Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A11P0106

AERODYNAMIC STALL AND COLLISION WITH TERRAIN

PACIFIC FLYING CLUB
CESSNA 152, C-GZDR
HARRISON LAKE, BRITISH COLUMBIA, 10 NM W
05 JULY 2011

Canada

Aviation Investigation Report

Aerodynamic Stall and Collision with Terrain

Pacific Flying Club
Cessna 152, C-GZDR
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Report Number A11P0106

Summary

On 05 July 2011, at 1500 Pacific Daylight Time, a Pacific Flying Club Cessna 152 (registration C-GZDR, serial number 15281615) with a flight instructor and student pilot on board departed Boundary Bay, British Columbia, for a mountain training flight. At approximately 1630, the aircraft collided with terrain at an elevation of 2750 feet above sea level, about 10 nautical miles west of Harrison Lake, in daylight conditions. The emergency locator transmitter activated and was detected by the SARSAT system at 1636. The Rescue Coordination Centre in Victoria, British Columbia, was alerted, and a search was commenced. The aircraft was destroyed by impact forces, and the occupants of the aircraft were fatally injured. There was no fire.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

Before departure, the student ordered full fuel, completed the pre-flight inspection of the aircraft and the sign-out procedure, and then met with the instructor for the pre-flight briefing. Pacific Flying Club (PFC) policy prescribed that pre-flight briefings should involve between 30 and 60 minutes of discussion about the intended flight; for mountain-flying training, a briefing on the hazards of mountain flying was also required. The content of the accident-flight briefing is unknown; however, the instructor's past practices consistently included a discussion of mountain flying and the procedures to be followed.

For the mountain-flying training element, during the latter portion of the flight, PFC instructors traditionally required students to make a number of diversions to their course through the mountain passes. Along the way, the instructor would provide demonstrations of various techniques and challenge each student on various decision-making processes.

The accident aircraft departed the Boundary Bay Airport (CZBB), British Columbia, at 1500 [1] and followed the planned itinerary north to Whistler via Indian Arm for a touch-and-go landing at Pemberton Airport, before heading back toward CZBB via Harrison Lake. According to the accident student's navigational flight log found in the aircraft, the accident aircraft followed the flight-planned routing.

The trip was expected to take a total of 158 minutes and to consume 17 gallons of fuel, leaving about 7 gallons remaining (which is equivalent to just over 1 hour of fuel in reserve).

At 1636, an emergency locator transmitter signal was detected by the search and rescue satellite (SARSAT) system. The Rescue Coordination Centre in Victoria, British Columbia, was alerted, and a search was carried out. The accident site was located 10 nautical miles (nm) west of Harrison Lake.

1.2 Injuries to Persons

Table 1. Injuries to persons

	Crew	Passengers	Others	Total
Fatal	2	–	–	2
Total	2	–	–	2

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

1.3 Damage to aircraft

The aircraft was destroyed as a result of the impact forces.

1.4 Other Damage

Other than a small amount of remaining fuel spilling in the environment and evaporating quickly, no other damage could be found.

1.5 Personnel Information

Table 2. Personnel information

	Instructor	Student
Pilot licence	Airline transport pilot licence, Class 2 instructor	Private pilot licence
Medical expiry date	01 April 2012	01 August 2011
Total flying hours	1600	125
Hours on type	650	91.5
Hours last 90 days	177	6.8
Hours on type last 90 days	77	5.3
Hours on duty before occurrence	7.5	3
Hours off duty before work period	15	n/a

1.5.1 The Instructor

The instructor pilot held a valid airline transport pilot licence and instrument rating, with a Category 1 medical certificate without limitations. A holder of a Class 2 flight instructor rating, the instructor pilot occupied the right-hand seat as the pilot-in-command (PIC), and was providing both commercial pilot instruction and mountain-flying training to the student pilot.

The instructor had accumulated about 1600 hours of flight time, much of which was as a flight instructor on the Cessna 152 (C152) while employed by PFC during the previous 2 years. The instructor pilot had graduated from the flight school's college program with top honors, and was considered among the best instructors at PFC. The instructor was a senior instructor at the flying school, and was the ground-school instructor for the mountain-flying portion of the college program. The ground-school curriculum and classroom presentations were written and prepared by the instructor pilot, with the input and approval of management.

The instructor had worked 23 of the previous 30 days. The day of the accident flight was the instructor's third day of work following 2 days off. The instructor had finished work the previous day at about 1800, and started work around 0900 on the day of the accident. The instructor had already conducted 2 flights that day, and at the time of the accident, had been on duty for 7.5 hours. Medical information revealed no physiological conditions that could have contributed to the accident.

1.5.2 The Student

The student held a valid private pilot licence, with single-engine land and sea endorsements. The private licence had been completed in 2007, and the student had acquired approximately 125 hours toward a commercial pilot licence at the time of the accident. The majority of the student's training and flight experience had been on a C152. The student was at the top of the class, was hard-working and diligent, and was considered to have been a good student by the flying school, by peers, and by the instructors.

1.6 Aircraft Information

1.6.1 General

The C152 is a small aircraft that has proven over the years to be a reliable training aircraft. The accident aircraft had 14 079 hours on the airframe, and was maintained according to the manufacturer's standards.

The last 100-hour inspection was 97 hours before the accident; a 10-hour extension to the period before the next inspection time had been granted in accordance with PFC's *Maintenance Control Manual* (MCM). The aircraft had flown twice on the day of the accident, and there were no reported mechanical defects.

1.6.2 Weight and Balance

The *Canadian Aviation Regulations* (CARs) require that an aircraft be operated within the allowable weight-and-balance limits; however, there is no CARs requirement to document the weight-and-balance calculations. PFC policy required the pilot to initial the flight release form indicating that a weight and balance had been calculated, and to enter the specifics of the calculation into the logbook before flight. The student indicated on the flight release form that a weight and balance had been completed. When the logbook was examined, no information relative to the accident flight had been entered. Without detailed documentation, the details of the weight-and-balance calculations could not be determined.

According to the student's flight plan and the corresponding fuel records, the fuel tanks had been filled to capacity before start-up. Based on the items retrieved at the crash site and the weight of the pilots, investigators calculated that the weight of the aircraft at departure was 1714 pounds, which is 44 pounds over the maximum permitted gross take-off weight for the aircraft. At the time of the accident, the aircraft had been flying for 1.5 hours, and would have consumed about 53 pounds of fuel. Accordingly, the aircraft would have been under maximum gross weight and within the center-of-gravity limits at the time of the accident.

1.6.3 Stall Warning System

The stall warning system on the C152, including the accident aircraft, is a pneumatic type consisting of a calibrated air inlet on the leading edge of the left wing, and is attached to an air-operated horn near the upper left corner of the windshield, inside the wing root. Electrical power is not required, because it operates on low pressure produced as the wing approaches a stall. A partial vacuum occurs when the vent air is pulled through the horn, where a small metallic reed, similar to the reed in musical instruments, produces an audible sound in the cockpit. The stall warning system is calibrated to sound 5 to 10 knots above the actual stall speed. There are no other indicators, such as an angle-of-attack indicator, or warning systems, to warn of imminent stall.

The stall warning system used on the accident aircraft, as with most other aircraft, does not show the progression toward a stall. The device is either activated or not. A pilot can be unaware of the increasing angle of attack, and then surprised when the stall warning horn comes on. Once activated, the system does not differentiate between approaching a stall or stalled, and a pilot will not be able to determine how close to the actual stall the aircraft is. In contrast, an angle-of-attack detector, or lift detector, provides the pilot with a continuous representation of the aircraft's state of lift, which may assist a pilot to safely control the aircraft during critical manoeuvres. It should be noted that although angle-of-attack and lift detectors are available, they are not required by regulation, and are not commonly installed in small training aircraft.

1.7 Meteorological Information

The weather-reporting station closest to the accident site is about 30 nm away, at Hope, British Columbia. The stations surrounding the area were all reporting clear skies, unlimited ceilings and visibilities, with light winds. At 1700, the outside air temperature at Hope was reported as 26°C. Weather reports and observations both indicated the possibility of some turbulence in the area at the time of the accident. The turbulence would most likely result from convective activity associated with uneven daytime heating. The nearest upper wind forecast was for Vancouver, and for the time of the accident, winds were light from the northwest. There was insufficient upper-wind to produce mountain wave effects, but air flowing through the passes creates turbulence and associated rising and descending air. There was also rising and descending air as a result of the slope of the mountains, solar heating, and the cooling effects of the snowfields. The strength and depth of these thermal and mechanical currents of air were not determined.

The most relevant weather information was recorded by the student's smart phone video taken by the pilots 30 minutes before the accident; the sky was clear with unlimited visibility. The weather at the time of the accident was suitable for the flight that was being conducted.

1.8 Aids to Navigation

Not applicable to this accident.

1.9 Communications

Not applicable to this accident.

1.10 Aerodrome Information

Not applicable to this accident.

1.11 Recorded Video Information

Both the instructor and the student were carrying smart phones. [2] Besides the ability to make phone calls and send text messages, these phones also have global positioning system (GPS) capability, and are able take pictures and record video. The smart phones were examined [3] and found to contain no useful GPS tracks. The student's smart phone did contain a video that was taken during the flight, approximately 30 minutes before the accident. The video shows the instructor flying and the student holding the camera/phone, as the aircraft is flown over a ridge at low altitude, followed by a turning descent into a valley. The video data were such that the position of the aircraft was able to be deduced. The location was on the planned flight route about 35 nm north of the accident site.

The aircraft appeared to cross the top of the ridge at a height less than 100 feet above ground level (agl). The manoeuvre as it was conducted was not one of the prescribed actions that was planned to be taught as part of the mountain training flight, and was below the 500-foot agl limit that PFC had for such manoeuvres. According to the literature that was used as reference material for the course, ridge crossing should be at a height that is adequate to approach the ridge, suffer a loss of engine power, and still be able to turn away from the ridge. The procedures also state that ideally, the crossing should be at 45° to allow the aircraft to turn away should it be necessary to do so. As seen on the video, the ridge crossing did not follow these procedures.

