Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A10P0244

COLLISION WITH TERRAIN

CONAIR GROUP INC.
CONVAIR 580 C-FKFY
LYTTON, BRITISH COLUMBIA, 9 NM SE
JULY 31 2010

Canada

Aviation Investigation Report

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Synopsis

On 31 July 2010 at 2002 Pacific Daylight Time, Conair Group Inc.'s Convair 580 (registration C-FKFY, serial number 129) operating as Tanker 448 departed Kamloops to fight a wildfire near Lytton, British Columbia. The bombing run required crossing the edge of a ravine in the side of the Fraser River canyon before descending on the fire located in the ravine. About 22 minutes after departure, Tanker 448 approached the ravine and struck trees. An unanticipated retardant drop occurred coincident with the tree strikes. Seconds later, Tanker 448 entered a left-hand spin and collided with terrain. A post-impact explosion and fire consumed much of the wreckage. A signal was not received from the on-board emergency locator transmitter; nor was it recovered. Both crew members were fatally injured.

Ce rapport est également disponible en français.

Factual Information

History of Flight

The aerial firefighting operation involved 2 aircraft: a bird dog aircraft (Rockwell Turbo Commander 690) and a tanker aircraft (Convair 580, called Tanker 448). The bird dog crew planned and directed the fire suppression activity, which included a demonstration of the bombing run and a verbal description for the tanker crew as they circled above. The tanker crew would then complete the same run and make the retardant drop as described.

The plan was for Tanker 448 (T448) to make 8 left-hand circuits, dropping 1/8 of its retardant load each time. The terrain imposed a requirement to modify the standard rectangular circuit [1] to a triangular-shaped circuit (Figure 1). This consisted of flying a combined downwind/base leg from the Fraser River northbound over the rising east side of the canyon to a point at the edge of the ravine.

A single left turn to final required a change of direction greater than 90° at a bank angle of up to 40°. T448 then had to descend 900 feet into the ravine to make the drop. After each drop, T448 was to proceed straight ahead over descending terrain in the ravine back toward the Fraser River.

