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

AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A21W0098

FUEL STARVATION

Air Tindi Ltd.
de Havilland DHC-6-300 Twin Otter, C-GNPS
Fort Providence, Northwest Territories, 6.7 NM NW
01 November 2021

Canada

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Summary

At 1748 Mountain Daylight Time on 01 November 2021, the Air Tindi Ltd. de Havilland DHC-6-300 Twin Otter aircraft (registration C-GNPS, serial number 558) departed Yellowknife Airport (CYZF), Northwest Territories, as flight TIN223, a visual flight rules flight to Fort Simpson Airport (CYFS), Northwest Territories, with 2 flight crew and 3 passengers on board.

Approximately 40 minutes into the flight, the flight crew realized that there was insufficient fuel to continue to CYFS or to return to CYZF. The flight crew diverted the aircraft to Fort Providence Aerodrome (CYJP), Northwest Territories, and informed the company of their decision. The left engine was intentionally shut down to conserve fuel. The right engine then flamed out.

A forced landing onto muskeg was performed at 1851 Mountain Daylight Time, 6.7 nautical miles (14 km) northwest of CYJP. A signal from the emergency locator transmitter was received by the Canadian Mission Control Centre shortly after. Approximately 4 hours after the forced landing, all occupants were recovered by rescue personnel. All occupants received minor injuries related to hypothermia. The aircraft sustained substantial damage.

1.0 FACTUAL INFORMATION

1.1 History of the flight

On 01 November 2021, the Air Tindi Ltd. (Air Tindi) de Havilland DHC-6-300 Twin Otter aircraft (registration C-GNPS, serial number 558) was scheduled to depart Yellowknife Airport (CYZF), Northwest Territories, at 1030[1] to conduct the following 3 return flights under visual flight rules (VFR):

- The 1st return flight was from CYZF to Whatì Airport (CEM3), Northwest Territories: flight TIN218 out and flight TIN220 back.
- The 2nd return flight was from CYZF to Wekweètì Airport (CYWE), Northwest Territories: flight TIN212 out and flight TIN213 back.
- The 3rd return flight was from CYZF to CEM3: flight TIN220 out and flight TIN221 back.

Following those 3 return flights, the last trip of the day was flight TIN223 from CYZF to Fort Simpson Airport (CYFS), Northwest Territories (Figure 1; see Appendix A for greater detail). The same flight crew was to conduct all 7 flights and then overnight in Fort Simpson. This was the first time this flight crew had flown together. All flights consisted of a mix of passengers and cargo and were to be conducted under *Canadian Aviation Regulations* (CARs) Subpart 703 (Air Taxi Operations), except for flight TIN212, which was to be conducted under CARs Subpart 704 (Commuter Operations).[2]

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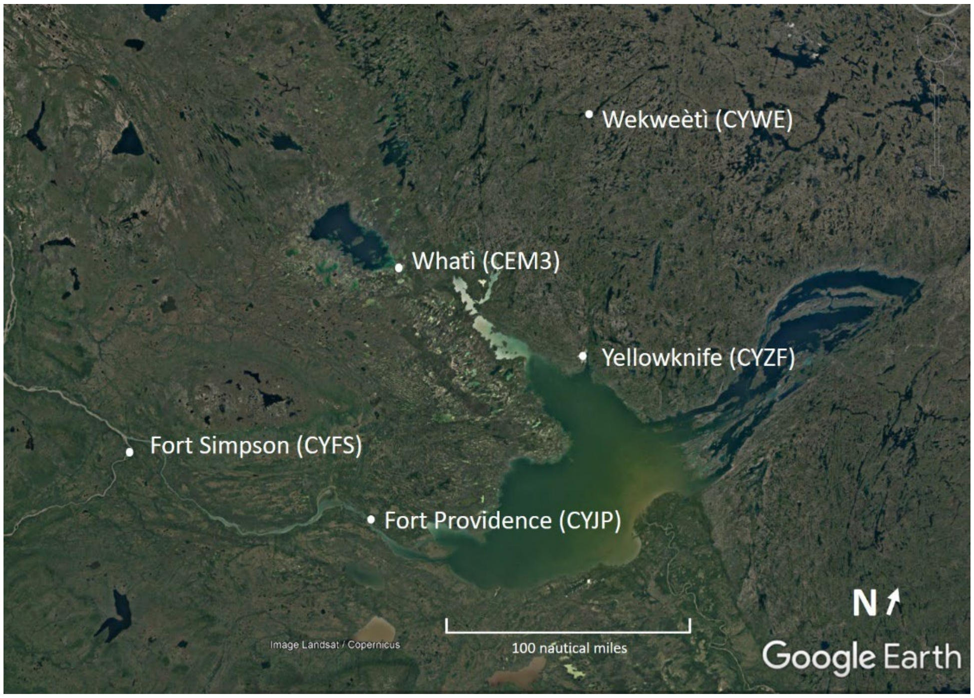
[1] All times are Mountain Daylight Time (Coordinated Universal Time minus 6 hours).

[2] Subpart 704 of the *Canadian Aviation Regulations* (CARs) applies when there are more than 9 passengers on board a flight; this flight had 10 passengers.

Figure 1. Area map showing locations (Source: Google Earth, with TSB annotations)



During the last inbound flight of the day to CYZF (flight TIN221 on the day of the occurrence), it was typical for the flight crew to inform the flight coordinator how much fuel was required for the next flight. The flight coordinator would then place an order for fuel with the fuel company. The investigation was unable to confirm whether the flight crew had requested fuel from the flight coordinator for the occurrence flight; however, the flight coordinator did not call the fuel company with a fuel order. Flight TIN221 arrived at CYZF at 1725. The crew and passengers deplaned and entered the passenger boarding lounge. Then, the process of unloading and preparing for the last flight of the day (flight TIN223 to CYFS) began.

At 1738, the first officer returned to the aircraft from the passenger boarding lounge and began the external pre-flight inspection. Approximately 1 minute later, the captain returned to the aircraft and entered the cockpit through the front left door. While getting into his seat, the captain observed a fuel receipt in the door map pocket and assumed it was for the fuel he thought he had ordered for the flight to CYFS. He did not read the fuel receipt, which was from a flight 3 days prior.

Since landing, no fuel truck had arrived at the aircraft and consequently no fuel was added to the aircraft. According to the operational flight plan, the aircraft would have arrived in CYZF on flight TIN221 with approximately 533 pounds of fuel remaining. The operational flight plan for flight TIN223 to CYFS indicated that 2500 pounds of fuel were to be on board, which was standard for this flight.

The captain began preparing the aircraft for engine start by conducting the Before Start checks of the *Air Tindi DHC6 Cockpit Checklist* (Appendix B) using a geographic flow.[3] At the same time, passengers started boarding the aircraft, and the captain interrupted the checks to converse with one of them with whom he used to work. After a short conversation, the captain resumed the checks.

At 1740, when passengers had finished boarding and the cargo had been loaded, the first officer briefed the passengers for the flight. The first officer then sat down in the cockpit and asked the captain if he would like to commence the Before Start checks. The captain declined and started the engines at 1743.

Unlike the first few legs of the day, the ensuing After Start, Taxi, and Line Up checks were completed by the captain from memory only. At 1747, the occurrence aircraft departed CYZF on flight TIN223, with the 2 pilots and 3 passengers on board. The aircraft climbed towards the planned cruising altitude of 6500 feet above sea level (ASL). The After Takeoff and Cruise checks were completed by the first officer without reference to the checklist. By this time in a typical flight, the flight crew would have been directed by *Air Tindi DHC6 Cockpit Checklist* on 3 separate occasions to observe the fuel quantity (see section 1.17.1.4 *Checklists* of this report).

At 1750, the fuel company at CYZF called the Air Tindi flight coordinator to ask whether the occurrence aircraft needed fuel. The flight coordinator informed the fuelling company that the aircraft was already airborne and on its way to CYFS.

Based on the fuel burn analysis (see section 1.16.1 *Fuel quantity calculation* of this report), the low-fuel-level caution light for the aft fuel tank illuminated at 1813. At this time, there were approximately 60 U.S. gallons of fuel left in the aircraft, including 8 U.S. gallons of fuel in the left-wing auxiliary tank and 9 U.S. gallons in the right-wing auxiliary tank. This would have given the aircraft about 40 minutes of flying time at cruise power before complete fuel exhaustion.

At 1826 (38 minutes after takeoff), when flight TIN223 was approximately halfway to CYFS, the flight crew noticed the illuminated low-fuel-level caution light for the aft fuel tank. The flight crew immediately realized that they had departed with insufficient fuel and began the process of determining where to divert to. It was decided that Fort Providence Aerodrome (CYJP), Northwest Territories, was the closest runway and, at 1829, flight TIN223 turned southbound towards it. During this time, the captain climbed the aircraft to 7000 feet ASL.