1.12 Wreckage and Impact Information

The wreckage was examined both at the accident site and again at the Transportation Safety Board (TSB) regional wreckage examination facility. The aircraft was found on a steep hillside of rocks and low scrub trees at the 2750-foot elevation (Photo 1). The wreckage was on the north side of a narrow valley between Mount Kessler and Winslow Peak, in an open area surrounded by tall trees. The wreckage was oriented heading down the slope away from the pass. There was no evidence of damage to any of the surrounding trees. Ground scars and damage to the aircraft was consistent with the aircraft colliding with terrain at a low forward airspeed, in a steep, nose-down attitude of about 30°, in a right bank of about 75°. Based on the damage to the aircraft, the estimated velocity at the time of impact was approximately 100 feet per second (60

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2 Smart phones are mobile telephones with an operating system capable of many other functions. They generally are able to take pictures and video, provide email, and play games, and many have built-in GPS functionality.

3 Transportation Safety Board (TSB) Laboratory report *LP085/2011 – Cell Phone Examination*

knots) or less. The first ground contact had been with the right wing tip on a large boulder. The propeller and the right landing gear then struck the ground before the fuselage struck another large rock. The aircraft came to rest only 28 feet from the first contact point. The propeller slashed cleanly through a 5-inch diameter tree trunk, leaving a cut that indicated the propeller angle and engine power at the time of impact. Tree-strike damage and the deformation of the propeller indicated that the engine was producing significant power at the time of impact.

Both wings were extensively damaged; the wing center and cabin ceiling had been torn off with the wings still attached. The fuselage was broken behind the rear bulkhead, and the tail section was folded over the wreckage. The tail itself only suffered minor damage. The wing fuel tanks were torn open, spilling the remaining fuel, but there was no fire. While no fuel was found in the tanks, traces of fuel were found in the soil beneath the main wreckage. All major components remained loosely attached with cables and torn metal. Only some small parts were ejected, and were found no more than 35 feet down-slope from the main wreckage.

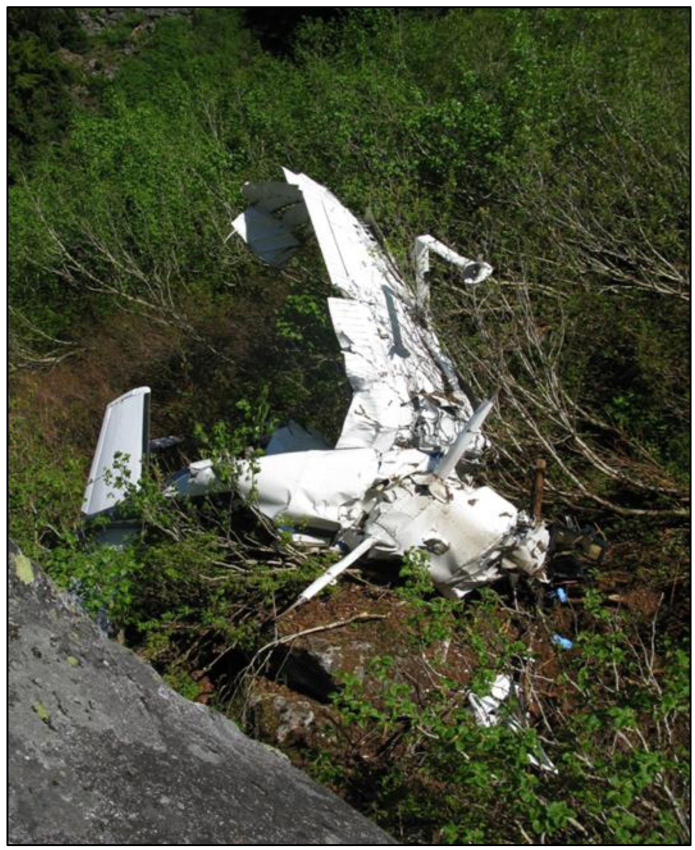

Photo 1. Wreckage of C-GZDR

The cockpit instruments were badly damaged; however, 2 instruments—the engine tachometer and the attitude indicator—were examined. Examination of the engine tachometer revealed a value of about 2400 revolutions per minute (rpm), which is consistent with high engine power being produced. Throttle position was all the way in after the crash; however, its position may not be indicative of its exact setting before the crash, due to the severity of the damage and the displacement of the engine compartment.

Examination of the attitude indicator revealed only that the internal gyro [4] was spinning at high speed, and did not give any useful information as to the attitude of the aircraft when it struck the ground. The clock mounted in the instrument panel was found stopped at 1630.

Examination of the flap actuator indicated that the flaps were in the up (0°) position at the time of impact.

4 The internal gyro of an attitude indicator normally spins at high speed to stabilize an artificial horizon.

All control surfaces were accounted for, and all damage to the aircraft was attributable to the impact forces.

The examination of the stall warning system on the wing revealed that the reed inside the horn was absent. Due to the extensive damage to the wing root area, the stall horn was exposed; the reed may have been dislodged during the accident or during the recovery of the wreckage. According to the aircraft manufacturer, the stall warning reed has been found dislodged after previous accidents. The investigation revealed that the stall warning horn was serviceable on previous flights on the day of the accident.

1.13 Medical and Pathological Information

Medical information about both pilots showed no physiological factors that could have contributed to the circumstances of this accident.

1.14 Fire

There was no post-impact fire.

1.15 Survival Aspects

The occupants remained within the aircraft, and both seat belts were found attached and buckled. Both pilot seats were badly deformed, indicating high vertical forces at impact. The engine and propeller were crushed upward into the cockpit firewall and instrument panel. The cockpit itself was largely intact, although the occupiable volume was reduced by the engine and forward floor being crushed in. The accident was not survivable due to the impact forces.

1.16 Tests and Research

The site of the occurrence is in a narrow canyon that branches off a larger valley. The floor of the valley rises steadily from Harrison Lake to the mouth of the canyon, where it then rises rapidly into the canyon. At the end of the canyon is a pass that is 3100 feet above sea level (asl) and leads to Stave Lake. Both sides of the canyon rise steeply, with slopes approaching 60°. Both sides of the pass were capped with snowfields starting at approximately 4000 feet asl and extending up to 6500 feet asl. The west side of the pass was in shadow below 4000 feet asl, while the east side of the pass was in bright sunshine. The investigation determined the likelihood that the aircraft turned in the canyon, resulting in a stall from a low altitude (Figure 1).

The canyon width above the occurrence site is approximately 1700 feet wide. At the altitude of the pass and at a typical manoeuvring speed of 70 knots indicated airspeed, the aircraft would have required approximately 900 feet of lateral spacing to reverse course using 45° of bank. There was only sufficient clearance to make that turn if the turn was initiated from close to either canyon wall. Starting the turn from the centre of the canyon requires an extreme bank angle, and there would be a risk of stall or collision with the canyon wall.

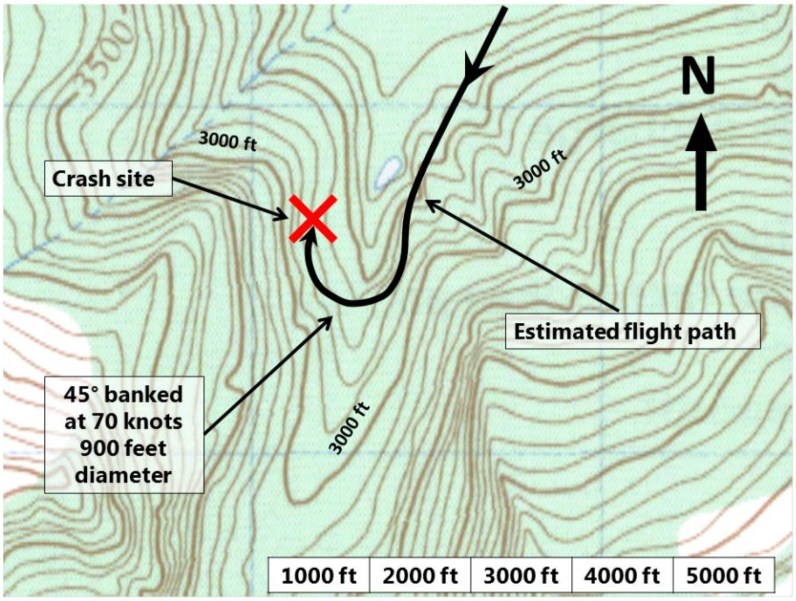

Figure 1. Estimated flight path and turn radius

To further examine the possible consequences of a turn in the canyon, a Level 2 flight training device (FTD) [5] was used to virtually fly through the accident valley to recreate the possible routing, altitude, and manoeuvres of the accident flight. The FTD used was a generic device that can be programmed to simulate many different aircraft types. For this simulation, the FTD was set up to represent a Cessna 172 (C172), as a C152 flight model was not available. The simulator was programmed to perform at maximum gross weight to simulate the performance of the accident aircraft, and was placed into the accident geographical area. In this configuration, a C172's flight characteristics are quite similar to a C152. The visual data for the flight are generated using satellite-based mapping technology, and are of sufficient quality that the features of the terrain are accurately depicted.

During the simulations, it became apparent that a turn in this location was very difficult and resulted in several crashes when the simulator was flown with the flaps up. From an altitude of 3000 feet asl, the aircraft was rolled into a 45° banked turn. If the bank angle was increased to 60° or more, the aircraft stalled and crashed 9 seconds after the beginning of the turn. The first several attempts resulted in crashes at the location of the accident. It became immediately apparent that the terrain blocks out all useful references to the horizon, and the desire to over-bank to avoid what looks like an impending impact is instinctual. With the use of full flaps and diligent use of instruments to maintain a 45° bank angle, the turn could be accomplished.