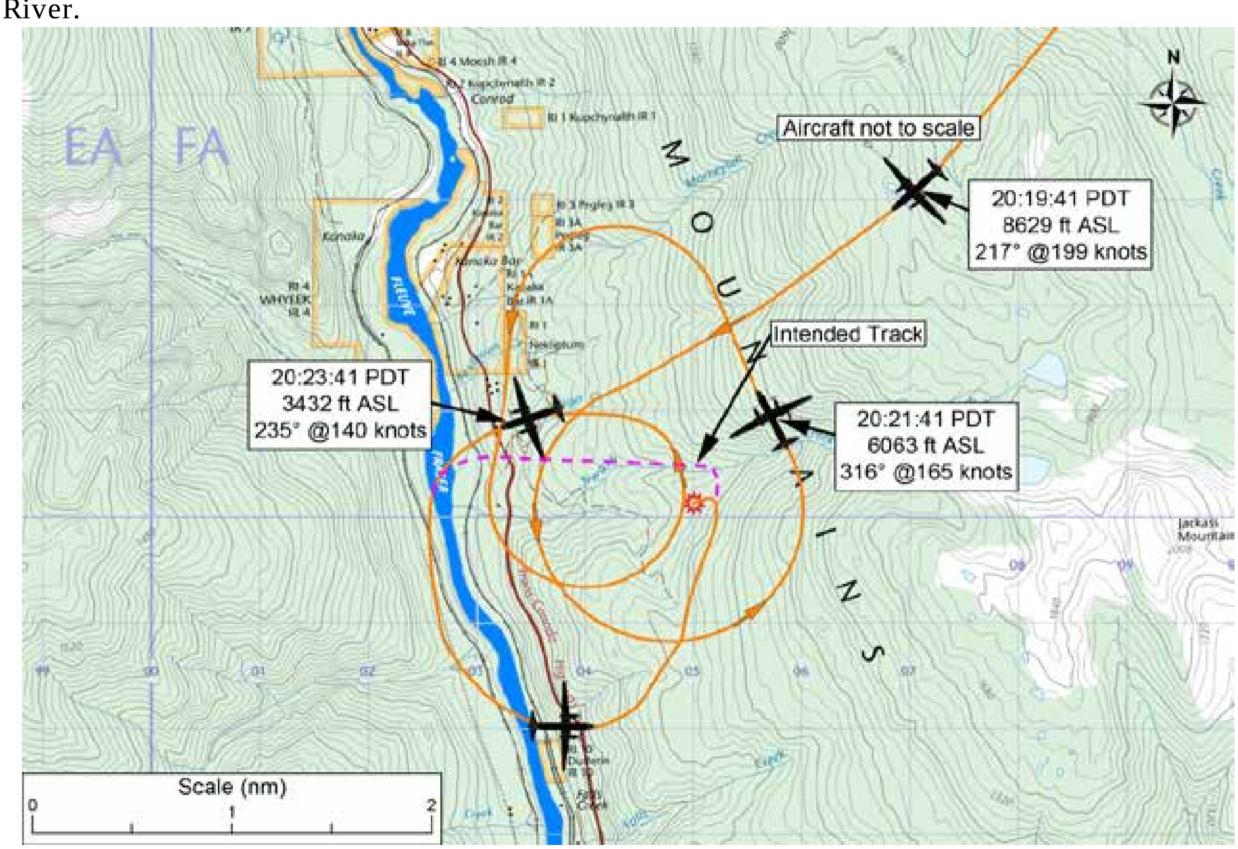

Figure 1. Estimated flight path

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[1] The standard circuit is comprised of 4 segments: crosswind leg, downwind leg, base leg and the final leg.

Normally, the Conair tanker procedure is to leave the circuit altitude at 1000 feet above the desired drop height on the base leg and level out at the desired drop height during the final approach leg. The modified circuit required T448 to maintain an altitude of 3100 feet above sea level (asl) until it crossed the edge of the ravine. This altitude provided about 100 to 150 feet of clearance above the trees where the bird dog aircraft had crossed the edge of the ravine. T448 could then turn final while descending 900 feet to the drop height.

The planned route and briefing included a safety exit which consisted of a left turn from any point along the downwind / base leg to proceed over descending terrain back toward the Fraser River.

An electronic tracking device installed on T448 transmitted a global positioning system (GPS) position report every 2 minutes. The data transmitted indicated that T448 had completed 2 orbits above the fire area while the bird dog aircraft demonstrated the bombing run. T448 joined the circuit for its first bombing run close to the Fraser River and then proceeded south-southwest at an altitude of 3432 feet asl and a groundspeed of 140 knots. This was consistent with Conair standard operating procedures (SOP). The last 36 seconds of the flight were captured on video taken from the bird dog aircraft.

Before the tree strikes, the aircraft appeared to be flying in a nose-high attitude with wing flaps selected to an undetermined extension and the landing lights (on the bottom of the wings) extended and illuminated. No safety exit turn was initiated and there were no radio communications during the circuit. All prior communications were normal. About 3 seconds before the tree strikes, the bird dog crew observed a change in T448's flight profile, which was interpreted as a change from level flight to descent.

An unanticipated retardant drop occurred coincident with the tree strikes. About 3 seconds later, T448 entered the left-hand spin [2] which continued for 1 revolution in 5 seconds in a steep nose-down attitude before the aircraft struck terrain 590 feet below.

Accident Site

There were 2 sites associated with this accident: the site of the tree strikes at the edge of the ravine, and the main accident site at the bottom of the ravine. T448 struck 3 trees on a knoll at the edge of the ravine at approximately 3020 feet asl about 8 seconds before the crash.

It could not be determined if T448 approached the exact location where the bird dog had crossed the edge of the ravine. Since the edge of the ravine generally sloped down from right to left, a track further to the right would encounter higher terrain.

The pattern of broken tree tops suggests the aircraft was climbing. Retardant was not found on the trees that were struck but rather 30 feet beyond.

The only aircraft debris found at the site of the initial tree strikes was a small washer, which was identified as a nut locking clip used to secure composite panels that cover the elevator hinges.

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[2] Manoeuvre of an airplane in which one wing is stalled while the other wing continues to produce lift. The nose drops, and the airplane descends slowly, with the wing producing lift pulling it around in a spiral path. *Dictionary of Aeronautical Terms*, 3rd edition. Dale Crane.

Video footage did not reveal any pieces leaving the aircraft in flight and none were found between the tree strikes and the main accident site.

Tree damage at the main accident site indicated that the final descent angle was 51°. The aircraft was carrying nearly a full load of retardant and a significant volume of fuel. The ground impact produced a fireball and the post-impact fire started another wildfire.

Post-impact fire damage was extensive and therefore limited the wreckage examination.

Weather

The 2000 [3] aviation routine hourly weather report (METAR) issued by an automatic observation station at Lytton, 9 nautical miles (nm) up-river from the accident site, reported the following: wind 170° true at 24 knots gusting to 30 knots, visibility 9 statute miles (sm) with a few clouds at 4500 feet above ground level (agl), temperature 22°C, altimeter setting 29.85 inches of mercury (Hg).