The captain informed the Air Tindi flight coordinator of the situation via the aircraft's satellite radio. The flight coordinator relayed a suggestion from the chief pilot to consider shutting 1 engine down to conserve fuel, and the pilot agreed. At 1834, the captain began to

[3] A check of switches, controls and gauges prescribed in the checklist but conducted without a checklist and done in a consistent order each time.

draw fuel out of the auxiliary fuel tanks located in the wings,[4] and the first officer briefed the passengers about the diversion. Shortly after, the captain commenced an intentional shutdown of the left engine and feathered the left propeller, which was completed at 1838. Power was then reduced on the right engine to conserve fuel and a slow descent was commenced. Fuel continued to be drawn from the right-wing auxiliary fuel tank. It was calculated during the investigation that an estimated 69 pounds of fuel remained in the forward fuel tank at this time and it is likely that the low-fuel-level caution light for the forward tank had illuminated.

At 1843, the captain noticed that the PUMP FAIL R TANK light had illuminated, indicating that the right-wing auxiliary fuel tank was nearly empty. The switch was then placed in the REFUEL position.

At 1847, flight TIN223 was about 11 nautical miles (NM) from CYJP, descending through 3300 feet ASL when the right engine began to surge. The flight crew shut down the engine and feathered the propeller, and the captain began slowing the aircraft to the optimal glide speed for maximum range of 86 knots[5] indicated airspeed. The first officer briefed the passengers for a forced approach to an off-airport landing. The captain looked for a suitable place to land. In the darkness, he was able to discern an area of muskeg and chose that area rather than a treed area.

Just before touchdown, the captain requested flaps to 10° and then full flap; the first officer selected those flap positions. The stall horn activated when the aircraft was just above the muskeg and seconds before touchdown. The aircraft touched down on the muskeg at 1851, 6.7 NM northwest of CYJP, and came to a stop in an upright position (Figure 2).

The Canadian Mission Control Centre, in Trenton, Ontario, received an emergency locator transmitter signal for the aircraft on frequency 406 MHz shortly after. Approximately 4 hours after the forced landing, all occupants were recovered by rescue personnel.

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4 See section 1.6.1 *DHC-6-300 fuel system* of this report for information.

5 See section 1.6.2.3 *Power-off glide speed for maximum range* of this report for information.

Figure 2. Photo of the occurrence aircraft after the forced landing in the muskeg, looking east (Source: Air Tindi Ltd.)

1.2 Injuries to persons

Two flight crew members and 3 passengers were on board the aircraft during the occurrence flight. All the occupants showed signs of and were treated for mild hypothermia. One passenger received a minor injury when walking out from the accident site.

Table 1. Injuries to persons

Degree of injury	Crew	Passengers	Persons not on board the aircraft	Total by injury
Fatal	0	0	–	0
Serious	0	0	–	0
Minor	2	3	–	5
Total injured	2	3	–	5

1.3 Damage to aircraft

The aircraft remained upright during the landing and damage was limited to the nose bulkhead area at station 60. The nose landing gear was displaced rearward and there was associated wrinkling of nose skins and nose structure.

1.4 Other damage

There was no other damage.

1.5 Personnel information

At Air Tindi, the DHC-6 aircraft are operated with 2 flight crew members who typically alternate between pilot flying and pilot monitoring on each flight. On the occurrence flight, the captain was the pilot flying, seated in the left seat, and the first officer was the pilot monitoring, seated in the right seat.

Table 2. Personnel information

	Captain	First officer
Pilot licence	Airline transport pilot licence (ATPL)	Commercial pilot licence (CPL) - Aeroplane
Medical expiry date	01 October 2022	01 November 2022
Total flying hours	6396.5	434.6
Flight hours on type	2945.1	84.9
Flight hours in the 7 days before the occurrence*	20.7	2.3
Flight hours in the 30 days before the occurrence*	75.7	10.7
Flight hours in the 90 days before the occurrence*	174.1	51.8
Flight hours on type in the 90 days before the occurrence*	174.1	51.8
Hours on duty before the occurrence	9.5	10.0
Hours off duty before the work period	63.5	15

*Flight hours from the Air Tindi flight and duty report as of 31 October 2021.

1.5.1 Captain

The captain joined Air Tindi in August 2008 and began working as a ramp assistant. This job involved the organizing and loading of cargo, primarily for the de Havilland DHC-7 operation. In November 2009, he became a flight coordinator. This position involved monitoring the progress of company flights and providing captains with operational information that may be required for the safe conduct of their flights, including meteorological data without analysis or interpretation. The duties also involved flight planning assistance, including fuel loads, and passenger and freight manifests.

In June 2011, he moved to the flight operations department and was trained and began to work as a first officer on the de Havilland DHC-6. He continued in this role until August 2013, when he was trained and began working as a first officer on the de Havilland DHC-7. In November 2017, he started flying as a captain on the single-pilot operated Cessna 208. In April 2019, he upgraded to a captain position on the DHC-6. In June 2021, the captain was approved by Air Tindi as a training pilot for line indoctrination on the DHC-6.

In December 2020, the captain completed both the online and in-person recurrent training for crew resource management (CRM) and the company's safety management system (SMS). In June 2021, the captain completed recurrent training in the DHC-6, which included a review of checklist usage. The captain successfully completed a pilot proficiency check for the DHC-6 in July 2021.

At the beginning of the day of the occurrence, his total flight time on the DHC-6 was 2945.1 hours, 1644.3 of which were as pilot-in-command. Air Tindi is the only company he had worked for as a pilot.

The captain held the appropriate licence and ratings for the flight in accordance with existing regulations.

1.5.2 First officer

The first officer was hired by Air Tindi in April 2021. By the end of April 2021, the first officer had completed both the online and in-person CRM training. His company indoctrination training was completed on 04 July 2021. By 31 August 2021, he was approved by Air Tindi as a first officer on the DHC-6.

The first officer held the appropriate licence and ratings for the flight in accordance with existing regulations.

1.6 Aircraft information

The occurrence aircraft, a de Havilland DHC-6-300 Twin Otter, is a twin-engine turbo-prop aircraft that features a high wing with struts, a fixed landing gear, and an unpressurized cabin. The aircraft was configured with seating for 8 passengers for flight TIN223.

Table 3. Aircraft information

Manufacturer	de Havilland*
Type, model, and registration	DHC-6 series 300, C-GNPS
Year of manufacture	1977
Serial number	558
Certificate of airworthiness/flight permit issue date	31 March 1989
Total airframe time	48 887.9 hours
Engine type (number of engines)	Pratt & Whitney Canada PT6A-34 (2)
Propeller type (number of propellers)	Hartzell (2) HC-B3TN-3DY (2)
Maximum allowable take-off weight	5670.0 kg
Recommended fuel types	Jet A, Jet A-1, Jet B
Fuel type used	Jet A-1

* Viking Air Ltd is the current type certificate holder for the DHC-6.

1.6.1 DHC-6-300 fuel system

The DHC-6-300 fuel system consists of 2 main fuel tanks located in the belly of the aircraft beneath the passenger cabin and contains a total of 382 U.S. gallons (2574 pounds), of which 378 U.S. gallons (2548 pounds) are usable.[6] The forward fuel tank feeds the right engine and has a capacity of 181 U.S. gallons (1220 pounds) of usable fuel. The aft fuel tank feeds the left engine and has a capacity of 197 U.S. gallons (1327 pounds) of usable fuel. There is also unusable fuel: 3.8 U.S. gallons (26 pounds) in the main fuel tanks and associated fuel lines. This amount is not considered part of the aircraft fuel tank capacity and is included in the basic weight of the aircraft.

Refuelling of the main forward and aft tanks is accomplished through 2 fuel filler ports located on the left side of the aircraft, just below the main cabin floor line. It takes approximately 15 minutes to upload 297 U.S. gallons (2000 pounds) of fuel with the equipment used by the fuel company that Air Tindi uses at CYZF.

The quantity of fuel in the main fuel tanks is indicated in the centre of the forward instrument panel and is viewable from either pilot seat. There is one gauge for each tank. The gauges are calibrated in pounds and are driven from a capacitance probe system in each fuel tank. There were no reports of erroneous readings for the occurrence aircraft and the gauges on the aircraft were reasonably accurate.

Two low-fuel-level caution lights are located on the caution light panel and are labelled FWD FUEL LOW LEVEL and AFT FUEL LOW LEVEL. Each light is controlled by a float switch in the related tank when a predetermined fuel level is reached. In level flight, the low level trigger point is 75 pounds of usable fuel remaining in the forward tank and 110 pounds of usable fuel remaining in the aft tank. An average fuel consumption rate for the DHC-6-300 is 10 pounds of fuel per minute. When both low-fuel-level lights illuminate, there are approximately 18 minutes of usable fuel left in the main fuel tanks before fuel exhaustion and loss of engine power. The aircraft flight manual (AFM)[7] advises pilots to land as soon as possible, and in no case later than 15 minutes, after illumination of both lights.

The occurrence aircraft was equipped with optional auxiliary fuel tanks located in the outboard section of each wing (wing fuel tank). These wing fuel tanks each contain 44 U.S. gallons (296 pounds) of fuel and are to be used in cruise flight only. Fuel can be added to the wing fuel tanks from over-wing fuel filler ports or from the main fuselage tanks while the aircraft is on the ground by utilizing the fuel pumps. The transfer rate is about 2.5 U.S. gallons per minute. The AFM prohibits the refuelling of the wing fuel tanks while in flight. The control panel for the wing fuel tanks is located on a lower panel on the captain's side of the flight deck (Figure 3). The selector is a 3-position locking lever toggle switch. The positions are: ENGINE, OFF, and REFUEL.