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5 Flight training device (FTD) Level 2 is a flight simulator that does not meet as high of a certification level as a true flight simulator. It may be a generic aircraft model, and may not have any physical motion to enhance the experience. It is safer and more cost effective than an actual aircraft for some flight training elements, and credit is given toward the pilot licensing process.

1.17 Organizational and Management Information

1.17.1 The Pacific Flying Club

PFC has been in business for 45 years, and currently operates out of CZBB. It provides flight training from ab-initio through to a commercial pilot licence with multi-engine instrument (IFR) rating. PFC has a fleet of 25 aircraft, consisting of C152s, C172s, Piper PA-28s, and Piper PA-34s. PFC also operates 3 different FTDs (simulators) at its Boundary Bay facility.

Although not required by regulation, PFC had established its own Safety Management System (SMS). In a review of its SMS records, several incidents were found regarding cross-country training flights in or near mountains. Although these incidents did not directly relate to the circumstances of this accident, the SMS process did identify some weaknesses with flight training in mountainous areas. One incident identified management oversight for mountain checks and cross-country flights as a possible corrective action, but did not provide for specific follow-up action.

PFC did not have a prescribed set of written descriptions or instructions on the various exercises to be included during the mountain training flight. Before being released to conduct mountain training flights, instructors were given a verbal briefing by the senior flight instructor on how to conduct mountain training. As well, the instructor would participate as an observer with another instructor during a mountain training flight. The location and profile of the flight exercises were at the instructor's discretion, leaving management unaware of the methods and practices that were actually being used by the individual instructors. Management did not check that instructors were conducting the training in the manner it intended.

1.18 Additional Information

1.18.1 Aerodynamic Stall

An aerodynamic stall occurs when the wing's angle of attack [6] exceeds the critical angle at which the smooth airflow begins to separate from the wing. When a wing stalls, the airflow breaks away from the upper surface, and the amount of lift is reduced to below that needed to support the aircraft.

The speed at which a stall occurs is related to the load factor of the manoeuvre being 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*. In a banked level turn, however, greater lift is required. It can be achieved, in part, by 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 speed at which the stall occurs. As a result, the

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[6] The angle of attack is the angle at which relative wind meets the wing. The angle of attack can be simply described as the difference between where a wing is pointing and where it is going.

manoeuvre is often accomplished with the addition of engine power to maintain airspeed. A stall that occurs as a result of a high load factor, such as bank angle increased beyond 30°, is called an accelerated stall. Accelerated stalls occur at higher airspeed due to the increased load factor on the wing, are usually more severe than unaccelerated stalls, and are often unexpected. As an example, a stall from a 60° or 70° bank will result in an aggressive departure from controlled flight that will result in the aircraft rapidly losing altitude.

From a steep angle of bank beyond 45°, a C152 aircraft will not remain in a stalled condition for more than a few seconds before it either enters a spin [7] or accelerates into a spiral dive. [8] At the stall speed in a steep turn, the aircraft's velocity is approximately 100 feet per second, and therefore, in the few seconds before the dynamics of the aircraft change from a stall, the aircraft would likely drop less than 200 feet. The aircraft could lose hundreds of more feet in the time it takes the pilot to react and recover the aircraft.

The typical recovery from a stall initially involves leveling the wings, releasing the back elevator pressure, or moving the elevator control forward (elevator down), and applying full or partial engine power. When the aircraft exhibits the first signs of recovery, a pilot gradually releases the nose-down pressure. As the recovery progresses and flight is regained, the nose-down pressure transitions to nose-up pressure (elevator up) to recapture the lost altitude.

1.18.2 Slow Flight Training

Transport Canada (TC) regulations state that all flight training shall be conducted in accordance with the applicable flight instructor guide, flight training manual, or equivalent document, and the applicable training manual on human factors. To comply with this requirement, flight instructors in Canada use TC guidance material [9] to develop lesson plans and to ensure that students are correctly taught to meet TC standards and gain the skill level needed to pass the flight test. Because of the range and amount of training required to become a pilot, it is not possible to test every manoeuvre during a flight test.

Slow flight training is taught to all student pilots in Canada to ensure that candidates have a feel for the decreasing performance of the wing in the low-speed portion of the flight envelope. It is described in the Canadian *Private Pilot Licence Flight Test Guide* as "the candidate's ability to establish the aircraft in flight near minimum controllable airspeed as indicated by a near-constant stall warning or aerodynamic buffet, to maintain flight control, to manoeuvre, while

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7 A spin occurs when a stall is allowed to progress into a deeper stall where 1 wing is providing less lift than the other. The aircraft enters a nose-down, steep angle of bank, and pivots around the vertical axis rapidly. The rapid turning makes it more difficult to recover from than a stall, and will result in more altitude loss.

8 A spiral dive is a steep descending turn with the aircraft in an excessively nose-down attitude. A spiral dive may be recognized by an excessive angle of bank, rapidly increasing airspeed, and a rapidly increasing rate of descent.

9 Transport Canada (TC), *Flight Instructor Guide* (TP 975); *Private Pilot Licence Flight Test Guide* (TP 13723); *Commercial Pilot Flight Test Guide* (TP 13462); *Guidance Notes: Private and Commercial Pilot Training – Stall / Spin Awareness* (TP 13747)

preventing a stall, at that speed and to recover promptly and smoothly to normal flight on command of the examiner." [10]

In Canada, the exercise is conducted by flying at a speed at which any further increase in angle of attack or in load factor, or reduction in engine power, will cause an immediate aerodynamic stall. To carry out this manoeuvre, the student slows the aircraft until the aural stall warning device sounds or the aircraft begins to exhibit characteristics of pre-stall buffet. It is important that the student use external visual cues and instrumentation to maintain this condition with a near-constant stall warning or aerodynamic buffeting; otherwise, the exercise is considered incomplete. As a result, slow flight training is routinely conducted with the stall warning system sounding.

This exercise is different from how it is conducted in some other countries and on larger commercial/airline aircraft. As an example, in the United States (US), slow flight is taught for the same purposes, but the flight training standards are specific in stating that the aircraft should be manoeuvred "at the slowest airspeed at which the airplane is capable of maintaining controlled flight without indications of a stall—usually 3 to 5 knots above stalling speed." [11] A similar approach is employed by the airlines, which teach their pilots to react and recover at the first indication of a stall, whether it is a warning device or pre-stall buffet. This lesson is done to reduce the risk of negative training that could result from repeatedly flying with the stall warning system sounding. The US literature goes on to say that it is important that the student use "both instrument indications and outside visual reference. It is important that pilots form the habit of frequent reference to the flight instruments, especially the airspeed indicator, while flying at very low airspeeds. However, a 'feel' for the airplane at very low airspeeds must be developed to avoid inadvertent stalls and to operate the airplane with precision."

1.18.3 Stall Training

Student pilots in Canada learn to identify stalls early in their training, and this learning is reinforced throughout the training process. Stall training is mandated in the CARs for all pilots. The requirement to demonstrate competency is identified in both the private and commercial flight test guides produced by TC.

With respect to stall training, the TC *Flight Instructor Guide* recommends training stalls and recovery from steep turns. [12] However, the TC flight test criteria do not require a specific angle of bank to be used for a turning stall on the flight test. A sample of local flight schools [13] determined that, in the absence of explicit direction, the generally accepted maximum amount of bank used for a turning stall is 30° or less. With the present training methods, a person can

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10 TC, *Private Pilot Licence Flight Test Guide*, TP 13723E (3rd edition, April 2010), page 14

11 Federal Aviation Administration (FAA), *Airplane Flying Handbook,* AA-H-8083-3A (2004), page 4-1

12 A steep turn is defined as a turn greater than 30° of bank.

13 During the investigation, the chief flight instructors and line instructors of at least 4 other schools on the west coast were sampled. According to the information gathered from this sample, most schools provided stall training to students at bank angles of 30° or less. Very few provided instruction with bank angles greater than 30°. If stall training was conducted beyond 30°, it was usually as part of a mountain-flying curriculum.

become a licensed private or commercial pilot without ever having experienced a stall with a bank angle greater than 30°.

The load factor for a 30° banked turn is 1.15 *g*. According to guidance in TC *Stall/Spin Awareness* (TP 13747), it is important to demonstrate the effects that a 60° bank turn will have on the stall speed and severity of the stall, and the actions required to recover from the stall.

The Cessna 152 is a docile aircraft with respect to stalls from a low bank angle. It gives good tactile input that a stall is beginning. Performance figures for the Cessna 152 show the flaps-up stall speed, with wings level and power off, occurring at an indicated airspeed of 38 knots. [14] The aircraft is easily recovered from these stalls with very little altitude lost. The same aircraft in a 60° bank will stall at 54 knots, and if the bank is further increased to 70°, the stall speed is estimated at 65 knots. [15] The recovery from a stall in a steep angle of bank will result in a greater altitude loss, and the resultant speed will be much higher. The flaps in the FULL down position will reduce the stall speed by 7 knots. All speeds mentioned are approximate, and are based on smooth air and ideal conditions; any turbulence will exacerbate the load factor and cause the aircraft to stall at a higher speed. [16]

At PFC, stalls were trained to a maximum of 30° of bank. This limitation was imposed by PFC's management, due to a belief that the C152 was not certified for accelerated stalls (beyond 30°). According to the aircraft manufacturer, the C152 is certified for all stalls (except whip stalls), [17] as long as the aircraft is flown within its operating envelope. The C152 manual says to use "slow deceleration" when entering a stall, and advises that "higher speeds can be used if abrupt use of controls is avoided." [18]

1.18.4 Mountain-flying Training in Canada

There are a number of challenges associated with mountain flying, and the scope and depth of knowledge that is required to safely fly through mountains is significant. A pilot needs to have a much broader knowledge of weather and winds specific to mountains, along with knowledge of the effects of density altitude, the illusions that deceive and trick the mind, as well as of procedures that would not be used anywhere else in aviation. In addition, pilots must be taught to rely on their instruments, as they may not be aware when they are encountering illusions caused by the surrounding mountainous terrain. This aspect can be particularly challenging for pilots with little instrument flight experience. Despite these challenges, there is no requirement

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14 This indicated airspeed is a calculated value of the stall speed given the accident aircraft's weight and center of gravity.