The video coverage showed smoke rising and drifting slowly from the target fire. The bird dog hand-held camera remained stable during the filming. Both of these factors demonstrate light wind and that the bird dog aircraft did not encounter turbulence or downdraughts. Weather was not a factor in this accident.

Flight Crew

Records indicate that the flight crew was certified and qualified for the flight in accordance with existing regulations. The captain held an airline transport pilot licence (ATPL) and had been employed by the operator since 1983. The captain had completed recurrent training in April 2010; the training included a pilot proficiency check / instrument flight test, as well as controlled flight into terrain (CFIT) avoidance (including prevention strategies and escape manoeuvre techniques and profiles) and pilot decision making / cockpit resource management. The first officer was assigned to this captain for line indoctrination training.

The first officer (FO) held an ATPL and was hired in May 2010. The FO had completed initial training, including a pilot proficiency check and instrument flight test in June 2010. As had the captain, the FO had training in CFIT avoidance, pilot decision-making / cockpit resource management, as well as aerial work and firefighting procedures. The FO was new to fire suppression operations and also new to the Convair 580 (CV580) (Table 1).

Table 1. Crew experience

Crew experience	Total flight time	Fire suppression experience	CV580 experience
Captain	17 000 hours	3500 hours	900 hours
First officer	5200 hours	26 hours	34 hours

3 All times arePacific Daylight Time (Coordinated Universal Time minus 7 hours).

The Conair training syllabus for a new FO allocated 1 hour of flight time to firefighting procedures training, which included terrain flying, approach to target area, overshoot, airspeeds, altitudes, and crew coordination. Operation of the aircraft at its maximum gross take-off weight (MGTOW) and an actual emergency drop (E-drop) of the retardant load were not included in the syllabus.

The crew's duty day began at about 1000 and included a 3-hour break from 1640 to 1940. Tanker action on the fire near Lytton was initiated at 1951. A review of duty schedules and the 72-hour history for both pilots did not identify fatigue as a factor.

Engine and Propeller Examination

Both engines and their associated components were extensively damaged by impact and fire. No engine accessories could be tested. To the extent that it was possible, examination of the engines suggests that they were producing maximum power at the time of impact.

The damage to both propellers was consistent with the blades striking terrain while under significant power. Examinations determined that both propellers were functioning normally.

Flight Control Examination

Flight control surfaces were extensively damaged by impact and fire. From the limited examinations that could be performed, no issues of concern were identified. Wing flaps were broken into many sections but sustained the least fire damage. The left wing hydraulic flap-drive motor was recovered, and examination determined that the flaps were extended to 12° at the time of impact. Wing flaps operate through the normal aircraft hydraulic system and are activated by a momentary-on switch. Flaps travel between 2° and 3° per second as long as the switch is held. The hydraulic system is normally depressurized by a crew selection for cruise flight. Selecting the hydraulic system to the pressure position is an item contained in the BOMBING CHECK checklist.

The differential torque tube, located in the fuselage belly between the inboard flaps, was examined. This assembly arrests further flap operation in the event of a split flap condition. There were indications of differential movement between the right and left wing flaps, but it could not be determined if this was a result of the initial tree strikes or the final impact or a flap dissymmetry. Review of the video did not show any rolling motion by the aircraft during the 3 seconds before the left turn that precipitated the spin, as would be expected if there were flap dissymmetry.

Bird Dog Procedures

The bird dog aircraft was a Rockwell Turbo Commander 690. This model operates at similar speeds to the CV-580.

The Conair company operations manual (COM) provides direction to bird dog aircraft pilots regarding limitations and considerations in the development of firefighting routes for air tankers, and includes the following:

> Section 7.25 - If the angle of bank must be increased beyond 30° to complete the turn, the area will still be considered suitable with the following restrictions:
>
> - The angle of bank at no time exceeds 45°.
> - The tanker pilot must be informed of a bank angle exceeding 30°.
> - If the angle of bank exceeds 45° during the turning radius then the area will be considered unacceptable.
>
> For all bird dog aircraft and air tankers, it must be emphasized that the approach must carry considerations for pilot error, distractions, visibility impairments, aircraft malfunctions, traffic avoidance, etc. with adequate capabilities of a safe exit. Ensure that the exit routes for air tankers following a drop will lead into level or descending ground.

