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

AVIATION INVESTIGATION REPORT A17Q0050

Collision with wires

Exact Air Inc.
Piper PA-31, C-FQQB
Schefferville Airport, Quebec, 3.5 nm NW
30 April 2017

Canada

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Summary

The Piper PA-31 (registration C-FQQB, serial number 31-310) operated by Exact Air Inc., with 2 pilots on board, was conducting its 2nd magnetometric survey flight of the day, from Schefferville Airport, Quebec, under visual flight rules. At 1336 Eastern Daylight Time, the aircraft took off and began flying toward the survey area located 90 nautical miles northwest of the airport. After completing the magnetometric survey work at 300 feet above ground level, the aircraft began the return flight segment to Schefferville Airport. At that time, the aircraft descended and flew over the terrain at an altitude varying between 100 and 40 feet above ground level. At 1756, while the aircraft was flying over railway tracks, it struck power transmission line conductor cables and crashed on top of a mine tailings deposit about 3.5 nautical miles northwest of Schefferville Airport. Both occupants were fatally injured. The accident occurred during daylight hours. Following the impact, there was no fire, and no emergency locator transmitter signal was captured.

Le présent rapport est également disponible en français.

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1.0 Factual information

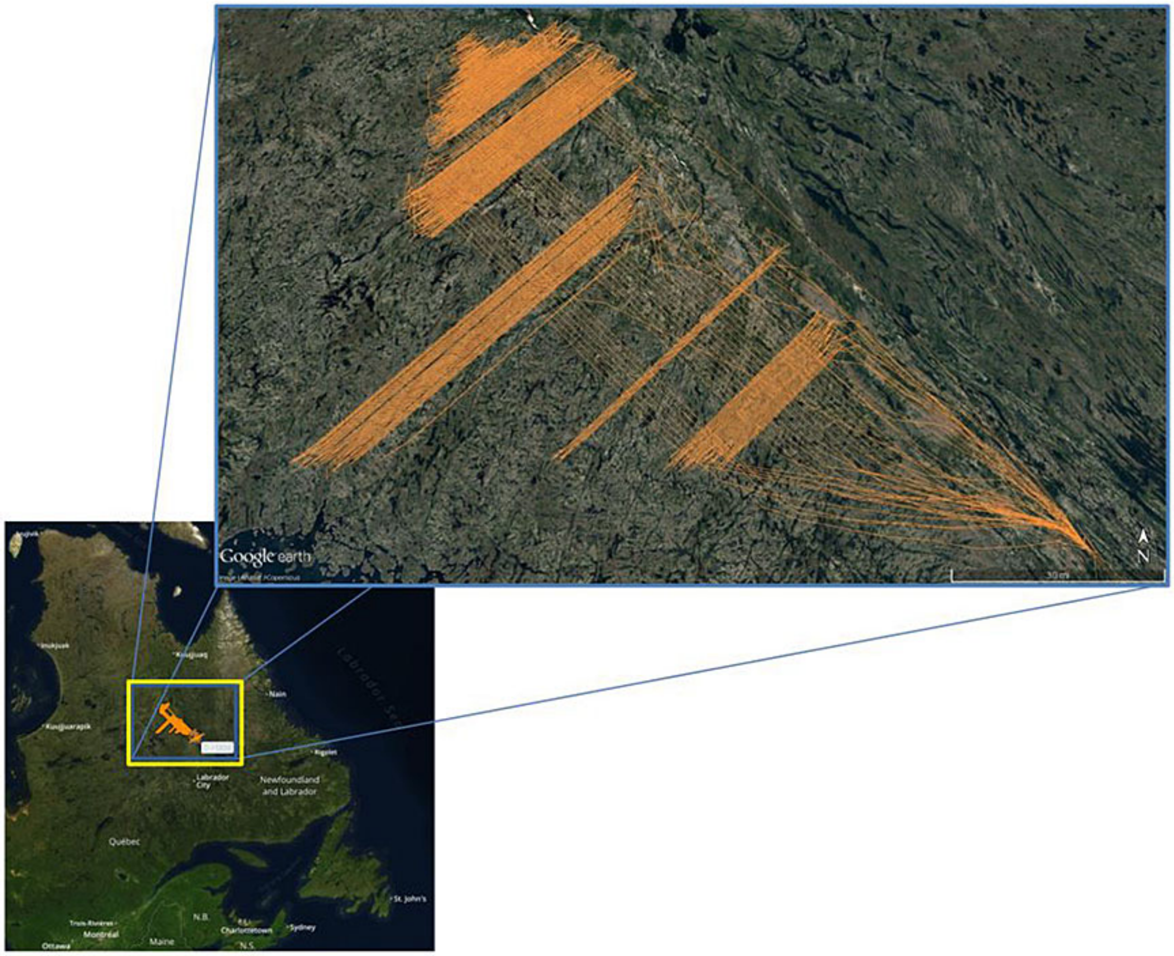
1.1 History of the flight

On 30 April 2017, the Piper PA-31 (registration C-FQQB, serial number 31-310), operated by Exact Air Inc., was conducting aerial magnetometric survey work[1] in the area of Schefferville Airport (CYKL), Quebec. The aircraft was accompanied by a 2nd aircraft (registration C-FVTL), also operated by Exact Air Inc., which was also performing aerial magnetometric survey work in the same area. These flights were conducted under visual flight rules (VFR).

