stall warning system deprived the pilot of the last line of defence against an aerodynamic stall and the subsequent loss of control of the aircraft.

5. The forward shifting of the unsecured cargo and the partial detachment of the rear seats during the impact resulted in injuries to the passengers.

6. During the impact sequence, the load imposed on the pilot's lap-belt attachment points was transferred to the seat-attachment points, which then failed in overload. As a result, the seat moved forward during the impact and the pilot was fatally injured.

Findings as to risk

1. If pilots do not obtain quality sleep during the rest period prior to flying, there is a risk that they will operate an aircraft while fatigued, which could degrade pilot performance.

2. If cargo is not secured, there is a risk that it will shift forward during an impact or turbulence and injure passengers or crew.

Other findings

1. Because the aircraft was equipped with a 406 MHz emergency locator transmitter that transmitted an alert message to the Cospas-Sarsat satellites system in combination with the homing signal transmitted on 121.5 MHz, the Joint Rescue Coordination Centre aircraft was able to locate the wreckage and occupants in a timely manner.

Safety action

The Board is not aware of any safety action taken as a result of this occurrence.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 17 January 2018. It was officially released on 24 January 2018.

Visit the Transportation Safety Board of Canada's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the key safety issues that need to be addressed to make Canada's transportation system even safer. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.

Appendices

Appendix A – TSB aviation investigation reports on stall-related accidents involving DHC-2 aircraft without a stall warning system

Occurrence	Fatalities	Summary
A15Q0120	6	The Air Saguenay (1980) inc. float-equipped de Havilland DHC-2 Mk. 1 Beaver (registration C-FKRJ, serial number 1210) stalled and crashed during a steep turn. The 6 occupants were fatally injured. The aircraft was not equipped with a stall warning system.
A14O0105	0	The Sudbury Aviation Limited float-equipped de Havilland DHC-2 Beaver aircraft (registration C-FHVT, serial number 284) stalled and crashed on approach to landing. The pilot and the passenger in the rear seat received minor injuries. The passenger in the right front seat was not injured. The aircraft was not equipped with a stall warning system.
A12O0071	2	The Cochrane Air Service de Havilland DHC-2 Mk.1 Beaver floatplane (registration C-FGBF, serial number 168) stalled and crashed during a go-around. The passenger in the front seat was able to exit the aircraft and was subsequently rescued. The pilot and rear-seat passenger were not able to exit and drowned. The aircraft was not equipped with a stall warning system.
A11C0100	5	The Lawrence Bay Airways Ltd. float-equipped de Havilland DHC-2 (registration C-GUJX, serial number 1132) stalled and crashed on departure. All 5 occupants were fatally injured. The aircraft was not equipped with a stall warning system.
A10Q0117	2	The Nordair Québec 2000 Inc. de Havilland DHC-2 Mk. 1 amphibious floatplane (registration C-FGYK, serial number 123) stalled and crashed on departure. Two of the 5 occupants were fatally injured. The aircraft was not equipped with a stall warning system.
A09P0397	6	The Seair Seaplanes Ltd. de Havilland DHC-2 Mk. 1 (serial number 1171, registration C-GTMC) stalled and crashed on departure. Six of the 8 occupants were fatally injured. The aircraft did not have a functioning stall warning system, which the TSB noted as a cause or contributing factor.
A08A0095	0	The Labrador Air Safari (1984) Inc. float-equipped de Havilland DHC-2 Beaver aircraft (registration C-FPQC, serial number 873) stalled and crashed during an attempted forced landing. Five of the 7 occupants were seriously injured. The aircraft was not equipped with a stall warning system.
A05Q0157	1	The float-equipped de Havilland DHC-2 Beaver (registration C-FODG, serial number 205) stalled and crashed during departure. The pilot, who was the only occupant, was fatally injured. The aircraft was not equipped with a stall warning system.

Occurrence	Fatalities	Summary
A04C0098	4	The Pickerel Arm Camps de Havilland DHC-2 Beaver (C-GQHT, serial number 682) stalled and crashed on approach. All 4 occupants were fatally injured. The aircraft was not equipped with a stall warning system.
A01Q0166	3	The Air Saint-Maurice Inc. float-equipped Beaver de Havilland DHC-2 Mk. 1 (registration C-GPUO, serial number 810) stalled and crashed on approach. Three of the 7 occupants were fatally injured. The aircraft was not equipped with a stall warning system, and the TSB noted this fact as a risk factor.
A01P0194	5	The Wahkash Contracting Ltd. de Havilland DHC-2 Beaver floatplane (C-GVHT, serial number 257) stalled and crashed on approach. All 5 occupants were fatally injured. The aircraft was not equipped with a stall warning system, and the TSB noted this fact as a finding.
A00Q0006	3	The Cargair Ltd. DHC-2 Beaver (C-FIVA, serial number 515) stalled and crashed during climb. Three of the 6 occupants were fatally injured. The aircraft was not equipped with a stall warning system.
A98P0194	0	The Air Rainbow Midcoast float-equipped de Havilland DHC-2 Beaver (C-GCZA, serial number 1667) stalled and crashed during an attempted overshoot. The occupants were not injured, but the aircraft suffered significant damage. The aircraft was not equipped with a stall warning system, and the TSB noted as a cause or contributing factor the fact that the pilot had no warning of the impending stall.