The bird dog aircraft was using the Kamloops altimeter setting of 29.74 in Hg and this setting was provided to and acknowledged by T448. This setting was 0.11 in Hg lower than the local altimeter setting reported for Lytton at 2000. The altimeters of both aircraft had been calibrated within the previous 24 months. The calibration tables indicated that they should have read within 2 feet of each other at the circuit altitude, which means that both flight crews would have had the same elevation reference to terrain for visual operations.

The bird dog crew had the benefit of flying consecutively lower circuits in the development of the bombing run to the target fire. The briefing from the bird dog to T448 included a description of the magnitude of the turn-to-final since it exceeded the normal parameters. Other than the bank angle of the turn-to-final, the bird dog aircraft did not encounter any issues of visibility impairment or other concerns while planning or conducting the demonstration run for T448 to observe.

Weight and Balance

The accident aircraft was modified in accordance with several Canadian supplemental type certificates which allowed for progressively higher MGTOW. The accident aircraft was approved for a MGTOW of 58 500 pounds. The aircraft departed Kamloops with a full load of retardant and nearly 8000 pounds of fuel. A weight and balance calculation showed that, at take-off, the aircraft was about 480 pounds over its MGTOW which placed it outside of the certificated limitations. By the time T448 was on the approach to the fire, enough fuel would have been consumed to place the aircraft weight and centre of gravity within the approved limitations.

Tanker Procedures

Conair's SOP recommend a maximum flap setting of 20° and an indicated airspeed of 140 knots for manoeuvres in a fire zone (5 nm radius). When in the circuit on the bombing run, wing flaps are normally extended to 30° with a target speed of 130 knots on the base leg, and to 40° with a target speed of 120 knots on the final leg. The anticipated go-around procedure following a drop for the CV-580 requires maximum-except-take-off (METO) power and flaps at 20°.

To comply with the initial firefighting plan, the flight crew had to set the retardant release selector to 1/8 of the tank capacity at maximum coverage and arm the system in accordance with the Conair CV580 BOMBING CHECK checklist. This set-up energized the normal drop switch on the left-hand grip of the left control wheel, which needs to be pushed to drop a load. The normal drop and communications (Com) switches were both operated by the pilot's left thumb and were located in proximity to each other. The normal drop switch was unreachable from the right seat and was protected from unintentional operation by a collar around the switch. The doors on the retardant tank operate through the aircraft normal hydraulic system and incorporate an emergency hydraulic accumulator to permit operation if the normal system were to fail. .

The retardant delivery system included a separate emergency drop function to jettison the entire load in an emergency situation. The emergency drop switch was within reach of both pilots (Photo 1). It was determined that only part of the retardant load was jettisoned on the accident flight, which was consistent with the plan to drop 1/8 of the load each time. It could not be determined if an emergency drop (E-drop) was verbally commanded or physically attempted, but it was unsuccessful.

Photo 1. E-Drop Switch

Conair had previously identified 2 hazards associated with retardant loads: unintended load retention and unintended load jettison. The following policies were developed to mitigate these risks.

Regarding unwarranted retention of the load, the Conair COM and CV580 aircraft operating manual (AOM) encourage tanker crews to drop the retardant load immediately if flight crew safety is in jeopardy:

- Tanker pilots should be prepared to drop their load should an immediate improvement in performance be required. (Conair COM section 7.21.2 (a))
- It should also be emphasized to air tanker pilots that if they inadvertently find themselves in a tight spot where manoeuvring becomes critical and the aircraft is being flown towards the edge of the performance envelope, in the interest of crew safety, the retardant load should be jettisoned immediately. (Conair COM section 7.25)
- In the event that the safety of the aircraft and crew are in jeopardy, either pilot may jettison the remaining load and set power as required. (CV580 AOM section 3.19)

With respect to unwarranted jettison of the load, the Conair policy is described in the CV580 AOM section 2 (Emergency Procedures / General):

> Any item that requires an irreversible action, or is a guarded switch (i.e. an E-handle, extinguisher discharge, fuel valve, etc.), will be confirmed prior to the action being taken. […] Of necessity, the "Jettison" action will require the Captain's initiation, whether the Captain is the PF [4] or PNF [5]. This is because in most aircraft the Captain has the only drop button, the aircraft may not, in the captain's opinion, be in a good position to jettison the load, and the Captain has the responsibility for the safety of persons and property on the ground. The Emergency Drop selector should only be used if the Captain's drop button fails.

Aircraft Operation and Systems

Records indicate that the aircraft was certified, equipped and maintained in accordance with existing regulations and approved procedures. Unscheduled maintenance was performed immediately before the accident flight and consisted of replacing the #1 alternating current (AC) generator. The aircraft is equipped with 2 AC generators, one on each engine; both were checked for correct operation after the maintenance work was completed. No safety concerns were identified with this maintenance action or with the general condition of the aircraft. The aircraft did not have any other reported or deferred defects. The aircraft was neither equipped with cockpit voice (CVR) or flight data (FDR) recorders, nor was it required to be by regulation.