15 This stall speed is beyond the published values in the pilot's operating handbook, and is determined mathematically.

16 The application of power will change the stall speed of the aircraft. Although the value for this aircraft is not published, power generally decreases the stall speed, due to the thrust of the engine partially supporting the aircraft weight and to the increased airflow over the wing roots.

17 A whip stall is a stall in which an aircraft goes into a nearly vertical climb, pauses, slips backwards momentarily, and drops suddenly with its nose down. (Source: *Collins English Dictionary: Complete and Unabridged*, 2003)

18 According to the *C152 Pilot's Operating Handbook*, Section 2 − Maneuver Limits

in Canada for student pilots to undergo mountain-flying training before flying in mountainous areas.

In 1986, TC hosted a task group, [19] and mountain flying was one of the areas examined. From that review, several recommendations were made to change the private pilot ground-school curriculum to include instruction on mountain flying as described in the TC films on mountain flying. [20] Those recommendations have not been carried out. More recently, the TC *Aeronautical Information Manual* (AIM), section 2.13 states "The importance of proper training, procedures, and pre-flight planning when flying in the mountainous regions is emphasized." However, neither the AIM nor CARs define proper training in the context of mountain flying. For other flight operations, CARs defines proper training.

One of the past obstacles cited by TC to creating standards for mountain-flying training in Canada relates to the proximity to mountains for flight training. Pilots who do not live near a mountainous area may not have the opportunity to conduct actual flights in the mountains. However, advancements in simulation make it possible for pilots to experience some of the challenges of mountain flying without actually flying in the mountains.

Other countries have included mountain flying as required content of both private and commercial pilot licences. As an example, the New Zealand Civil Aviation Authority (CAA) has recently developed a comprehensive program to ensure pilots receive proper training for flight in the mountains. [21] The program includes, in part, the following:

- a comprehensive booklet on the hazards and on procedures to be used;
- a minimum experience level that an instructor must have to teach mountain flying;
- exercises and ground-school theory;
- a practical guide to safe teaching methods; and
- a comprehensive method of grading the student on proficiency.

In Canada, mountain flying is mentioned in many places during the private and commercial pilot training process, but there is no requirement to conduct ground instruction or a flight evaluation of a student's abilities or knowledge of mountain-flying practices.

The available literature from TC consists mainly of 4 written documents, the latest of which (*Take Five … for safety*) [22] was produced in 2007. *Take Five … for safety* was produced as a safety action in the aftermath of a 2006 occurrence (TSB aviation investigation report A06P0087) in which the lack of mountain-flying training standards was identified as a finding. Before 2007, TC's guidance on mountain-flying training consisted of 3 documents with similar names. *Tips*

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[19] Canadian Airspace Review, *Mountain Flying*, Task Group 1.5.1, Final Staff Study

[20] TC, *Mountain Flight (*TC V144) and *Flying the Mountains (*TC V017)

[21] Civil Aviation Authority (CAA) of New Zealand, *Mountain Flying Training Standards Guide – Private Pilot, Commercial Pilot, and Flight Instructor: Aeroplane* (2010)

[22] TSB Aviation Safety Letter, TP 2228-32 (01/2007), *Take Five ... for safety: Flying VFR in the Mountains*

on Mountain Flying, produced by Civil Aviation System Safety in the late 1990s or early 2000s, [23] is the oldest version. This version is 23 pages long and contains good information, particularly in the section "Do's and Don'ts of Flight Planning in the Mountains." However, it does not discuss canyon turns or provide an in-depth explanation of illusions in mountains.

A newer version of *Tips on Mountain Flying*, which was produced a few years later by System Safety Pacific Region, is 6 pages long, generic in nature, and contains very little information related to actual mountain-flying techniques, such as how to handle downdrafts, carrying out canyon turns, and proper route selection. It starts out in the first paragraph by stating that mountain flying can be extremely enjoyable, but that it has also has led to many accidents in blind valleys and poor weather, and to stalls. However, the article does not provide any recommended best practices if one encounters these dangers. In 1997, a 2-part series of articles entitled "Tips on mountain flying" was published in *Aviation Safety Letters* (ASLs) 4/97 and 1/98. These ASL articles consisted of a collection of thoughts and tips from a single author. The content contains some good information, but is generic in nature.

In conjunction with the written documentation, 2 videos were produced by, and are available through, TC. The first video, produced in 1982, is a compilation of mountain-flying accidents and their associated hazards and likely causes. The video does not provide the viewer with recommended safe practices. The second video, dated 1988, features Sparky Imeson as the principal source of information and narrator of the video. Sparky Imeson was considered to be the leader in mountain-flying training, having written several of the most common books on the subject. Although quite dated, the video gives good direction and information on the subject of mountain flying. However, the video does not address several key aspects of mountain flying, such as the best method of conducting a canyon turn, or the best course of action to take when encountering a strong downdraft.

One of the challenges for flight schools, instructors, and students involved in mountain-flying training is deciding what information is correct, what should be taught, and how it should be taught. Some mountain-flying topics are not well documented, and in other instances, information is sometimes conflicting. For example, although canyon turns and downdraft recoveries are mentioned in almost all of the literature and videos related to mountain flying, there is an absence of documented, authoritative techniques for conducting these manoeuvres. When comparing the various sources of information on these subjects, a pilot would not know which method would be the safest to adopt. Where a source or book has suggested a course of action, there may not be supporting documentation to show that the published procedure is the result of extensive testing. See Appendix B for a discussion related to 2 different techniques for dealing with downdrafts.

1.18.5 Mountain-flying Training at Pacific Flying Club

As previously mentioned, the instructor pilot prepared PFC's mountain-flying course training material. This material was prepared using reference material, the instructor's personal experience, as well as the experience of management personnel. Management routinely monitored instructor pilots' classroom instructional abilities and the content of the presentation.

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[23] Dates are approximate. No date is indicated on either of TC's *Tips on Mountain Flying*.

Many flight instructors teach what they have learned as students, which may allow weaknesses in the methods and procedures of mountain flying to be perpetuated. In the mountain-flying training program at PFC, college students receive a ground-school presentation and a book on mountain flying. There is no set of mountain-flying procedures published in any company-approved PFC manuals. As a result, instruction on mountain-flying techniques is limited to the ground school and any briefings carried out by instructors with their students. Students who do not take part in the college program taught at PFC do not receive the presentation, and the book is merely recommended to them. For those students, the instructor would typically spend some additional time during a pre-flight briefing to describe the mountain-flying information needed for that flight. To provide for those pilots not in the college program, or as a refresher, PFC does occasionally offer a mountain-flying seminar that anyone is able to attend.

The student in this accident did not receive the college ground-school course. The student likely received a 1-hour pre-flight briefing regarding mountain flying. It is not known what amount of pre-flight self-study was done, or whether the student pilot had attended the mountain-flying seminar.

There are many subjects taught in the PFC mountain-flying presentation. According to the company's presentation and several of the mountain-flying reference documents, it can be advantageous to fly on the upwind or the sunny side of the valley, as doing so will likely give the aircraft a performance boost due to the uprising air. As such, PFC instructors and students were taught to, and routinely did, fly on the sunny side of a valley. The instructor was also an advocate of flying on the sunny side of the valley. Much of the literature also cautions that where there is ascending air, there must also be descending air close by. The likely place for the descending air is on the opposite side of the valley, the shadowed or downwind side. In almost all cases, pilots are cautioned about the possibility of having to turn around in the valley and encountering descending air. If the aircraft is already in a reduced performance state and the pilot is trying to avoid rising terrain, a turn into descending air could be disastrous. The PFC material does not contain any reference to the cautions associated with conducting canyon turns toward a shaded side of the valley.

In addition, the instructor had added notes to the ground-school presentations regarding crossing a ridge. Those notes state that a ridge should be approached at an angle of 45°, so that one can easily turn away from the ridge if needed. The notes also indicate that a pilot should be wary if the mountain behind the ridge starts to disappear, which means that one has insufficient altitude to safely cross the ridge. The notes also advise crossing at altitudes of 2000 feet above the ridge in strong winds or 500 feet in light winds.

According to PFC's mountain-flying training presentation, there are 2 laws that must be followed when flying in mountainous regions. The 2 laws, as stated in the presentation, are as follows:

- The first law, which involves being able to turn away from the terrain while having some extra altitude to descend, encompasses the idea that one never enters into a canyon if there is not sufficient room to turn around.

- The second law requires the pilot to establish a turn-around point whenever flying upslope terrain. The point of no return is defined as a point on the ground of rising terrain where the terrain out-climbs the aircraft.

These 2 laws are described differently in various sources, but the intent is for the pilot to always be judging the flight path ahead of the aircraft to determine where an escape manoeuvre can still be safely made, and to never go beyond that point.

1.18.6 Canyon Turn Procedure

A common mountain-flying technique is the canyon turn procedure, which is a set of actions that are to be conducted in the event that a pilot needs to do an emergency turn in a confined area. Due to the nature of this manoeuvre, it will result in a turn with a small radius. To illustrate, Figure 2 compares the turning distances and levels of risk at different airspeeds for a small training aircraft, such as a C152 or C172. The diagram depicts the substantial reduction in the turning distance that can be accomplished by simply reducing speed and increasing the angle of bank to 45 degrees. The figure also shows that the risk of stalling becomes greater as the turning distance is reduced, and suggests an ideal compromise between the dangers of turning too tightly and approaching a stall, and the dangers of turning too widely and colliding with terrain.