The magnetometric survey work was conducted at low altitude (300 feet above ground level [AGL]) above an area determined according to a flight profile pre-established by the client. Each aircraft had on board 2 pilots, who took turns as pilot flying during flight segments generally spread over 2 daily flight blocks lasting up to 5 hours each. A typical flight block consisted of a takeoff from Schefferville Airport, which was considered the operating base; a flight segment to the survey area; multiple parallel flight segments at an altitude of 300 feet AGL within the survey area; and a return flight segment followed by a landing at the base (Figure 1).

1 The work was carried out in accordance with Subpart 702 of the *Canadian Aviation Regulations*, Aerial Work.

Figure 1. Flight paths over a 7-day period representing survey areas and flight segments between the operating base and the survey areas of the occurrence aircraft (Source: Google Earth, with TSB annotations)



On the day of the accident, after conducting an initial flight block of 5 hours, the 2 aircraft returned to the base and were refuelled.

At approximately 1336,[2] the 2 aircraft took off again with the same crews and flew toward the survey area.

At approximately 1738, having completed the work, the 2 aircraft began their return flight segment to CYKL. At that time, C-FQQB was about 10 minutes ahead of C-FVTL and was approximately 53 nautical miles (nm) northwest of CYKL. C-FQQB headed for the airport and descended to an altitude of 100 to 40 feet AGL.

At 1756, while the aircraft was flying over railway tracks, it struck the conductor cables of a power transmission line and crashed on top of a mine tailings deposit located approximately 3.5 nm northwest of CYKL[3] (Figure 2). There was no fire, but the aircraft was completely

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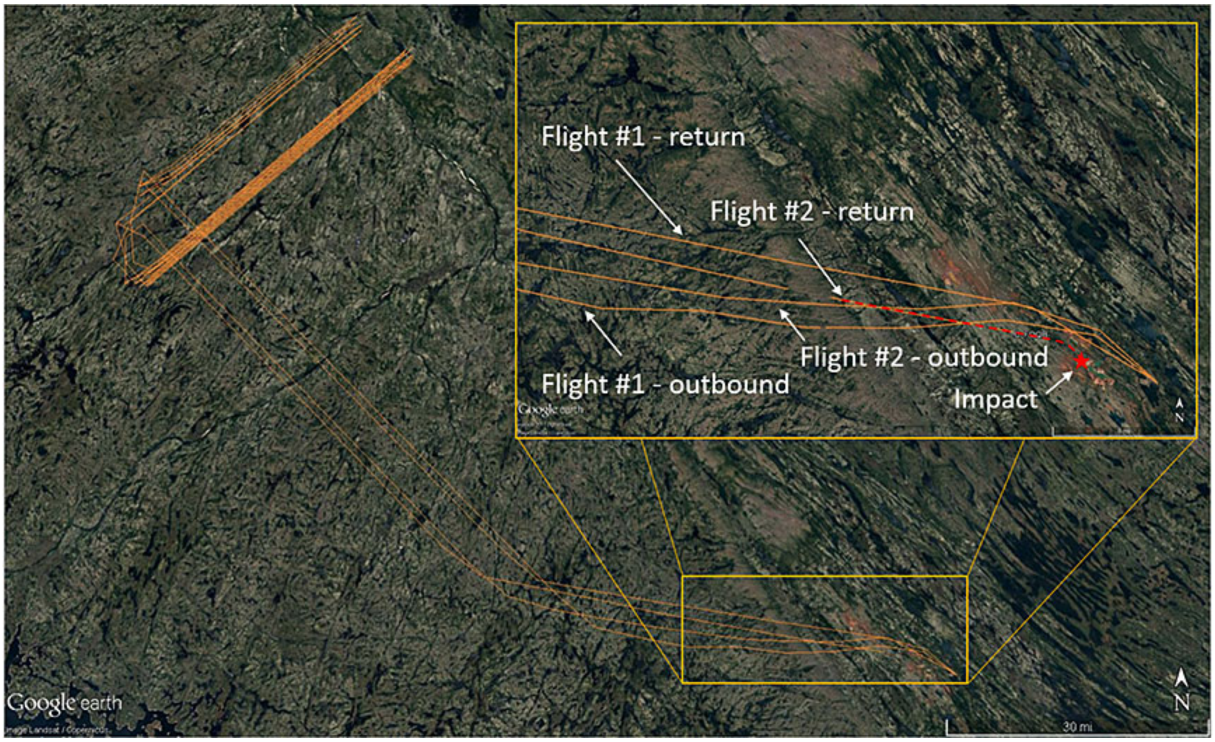
2 All times are Eastern Daylight Time (Coordinated Universal Time minus 4 hours).

3 The aircraft crashed at 54°49'12.309" N, 066°54'28.297" W.

destroyed by the impact forces, and both pilots were fatally injured. No emergency locator transmitter (ELT) signal was captured.

Figure 2. The 2 flights conducted by C-FQQB on the day of the accident, with detail showing the very-low-altitude flight segments (Source: Google Earth, with TSB annotations)



On arriving at the operating base, the 2 pilots of C-FVTL realized that C-FQQB had not landed. After unsuccessful attempts to make radio contact, a search was initiated. Less than an hour later, the wreckage of the missing aircraft was located.

1.2 *Injuries to persons*

Table 1. Injuries to persons

	Crew	Passengers	Others	Total
Fatal	2	-	–	2
Serious	0	–	–	0
Minor/None	0	–	–	0
Total	2	-	–	2

1.3 *Damage to aircraft*

The aircraft was destroyed by impact forces. There was no fire.

1.4 Other damage

The 3 conductor cables of the power transmission line were severed. Less than 252 L of aviation fuel was absorbed into the ground.

1.5 Personnel information

1.5.1 General

Records indicate that the flight crew held the necessary licences and qualifications for the flight, in accordance with existing regulations (Table 2).