Conair maintenance personnel performed an inspection [6] of the retardant tank every 14 days. The inspection was performed 11 days before the accident; this inspection recommended a functional check of the E-drop system. However, a functional check may not be performed since opening the retardant tank doors results in spillage of residual retardant and creates environmental concerns on the airport apron. The normal flight checklists, or any other operational document available to the flight crew, do not contain any item requiring a functional check of the E-drop system by the flight crew in lieu of the maintenance inspection.

The retardant delivery system included a separate E-drop function activated through a switch located between the pilot seats on an aft-facing switch panel on the centre pedestal (Photo 1). This switch was 1 of 3 guarded switches on a panel of 6 adjacent switches which were located in proximity to the pilots' elbows and which could be operated by either pilot. The system was functional any time both the aircraft electrical and hydraulic systems were energized. The system requires up to 5 seconds to jettison a full retardant load, approximately 18 000 pounds.

The CV-580 was certified without a stall warning device and T448 was not equipped with one. The stall speeds of the aircraft did not change due to the installation of the retardant aerial delivery system. The location of the retardant tank on the aircraft belly placed it in an area most vulnerable to impact damage; consequently, the extent of damage precluded meaningful

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[4] Pilot flying.

[5] Pilot not flying.

[6] Refers to the Conair CV-580 maintenance "A" inspection.

examination. The aircraft was equipped with an angle-of-attack (AOA) indicator installed in accordance with a supplemental-type certificate (Photo 2).

Photo 2. Angle-of-attack (AOA) indicator

The AOA indicator was located on the far left side of the captain's instrument panel adjacent to the airspeed indicator. The AOA indicator was marked with color-coded arcs. It did not provide any aural or visual warning annunciations. The indicator needle and the coloured arcs (on the right-hand side of the instrument face) were not completely visible from the right pilot seat.

Conair training practices says that the AOA indicator should be a primary reference during low-level manoeuvring and that it is a responsibility of the PNF to announce deviations such as the AOA indicator needle trending upward through the 3 o'clock position toward the 12 o'clock position.

In Conair CV580 operations, there are 2 types of overshoot procedures used: the anticipated and the unanticipated overshoot. Both procedures are based upon a pre-determined minimum airspeed on the approach. The anticipated overshoot is used following a retardant drop. This procedure normally involves a power increase to maximum except take-off (METO) power and a flap retraction to the 20° position. The unanticipated overshoot is an unplanned event. This requires maximum available power, a flap setting of 15° and, if applicable, raising the landing gear.

This aircraft model is known to pitch up during an overshoot. In both procedures, the retraction of flaps will result in a reduction of lift as well as a reduction of drag. In accordance with Conair SOP, T448 could have been approaching the ravine at 140 knots with flaps set to 20° or 130 knots with flaps set to 30°. These figures can change at the captain's discretion. Lower airspeeds can result in a state of low energy, commonly known as the back side of the power curve.

The Conair COM recognizes this risk in Section 7.24.2 which states:

> Operation on the "back side of the power curve" also known as the "region of reversed command" is one in which a reduction in airspeed brings about a need for increased power if altitude is to be maintained.
>
> The combination of low airspeed and high power settings (in level flight) will result in a high angle of attack. The normal solution to this situation is to increase power, increase airspeed or preferably a combination of both.
>
> This flight regime may be entered by inadvertently getting too low while approaching a ridge, during an unusually "flat" approach to the target or in gusty wind conditions . . . At low altitude and without additional power available for acceleration, there may be no means of obtaining the performance necessary to clear obstacles . . . Since angles of attack are already high, a stall can occur on the overshoot, particularly if the exit requires immediate manoeuvring for terrain avoidance.

During a National Transportation Safety Board (NTSB) investigation, NTSB-AAR-70-27, into a 1968 CV-580 accident, a qualitative flight test was conducted with a CV-580 to demonstrate the basic aircraft stability and control in the go-around configuration. It was found that the aircraft tended to pitch up with the application of maximum available power. The test indicated that airspeed can be maintained by exerting a (pushing) force on the control yoke of 47 pounds or less throughout the centre of gravity range. The aircraft also exhibited heavy pre-stall buffet and recovery characteristics were positive. All flight controls were effective in the deep buffet region of flight.