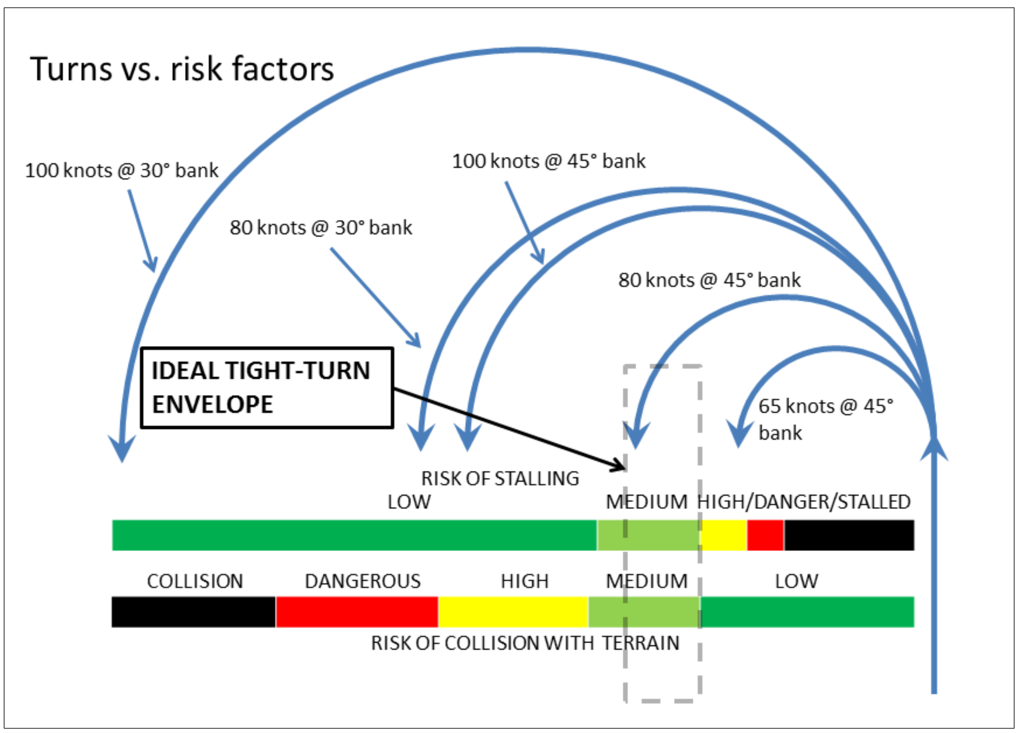

Figure 2. Comparison of the risk levels of turning distances at different airspeeds, based on speeds relative to small training aircraft (not for actual use)

There is no single, universally accepted canyon turn procedure, and there is no preferred method of determining the ideal canyon turn procedure for a specific aircraft type. However, it is widely accepted that planning is a critical aspect of the canyon turn procedure. While canyon turn procedures may share a number of similarities, one generic procedure will not work for every aircraft type. It is important that an appropriate canyon turn procedure be customized for each aircraft type, to ensure proper aircraft configuration. If an aircraft is improperly configured, performance will be degraded, and safety margins will be reduced. See Appendix C for a brief comparison of 3 sources of canyon turn procedure techniques.

While there are some differences between the 3 sources of canyon turn procedure techniques listed in Appendix C, all 3 sources recommend only partial flap. See Table 1 below for a comparison of the reference to flap usage. All 3 sources also advocate careful airspeed selection and control. There is also mention in the TC *Flight Training Manual* that power may have to be added while entering the turn. In addition to the above-cited references, *Mountain Flying* by Sparky Imeson also recommends that operators conduct "research prior to flight to determine best bank angles, speeds, to give turn area."

Table 3. Flap usage comparison

Flight Training Manual **(TP1102E, Transport Canada [TC])**	***Mountain Flying*** **(Doug Geeting and Steve Woerner)**	***Mountain Flying*** **(Sparky Imeson)**
Small amount of flap to increase safety margin.	Partial flaps at discretion.	Flaps can be used up to about one-half travel; beyond that, flaps will increase drag and become detrimental.

PFC developed its own canyon turn procedure (Figure 3), using 2 of the references cited in Table 1 [24] and the experience of its flight instructors. The most significant differences between the cited procedures and the PFC procedure are related to power management, the selection of full flaps, and the absence of a defined airspeed. There is no indication that PFC conducted specific flight testing to validate the canyon turn procedure in the C152 before it was introduced during its mountain-flying ground school, and the procedure was not incorporated into any company-approved manuals. Instead, it was shown to students during the mountain-flying ground school, or explained to students during the pre-flight briefing.

Figure 3. PFC canyon turn procedure

PFC canyon turn procedure

Power − to IDLE
Flaps − to FULL
Bank − 45 degrees
Power − to Full
Roll Out

According to senior management at PFC, it was not unusual for the stall warning horn to sound during the canyon turn procedure. The investigation determined that some students remembered hearing the stall warning horn while carrying out the canyon turn procedure with the occurrence flight instructor.

24 The Pacific Flying Club (PFC) offered 2 books as reference material for its mountain-flying training: *Mountain Flying* by Sparky Imeson (2nd Edition, 1982) and *Mountain Flying* by Doug Geeting and Steve Woerner (1st Edition, 1988).

1.18.7 Instructor-Student Interaction

One of the biggest challenges for an instructor is to allow a student to make mistakes. It is an established aspect of learning any activity that a person learns best by performing an activity, then identifying errors and correcting them. In flight training, it is called the demonstration-performance method, and it is the most useful way to teach flying. The adage used to describe it is "No one ever learns except through their own activity and there is, strictly speaking, no such art as teaching, only the art of helping people to learn." [25]

In the normal routine of flight training, these errors are caught and corrected repeatedly throughout the training process, without safety being compromised. During relatively routine exercises, an error will be allowed to exist until the student recognizes it, or until the instructor brings the error to the attention of the student and has the student then correct it. This is the best method for the student, as it allows the student the opportunity to learn the lesson by performing the action.

During critical phases of flight, an error may be allowed to exist for only a few seconds before the instructor takes control of the aircraft, makes the correction, and, once it is safe to do so, explains the error to the student. This is not the preferred method, and instructors prefer students to recognize and solve errors themselves.

An instructor must be prepared to allow a student to make errors, recognize those errors, and then rectify mistakes without compromising safety. The process of deciding which errors to allow, and for how long, is difficult for any instructor. The instructor adjusts this decision-making process based on personal experience and confidence, as well as on the student's experience and skill level.

There is always potential for an instructor to misjudge this fine point of when to take control or point out an error. In most exercises, the difference of a few seconds of indecision is not a dangerous error. In some exercises, it can be catastrophic.

1.18.8 Instructor's Training Techniques

The occurrence flight instructor was highly regarded by students, largely due to instructional style. The ground-school presentation contained notes made by the instructor, explaining that the visual aspects of mountain flying can be very deceiving, and that "You must do it; you cannot visualize what it is really like." In keeping with this approach, this instructor allowed students to recognize and learn from their mistakes, and was not hasty to intervene unless the situation was becoming dangerous. Although all instructors should do this to some extent, some are quicker to intervene than others.

The instructor had completed a number of mountain training flights on this same route with previous students. The actual number of mountain training flights could not be determined, as there was no record of this at PFC. Traditionally, the instructor conducted the mountain training flights according to the pre-planned flight plan, and each trip was similar with respect

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25 TC, *Flight Instructor Guide* (TP 975), 2004

to the location where the various exercises were carried out. In particular, the instructor would demonstrate a ridge-crossing procedure between Whistler and the Lytton Creek area. The instructor also demonstrated a canyon turn procedure during the earlier portion of the trip in the Squamish to Pemberton area, in a wider section of the valley and at an altitude of several thousand feet above the valley floor.

On past training flights, the instructor did not have the student practise the canyon turn procedure until they were actually in a valley on the return leg of the trip, usually in the Tretheway Valley, at a level below the tops of the mountains and in an area that was more confined than where the instructor had demonstrated it earlier in the flight.

1.18.9 Spatial Orientation and Optical Illusions

Spatial orientation refers to our natural ability to maintain our body orientation and/or posture in relation to the surrounding environment at rest and during motion. Humans are designed to maintain spatial orientation on the ground. The flight environment is hostile, unnatural and unfamiliar to the human body. The mind takes information from the eyes, the inner ear, and the body's muscle response to tell one how one is situated in the environment. Any acceleration other than gravitational acceleration confuses the sensory system. When the point that we perceive to be down is no longer pointing to the centre of the earth, it creates sensory conflicts and illusions that make spatial orientation difficult and, in some cases, even impossible to achieve.

A pilot must learn to ignore much of the body's physical feedback and rely on the eyes to establish reference, either visually with the environment or through instrumentation. During flight, 80% of orientation is dependent on the visual sense. [26] When the pilot has good external visual reference, the motion and position systems add to the visual system to give orientation and situational awareness. During flight without good external visual reference, the mind attempts to use the vestibular system (inner ear) to provide orientation information. However, the vestibular system may be misinterpreting the ongoing movements, and therefore cannot be relied on.

Visual orientation requires perception, recognition, and identification; one must determine one's position by understanding the size and location of other objects in relation to oneself. The images we perceive throughout our lifetime are stored in memory so that we may compare their size to our own position relative to them. For example, a 5-ton cargo truck is a known size; therefore, we can judge our distance from it.

Without experience and familiarity in the mountains, it is difficult to determine the scale, and therefore the distance, from the mountainsides when flying in close proximity to large mountains. In a confined area, a pilot must fly close to the side of the mountain to allow room to turn. This task can be difficult for those without experience, and students tend to be further from the mountains than they think they are (Figure 4 and Figure 5, courtesy of the New Zealand Civil Aviation Authority).