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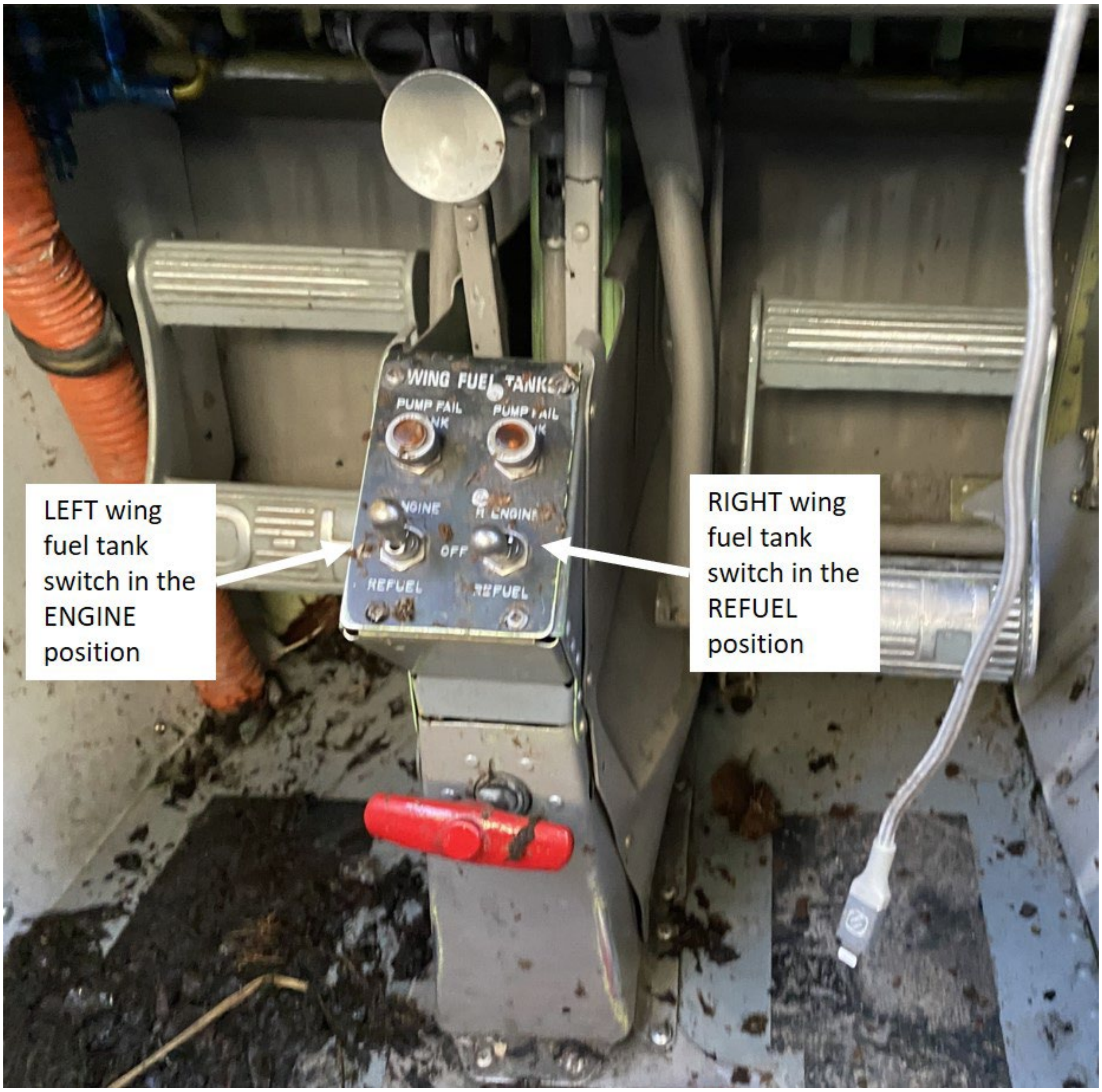
6 Viking Air Ltd., *Pilot Operating Handbook and Aircraft Flight Manual DHC-6 Series 300 (Twin Otter) and Variants* (10 September 2010), Section 7.12: Fuel System, pp. 7-67–7-78.

7 Ibid., Section 3.13.3: Fuel Low Level Light Illuminated, pp. 3-44–3-45.

Figure 3. Photo of the occurrence aircraft's wing fuel tank panel after the accident (Source: Air Tindi Ltd., with TSB annotations)



During single-engine operation, it is possible for fuel from the wing tank of the shutdown engine to be used by the operating engine. Press-to-test amber caution lights marked PUMP FAIL L TANK and PUMP FAIL R TANK are located on the control panel. These illuminate when there is insufficient pressure from the associated wing-tank pressure pump.

A post-accident examination of the occurrence aircraft revealed that there were no issues with the airframe fuel system, engine fuel system, or fuel quantity indication and alerting systems, and no fuel leaks were noted. During recovery of the aircraft, 7.0 U.S. gallons of Jet A-1 fuel were drained from the right-wing fuel tank and 5 U.S. gallons of Jet A-1 fuel were drained from the left-wing fuel tank, for a total of 12.0 U.S. gallons (80.7 pounds) of fuel. Negligible fuel was observed in the forward and aft main fuel tanks, but 5 U.S. gallons total were recovered from the fuel lines before the aircraft was recovered from the accident site.

1.6.2 Aircraft performance

During the investigation, several performance calculations relevant to this accident were conducted to estimate the two-engine long-range cruise, the single-engine long-range cruise and the power-off glide speed for maximum range. The conditions at the time the crew noticed the fuel situation were used for the calculation were as follows: temperature International Standard Atmosphere of +10°C at an altitude of 7000 feet ASL and an aircraft weight of approximately 9000 pounds.

1.6.2.1 Two-engine long-range cruise

Using the chart for supplementary operating and performance data (landplane)[8] given in the AFM, long-range cruise performance can be calculated. This chart requires an aircraft configuration of both engines operating, the intake deflectors retracted, and the engine bleed air off. Taking the conditions at time when the fuel situation was noticed by the crew, a specific range of 0.325 NM per pound of fuel at a true airspeed of 136 knots is calculated.

1.6.2.2 Single-engine long-range cruise

For single-engine long-range cruise performance,[9] the chart requires an aircraft configuration of one engine at maximum continuous power, one engine shut down with the propeller feathered, the engine intake deflectors retracted, and the engine bleed air off. Taking the conditions at time when the fuel situation was noticed by the crew, a specific range of 0.394 NM per pound of fuel at a true airspeed of 143 knots is calculated.

1.6.2.3 Power-off glide speed for maximum range

The maximum glide range for the DHC-6 is predicated on a descent gradient of 8.18% or approximately 2 NM of horizontal distance for every 1000 feet of descent. To achieve this gradient, the aircraft must be at the correct speed for its weight and be configured with flaps retracted and both propellers feathered. Using the data in the AFM[10] and an aircraft weight of 9000 pounds, a calibrated airspeed of 86 knots is calculated.

1.7 Meteorological information

On the day of the occurrence, a high pressure system was dominating the Northwest Territories and Yukon. The high pressure system featured high scattered clouds and local mist in the valleys. The CYFS upper wind forecast for the time of the occurrence for 6000 feet ASL was: wind direction 250° true at 9 knots with an outside air temperature of 12 °C.

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8 Ibid., Part 5: Supplementary Operating and Performance Data (Landplane), Section 3: Cruise Data, Figure 5-3-3 Nautical Air Miles per Pound of Fuel ISA +10°C, p. 5-3-4.

9 Ibid., Figure 5-3-5 Nautical Air Miles per Pound of Fuel (One Engine Inoperative-Landplane), p. 5-3-6.

10 Ibid., Section 3: Emergency and abnormal procedures, Figure 3-1 Glide Speed Graphs (both propellers feathered)), p. 3-26.

CYJP, located about 7 NM southwest of where the occurrence happened, does not have an aviation surface weather observation program, nor does it have an aerodrome forecast program. The Meteorological Service of Canada operates a non-aviation automated weather station, from which basic meteorological information (i.e., temperature, dew point, and wind) can be obtained. CYFS surface weather observations issued 9 minutes after the time of the forced landing indicated a temperature of −2.7 °C, a dew point of −4.9 °C, and a wind direction of 140° true at a speed of 1 knot.

At the time of the occurrence, the altimeter setting was 29.90 inches of mercury at CYZF and 29.83 inches of mercury at CYFS.

1.8 Aids to navigation

The aircraft was equipped with an all-in-one Garmin GNS 530 GPS [global positioning system]/navigation/communication unit. In addition, each flight crew member had a computer tablet with the ForeFlight mobile application and GPS "own ship" position, providing a moving map depiction of the aircraft's position.