Table 2. Personnel information

	Pilot-in-command	Co-pilot
Pilot licence	Commercial pilot licence (CPL)	Commercial pilot licence (CPL)
Medical expiry date	01 July 2017	01 October 2017
Total flying hours	461.7	1693
Flight hours on type	110.7	(estimated) 650
Flight hours in the last 7 days	31.9	31.9
Flight hours in the last 30 days	110.7	102.9
Flight hours in the last 90 days	114.7	176.4
Flight hours on type in the last 90 days	110.7	176.4
Hours on duty prior to the occurrence	12	12
Hours off duty prior to the work period	48	48

1.5.2 Flying experience

The pilot-in-command had been employed by the company since March 2016. This was his first magnetometric survey contract, and he had conducted about 16 flights as co-pilot to familiarize himself with this type of aerial work before being assigned to the role of pilot-in-command the week before the accident. At the time of this occurrence, it is highly likely that the pilot-in-command was the pilot flying, seated in the left seat.

The co-pilot had been employed by the company since September 2014. This was his 4th magnetometric survey contract, and he had trained the occurrence pilot-in-command during the first flights of the contract. At the time of the accident, the co-pilot was the pilot monitoring, seated in the right seat.

The 2 pilots alternated the roles of pilot-in-command and co-pilot on each flight.

The pilots arrived at CYKL on 11 April and began the magnetometric survey work the next day. Over the 19 following days, the 2 pilots conducted 21 magnetometric survey flights in

12 working days. The 2 pilots accumulated about 94 flying hours, with a daily average of 7.8 flying hours and 10.3 hours of flight duty time.

1.5.3 Flight crew training

1.5.3.1 Aerial work training

Under the *Canadian Aviation Regulations* (CARs),[4] flight crew members may conduct aerial work if they have passed a pilot proficiency check (PPC) or a proficiency check on the type of aircraft used. The proficiency check is administered by an approved check pilot (ACP),[5] or the pilot designated by the chief pilot with the necessary qualifications to provide training.

The 2 occurrence pilots had been trained seated on the left-hand side, as pilot-in-command. The co-pilot and the pilot-in-command had passed their proficiency checks on 08 July 2016 and 31 March 2017, respectively.

1.5.3.2 Additional training

Although the regulations do not require it, the company decided to add a 2nd pilot on board the magnetometric survey flights and gave the pilots additional training in the right-hand seat on standard operating procedures (SOPs), including instrument approaches using the global positioning system (GPS). Subsequently, although not required for magnetometric survey flights, the pilots underwent PPCs as co-pilots in preparation for possible future air-taxi flights conducted under Subpart 703 of the CARs. The PPC is conducted by a Transport Canada (TC) inspector or by a company ACP.

The co-pilot and the pilot-in-command had passed their PPCs on 29 September 2016 and 06 April 2017, respectively.

1.5.4 Fatigue

It was not possible to obtain sleep data for the occurrence pilots, so a thorough analysis of fatigue could not be completed. However, the pilots had had an opportunity to obtain sufficient rest between flight duty periods on 19, 20, and 24 April, and had had 2 days of leave preceding the day of the accident. The pilots had therefore had the opportunity to obtain sufficient rest prior to the day of the occurrence flights, and it is unlikely that they were physiologically fatigued at the time of the accident.

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4 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, paragraph 702.65(c).

5 Information about the ACP program can be found on Transport Canada's website, at https://www.tc.gc.ca/eng/civilaviation/standards/commerce-operationalstandards-acp-menu-380.htm (last accessed on 18 June 2018).

1.6 *Aircraft information*

Records show that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures, and had no known anomaly prior to the occurrence flight (Table 3).

Table 3. Aircraft information

Manufacturer	Piper
Type and model	PA-31
Year of manufacture	1968
Serial number	31-310
Certificate of airworthiness issue date	20 June 2016
Total airframe time	20 180 hours
Engine type (number of engines)	TEXTRON LYCOMING TIO-540-A2B (2)
Propeller/Rotor type (number of propellers)	HARTZELL HC-E2YK-2RBSF (2)
Maximum allowable take-off weight	6500 pounds
Recommended fuel type(s)	100/130 aviation fuel
Fuel type used	100/130 aviation fuel

The aircraft's weight and centre of gravity were within the limits prescribed by the manufacturer at the time of the occurrence. There is nothing to indicate airframe or engine failure or system malfunction prior to the collision. All damage to the aircraft was consistent with overload forces from the impacts with the wires and the ground.

1.7 *Meteorological information*

The graphical area forecast (GFA) for the Atlantic region[6] that was valid at the time of the accident shows a high-pressure system about 200 nm west of CYKL. According to the GFA, weather conditions in the area of CYKL were favourable for visual flight, with clear skies and northerly surface winds.

The (automatic) aviation routine weather report (AUTO METAR) issued for CYKL at 1800,[7] i.e. about 4 minutes after the accident, reported wind from 320° true (T) at 17 knots gusting to 23 knots; visibility of 9 statute miles; and clear skies. The temperature was −3 °C, the dew point −13 °C, and the altimeter 30.09 in.Hg. There is nothing to indicate that weather conditions may have contributed to this occurrence.

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6 GFACN34 issued by NAV CANADA on 30 April 2017 at 2331 Coordinated Universal Time (UTC) and valid until 01 May 2017 at 0000 UTC.