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26 Australian Transportation Safety Bureau, *Aviation Research and Analysis Report B2007/0063 – An overview of spatial disorientation as a factor in aviation accidents and incidents* (2007)

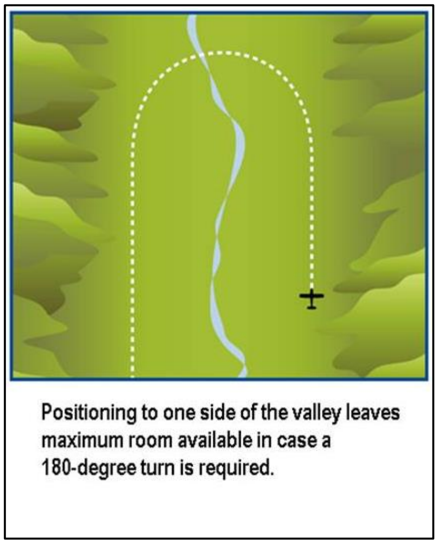

Figure 4. Good positioning

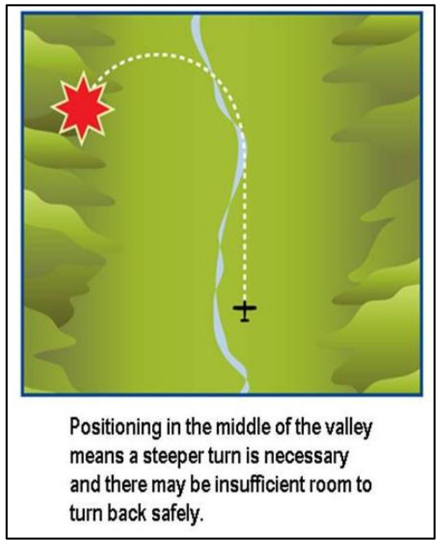

Figure 5. Poor positioning

Another illusion encountered while flying in the mountains is the inability to accurately define the actual horizon. [27] The mountains block the view of the actual horizon, and the pilot can perceive it to be higher than it is. This perception can cause the pilot to initiate a climb when trying to fly level. This slow climb can result in a loss of airspeed and an increasing angle of attack (Photo 2).

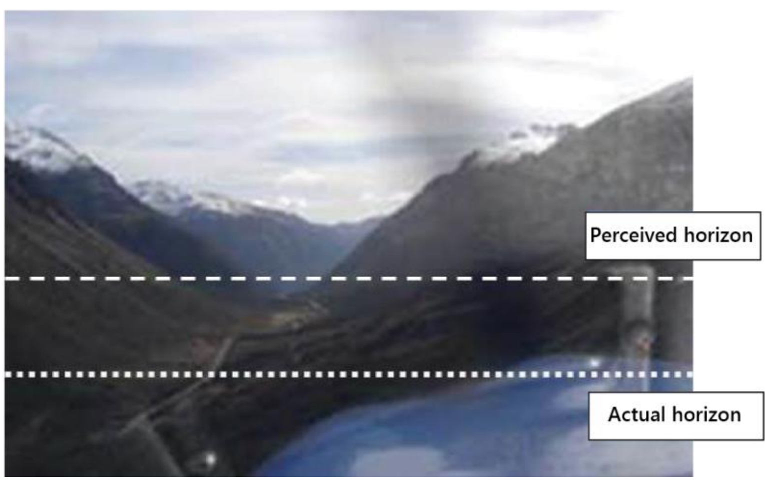

Photo 2. Actual and perceived horizon

Spatial disorientation can also occur when what one sees is tilted, such as a sloping cloud bank, or sloping terrain like the slopes of mountains. Disorientation associated with sloping mountain terrain is most noticeable when turning toward a mountainside, when the mountain completely blocks all reference to the actual horizon. If additional *g* force is applied while turning, it alters

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[27] The actual horizon is the line at which the sky and earth meet, ignoring irregularities and obstructions such as mountains.

the pilot's perception of down. This alteration can lead to errors in a pilot's perception of the true horizon.

The investigation determined, during simulator flight testing, that loss of the natural horizon, combined with sloping mountain surfaces, can make it very difficult to estimate the bank angle accurately. In addition, test candidates consistently demonstrated a tendency to over-bank the aircraft in an attempt to avoid the surrounding terrain.

To combat the effects of spatial disorientation, pilots are taught to rely on the aircraft's instruments. [28] When operating in the mountains, this reliance would necessitate the splitting of a pilot's attention between looking inside at the cockpit instruments and looking outside to ensure terrain avoidance. The transition from flying with visual reference outside the aircraft to instruments inside the cockpit, in what is immediately an emergency situation, is not taught to private or commercial pilots, and is very difficult to do when the pilot's underlying desire is to look outside. The illusions encountered in the mountains are dangerous for those who do not have the experience or the training to recognize and compensate for them.

1.18.10 Safety Management Systems and the Use of Flight Data Monitoring

The recent change in safety processes for aviation has been the implementation of SMS. SMS in Canada began with the larger air carriers, and eventually is to be expanded to all commercial operators. At the time of the accident, many companies were implementing their own systems to gain the benefits of an SMS. While some companies have embraced SMS, implementation of SMS in Canada has been challenging. In June 2012, the TSB released its updated Watchlist, which identified the safety issues investigated by the TSB that pose the greatest risk to Canadians. One of the safety issues identified in the Watchlist is SMS.

One of the strengths of SMS is the risk assessment process, whereby incidents are examined and decisions to improve safety are made based on safety gains and cost. The risk assessment process is an essential component of an approved TC SMS. PFC had established its own system and used it to enhance its safety management processes.

PFC management did not have a method of monitoring the flight in real time, and there was no immediate post-flight process to evaluate the activities of the flight. Instructors were monitored and graded on their abilities to conduct ground training. Senior instructors or management did not monitor an instructor's training methods during flight by periodically occupying an observer seat. Instead, senior instructors and PFC management used the students' abilities and performance as a measure of how well an instructor was teaching flying skills. Students were asked to provide feedback after the ground school, and college students were asked for feedback at midterm and at the end of the program.

In this occurrence, the in-flight video documented an act of which PFC management was unaware and which was not conducted as intended by management. There have been several accidents investigated by the TSB at other organizations, where it was concluded that management was unaware that an employee or instructor was operating in a manner

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28 Some instrument flight practices are taught to all private pilots, to enable them to have the basic ability to maintain flight with reference to instruments alone.

inconsistent with either TC regulations or company policy. An example is TSB investigation A09Q0065, which found that, unknown to management, the instructor was flying much lower than company policy allowed.

Flight data monitoring (FDM) has been implemented in many countries, and it's widely recognized as a cost-effective tool for strengthening a company's SMS. In the US and Europe—thanks to ICAO—many carriers have had the program for years. Some helicopter operators have it already, and the Federal Aviation Administration (FAA) has recommended it.

The development of lightweight flight recording system technology presents an opportunity to extend FDM approaches to smaller operations. Using this technology and FDM, these operations will be able to monitor, among other things, compliance with standard operating procedures, pilot decision-making, and adherence to operational limitations. Review of this information will allow operators to identify problems in their operations and initiate corrective actions before an accident takes place. There is no CARs requirement for a tracking system on aircraft.

In the event that an accident does occur, recordings from lightweight flight recording systems can provide useful information to enhance the identification of safety deficiencies in the investigation.

Therefore, the Board made a recommendation as part of the 2011 accident investigation A11W0048: that the Department of Transport work with industry to remove obstacles and develop recommended practices for the implementation of flight data monitoring and the installation of lightweight flight recording systems for commercial operators not required to carry these systems.

1.19 Useful or Effective Investigation Techniques

Video obtained from the student's smart phone provided investigators with valuable information related to the altitudes being flown by the instructor.

2.0 Analysis

The 2 occupants of the aircraft were fatally injured in the accident. There were no witnesses to the final moments of the flight, and there were no on-board recording devices to assist investigators. There was no indication that an aircraft system malfunction or the weather contributed to this occurrence. The aircraft impacted the ground in a steep, nose-down attitude, suggesting a stall and in-flight loss of control. This analysis will examine how the aircraft departed controlled flight and collided with terrain. In addition, the analysis will also discuss several issues related to pilot training, mountain flying, and flight data monitoring, in an effort to advance transportation safety.

2.1 Wreckage and Site Analysis

The steep, nose-down attitude and low forward speed are consistent with a situation of loss of control in flight. Both these conditions are consistent with the aircraft having conducted a steep right turn and stalling from a height less than 200 feet above the ground. Had the aircraft stalled at a higher altitude, the dynamics of the crash and the wreckage pattern would have been different. It is not likely that the aircraft had yet entered a spin, as the engine was found to be at a high power setting (the first step in the spin recovery procedure is to immediately reduce engine power), and there was still forward movement when the aircraft struck the ground.

2.2 Possible Accident Conditions and Actions

The accident occurred close to a route commonly used by the instructor for mountain-flying training. It could not be determined why the aircraft entered this canyon; but, with insufficient performance to climb above the terrain at the highest point of the pass, it is likely that the pilots executed a turn in the canyon. Since the left-hand (east) side of the pass would have been exposed to the sun, it is more likely that they were flying on the left-hand side of the valley and attempted a right-hand turn. This attempt would have resulted in a turn toward a shadowed, steeply sloping surface. The lack of references associated with flying in the valley would have made it difficult for the pilots to visually determine their angle of bank relative to the horizon (Figure 6).