1.9 Communications

During the diversion to CYFS, the satellite phone on the aircraft was switched to emergency mode, which broadcasts position data and prevents outgoing calls. When the flight crew attempted to contact the company after landing, the outgoing call could not be completed given that the phone was still in emergency mode. The flight crew contacted the Air Tindi flight coordinator using a cell phone. The flight coordinator told the crew to turn off the emergency mode in order to regain the calling feature of the satellite phone.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

The occurrence aircraft was equipped with a cockpit voice recorder (CVR) in accordance with the CARs. The recorder was retrieved from the aircraft and sent to the TSB Engineering Laboratory in Ottawa, Ontario, for download. The 30-minute recording was of good quality and captured the events from the realization of the low fuel level to the touchdown. Because the recording was only 30 minutes long, the events that occurred on the previous flight and during start-up and takeoff were not captured.

In November 2010, the International Civil Aviation Organization (ICAO) introduced the requirement for all CVRs "to retain the information recorded during at least the last 2 hours of their operation"[11] effective 01 January 2016. In May 2019, amendments to the CARs for CVRs were published in the *Canada Gazette*, Part II. These amendments are based on ICAO's 2010 requirements and include the requirement for all CVRs to have a recording capacity of at least 2 hours. This requirement will not become effective until May 2023.

Commercial aircraft operating internationally must comply with the requirements included in ICAO's Annex 6, Part I; however, Canadian operators are still conducting international flights on aircraft equipped with CVRs with a 30-minute recording capacity owing to Transport Canada (TC)'s delay in updating the CVR requirement.

Since 01 January 2016, and in support of TSB investigations, the TSB laboratory has analyzed 12 CVRs with a 30-minute recording capacity. Of these 12 investigations, 3 identified[12] a finding as to risk where the investigation was hampered by insufficient data due to the 30-minute length of the CVR recording and a more complete understanding of the safety issues was not possible.

1.12 Wreckage and impact information

The aircraft touched down in partially frozen muskeg. No trees were struck during the approach or after touchdown. The aircraft remained upright, which contributed to the damage being limited to the nose landing gear and associated structure.

1.13 Medical and pathological information

There was nothing to indicate that the flight crew's performance was degraded by medical or physiological factors, including fatigue.

1.14 Fire

There was no fire either before or after the occurrence.

1.15 Survival aspects

After the aircraft came to rest, the flight crew assessed the passengers and themselves for injuries; there were none. At 1856, 9 minutes after landing, the Canadian Mission Control Centre called the Joint Rescue Coordination Centre in Trenton, Ontario, to inform it that a transmission had been received from the occurrence aircraft's 406 MHz emergency locator transmitter.

Initial attempts by the crew to get in touch with the company on the satellite phone were unsuccessful owing to the phone being placed in "emergency mode" while the aircraft was in flight. The flight crew used a passenger's cell phone to inform Air Tindi that they were "all

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11 International Civil Aviation Organization (ICAO), Annex 6 to the Convention on International Civil Aviation, *Operations of aircraft*, Part 1 – International Commercial Air Transport — Aeroplanes, Eleventh Edition, (July 2018), Section 6.3.2.3.1, p. 6-7.

12 TSB air transportation safety investigation reports A19O0117, A18A0088, and A17C0132.

okay." Air Tindi relayed the last position of the aircraft to the Royal Canadian Mounted Police (RCMP) to facilitate the ground search. By 1930, the satellite phone was returned to normal mode and the flight crew resumed communicating on it.

Initially, 2 passengers attempted to walk away from the aircraft to higher ground. Given the difficult walking conditions and encouragement from the first officer to come back, they returned to the aircraft. The captain retrieved the survival kit and got the space blankets out to keep the passengers warm.

At 2000, a ground search party from Fort Providence (RCMP, fire rescue and medical people) were travelling out to the accident site. A local road was used to get close and the search team then saw the lights of the aircraft, which was about 1 km away, from the road. The flight crew had been cycling the aircraft lights on and off every 30 minutes in order to aid the ground search crew in locating them.

From the road, the ground search party started towards the aircraft using all terrain vehicles. The partially frozen muskeg proved too difficult for these vehicles. The search party members decided to leave the vehicles and to make their way to the aircraft on foot. This was particularly difficult given that the ice was thin and they often fell through the ice into knee- and waist-deep water.

At 2120, the ground search party had arrived at the aircraft and a decision was made to walk back to the road. At 2225, the ground search party, passengers, and flight crew reached the road and were on their way to Fort Providence. At 2300, health assessments were being done and all aircraft occupants were given treatment for mild hypothermia.

1.16 Tests and research

1.16.1 Fuel quantity calculation

A fuel quantity calculation was performed to develop a better understanding of the fuel quantity in each tank during the flight. CVR data, interviews, and flight path data were combined with known fuel-flow data to determine fuel quantities at various times during the flight. The calculations were started with the aircraft's known fuel state when the aircraft was being prepared for recovery from the accident site. Working backwards from that known fuel state, a take-off fuel weight of 534 pounds was derived. This amount is reasonable given that the fuel loads and flight times from the operational flight plan indicated that aircraft would have had 533 pounds at takeoff from CYZF.

1.16.2 TSB laboratory reports

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

- LP026/2022 – CVR Download and Analysis

1.17 Organizational and management information

1.17.1 Air Tindi Ltd.

Air Tindi is based in Yellowknife and holds an air operator certificate delivered by TC for the following operations: aerial work (CARs Subpart 702), air taxi (CARs Subpart 703), commuter (CARs Subpart 704), and airline (CARs Subpart 705). The company operates a fleet of single- and multi-engine turbo-prop aircraft and provides daily scheduled flights serving isolated communities, air ambulance services, flights throughout northern Canada, and charter flights for mining, tourism, government, and community support services.

1.17.1.1 Safety management system

Air Tindi has a TC-approved SMS for its CARs Subpart 705 operation, and the SMS is utilized throughout the company, including its CARs Subpart 703 and CARs Subpart 704 operations.

A review of the safety reports filed in the Air Tindi SMS database revealed that several reports submitted were related to fuel issues on other aircraft (King Air 200/300, DHC-7, C208), but none were related to checklist usage or fuel in the DHC-6 fleet.

1.17.1.2 Flight operations manual

The Air Tindi *Flight Operations Manual* (FOM) (version 5 of the 4th edition) was reviewed and approved by TC on 08 March 2021. The manual contains information "for the use and guidance of flight operations personnel in the execution of their duties"[13] and further states that "[t]he company requires that personnel know the contents of the manual and apply the policies and procedures accordingly."

With regards to this occurrence, the following sections of the FOM are relevant:

For the captain:

> The Captain is responsible to the Chief Pilot for the safe conduct of assigned flights. Specific duties include: […]
>
> - checking weather, all applicable NOTAMs where available, determining fuel and oil requirements; […]
> - conducting flights in strict adherence with the company aeroplane *Standard Operating Procedures* (when applicable); and,
> - conducting flights in accordance with Canadian Aviation Regulations, the *Aircraft Flight Manual*, and this *Flight Operations Manual*.[14]

For the first officer:

> The First Officer's duties include, but are not limited to the following: […]
>
> - conduct flights in strict adherence with the company aeroplane *Standard Operating Procedures*; […]

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[13] Air Tindi Ltd., *Flight Operations Manual*, Edition 4, Version 5 (15 January 2021), Chapter 1, Section 1.2: Preamble, p. 1-2.

[14] Ibid., Chapter 6, Section 6.6.10: Captain, p. 6-15.

> - assist the Captain in the management and operation of the flight;
> - participate in the execution of cockpit procedures, emergency procedures, checklist procedures, and instrument approach procedures as directed by the Captain and, in accordance with the procedures outlined in this manual, the *Aircraft Flight Manual*, and the aircraft *Standard Operating Procedures*; […]
> - shall be responsible to inform the Captain immediately of any situation when the aircraft is being handled improperly or placed in jeopardy.[15]

For aircraft fuel and oil requirements for night VFR flight:

> The company shall not authorize and the flight crew shall not commence a flight, or during flight, change the destination aerodrome set out in the flight plan or flight itinerary unless the aircraft carries sufficient fuel and oil to:
>
> - fly to the destination aerodrome; and,
> - then fly for a period of 45 minutes at normal cruising speed plus contingency fuel.[16]

For monitoring of fuel during flight:

> All personnel involved in the fuelling, dispatch and conduct of a flight must be extremely vigilant at all times with respect to ensuring that the required fuel is on-board. Flight crew members must closely monitor the fuel status throughout the flight and be alert to any conditions that could deplete fuel reserves. If there is any indication of problems with the fuel system it is crucial that the problem be correctly identified and that the proper checklist is followed. Assumptions concerning the accuracy of an indicator or fault warning should be made with extreme caution, in consultation with the *Aircraft Flight Manuals* and *Standard Operating Procedures*, as applicable. Flight crew shall record the progress of the fuel state on the OFP.[17]

For the flight crew preparation duties:

> In preparation for a flight and prior to the Captain dispatching the flight, the flight crew members shall ensure the following […]:
>
> - technical dispatch: […]
>   - aircraft fuel and oil requirements are met;
> - aircraft load including passengers/persons:
>   - fuel calculated and loaded;[18]

For fuelling supervision:

> Flight crew members will supervise the fuelling of their aeroplanes.[19]

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15 Ibid., Chapter 6, Section 6.6.11: First Officer, pp. 6-15–6-16.