7 The METAR read as follows: CYKL 302200Z AUTO 32017G22KT 9SM CLR M03/M13 A3009 RMK SLP231.

1.8 Aids to navigation

1.8.1 Air navigation charts

Navigation charts are one of the tools available to pilots for identifying power transmission lines. According to NAV CANADA,

> The VFR Navigation Chart (VNC) is used by VFR pilots on short to extended cross-country flights at low to medium altitudes and at low to medium airspeeds.[8]

The applicable chart for the area was the Wabush VNC (AIR 5019). NAV CANADA publishes the VNCs for Canadian airspace in accordance with International Civil Aviation Organization (ICAO) standards.[9]

According to ICAO, all structures over 300 feet (about 90 m) high are considered obstacles and must be shown on a VNC. NAV CANADA considers references to cultural features below that height to be exclusively for navigation purposes rather than for obstacle avoidance. Not all obstacles are shown, because it is impracticable to guarantee that all obstacles have been included, and not all geographical or aeronautical features can be shown.

The power transmission line severed by the occurrence aircraft was not depicted on the Wabush VNC and there was no regulatory requirement for it to be shown. In general, power transmission lines are depicted on a VNC because they are useful cultural landmarks that can assist in visual navigation. They are portrayed based on the availability of source data and the application of the product specification. Segments of power transmission lines may be suppressed and/or masked in order to ensure readability at chart scale (1:500 000). Based on specification rules, other linear cultural landmarks, such as roads and railways, take priority over power-line depiction, if their proximity to one another poses readability concerns (e.g., if text and features overlap).

The investigation could not determine whether the flight crew had the chart in its possession or whether the chart was reviewed prior to departure.

1.9 Communications

Not applicable.

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8 NAV CANADA, "VFR Navigational Charts (VNC)," at http://www.navcanada.ca/EN/products-and-services/Pages/aeronautical-information-products-charts-VFR-navigational-charts.aspx (last accessed on 18 June 2018).

9 International Civil Aviation Organization, Annex 4 to the Convention on International Civil Aviation – Aeronautical Charts, Eleventh Edition, July 2009.

1.10 Aerodrome information

Schefferville Airport is adjacent to the city of Schefferville, Quebec, and has 1 asphalt runway (17/35) that is 5002 feet long and 150 feet wide.

1.11 Flight recorders

The aircraft was not equipped with a flight recorder, either for flight data (flight data recorder) or for cockpit conversations (cockpit voice recorder), and existing regulations did not require one.

1.12 Wreckage and impact information

The accident occurred at the mouth of a small valley created artificially by a former mine tailings deposit located on either side of a railway track (Figure 3). A power transmission line spanned across the tracks just before the mouth of the valley.

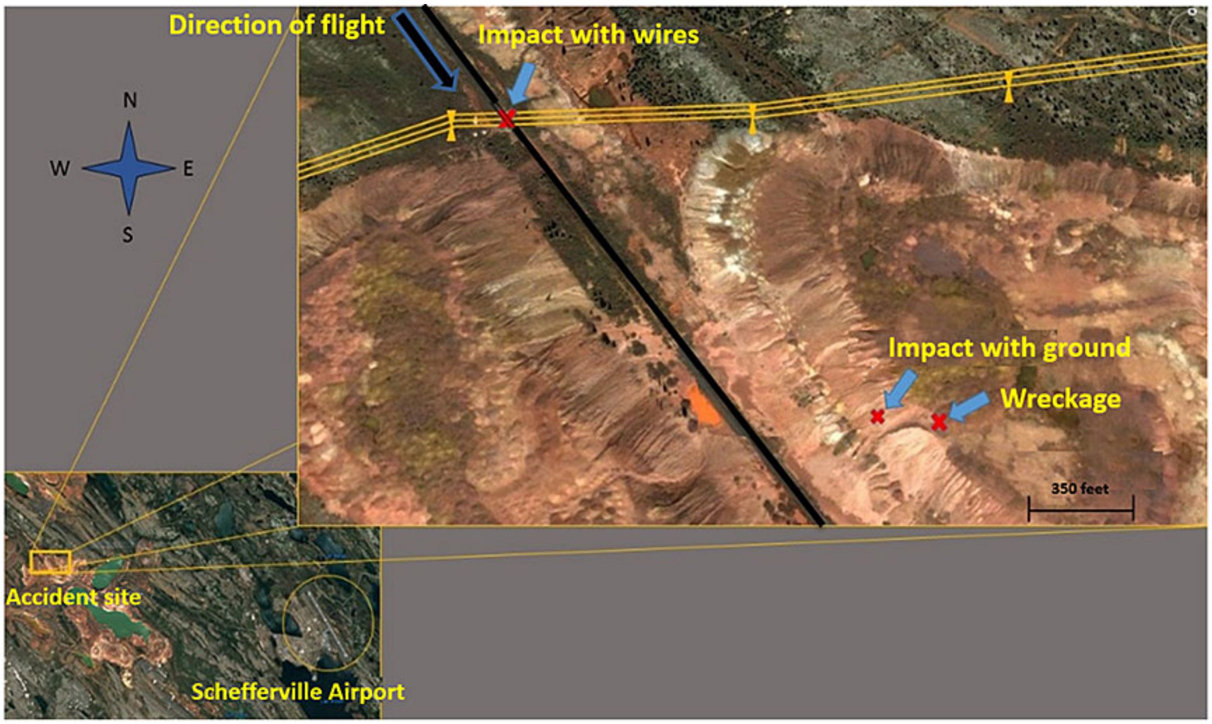
After striking the wires, the aircraft remained airborne and deviated to the left before colliding with the ground, close to the top of the ascending slope of the mine tailings deposit, on the east side, approximately 1400 feet southeast of the impact with the power transmission line.