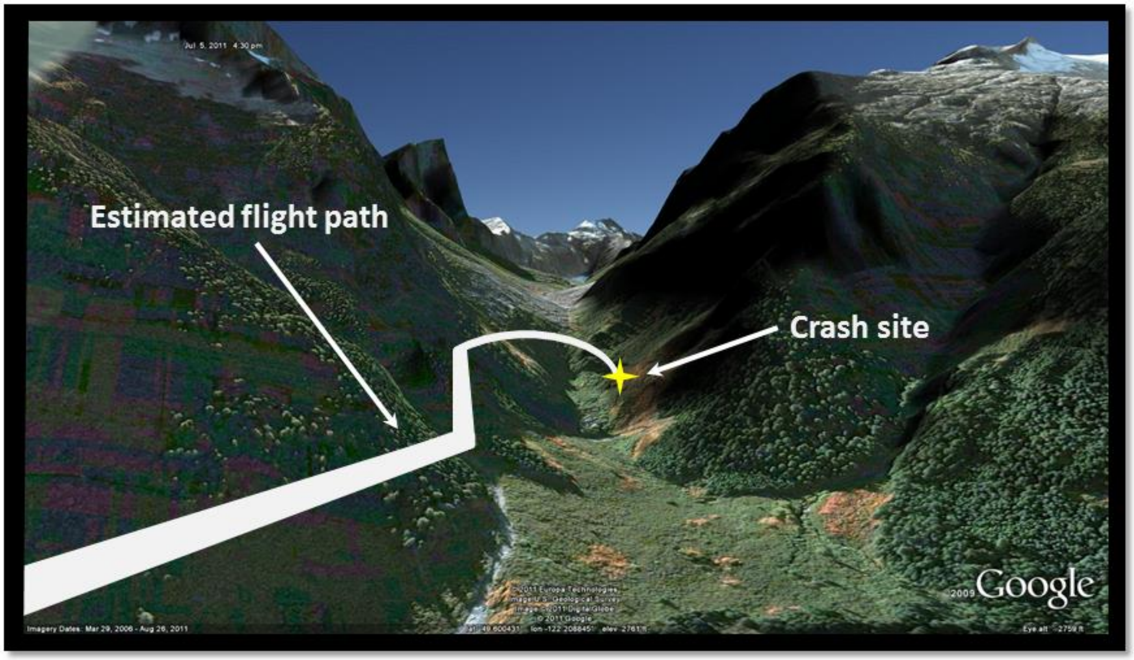

Figure 6. Estimated flight path with shadows at the time of the accident (Image: Google Earth)

It is not known why the aircraft was at such a low level before the crash. However, conducting a turn at a low altitude would have increased the risk level of the manoeuvre, and was not in accordance with PFC policy regarding minimum flight altitudes. If the instructor delayed the decision to initiate the turn-around, it would have further reduced safety margins. With the flaps in the up position, the stall speed would have been 7 knots higher than if the flaps had been down fully. In addition, it is possible that once the turn was initiated, the aircraft encountered a downdraft on the shadow side of the valley, which could have caused the aircraft to sink. If the pilots were not cross-checking their instruments, it is also possible that the loss of horizon and visual illusions caused by the surrounding terrain may have caused the pilots to inadvertently stall the aircraft while conducting the turn.

Although the throttle was found in a high power position, a reduction of power for even a few seconds during a critical manoeuvre would negatively affect aircraft performance. It is possible that the throttle was reapplied once the loss of performance was noted by the pilots. Any 1 of these factors, or a combination of all of them, could have caused the pilots to increase bank angle and increase angle of attack by pulling back on the control column, causing an aerodynamic stall. It is likely that the aircraft stalled aerodynamically while attempting a turn at an altitude from which the pilots could not recover before impact with terrain.

2.3 Other Operational Issues

2.3.1 Safety Management Systems and Flight Data Monitoring

PFC Management did not have a method of monitoring/tracking flights, nor was it required by regulation. There was no post-flight process to evaluate the activities of flights or the actions of the instructors. For example, management was not aware that the occurrence instructor was conducting ridge crossings at altitudes below the company-specified minimum flight altitudes, or that the instructor had the students practise canyon turns in relatively confined areas. As previously identified in TSB investigation A09Q0065 of an accident at another organization, management may not always be aware that aircraft are not being flown in accordance with company policy.

The occurrence aircraft was not equipped with any type of on-board recorder, nor was it required by regulation. Using lightweight flight recording system technology and FDM can help ensure compliance with standard operating procedures and adherence to operational limitations. It can also allow operators to identify problems in pilot decision-making and initiate corrective actions before an accident takes place. Without flight tracking or some system of post flight monitoring, there is a risk that management will not be aware of deviations from a school's standards that expose the flight to hazards.

In the event that an accident does occur, recordings from lightweight flight recording systems can provide useful information to enhance the identification of safety deficiencies in an investigation and the communication of safety deficiencies to advance transportation safety.

2.3.2 Weight and Balance

The occurrence aircraft departed over gross weight, but due to consumption of fuel, was under the maximum permissible gross weight at the time of the accident. The student had indicated, by initialling the flight release, that a weight-and-balance calculation had been completed. However, there were no details of the calculation, nor is it required by regulation. In addition, there was no established procedure at PFC to retain the information at the point of departure verifying that its aircraft were being operated within the approved weight-and-balance limits established by the manufacturer. If weight-and-balance calculations are not documented, there is increased risk that an aircraft will take off over the maximum approved gross weight.

2.3.3 Stall Warning Systems

Stall warnings systems are designed to alert a pilot of an impending stall. It is critical that a stall warning provide ample opportunity for the pilot to receive the warning and have time to avoid a stall. Unlike angle-of-attack indicators, the stall warning systems on many aircraft do not show progression toward a stall. As a result, pilots may be unaware that an aircraft is nearing a stall while manoeuvring until the stall warning system begins to sound. At that point, there may be insufficient time for the pilot to recover should a stall be encountered. Pilots sometimes fly with the stall warning on during some manoeuvres, eliminating the safety margin. An angle-of-attack indicator reduces the likelihood of an inadvertent stall situation, as the pilot receives a continuous indication of the aircraft's state of lift. The reliance on an aircraft's stall warning system, that provides little warning of an impending stall, increases the risk of a pilot inadvertently entering a stall.

2.4 Training

2.4.1 Slow Flight Training

In Canada, slow flight training is conducted to the point at which the aircraft is either exhibiting stall indications or the stall warning is on in a near continuous state. Other countries, and larger commercial air operators, avoid this practice to reduce the risk of negative training. Instead, pilots are taught to react and recover from a stall warning or other sign of an impending aerodynamic stall. If slow flight is conducted with the stall warning system sounding continuously, students and instructors can become desensitized to the warning. Therefore, if pilots are taught to fly with the stall warning activated during slow flight, there is increased risk that the aircraft may inadvertently stall during slow flight manoeuvring.

2.4.2 Stall Training

Despite the fact that Transport Canada (TC) has recognized the importance of training stalls at angles of bank greater than 30°, it is not a required item in the training. Flight test criteria do not require stalls from a steep turn or specify the angle of bank to be used for turning stalls. As a result, flight schools are allowed to establish their own angle-of-bank limitations for turning stalls. Many flight training organizations, including PFC, established a maximum angle of bank of 30°. As a result, pilots who encounter a stall at an angle of bank greater than 30° may not be familiar with the severity of such a stall, as well as the recovery characteristics in those situations. If pilots are not taught how to recognize and recover from high angle-of-bank stalls, there is an increased risk of collision with terrain if one is encountered.

2.4.3 Mountain-flying Training

Mountain flying presents many complex and challenging situations. There is no requirement for pilots in Canada to undergo mountain-flying training before flying in mountainous areas. In addition, there is no requirement for ground-school instruction, or a written test for mountain-flying training. As a result, pilots may receive no training or be left to self-study the available material. A pilot wanting to learn the correct methods of flight in the mountains does not have access to a set of acceptable standards to get that information. There is valuable information to be shared; however, without in-depth classroom instruction, a pilot might not gain adequate knowledge of the significant hazards of mountain flying and the recommended practices for avoiding them. In addition, advances in simulation make it possible for pilots to experience some of the challenges of, and gain the skills associated with, mountain flying. Without proper training in mountain-flying techniques, pilots and passengers are exposed to increased risk of collision with terrain when conducting mountain flying.

2.4.4 Canyon/Tight Turns

There is no one specific ideal canyon/tight turn that can be used on all aircraft types. Instead, a turn procedure should be developed for use with each type, to ensure safety and minimize turn radius. As identified in section 1.18.4 of this report, PFC relied on several different sources of information for developing its mountain-flying course and canyon/tight-turn procedure. There are significant differences between the reference procedures (Appendix C) and what PFC had developed: specifically, the use of flaps, application of power, and reference to airspeed. Several items on the PFC canyon turn procedure have been examined to define what effects the actions will have on aircraft performance and on the pilot's ability to safely conduct the manoeuvre.

The first action, the complete removal of power by pulling the throttle to IDLE, is intended to rapidly slow the aircraft, assuming that it is at a speed greater than that allowable for the application of full flaps. This action, if taken when the aircraft is already in a situation where all of its performance is required, such as climbing to clear terrain, would immediately and dramatically reduce the performance and speed of the aircraft.

The second action of applying full flaps is meant to slow the aircraft, and provides a safety margin by reducing the stall speed of the wing. The reference data recommend some flap; however, the application of full flaps produces high drag, and therefore lowers the performance of the aircraft during a turn where maximum performance may be necessary.

The rest of the actions are generally in agreement with the descriptions in the reference material. However, the PFC procedure does not define an airspeed that is to be maintained in order to provide a safety margin above the stall speed. The importance of defining this speed is mentioned in all of the reference material.

These are issues that should be addressed during the research and testing phases of introducing a new emergency procedure. As explained in *Mountain Flying* by Sparky Imeson, it is important that emergency procedures, such as the canyon turn, be researched and tested on a particular aircraft type before being introduced into flight operations. Therefore, if emergency procedures are not validated before implementation, there is increased risk that safety margins will be reduced due to unexpected performance degradation. In addition, if a flight school's standards and procedures are not incorporated into company manuals, flight instructors may deviate from company-approved methods of instruction.