16 Ibid., Chapter 8, Section 8.11.2: Night VFR (702/703/704), p. 8-12.

17 Ibid., Section 8.11.5: Monitoring of Fuel During Flight, p. 8-13.

18 Ibid., Chapter 13, Section 13.7.2: Flight Crew Flight Preparation Duties, pp. 13-10–13-11.

19 Ibid., Chapter 15, Section ,15.9.1: Fuelling procedures - Supervision, p. 15-11.

Despite this requirement, this fuelling supervision procedure was not being used by Air Tindi at the time of the occurrence. Management was in the process of having this requirement amended for the next version of the FOM. There were instances where aircraft fuelling could not be monitored by flight crew, such as when fuelling the aircraft the night before a flight originating in CYZF.

1.17.1.3 Standard operating procedures

The Air Tindi standard operating procedures (SOPs) for the DHC-6 (version 2 of the 1st edition) were reviewed and accepted by TC on 26 February 2020. The SOPs are issued for "guidance in the operation of the Twin Otter aircraft within the limitations of the Aircraft Flight Manual."[20] The SOPs go on to state:

> Although SOPs ensure standardization for flight crewmembers to complete their duties, they do not encompass all situations. Crewmembers are therefore expected to exercise judgment and consistency in their application. Any deviations from the SOPs should be thoroughly briefed and understood by all concerned.[21]

The SOPs refer to the FOM on how the various checklists are to be performed.

1.17.1.4 Checklists

Flight crew checklists are designed to ensure pilots complete a list of tasks in an appropriate order, without omissions. They prompt either pilot to perform these tasks during normal, abnormal, and emergency operations, standardizing performance and therefore improving cockpit safety. Specifically, checklists:

- reduce the probability of any omissions because they serve to remind the pilot of each required step in the required order, and
- increase the probability of detecting any omissions because when they are read aloud, the other pilot can hear if a step is missed.

However, to be effective, the operating culture and CRM must encourage and maintain the practice of using checklists routinely. The improper use, or the non-use of a checklist, is sometimes cited as a causal or contributing factor to an aircraft accident. In such scenarios, pilots have either inadvertently missed a critical step on the checklist, usually as a result of an interruption or distraction, or they have intentionally omitted a checklist or parts of it, usually as a result of an adaptation to the required cockpit routine.

The Air Tindi FOM states in part:

> Checks, Checklists, and Drills have been developed for the operation of the aircraft to ensure required actions are not inadvertently omitted or completed in an inappropriate sequence. Check[s] and drills are not to be completed from memory

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20 Air Tindi Ltd., *Standard Operating Procedures – De Havilland Twin Otter (DHC-6)*, Edition 1, Version 2 (01 February 2020), Chapter 1, Section 1.2: Preamble, p. 1-2.

21 Ibid.

> unless indicated. Generally, the only memory procedures are for emergency drills that require immediate action.[22]

Checks are actions, a checklist is the physical written document associated with the checks, and drills are "memory items for an abnormal or emergency situation requiring immediate action."[23] Should checklist be interrupted, "the check must be re-started from the beginning or commenced from the last item known to be completed."[24]

The Air Tindi FOM indicates that normal checklists can be completed using a combination of methods: non-verbal checks, verbal challenge and response checks, and verbal action and confirmation checks.[25] The FOM also states that "[i]t cannot be overstated that the proper completion of normal checklists is the cornerstone for pilot standardization and cockpit safety."[26]

Non-verbal checks "are completed silently with or without reference to the printed checklist."[27] For the DHC-6, the cockpit and cabin preparation checklists are non-verbal checks.

For the items that Air Tindi has deemed most critical for safety of flight, the verbal challenge and response technique is used. These checks require both flight crew to participate and these checks are not completed from memory. For the DHC-6, the following checks are verbal challenge and response checks: After Start, Run-Up, Taxi, Line Up, and Descent/Approach (Appendix B).

The verbal action and confirmation checks "do not require the challenge of other crew members. The checks are carried out by a crew member and can be completed either from memory or by reference to the checklist."[28] The following checks can be performed this way for the DHC-6: Pre-Flight Setup, Before Start, After Takeoff, Cruise, Before Landing, Downwind, After Landing, and Shutdown (Appendix B).

To sum up, most of the checks for DHC-6 operations do not necessarily require reference to the checklist. Further, of the 3 checks that include checking the fuel quantity (Before start, Taxi, and Cruise), only the Taxi checks require a full verbal challenge and response using the checklist.

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22 Air Tindi Ltd., *Flight Operations Manual*, Edition 4, Version 5 (15 January 2021), Chapter 13, Section 13.28.1: General procedures, p. 13-30.

23 Ibid.

24 Ibid., Section 13.28.2: Completion of checks, p. 13-30.

25 Ibid., Section 13.28.4: Normal checklists, p. 13-31.

26 Ibid.

27 Ibid.

28 Ibid., p. 13-32.

All abnormal and emergency checklists are found in the *Air Tindi DHC-6 Emergency Procedures Quick Reference Handbook* (QRH). The Air Tindi SOPs[29] provide direction on the use of the QRH. Drills associated with emergencies are to be completed by memory and followed up with the appropriate QRH checklist once the drills are completed and the flight path is under full control. QRH checklist items relevant to this occurrence are: Engine Failure/Fire In Flight (In Flight Shutdown), Fuel Low Level Light Illuminated, Actual Low Fuel Level, and Forced Landing.

1.17.2 Transport Canada oversight

In the 5 years leading up to the occurrence, the following TC surveillance activities took place:

- An assessment of Air Tindi was conducted in May 2017. Two findings were identified: one related to flight duty time and the other related to the maintenance quality assurance program. Corrective action plans were submitted by Air Tindi, and approved and closed by TC in March 2018.
- A process inspection was conducted in February 2019. The inspection identified one finding related to an aircraft checklist, but unrelated to fuel, that was not consistent with the AFM. Corrective action plans were submitted by Air Tindi, and approved and closed by TC in September 2019.

1.18 Additional information

1.18.1 Development of adaptations

While policies and operating procedures are prescribed to set boundaries for safe operations, individuals may experiment with the boundaries to become more productive or to obtain some other benefit. For example, if there is a shift in a pilot's focus from the safety of a flight (threat-oriented), to the achievement of a flight (goal-oriented), the risks associated with the flight may not remain as low as reasonably practicable. Specifically, when the focus becomes goal-oriented, this may increase risk-taking behaviour, which often results in the development of adaptations and, over time, unsafe practices.[30]

Individuals who perform higher-risk activities with no, or few, negative repercussions, are likely to continue taking risks. Over time, they may become desensitized or habituated to the level of risk taken. For example, repeated success may lead pilots to believe they will have continued success in the same situations. This previous success therefore influences

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[29] Air Tindi Ltd,. *Standard Operating Procedures – De Havilland Twin Otter (DHC-6)*, Edition 1: Version 2 (01 February 2020), Chapter 9: Emergencies.

[30] J. Rasmussen, "Risk management in a dynamic society: a modeling problem," *Safety Science*, Vol. 27 , Issue 2/3 (1997), p. 197.

future risk-taking behaviour, which in turn creates a new baseline comfort level.[31] Without mitigations in place to recalibrate risk perception, the subjective evaluation of low personal risk may lead to increases in high-risk activities.[32] For example, the unsafe practice of adapting the use of checklists will continue and eventually become a routine part of each flight.

In this occurrence, a few of the experienced DHC-6 captains within the company had developed the unsafe practice of performing some of the checks by memory only. This had become routine for most of their flights.

1.18.2 Group dynamics and influence

Making decisions as a crew, either before or during the flight, can be very effective. However, in a safety critical environment, such decisions need to be bound by objective procedures and hazard management, such as SOPs and checklists, to ensure that they are not affected by any associated group-based dynamics or biases.

Individuals are often unaware of how or when they have been influenced by other people. As a result, they may end up making decisions or changing their behaviour in a way they would not normally choose to do. Whether someone is influenced by another individual or group of individuals depends on many factors, such as experience, seniority, personality, social status, or motivation.

There are 2 main types of influence: normative and informative.[33] Normative influence is driven by the expectations of others, i.e., a person makes a decision to do something (or not do something) because they perceive it is expected, the norm will be socially preferred. However, this individual may not necessarily believe in the decision or behaviour. For example, one may decide to consume an alcoholic drink before driving, only because the remaining group are doing so. However, they still continue to believe that one should not drink and drive. Conversely, informative influence is driven by information, i.e., a person makes a decision to do something (or not do something) because their opinions have been influenced and they now believe in the new decision or behaviour.

Some specific examples of influence include:[34,35]

- Compliance: when an individual performs (or does not perform) a task just because someone has requested they do it (or not do it). The probability of compliance is influenced by what the requester has previously asked the person to do and the status

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31 J. Hollenbeck, D. Ilgen, J. Phillips, et al., "Decision risk in dynamic two-stage contexts: beyond the status quo," *Journal of Applied Psychology*, Vol. 79, Issue 4 (1994), pp. 592–598.