The 69 kV auxiliary power transmission line that was severed by the aircraft is operated by Hydro-Québec.[10] At the point of impact, the line crosses the railway tracks at a height of 70 feet and an angle of approximately 45°. The segment of the severed wires spanned 944 feet and was suspended between 2 wooden structures (pylons) that supported the 3 conductor cables, which were 0.56 inches in diameter and composed of 6 aluminum strands and 1 steel strand. At the time of the accident, the cable was subject to a failure analysis and was therefore not energized.

The 3 cables were severed, with 2 remaining hooked to the aircraft's left engine until fully extended, when they were again severed at their anchor point on the aircraft.

10 Hydro-Québec is a Crown corporation of the Quebec government.

Figure 3. Accident site details (Source: Google Earth, with TSB annotations)



The aircraft wreckage was found at the top of the plateau, about 134 feet east of the initial point of impact with the ground (Figure 4). The left engine was separated from the wreckage (Figure 5) and was found slightly farther away, with the propeller. Sections of the conductor cables were wrapped around the left engine propeller drive shaft. All main sections of the aircraft were accounted for. The flaps and landing gear were in the retracted position. The throttle levers were at maximum power.

Figure 4. Wreckage of C-FQQB

Figure 5. Left engine of C-FQQB: the circle shows the severed pieces of cable wrapped around the propeller drive shaft

1.13 Medical and pathological information

Toxicology testing of the pilots did not reveal the presence of any substance that could have impeded their performance. TC's examination of the pilots' medical records did not reveal any medical or pathological factor that could have affected their performance.

1.14 Fire

There was no pre- or post-impact fire.

1.15 Survival aspects

The damage to the aircraft and the impact forces associated with this occurrence were not survivable.[11]

11 "A survivable accident is one in which the forces transmitted to the occupant through the seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations and in which the structure in the occupant's immediate environment remains substantially intact to the extent that a livable volume is provided throughout the crash sequence." (Source: U.S. National Transportation Safety Board, Safety Report, NTSB/SR-83/01, *General Aviation Crashworthiness Project, Phase One*, 27 June 1983, p. 3.)

1.15.1 Emergency locator transmitter

The aircraft was equipped with a 406 MHz ELT; however, the Cospas-Sarsat system did not receive a signal from the ELT.[12] Seventy-two hours after the crash, the ELT's battery voltage was measured at 0 volts, and the ELT's antenna and coaxial cable were damaged.

During its investigation into the May 2013 occurrence involving the controlled flight into terrain of a helicopter near Moosonee, Ontario,[13] the TSB expressed concerns regarding ELT crashworthiness. The TSB also noted previous accidents in which an ELT antenna broke off during the impact sequence, or the wire to an antenna was damaged, and no signal was received by the search-and-rescue satellite system. The investigation into the 2013 occurrence determined that although the crashworthiness design specifications are robust for the ELT unit itself, the specifications are significantly less stringent for the other key components of the ELT system (i.e., the wiring and antenna).

Following that occurrence, the Board recommended that

> the International Civil Aviation Organization establish rigorous ELT system crash survivability standards that reduce the likelihood that an ELT system will be rendered inoperative as a result of impact forces sustained during an aviation occurrence.
>
> **TSB Recommendation A16-02**
>
> the Radio Technical Commission for Aeronautics establish rigorous ELT system crash survivability specifications that reduce the likelihood that an ELT system will be rendered inoperative as a result of impact forces sustained during an aviation occurrence.
>
> **TSB Recommendation A16-03**
>
> the European Organisation for Civil Aviation Equipment establish rigorous ELT system crash survivability specifications that reduce the likelihood that an ELT system will be rendered inoperative as a result of impact forces sustained during an aviation occurrence.
>
> **TSB Recommendation A16-04**
>
> the Department of Transport establish rigorous ELT system crash survivability requirements that reduce the likelihood that an ELT system will be rendered inoperative as a result of impact forces sustained during an aviation occurrence.
>
> **TSB Recommendation A16-05**

The Board, encouraged by the responses received from these organizations regarding updates to industry specifications as they relate to antenna, cabling, and crash-safety specifications, has assessed the responses to these recommendations as showing **Satisfactory Intent**.

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12 Emergency locator transmitter signals are captured by the Joint Rescue Coordination Centre's satellite-based search-and-rescue monitoring system.

13 TSB Aviation Investigation Report A13H0001.

However, the current ELT system design standards do not include a requirement for a crashworthy antenna system. As a result, there is a risk that potentially life-saving search-and-rescue services will be delayed if an ELT antenna is damaged during an occurrence.

1.15.2 Use of safety belts by crew members

In accordance with CARs section 702.44, the aircraft was equipped with restraints consisting of lap belts and shoulder harnesses. The investigation determined that the pilot-in-command, who was the pilot flying and was seated on the left, was wearing the full restraint, but that the co-pilot was not wearing his restraint and was ejected from the aircraft.

The TSB has found that the risk of serious injury or death is increased for occupants of light aircraft who are not wearing upper-torso restraints.[14] Crashworthiness studies conducted in the United States[15] and Canada[16] have consistently concluded that the probability of surviving impact forces is significantly greater if occupants of small, general aviation aircraft are protected by upper-torso restraints. In 2010, a Federal Aviation Administration study examined 649 accidents from 2004 and 2009, 97 of which included fatal or serious injuries. The Federal Aviation Administration determined that 40% of the deaths could have been prevented by enhanced crashworthiness, and nearly half of those might have been avoided with the use of shoulder harnesses, primarily in passenger seats.

The use of a 3-point or 4-point safety restraint (belt and shoulder harness) is known to reduce the severity of upper-body and head injuries and more evenly distribute impact forces.[17] If restrained and protected during the impact sequence, occupants have a better chance of survival.