3.0 Findings

3.1 Findings as to Causes and Contributing Factors

1. It is likely that the aircraft stalled aerodynamically while attempting a turn at an altitude from which the pilots could not recover before impact with terrain.

3.2 Findings as to Risk

1. If weight-and-balance calculations are not documented, there is increased risk that aircraft will take off over the maximum approved gross weight.

2. Without proper training in mountain-flying techniques, pilots and passengers are exposed to increased risk of collision with terrain due to the complex nature of mountain flying.

3. The reliance on an aircraft's stall warning system that does not show progression toward an impending stall increases the risk of a pilot inadvertently entering a stall.

4. If pilots are taught to fly with the stall warning activated during slow flight, there is increased risk that the aircraft may inadvertently stall during slow flight manoeuvring.

5. If pilots are not taught how to recognize and recover from a high angle-of-bank stall, there is an increased risk of collision with terrain if one is encountered.

6. If emergency procedures are not validated before implementation, there is increased risk that safety margins will be reduced due to unexpected performance degradation.

7. If a flight school's standards and procedures are not incorporated into company manuals, flight instructors may deviate from company-approved methods of instruction.

8. Without flight tracking or some system of post-flight monitoring, there is a risk that management will not be aware of deviations from a school's standards that expose the flight to hazards.

9. If cockpit and data recordings are not available to an investigation, this unavailability may preclude the identification and communication of safety deficiencies to advance transportation safety.

4.0 Safety Action

4.1 Safety Action Taken

4.1.1 Safety Action Taken by Pacific Flying Club

Following the occurrence, Pacific Flying Club implemented the following safety actions:

- Suspension of mountain-flying instruction pending review and analysis using safety management system (SMS) principles;
- The creation of a formal, regimented *Mountain Flying Training Syllabus*, and training for all instructors that includes defined procedures for canyon turns, minimum altitudes, mandatory routing, and standard operating procedures;
- Modifications to the mountain-flying program, including a ground school before flight, prescribed new routing, and the use of flight training devices to enhance pilot awareness of hazards;
- Mandatory written test on mountain-flying awareness to ensure students have comprehension of the principles taught before flight;
- Mountain-flying review seminars open to the public and aimed at past and current students who are interested in the latest information and the revised syllabus;
- Workshops held for instructors in effective leadership and risk management, and focusing on the identification of instructors taking control at appropriate points in different training scenarios, flight management under different training scenarios, and identification and appropriate management of student and air exercises based on experience and training;
- Change to sign-out sheet to require pilot to insert actual take-off weight and take-off arm, with initialling by both student and instructor required;
- Portable global positioning system (GPS) to be carried on all flights outside Lower Mainland, to allow for increased oversight by both senior management and instructional staff.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 17 July 2013. It was officially released on 6 November 2013.

Visit the Transportation Safety Board's Web site (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the transportation safety issues that pose the greatest risk to Canadians. 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 – List of Transportation Safety Board Laboratory Reports

The following Transportation Safety Board (TSB) Laboratory reports were completed:

LP085/2011 - Cell Phone Examination
LP086/2011 - Aircraft Flight Instrument Examination
LP126/2011 - Graphical Presentation A11P0106

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

Appendix B – Example of a Disputed Theory on Mountain-flying Techniques

Downdraft Recovery

This subject has been discussed in most of the literature and information regarding mountain flying. According to some sources, the best practice in the case of encountering a strong downdraft is to lower the nose and fly quickly out of the down-flowing air. A few simple calculations using rate of climb and ground speed show that this claim may not be true.
The graph (Figure 7) shows 2 possible flight paths that aircraft could take when encountering an area of down-flowing air that is the result of a 15-knot wind flowing down a 30° slope. Both aircraft start at the same cruise speed of 100 knots. Both aircraft go to maximum power, and both would be climbing in still air. The solid blue line indicates the flight path of an aircraft that reacts by sacrificing forward speed for an initial climb while reducing speed to the best-rate-of-climb speed of 65 knots. The aircraft clears the hill with 500 feet to spare. The red dashed line depicts the path an aircraft would take if it accelerated and maintained 110 knots. At this higher speed, the aircraft impacts the hill just below the top. This example may not reflect what would happen in an actual event. However, it does show that there is a discrepancy in the theory, and that further research into this subject may be necessary.

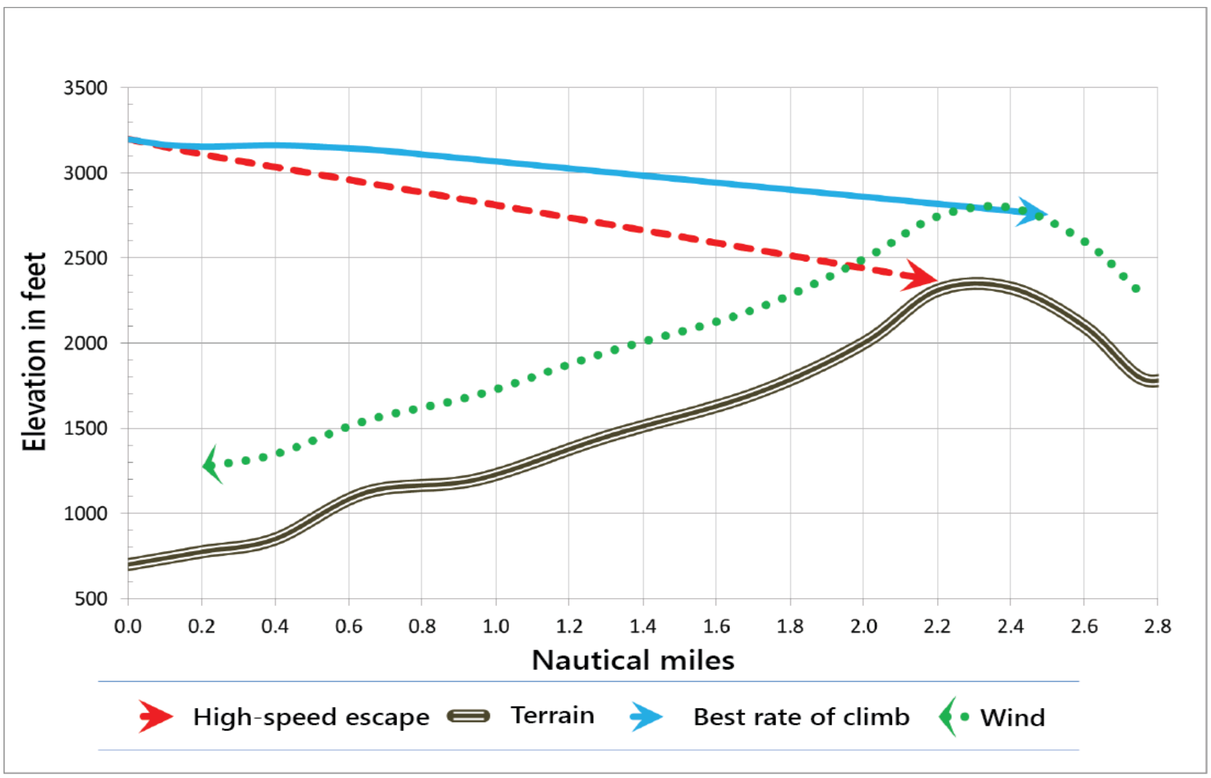

Figure 7. Flight path comparison in downdraft

Appendix C – Reference Material on Canyon Turn Techniques

Various methods of conducting minimum-radius turns		
Flight Training Manual (TP1102E, Transport Canada)	*Mountain Flying* (Doug Geeting)	*Mountain Flying* (Sparky Imeson)
Canyon turns / tight turns / 180° escape		
• Use a steep turn with steep angle of bank (i.e., more than 30°; the manual does not define "steep," but defines 30° as a medium turn). • As for all steep turns, maintain correct pitch attitude during roll-in. • Increase power as aircraft is rolled beyond 30° bank. • Airspeed should be reduced. The manual specifies that airspeed should be not less than that for maximum endurance. • Small amount of flap to increase safety margin. • The manual notes that the need for this turn is likely due to poor decision-making.	• Author notes that poor attention on the part of the pilot likely led to turn. Better planning will reduce the need to use this manoeuvre. • Hammerhead or chandelle are not to be used. • Reducing airspeed will reduce turn area. • Steeper angle of bank will reduce turn area. • Position in valley to one side—preferably the downwind side, so that a turn will be into wind. • Sufficient airspeed must be maintained. • The airspeed should be calculated on the performance of the aircraft and perhaps placarded. Suggests 1.83 x V_S = V_{REF} • Go to best angle of climb to sacrifice speed for altitude. • Go to predetermined V_{REF} speed. • Roll into 60° bank. • Partial flaps at discretion. • If tighter turn is required, altitude must be sacrificed. More flaps to control speed in descent. • Can be accomplished below 1000 feet agl. Practise it above 3000 feet agl.	• Fly on updraft side of canyon unless it is a narrow canyon, in which case fly on downwind or downdraft side. • Pick an airspeed faster than best angle of climb speed. Best-rate-of-climb speed is best. If rough air, add 10 to 20 knots. Do not go below this speed. • Sacrifice airspeed for altitude. • Do not fly up canyons without enough altitude to cross ridge, allowing for downdrafts. • Do not fly past point of no return, where if engine fails, you still have room to turn. • Hammerhead or wingover not recommended. Steep turns are best. • Consider load factor, increased stall speed, power limits, and manoeuvring speed. • Do research before flight to determine best bank angles, speeds, to give turn area. • Flaps can be used up to about one-half travel; beyond that, flaps will increase drag and become detrimental.