32 G. J. S. Wilde, "Homeostasis drives behavioural adaptation," *Behavioural Adaptation and Road Safety: Theory, Evidence and Action* (2013), Chapter 5, pp. 61–86.

33 D. P. Gradwell, D. J. Rainford, "Crew resource management", *Ernsting's Aviation and Space Medicine*, 5th Edition (CRC Press, 22 January 2016), Chapter 45, p. 668.

34 R. D. Campbell, M. Bagshaw, *Human Performance and limitations in aviation*, 3rd Edition (1991), pp. 138–140.

35 R. A. Baron, D. Byrne, *Social Psychology: Understanding Human Interaction*, 6th edition (1991), pp. 462–463.

(e.g., seniority) of the requester. This is different from obedience, which follows a direct order.
- Conformity: when an individual gradually changes their behaviour to make it more in line with the group norm. This infers the individual has knowledge of the behaviour and attitudes of the remaining group.
- Groupthink: when the motivation of individuals in a group to maintain group consensus overrides their motivation to evaluate all potential courses of action.

A few of the junior first officers within the company, including the occurrence first officer, were aware, and had discussed amongst themselves, that when flying with some of the senior captains, these captains had adopted the practice of performing some of the verbal challenge and response checklists silently, by memory only and by themselves, i.e., without necessarily the input or challenge from the first officer. Some of these senior captains in question used to be first officers within the company before being promoted to captain. The occurrence first officer and certain other first officers accommodated this practice without any safety reports being submitted to the company; however, they had informally discussed the checklist practice with some of the training captains on the DHC-6. Because safety reports were not submitted on this issue, company management, as a whole, was not fully aware of the issue.

First officers were also aware that the company was passing these senior captains during check flights and permitting these captains to continue flying. However, the investigation determined that the DHC-6 captains were performing in accordance with SOPs during their check flights.

2.0 ANALYSIS

The investigation did not identify any mechanical issues with the aircraft, medical or physiological issues with the pilots, or issues related to the weather. Faced with low fuel, the crew shut down the left engine; the loss of power on the right engine was a result of fuel starvation. Consequently, the analysis will examine the flight crew's approach to using checklists and how that contributed to the aircraft departing without sufficient fuel. The analysis will also examine flight crew actions during the diversion to Fort Providence Aerodrome (CYJP).

2.1 Flight preparations

While on the inbound flight to Yellowknife Airport (CYZF) on the second-last leg of the day, the flight crew likely did not request fuel through the flight coordinator, even though they typically had done so in the past. When the captain entered the aircraft to prepare for the last flight of the day, he observed a pink fuel slip in the door and assumed it was for the fuel that he thought he had ordered for the flight.

Finding as to causes and contributing factors

When the captain saw the pink fuel slip in the door of the aircraft, it reinforced his belief that the aircraft had been fuelled for the last flight of the day, when, in actuality, it had not been refuelled.

The captain then performed the Before Start checks from memory, as allowed by company standard operating procedures (SOPs). Fuel quantity is checked as one of the items on this checklist. As he was completing this check, passengers began boarding the aircraft. The captain conversed with one of the passengers who used to work with him. After the short conversation, the captain resumed the checks, but did not note that the fuel quantity was insufficient for the planned flight.

Finding as to causes and contributing factors

While conducting the Before Start checks from memory, the captain interrupted his routine by conversing with a passenger. Consequently, the fuel quantity check was missed and the preparation for flight continued without the captain being aware that the aircraft did not have sufficient fuel for the flight on board.

2.2 Checklist usage adaptations

2.2.1 Captain

Flight crew checklists prompt pilots to perform specific tasks, reducing the probability that they omit a safety critical step. At Air Tindi, checklists that contain the most critical items for flight safety are performed using the challenge and response technique. The technique increases the probability of detecting any omissions because when checklist items are read aloud by one pilot and responded to by the other pilot, omissions are more likely to be avoided. However, to be effective, the operating culture and crew resource management practices must encourage and reinforce the routine use of challenge and response checklists.

The occurrence captain, along with a few of the other experienced captains within the company, had developed the practice of performing some of the challenge and response checks silently, by memory only, and by themselves. This adaptation was perceived as more efficient. The lack of negative repercussions each time this adaptation occurred likely reinforced the captain's decision to continue with this practice until it became a normal part of his routine.

Finding as to causes and contributing factors

Over time, the captain developed an adaptation of not conducting the challenge and response checklists where required by the SOPs. The absence of negative consequences reinforced the captain's practice until it became routine.

2.2.2 First officer

The day of the occurrence was the first time that the first officer and captain had flown together. At the start of the day's first flight, the first officer expected operations to proceed per the SOPs, i.e., checks would be performed as required by both pilots, and they did. However, as the flights progressed throughout the day, the first officer soon recognized the captain's adaptations. Although the captain did not prohibit the first officer from performing any checklist activity, the first officer became progressively more passive. This further increased the probability that omissions would not be detected. This passiveness was likely the result of the first officer being influenced in general by:

- the knowledge that other first officers were aware of such adaptations and that they tolerated them; and
- other captains with whom the first officer flew also did not routinely use checklists.

The first officer was also influenced on this particular day by:

- the fact that the company continued to approve the captain;
- the comparative seniority of the captain; and
- the fact that the captain had completed other tasks without checklists without any apparent repercussions.

Specifically, it is likely there was a normative influence, driven by the expectations of others. The first officer was influenced by the non-standard use of checklists by this captain as well as other captains, and followed that behaviour because he perceived it to be the norm and that it would be socially preferred.

Finding as to causes and contributing factors

On the day of the occurrence, the first officer's adaptation regarding checklist usage was influenced by the seniority of the captain, the captain's non-standard use of checklists, and the absence of negative repercussions from this adaptation.

2.3 Taxi and takeoff

The aircraft had not been refuelled before takeoff. While taxiing for takeoff, the captain completed the Taxi checks on his own from memory, rather than by verbal challenge and response with the first officer. While doing the checks, he omitted to check the fuel gauge and therefore did not notice that the aircraft had not been fuelled to the planned 2500 pounds, which was standard for this flight. The first officer had adopted a more passive role in the cockpit and did not perform a mental checklist including checking the fuel gauge. As a result, he did not detect the captain's omission.

Finding as to causes and contributing factors

While taxiing to the runway, the captain conducted the Taxi checks alone, silently, and from memory. Consequently, the fuel check on the checklist was missed and the aircraft departed with insufficient fuel for the flight.

2.4 Climb and cruise

During the initial climb, the After Takeoff checks are normally performed by the pilot monitoring. On the occurrence flight, these checks were completed by the first officer silently and without reference to the checklist. Once the aircraft reached cruise, the Cruise checks were completed by the first officer and, once again, they were done silently rather than by verbal action and confirmation. This was the last opportunity for both the captain and the first officer to realize that there was insufficient fuel for the flight.

Finding as to causes and contributing factors

The first officer completed the cruise checks silently and without reference to a checklist. As a result, the fuel state of the aircraft was not identified by either flight crew member.

The low-fuel-level caution light for the aft fuel tank illuminated about 25 minutes after the aircraft took off from CYZF. At this time, there were approximately 60 U.S. gallons of fuel left in the aircraft, including the wing fuel tanks, which gave the aircraft about 40 minutes of flying time before complete fuel exhaustion. However, the flight crew did not observe the AFT FUEL LOW LEVEL light for another 13 minutes, at which point approximately 28 minutes of fuel remained.

Finding as to risk

If flight crews do not maintain a scan of the flight instrument panel and alerting systems, there is a risk that they will not identify an abnormal aircraft state that escalates to an unsafe situation.

2.5 Diversion

2.5.1 Flight for maximum range

When the flight crew became aware that fuel quantity was an issue, a diversion was started toward Fort Providence Aerodrome (CYJP) and engine power was reduced to conserve fuel. No performance charts were consulted to determine what the ideal power setting would have been to achieve the maximum distance for the amount of fuel remaining (flight for maximum range). The abnormal procedures checklist for FUEL LOW LEVEL light does not provide guidance to refer to performance charts for a low fuel situation and indicates only that there is approximately 15 minutes of fuel remaining if both low level lights are illuminated.

2.5.2 Intentional left-engine shutdown

While diverting to CYJP, the captain communicated with Air Tindi via the satellite telephone. During one of the communications, it was suggested that he shut 1 engine down to conserve fuel. This suggestion originated from the chief pilot through the flight coordinator.

The DHC-6 aircraft flight manual provides performance figures on single-engine cruise fuel consumption per nautical mile. These numbers indicate that at 7000 feet above sea level (ASL) and an aircraft weight of 9000 pounds, with the remaining engine set to maximum continuous power, the fuel consumption per nautical mile would be 21% less if the flight was continued on 1 engine rather than 2.

Neither the flight crew nor the chief pilot consulted these charts during the occurrence flight; however, given the limited time available, this may not have been practical. Given that the engine shutdown was followed by a gradual descent at a single-engine power setting below maximum continuous power, it could not be determined to what extent the intentional shutdown affected the remaining range.