The NTSB report concluded that the accident CV-580 was in a climbing attitude with indicated airspeed (IAS) decreasing through 105 knots before initiating an overshoot with maximum power and flaps selected to 15°. The aircraft continued slowing in the climb with the gear retraction occurring at 85 knots. At 80 knots, an abrupt and rapid loss of altitude and sharp left turn occurred.

Visual Illusion

On the day of the accident, the bird dog aircraft crew did not report experiencing a visual illusion while demonstrating the flight path. When the bombing run flight path was flown by TSB investigators several weeks after the accident, a visual illusion was observed. During the combined downwind / base leg, at 3100 feet asl to 3200 feet asl proceeding toward the known site of the initial tree strikes, estimated 1 nm away, the site appeared to be about 400 feet to 500 feet below the aircraft altitude when it was actually 150 feet below. Unlike the accident flight where visibility was 6 to 9 sm in smoke, about 1 hour before sunset, the investigation flight was conducted under good daytime visual conditions.

Visual illusion has been identified as a contributing factor in other accident investigations. An illusion creates a false perception that may be described as a form of unrecognized spatial disorientation regarding terrain.

The TSB investigation, report number A03P0194, into the crash of a Lockheed L-188 Electra air tanker also in British Columbia, concluded that: "The characteristics of the terrain were deceptive, making it difficult for the pilots to perceive their proximity and rate of closure to the rising ground in sufficient time to avoid it."

Additionally, an investigation, number 13807, conducted by the Canadian Forces Directorate of Flight Safety into the crash of a military DHC-6 Twin Otter in Alberta, concluded that visual illusion was a principal contributing factor.

The Aeromedical Training for Flight Personnel manual [7] includes the following:

> Illusions give false impressions or misconceptions of actual conditions; therefore, aircrew members must understand the type of illusions that can occur and the resulting disorientation. Although the visual system is the most reliable of the senses, some illusions can result from misinterpreting what is seen; what is perceived is not always accurate. Even with the references outside the cockpit and the display of instruments inside, aircrew members must be on guard to interpret information correctly.
>
> Spatial Disorientation TYPE I (UNRECOGNIZED) - A disoriented aviator does not perceive any indication of spatial disorientation. In other words, he does not think anything is wrong. What he sees—or thinks he sees—is corroborated by his other senses. Type I disorientation is the most dangerous type of disorientation. The pilot - unaware of a problem - fails to recognize or correct the disorientation, usually resulting in a fatal aircraft mishap:
>
> - The pilot may see the instruments functioning properly. There is no suspicion of an instrument malfunction.
> - There may be no indication of aircraft-control malfunction. The aircraft is performing normally.
> - An example of this type of spatial disorientation would be the height-/depth-perception illusion when the pilot descends into the ground or some obstacle above the ground because of a lack of situational awareness.

The following TSB Laboratory reports were completed:

LP156/2010 – Instrument Analysis (Horsepower gauges)

LP163/2010 - Analysis of Turbine Splatter

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

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7 Department of the Army (US), Field Manual No. 3-04.301 (1-301) Chapter 9 - Spatial Disorientation http://www.cavalrypilot.com/pdfpubs/fm3_04x301.pdf

Analysis

General

For the aircraft to be climbing through 3020 feet when it struck trees, it had to have descended more than 400 feet along the circuit route after it joined the crosswind leg at 3434 feet asl. The investigation determined that both engines were delivering maximum power and both propellers were operating in the same, normal, manner at the time of the crash. There were no identifiable in-flight airframe failures or system malfunctions. The crew did not communicate any concerns or make any attempt to abort the bombing run. Therefore, the change of altitude during the circuit was not due to technical malfunction.

The operation of the landing lights and the flap setting confirms that the BOMBING CHECK checklist had been completed. The partial retardant drop confirmed that the hydraulic system was pressurized and operating normally and that the retardant delivery system was operational and was selected to the requested drop volume. Since the drop button could only be operated from the left seat, its operation confirmed that the captain was not incapacitated.

When the overshoot was initiated, the first priority was to clear the terrain. The required nose-down elevator control input could be accomplished by exerting a pushing force on the control wheel to prevent an aerodynamic stall. Since the aircraft was not yet near a position to make the planned retardant drop, it is unlikely that the pilot would have been flying with his thumb on the protected drop switch and operated it in error while attempting to push the nose down. The captain likely intended to drop the pre-selected load in an attempt to improve climb performance.

A left turn down the ravine was the only exit route to avoid terrain after striking the trees. However, it cannot be determined if the left turn was initiated by the crew either as a result of damage to the aircraft, or as a consequence of attempting a go-around in a low energy state. In any case, a loss of control occurred.