1.16 Tests and research

1.16.1 Global positioning system data analysis

Although the data were not accessible to Exact Air, the specialized GPS for magnetometric survey work recorded the date, time, position, speed, and altitude of the aircraft every second. Data extracted from the GPS showed that, at 1738, after completing the magnetometric survey work, the aircraft descended to a height of less than 100 feet AGL and

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14 Transportation Safety Board of Canada, Aviation Safety Study SA9401, A Safety Study of Survivability in Seaplane Accidents.

15 U.S. Federal Aviation Administration, Aviation Safety, Alaskan Region, *Fatal and Serious Injury Accidents in Alaska, A Retrospective of the years 2004 through 2009 with Special Emphasis on Post Crash Survival*, December 2010.

16 *Small Aircraft Crashworthiness*, Volume 1, TP 8655E (prepared by Sypher: Mueller International Inc., July 1987), p. 46; Canadian Aviation Safety Board, *Study of the Influence of Shoulder Harnesses in Aviation Safety* (1987).

17 U.S. National Transportation Safety Board, Safety Report, NTSB/SR-85/01, *General Aviation Crashworthiness Project, Phase Two – Impact severity and potential injury prevention in General Aviation accidents*, 15 March 1985.

maintained this altitude until colliding with the wires at 1756. Its ground speed during the last minute before the impact was 169 knots, or 286 feet per second.

1.16.2 TSB laboratory reports

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

- LP128/2017 – Data Recovery

1.17 Organizational and management information

1.17.1 Exact Air Inc.

1.17.1.1 General

Exact Air Inc. holds a valid air operator certificate for its CARs subparts 406, 702, and 703 operations. Its headquarters are located at St-Honoré Airport, Quebec. At the time of the occurrence, the company operated a fleet of 34 aircraft, including Beechcraft A100s, Piper PA-31s, Cessna 310s, Cessna 182s, Cessna 172s, and Cessna 152s.

1.17.1.2 Operational control

1.17.1.2.1 Flight authorization and control

According to the Exact Air Inc. operations manual [translation], "The role of the director of operations is to ensure the safety of flight operations."[18] The manual also stipulates that [translation]

> All flights or series of flights [...] must be authorized prior to departure by the director of operations or the chief pilot [...]. The director of operations delegates operational control of a flight to the pilot-in-command but remains responsible for the operation of all flights.[19]

1.17.1.2.2 Flight following and monitoring

For the purposes of flight operations monitoring, the pilot notifies the company by email of the planned departure time, the itinerary, and the planned flight time. An online flight-monitoring system, supplied by the client, records the aircraft's position and altitude on the flight-monitoring service provider's server every 2 minutes. Although these data are available, Exact Air had no operational policy to use them for flight monitoring by observing the aircraft's position in flight. After landing, the pilot notifies the company by email that the flight has been completed.

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18 Exact Air Inc., *Manuel d'exploitation d'EXACT AIR*, modification 27 (February 2015), paragraph 1.4.1(ii), p. 1-3.

19 Ibid., section 2.1.1, p. 2-1.

1.17.1.2.3 *Flight time and flight duty time*

Under the CARs,[20] air operators must not assign flight time or flight duty time to a flight crew member if this would result in the flight crew member's time exceeding maximum authorized hours. Moreover, flight crew members must not accept such an assignment.

The CARs also stipulate that

> a flight crew member who reaches a flight time limitation established by this section is deemed to be fatigued and shall not continue on flight duty or be reassigned to flight duty until such time as the flight crew member has had the rest period required by section 700.16 or 700.19.[21]

Exact Air Inc. uses the application FLTDUTY XLS to control the flight time, flight duty time, and rest periods of its flight crew members. For this reason [translation], "all pilots must keep an up-to-date log of their hours."[22] These data are then sent to the chief pilot on the first day of each month.

The director of operations, aware that the pilots at CYKL had made several long flights in a short amount of time, was to cross-reference the hours worked in order to ensure that the limit of 60 hours within 7 consecutive days[23] would not be exceeded. Thus, using another pilot who was qualified as a pilot-in-command and available at CYKL on 18 April, the occurrence flight pilots had completed 59.7 and 59.9 flying hours, respectively, during the week of 12 to 18 April 2017.

1.17.1.3 *Operations safety management*

All organizations have an obligation to manage the risks associated with their air operations. Safety management systems (SMSs) provide a framework to achieve this end, and many companies implement a formal SMS either voluntarily or to comply with CARs SMS requirements.[24] Even small companies need to have some safety processes in place to manage risk.

At minimum, risk management consists of

- recognizing and reporting hazards;
- identifying and choosing measures to mitigate these hazards;

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20 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, subsections 700.15(1) and 700.16(1).

21 Ibid., subsection 700.15(3).

22 Exact Air Inc., *Manuel d'exploitation*, modification 27 (February 2015), paragraph 3.10.1, p. 3-13.

23 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, paragraph 700.15(1)(e).

24 Ibid., Subpart 107.

- assigning responsibility for managing these measures; and
- measuring and monitoring the effectiveness of measures and established control methods.[25]

After assessing the risks and operational requirements of the magnetometric survey flights at low altitude, Exact Air adopted the following measures to minimize the risks associated with these flights:

- assigning 2 pilots to the survey flights to reduce the workload and share the flight segments requiring greater concentration; and
- providing survey-flight training with an experienced pilot before assigning a pilot as pilot-in-command.