Finding as to risk

If flight crews do not refer to performance charts when attempting to fly for maximum range, an inappropriate power setting and aircraft configuration may be selected and maximum range may not be achieved.

2.5.3 DHC-6-300 fuel system

Finding: Other

The aircraft fuel quantity indication and alerting systems were functional and performed as designed. There were no leaks or abnormalities in the aircraft airframe or engine fuel systems.

When the left engine was shut down, fuel was being drawn from the left-wing tank. After the left engine shutdown, 5 U.S. gallons of fuel remained in the left-wing fuel tank. With the left engine shut down and the associated fuel pump off, this fuel was unavailable to the right engine unless the flight crew reconfigured the fuel system. Five minutes later, the flight crew noticed that the PUMP FAIL R TANK light had illuminated, indicating that the quantity was getting low. It was calculated that there would have been about 1 U.S. gallon in that right-wing tank at this time.

When the captain moved the right wing fuel tank switch from ENGINE to OFF, to return to feeding the right engine from the forward main fuel tank, he likely went through the OFF position to the REFUEL position. Rather than feeding the right engine, this setting would have transferred fuel from the forward main tank to the right-wing fuel tank, which is consistent with the 7 U.S. gallons of fuel found in the right tank after the forced landing. The fuel system could have transferred 6 U.S. gallons from the main fuel tank to the wing tank in the 4 minutes before the right engine flamed out. Additionally, with the switch in the REFUEL position, fuel from the right-wing fuel tank was not available to the right engine.

There are no cockpit indications when REFUEL has been selected. Although the aircraft flight manual prohibits refuelling in flight, there are no defenses in place to prevent the switch from being placed in the REFUEL position.

Finding as to risk

The DHC-6 wing fuel tank switch is designed such that it can be moved to the REFUEL position in flight, increasing the risk of inadvertent transfer of fuel from the main fuel tank to the respective wing fuel tank.

Finding: Other

The aircraft landed with a total of 12 U.S. gallons of usable fuel, 6.7 nautical miles (NM) from CYJP. This amount of fuel was sufficient for approximately 8 minutes of flight at cruise speed, or a range of about 20 NM.

2.5.4 Forced approach to an off-airport landing

The right engine flamed out owing to there being insufficient fuel in the forward main fuel tank. The aircraft was 11.8 NM from CYJP and was at 2800 feet above ground level. The aircraft was flown in the best configuration for maximum glide distance and glided 5.1 NM during the descent. The descent started (6500 feet above ground) after the intentional left-engine shutdown, placing the aircraft 3700 feet lower when the right engine failed. This extra 3700 feet would have resulted in about 6.5 NM of extra glide range.

Finding as to causes and contributing factors

As a result of fuel starvation, the flight crew conducted a forced landing into muskeg, which resulted in significant aircraft damage.

Finding as to risk

If flight crews descend rather than maintain altitude in fuel-critical situations where a possibility of fuel exhaustion is likely, the aircraft's gliding distance will be reduced, increasing the risk of landing on unsuitable terrain.

2.6 Company safety management system

To be aware of developing issues within a company, reporting is extremely important to a properly functioning safety management system (SMS). The reporting function of the Air Tindi SMS was established and being used often. The investigation revealed that DHC-6 first officers who experienced deviations from company SOPs tended to report informally to the training captains rather than use the SMS. As a result, company management, as a whole, was not fully aware of the deviation from SOPs regarding checklist usage on the DHC-6 fleet, and did not have an opportunity to evaluate the risk and pursue a corrective action plan through the SMS.

Finding as to risk

If flight crews do not use the company reporting procedures to communicate safety concerns related to operational deviations, there is a risk that company management will be unaware of unsafe practices and unable to take corrective action.

3.0 FINDINGS

3.1 Findings as to causes and contributing factors

These are conditions, acts or safety deficiencies that were found to have caused or contributed to this occurrence.

1. When the captain saw the pink fuel slip in the door of the aircraft, it reinforced his belief that the aircraft had been fuelled for the last flight of the day, when, in actuality, it had not been refuelled.

2. While conducting the Before Start checks from memory, the captain interrupted his routine by conversing with a passenger. Consequently, the fuel quantity check was missed and the preparation for flight continued without the captain being aware that the aircraft did not have sufficient fuel for the flight on board.

3. Over time, the captain developed an adaptation of not conducting the challenge and response checklists where required by the standard operating procedures. The absence of negative consequences reinforced the captain's practice until it became routine.

4. On the day of the occurrence, the first officer's adaptation regarding checklist usage was influenced by the seniority of the captain, the captain's non-standard use of checklists, and the absence of negative repercussions from this adaptation.

5. While taxiing to the runway, the captain conducted the Taxi checks alone, silently, and from memory. Consequently, the fuel check on the checklist was missed and the aircraft departed with insufficient fuel for the flight.

6. The first officer completed the cruise checks silently and without reference to a checklist. As a result, the fuel state of the aircraft was not identified by either flight crew member.

7. As a result of fuel starvation, the flight crew conducted a forced landing into muskeg, which resulted in significant aircraft damage.

3.2 Findings as to risk

These are conditions, unsafe acts or safety deficiencies that were found not to be a factor in this occurrence but could have adverse consequences in future occurrences.

1. If flight crews do not maintain a scan of the flight instrument panel and alerting systems, there is a risk that they will not identify an abnormal aircraft state that escalates to an unsafe situation.

2. If flight crews do not refer to performance charts when attempting to fly for maximum range, an inappropriate power setting and aircraft configuration may be selected and maximum range may not be achieved.

3. The DHC-6 wing fuel tank switch is designed such that it can be moved to the REFUEL position in flight, increasing the risk of inadvertent transfer of fuel from the main fuel tank to the respective wing fuel tank.

4. If flight crews descend rather than maintain altitude in fuel-critical situations where a possibility of fuel exhaustion is likely, the aircraft's gliding distance will be reduced, increasing the risk of landing on unsuitable terrain.

5. If flight crews do not use the company reporting procedures to communicate safety concerns related to operational deviations, there is a risk that company management will be unaware of unsafe practices and unable to take corrective action.

3.3 Other findings

These items could enhance safety, resolve an issue of controversy, or provide a data point for future safety studies.

1. The aircraft fuel quantity indication and alerting systems were functional and performed as designed. There were no leaks or abnormalities in the aircraft airframe or engine fuel systems.

2. The aircraft landed with a total of 12 U.S. gallons of usable fuel, 6.7 nautical miles from the Fort Providence Aerodrome. This amount of fuel was sufficient for approximately 8 minutes of flight at cruise speed, or a range of about 20 nautical miles.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 Air Tindi Ltd.

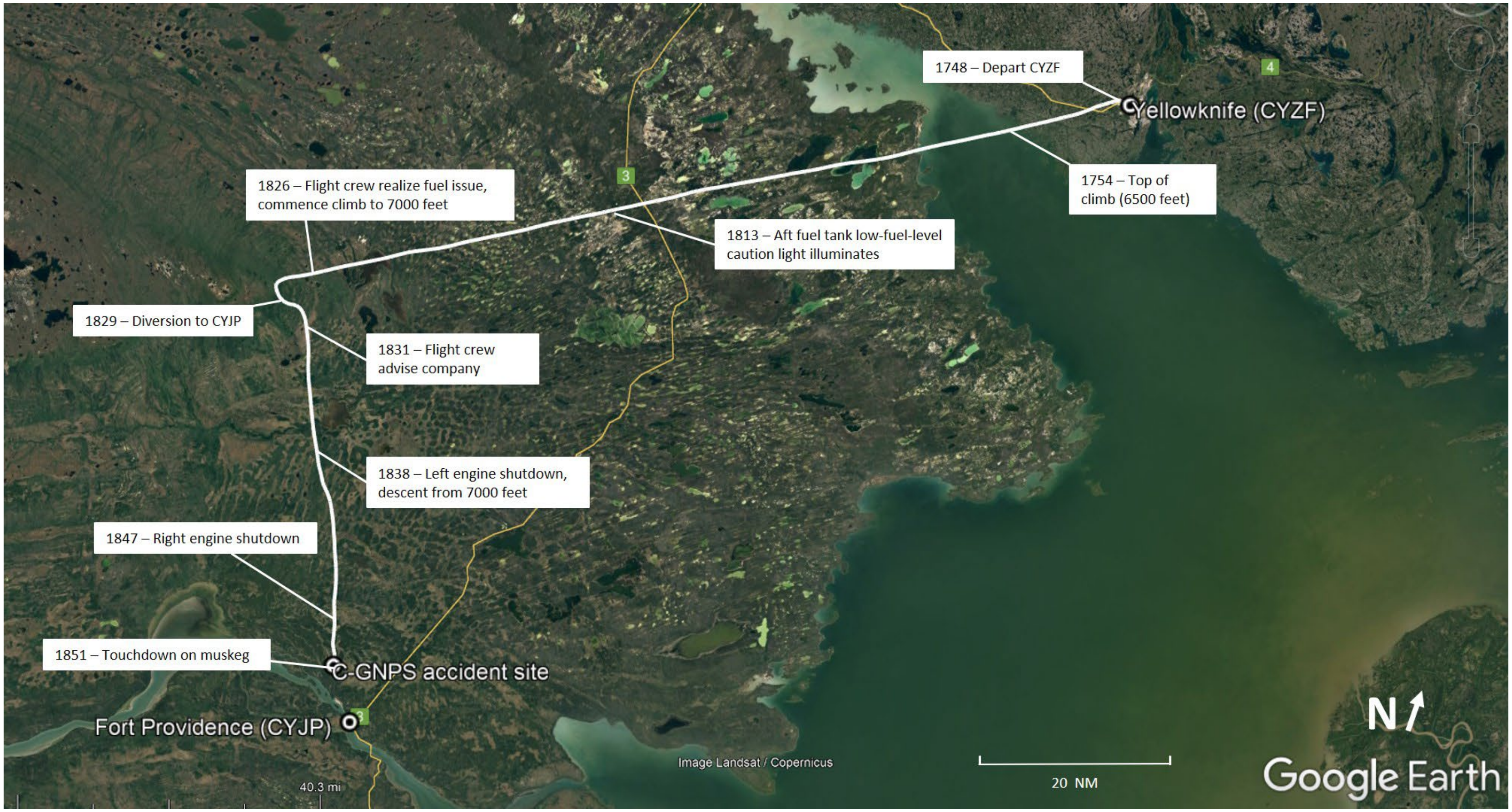
The following actions were taken by Air Tindi Ltd. after the occurrence:

- Individual de-briefs were conducted with each flight crew member that flies the DHC-6.
- A company memo was sent to flight crews, emphasizing the requirement to follow all procedures and checklists.
- A company memo was sent to flight crews requiring the captain to verify fuel uplift and sign an acknowledgement on every fuel slip before engine start.
- A company memo was sent to flight crews to inform them of the requirement to communicate fuel on board to the Operations Control Centre before each departure.
- The fleet *challenge – response* checklists were revised to become *challenge – response – verification* checklists.
- Amendments to the company standard operating procedures were made to reflect the new checklist revisions.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 19 October 2022. It was officially released on 24 November 2022.

APPENDICES

Appendix A – Sequence of events



Source: Google Earth, with TSB annotations

Appendix B – Air Tindi DHC-6 cockpit checklist

Yellow boxes (TSB annotation) indicate when flight crew are to check the fuel quantity.

COCKPIT CHECKLIST — Air Tindi — DHC-6

PRE-FLIGHT SETUP ... (FO)
Exterior and Cockpit Check ... Complete
Left Rear Cabin Door ... Locking Pins Secure
IPAD, Documents & Logbook ... Onboard
Parking Brake ... Set
Circuit Breakers ... Checked
Radio Master ... Off
Fuel Emergency Shut-Off ... Normal
Ignition Switch ... Normal
Unnecessary Electrics ... Off
Generator Switches ... Off
Bus Tie ... Normal
Bleed Air ... Off
Position lights ... On

BEFORE START ... (CA)
Passenger Briefing ... Complete
Control Locks ... Removed
Engine Plugs and Ties ... Removed
Caps, Doors and Pogo ... Secure
Power Levers ... Idle/Zero Thrust
Prop Levers ... Forward
Fuel Levers ... Off
Battery and Master Switches ... On
Fuel Quantity ... CHECKED ______ lbs.
Boost Pumps ... On
Hydraulic Pressure ... CB in, Pressure Up Twice
Beacon ... ON
--- ENGINE START (CA) ---
Engine Prop Area ... Clear
Engine ... Start

AFTER START ... (FO...CA)
External/Battery Switch ... Battery
GPU ... Disconnected
Generators ... On/Checked
Engine Instruments ... Checked
Avionics Master ... On
Auto-feather ... Selected
Cabin Signs ... As Required
Flaps ... Set____
Trims ... 3 Set
Circuit Breakers ... Checked
"After Start Complete, Taxi Check To Go"

***RUN-UP ... (FO...CA)**
Manual Feathering ... Checked
Autofeather ... Checked
Over Speed Governors ... Checked
Ice Protection Equipment (if Required) ... Checked
Beta Backup (if required) ... Checked
First flight of the day only

TAXI ... (FO...CA)
Brakes/Hydraulics ... Off/Checked
Flight/NAV Instruments ... Set/Cross-Checked
Fuel System ... Normal/Tips __/No Lights/____ Lbs.
Flaps ... ___ Indicating
Flight Controls ... Free/Correct 6 Ways
T/O Briefing ... Understood
"Taxi Check Complete, Line Up Check To Go"

LINE UP ... (FO...CA)
Landing Lights ... On
Transponder ... Alt
Bleed Air ... As Required
Ice Protection ... As Required
Caution Panel ... Checked, Normal
Headings ... Checked, Runway Heading
Wings ... Clean
"Line Up Check Complete, After Takeoff Check To Go"

AFTER TAKEOFF ... (PM)
Landing Lights ... As Required (CA)
Flaps ... Up
Climb Power ... Set
Electrical Load ... Checked
Engine Instruments ... Checked
Autofeather ... Off (CA)
Nose Wheel Steering ... Centered (CA)
Time Off ... Recorded
Dispatch ... Advised
"After Takeoff Check Complete, Cruise Check To Go"

CRUISE ... (PM)
Cruise Power ... Set
Landing Lights ... Off (CA)
Fuel ... Normal/Tips On, Landing With___Lbs
Trend ... Complete
"Cruise Check Complete, Descent/Approach Check To Go"

DESCENT/APPROACH ... (PM...PF)
Approach Setup/Briefing ... Complete/Understood
Radar Altimeter ... Set
Altimeters ... Set and CROSS-CHECKED
Gyros ... Slave/Free
CDI ... GPS or VOR/LOC
GPS RAIM Check ... Complete/Not Required
Ice Protection ... AS REQ'D
"Descent/Approach Check Complete, Before Landing To Go"

BEFORE LANDING ... (PM)
Brakes/Hydraulics ... Off/Checked
Nose Wheel Steering ... Centered (CA)
Fuel System ... Normal, No Lights
Landing Lights ... On (CA)
"Complete To the Line"
--- SHORT FINAL ---
Flaps ... Set For Landing
Props ... Forward
"Before Landing Check Complete"

AFTER LANDING ... (FO)
Flaps ... Up
Ice Protection ... Off
Unnecessary Electrics ... Off
Transponder ... Stby
Landing Lights (Exiting Runway Environment) ... Off (CA)
Time Down ... Noted
Dispatch ... Advised
"After Landing Check Complete"

May 1, 2019

Source: Air Tindi Ltd., *Standard Operating Procedures – De Havilland Twin Otter (DHC-6)*, Edition 1, Version 2 (01 February 2020).

COCKPIT CHECKLIST	Air Tindi	DHC-6

SHUT DOWN .... (CA)

Parking Brake .... Set
Avionics Master .... Off
Bleed Air Valves .... Off
Electrical Switches .... Off
Generators .... Off
Prop Levers .... Feather
T5 .... Stable < 660C
Fuel Levers .... Off
Fuel Pumps .... Off (Below 5% Ng)
Beacon Lights .... Off
Position Lights .... On
Master Switches .... Off
Control Locks .... Installed
Plugs/Ties .... Secured

DOWNWIND .... (PM)

Flaps .... Up
Power .... Set
Autofeather .... Off
Nose Wheel Steering .... Centered
Hydraulic Pressure .... Check
Landing Briefing .... Complete
Time Off .... Recorded

---------------------------SHORT FINAL---------------------------

Flaps .... Set For Landing
Props .... Forward

V REF SPEEDS (1.3 X VS KTS IAS) ....

	12300	11500	10500	9500	8500
0	95	92	87	83	79
10	85	83	79	75	71
20	80	77	73	70	66
30	77	75	72	68	64
37.5	74	70	67	64	60

COCKPIT PREPARATION

Control Locks .... Installed
Parking Brake .... On
Ram Air Lever .... As Required
Pitot Static Selector .... Norm
Unnecessary Electrics .... Off
Circuit Breakers .... In
Position lights .... On
External/Battery Switch .... As Required
DC Master .... On
Ignition .... Normal
Bus Tie .... Normal
Caution Light Test .... Test
Generator Switches .... Off
Inverter .... No. 1 / 2
Bleed Air .... Off
Power Levers ....As Required (caution if on blade latches)
Prop Levers .... As Required
Fuel Levers .... Off
Prop Autofeather .... Off
Fire Detection .... Test
Fuel Emergency Shut-Off .... Normal
Fuel Selector .... Tested, Normal
Fuel Pump Auto Crossover .... Test

CABIN PREPARATION

Fire Extinguishers .... Charged and Secure
First Aid Kit .... Sealed and Secure
Exit Doors .... Unobstructed and Secure
Life Vests .... Checked
Cabin Furnishings .... Checked
Passenger Safety Briefing Cards .... Present
All Interior Lights .... Checked
Herc Straps .... 4 Present
Tundra Ties/Shovel/Axe .... Present
Fuel Kit .... Checked/Present

Source: Air Tindi Ltd., *Standard Operating Procedures – De Havilland Twin Otter (DHC-6)*, Edition 1, Version 2 (01 February 2020).