It is likely that the aircraft was damaged because trees were struck. It could not be determined exactly what effect this had on the controllability and the resulting spin.

Company Procedures

In accordance with proactive safety management practices, Conair had previously identified several safety issues such as:

- low energy flight conditions;
- visual illusions;
- engine power management procedures;
- impending stall awareness;
- unwarranted retention or jettison of the retardant load; and,
- emergency procedures for jettison of the retardant load.

Company policies, procedures, equipment and training had evolved to mitigate these risks. Despite these efforts, this accident occurred.

Conair training practices recommend that the AOA indicator be used as a primary reference during low-level manoeuvring for the PNF to announce deviations trending toward the yellow or red arcs.

However, the AOA indicator's location made it difficult to see the entire needle and the colour-coded arcs on the instrument face from the right-hand pilot seat, which may limit effective use of this tool.

Operational Factors

Had the aircraft been equipped with recorders which survived the crash, information such as verbal exchanges between crew members regarding procedures, intentions, briefings, instructions, commands, systems operations, propeller speeds, etc. could have been identified from a CVR. Control inputs and system selections could have been identified from a FDR. In the absence of concrete data from recorders, the investigation looked at 2 possible operational factors:

- The flight inadvertently entered a low energy condition approaching the ravine in an attempt to recover altitude.
- A visual illusion affected the crew's ability to recognize and assess the aircraft's proximity to the rising terrain resulting in this being a CFIT accident.

It was established that T448 descended more than 400 feet early in the circuit and was flying in a slow climb toward the edge of the ravine. A slow climb, rising terrain and the lack of a good horizon reference, are criteria that could contribute to the development of a low energy condition. Regardless of engine power, the low energy condition may not have allowed the aircraft sufficient time to pull up and establish an adequate climb, even with the benefit of the partial retardant drop. Airspeed and AOA indicators should have provided visual indications of low energy conditions and impending stall awareness. But there was no audible or visual alert that would have drawn the crew's attention to these indicators.

If the airspeed was low and an overshoot was commanded, the flaps would have to be retracted to 15°. This would result in a reduction in the initial rate of climb. The aircraft was interpreted as going into a descent when observed by the bird dog crew. However, the bird dog crew did not know that T448 was climbing. Without a horizon reference, a reduction of the climb angle could appear to the bird dog crew as a change from level flight to a descent. Maximum power and 12° of flap, as found, would be consistent with an attempted go-around. While retracting flaps for a go-around, inadvertently holding the flap selector switch for 1 additional second would result in 2° or 3° more flap retraction than the target setting of 15°. There is no performance data in the AOM to determine a potential rate of climb. However, this should not be an issue because the plan to climb out following the first intended drop and accelerate from 120 knots to 140 knots in the 20° flap configuration, with 7/8 of the load remaining on board, is indicative of the airplane capability at an appropriate airspeed.

Furthermore, a visual illusion may have affected the crew's ability to recognize, or accurately assess the aircraft's flight path relative to the elevation of the rising terrain which, unbeknownst to the crew, put the aircraft too low before the edge of the ravine.

The local terrain was mountainous and precluded a good horizon reference. The flight occurred during the last hour of daylight in growing shadows and some smoke, which are factors that affect visibility. The action to continue the bombing run rather than take the exit route and circle for another attempt or to jettison the retardant load to improve the climb performance suggests the crew did not recognize the imminent danger ahead of them and may have neglected the altimeter, believing it was reasonable to continue and assess their progress visually. The criteria (a slow climb, rising terrain, lack of a good horizon reference) conducive to a low energy condition can also be conducive to a visual illusion producing a false sense of height, as observed during the TSB investigation flight.

Given the last-second response to avoid a collision with terrain at the edge of the ravine, and the partial retardant load drop, it is likely the crew was under the influence of a visual illusion. The aircraft's proximity to terrain came as a surprise to the crew and as a result, affected the crew's decisions and actions leading up to the event.

The bird dog pilot, however, had the benefit of flying consecutively lower circuits in the development of the bombing run to the target fire, and lighting conditions may have been slightly different. This opportunity may have reduced the likelihood of a height or depth-perception illusion, and illusions were not discussed in any briefings to T448.

Emergency Drop System

The crew likely recognized very late that a collision with trees or terrain was imminent, and immediate action was taken at that point. Assuming that the E-drop system was functional, a critical and missing element of the sequence of events was that the entire retardant load was not jettisoned. Given that retardant was not deposited on the trees that were struck, a full or partial retardant drop may not have changed the sequence of events. However, in an emergency, it would be expected that the full load would have been jettisoned. The fact that it was not is worthy of analysis.