Operators subject to subparts 406, 702, 703, and 704 of the CARs are not required to implement an SMS. Therefore, Exact Air Inc. was not required to incorporate a formal SMS. However, the company voluntarily developed an SMS and published its SMS manual in February 2006.

The TSB has repeatedly emphasized the benefits of SMSs. When implemented properly, SMSs allow companies to manage risks effectively and enhance the safety of their operations.

1.17.2 Transport Canada Civil Aviation regulatory oversight

With regard to regulatory oversight, TC has adopted "a contemporary approach, which includes methodologies such as assessments, program validation inspections (PVIs) and process inspections."[26] With this approach, "TCCA's role is to ensure that all enterprises have effective systems in place to ensure they comply with regulatory requirements on an on-going basis and that surveillance activities confirm that these systems remain effective."[27]

The TSB examined the surveillance activities conducted by TC and the company's responses over the 6 years preceding the occurrence. In January 2016, TC conducted the most recent PVI, and a result of those findings, on 07 September 2016, the company submitted a corrective action plan, which TC accepted.

Because no SMS was required by regulation, the company's SMS was not subject to TC surveillance and inspections and the PVI did not take it into account.

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25 A. J. Stolzer, C. D. Halford and J. J. Goglia, *Safety Management Systems in Aviation* (Aldershot: Ashgate, 2008), p. 157.

26 Transport Canada, Staff Instruction, SI SUR-001, "Surveillance Procedures," Issue No. 05, 28 June 2013, p. 8.

27 Ibid., p. 9.

1.18 Additional information

1.18.1 Magnetometric survey work

Magnetometric survey work is performed using a specially modified aircraft flown at low altitude following predetermined flight lines. The flight profile is usually established by the client, who also supplies the specialized on-board equipment and technical support to the aircraft operator. This type of survey work is performed only in daytime VFR conditions; certain factors (for example solar activity, which can influence the earth's magnetic field) may prevent the taking of readings. Consequently, flight time must be maximized when conditions are favourable.

While flying above the survey area, in addition to performing the usual flying-related tasks, the pilot must constantly monitor information displayed on specialized indicators in order to comply with the flight profile necessary for the survey.

Magnetometric survey flights for the contract at CYKL consisted of a flight segment to reach the survey area, parallel flight lines at an altitude of 300 feet AGL for the survey readings, and the return flight segment to the airport. Because survey flights are conducted at low altitude, the crew had conducted a reconnaissance flight over the survey area to identify potential hazards. The flight altitude for the outbound and inbound flight segments was not subject to restrictions imposed by the CARs or the company and did not require a reconnaissance flight; therefore, it was at the pilots' discretion.

1.18.2 Low flying

The CARs state, "No person shall operate an aircraft in such a reckless or negligent manner as to endanger or be likely to endanger the life or property of any person."[28] However, when an aircraft is not flying over a person, ship, vehicle, or structure, and is operated for the purposes of aerial work under Subpart 702 of the CARs, there is no minimum altitude requirement above terrain.

Nevertheless, "no person shall operate an aircraft in such a reckless or negligent manner as to endanger or be likely to endanger the life or property of any person."[29]

The *Transport Canada Aeronautical Information Manual* (TC AIM) contains the following warning regarding low flying:

> **Warning – Intentional low flying is hazardous. Transport Canada advises all pilots that low flying for weather avoidance or operational requirements is a high-risk activity.**[30]

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28 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, paragraph 602.14(2)(b).

29 Ibid., section 602.01.

30 Transport Canada, TP 14371E (2016-1, 31 March 2016), *Transport Canada Aeronautical Information Manual*, AIR - Airmanship, section 2.4.1, p. 400.