Factors that could have influenced an attempt to execute an E-drop include the following:

- A visual illusion could have precluded timely recognition, or accurate assessment, of the aircraft's flight path relative to the terrain thereby obviating the need to execute an E-drop.

- The FO training did not include an E-drop exercise. Since the FO was new to the job and the aircraft, he likely relied heavily upon the captain's instructions. Given the direction in the company's manuals regarding load jettisons, the FO probably would not have executed an E-drop on his own initiative under any circumstance. Company procedures regarding unwarranted jettison of the load were quite specific in pointing out the following:
    - An irreversible action or guarded switch will be confirmed prior to operation.
    - Jettison action will require the captain's initiation.
    - The E-drop selector should only be used if the captain's drop button fails.

- In most cases the E-drop selector would be operated by the FO but, in accordance with SOP, that would still require a verbal command by the captain and recognition by the FO of the, likely unanticipated, command.

- To execute an E-drop, the location of the E-drop selector required a significant diversion of attention by both pilots to identify and confirm it among other guarded switches. This procedure may have consumed more time and attention than was available.

Since the recommended maintenance inspection task to perform a functional check of the E-drop system may not be performed due to environmental concerns, and there is no requirement for flight crews to test the E-drop system in lieu of the maintenance ground check, a functional test of this emergency system may not occur to confirm its continued operation once the fire season begins.

Findings as to Causes and Contributing Factors

1. It could not be determined to what extent the initial collision with trees caused damage to the aircraft which may have affected its controllability.

2. Visual illusion may have precluded recognition, or an accurate assessment, of the flight path profile in sufficient time to avoid the trees on rising terrain.

3. Visual illusion may have contributed to the development of a low energy condition which impaired the aircraft performance when overshoot action was initiated.

4. The aircraft entered an aerodynamic stall and spin from which recovery was not possible at such a low altitude.

Findings as to Risk

1. Visual illusions give false impressions or misconceptions of actual conditions. Unrecognized and uncorrected spatial disorientation, caused by illusions, carries a high risk of incident or accident.

2. Flight operations outside the approved weight and balance envelope increase the risk of unanticipated aircraft behaviour.

3. The recommended maintenance check of the emergency drop (E-drop) system may not be performed and there is no requirement for flight crews to test the E-drop system, thereby increasing the risk that an unserviceable system will go undetected.

4. The location of the E-drop selector requires crews to divert significant time and attention to identify and confirm the correct switch before operating it. This increases the risk of collision with terrain while attention is distracted.

5. The location of the angle-of-attack indicator on the instrument panel makes it difficult to see from the right seat, reducing its effectiveness.

6. When cockpit recordings are not available to an investigation, this may preclude the identification and communication of safety deficiencies to advance transportation safety.

Other Finding

1. Although the aircraft was equipped with an automatic position reporting system, which was invaluable, the reporting frequency of 2 minutes was insufficient to capture all of the data critical to the analysis of the accident.

Safety Action Taken

Conair Group Inc.

Since the accident, Conair has taken further action to mitigate the risks of recurrence.

1. The glare shield over the flight instrument panel in the Convair 580 has been modified to improve both pilots' view of the top row of flight instruments, which include the airspeed indicators and the angle-of-attack indicator.

2. A project has been initiated to change the emergency drop selector from a guarded toggle switch to a large push-button type switch and relocate it to the middle of the glare shield, in full view and within reach of both pilots.

3. A project is underway to modify the existing load release button on the left-hand control wheel to include a safety function which will jettison the entire retardant load if the button is depressed 5 times within 3 seconds.

4. The Conair pilot training program is being amended to incorporate more emphasis on emergency drop procedures.

5. Conair is developing a stall-g-speed (SgS) [8] system for air tanker operations. This system will be initially installed on the Lockheed L-188 Electra air tanker.

B.C. Ministry of Forest Lands and Natural Resource Operations

The B.C. Ministry of Forest Lands and Natural Resource Operations (MFLNRO) staff is in the process of clarifying and communicating procedures that allow air tanker operators to conduct ground testing of E-dump systems as required by the operators on MFLNRO tanker bases.

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[8] SgS defines a safety flight envelope for "low speed warning", "vertical acceleration (g) warning" and "overspeed warning". This system will provide flight crews with trend information relating airspeed, angle-of-attack, and "g" load information in a visual display with audio warnings and a stick-shaker function.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 18 April 2012. It was officially released on 27 April 2012.

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