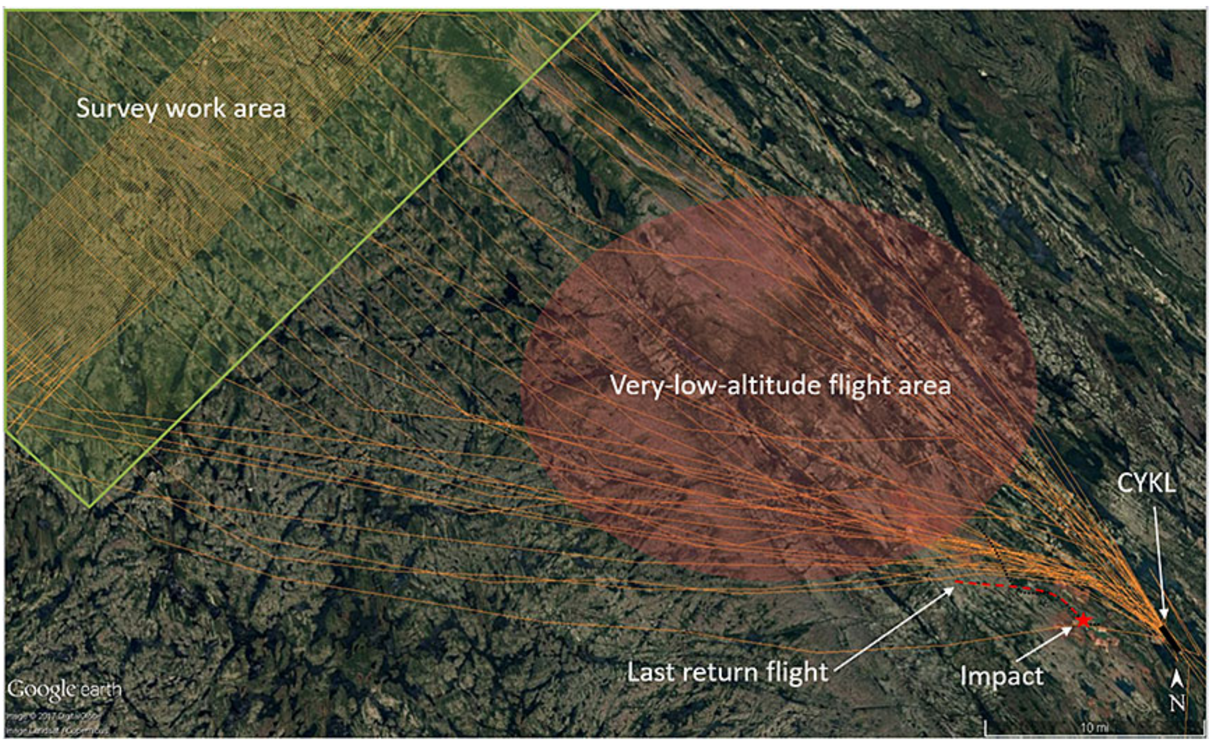
1.18.2.1 Very-low-altitude flying

On the day of the accident, the crew had logged almost 10 hours of low-altitude flying (300 feet AGL) in a 12-hour period.

Very-low-altitude flying[31] differs from the magnetometric survey flights at 300 feet AGL, which are conducted according to an established plan. Very-low-altitude flying was not necessary for the magnetometric survey work performed under this contract at CYKL.

Over a period of 19 days before the accident, the pilots had conducted 21 magnetometric survey flights at low altitude. During these flights, analysis of GPS data shows that the occurrence pilots had conducted 27 segments of flights involving very-low-altitude flying (less than 100 feet AGL) during round trips without incident (Figure 6).

Figure 6. Very-low-altitude flight zones in the 19 days preceding the accident (Source: Google Earth, with TSB annotations)



1.18.2.2 Risk taking

1.18.2.2.1 Sensation seeking

Sensation seeking is the tendency to seek novel, varied, complex, and intense sensations and experiences. Low flying produces intense sensations in pilots by requiring high levels of cognitive and attentional resources in an unforgiving environment. Men and younger

[31] For the purposes of this report, very-low-altitude flying means the portions of flight conducted at less than 100 feet AGL.

persons typically score higher on sensation-seeking scales than do women and older persons, with peak levels occurring in late adolescence (18 to 20 years of age).[32]

The occurrence pilots were 24 and 25 years old. The investigation determined that the co-pilot had previously expressed his enjoyment of low flying, but there was nothing to indicate that this was the case for the pilot-in-command. However, an analysis of GPS data showed that the pilots had conducted 27 flight segments at very low altitude.

After departing the survey area, while on the return flight, the pilots conducted a very-low-altitude flight (varying between 100 and 40 feet AGL) that lasted 18 minutes (from 1738 until the impact at 1756).

1.18.2.2.2 Sustained attention and mental fatigue

Unlike sleep-related fatigue, mental (or task-related) fatigue is a psychological state that results from spending extended or intense periods of time on a task.[33,34] Although people experiencing mental fatigue may feel tired, they do not necessarily fall asleep more quickly than a normally rested person; that is, they are not necessarily sleepy. Concentrating for long periods of time can result in mental fatigue and corollary performance impairments, including decreased vigilance and situational awareness, reduced attention-switching abilities and increased tendency to take risks.[35,36,37]

1.18.2.3 Risk perception

All activities carry a degree of associated risk. It is up to the individual to assess the level of risk associated with an activity when deciding whether or not to engage in it. Because it leaves little margin for error in terms of emergency manoeuvres and navigation, low flying is considered a high-risk activity.

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32 M. Zuckerman, *Behavioral Expressions and Biosocial Bases of Sensation-seeking* (Cambridge: University of Cambridge Press, 1994).

33 T. J. Balkin and N. J. Wesensten, "Differentiation of Sleepiness and Mental Fatigue Effects," in P. L. Ackerman (ed.), *Cognitive Fatigue: Multidisciplinary Perspectives on Current Research and Future Applications* (Washington, DC: American Psychological Association, 2011), pp. 47-66.

34 J. Leonard, L. J. Trejo, R. Kochavi, K. Kubitz, L. D. Montgomery, R. Rosipal, and B. Matthews, "Measures and Models for Estimating and Predicting Cognitive Fatigue," *Proceedings of the 44th Annual Meeting of the Society for Psychophysiological Research* (Santa Fe, NM: 2004).

35 D. Linden, M. Frese, and T. F. Meijman, "Mental fatigue and the control of cognitive processes: effects on perseveration and planning," *Acta Psychologica*, Volume 113, No. 1 (2003), pp. 45–65.

36 D. M. Webster, L. Richter, and A. W. Kruglanski, "On Leaping to Conclusions When Feeling Tired: Mental Fatigue Effects on Impressional Primacy," in *Journal of Experimental Social Psychology*, Volume 32, Issue 2 (1996), pp. 181–195.

37 L. J. Trejo, K. Kubitz, R. Rosipal, R. L. Kochavi, and L. D. Montgomery, "EEG-Based Estimation and Classification of Mental Fatigue," *Psychology*, Volume 6, No. 5 (2015), pp. 572–589.

Individuals who repeatedly perform a dangerous activity with no, or few, negative repercussions may become desensitized or habituated to the high level of risk. Problems can arise when perceived risks no longer match the actual risks and dangers associated with an activity. Without mitigations in place to recalibrate risk perception, the subjective evaluation of low personal risk may lead to increases in the performance of high-risk activities.[38] The risk can increase further when, as group values shift, higher-risk decisions become normal and accepted within a given group.

1.18.3 Visibility of wires

Wires can be difficult to see during flight. According to an article published in *Aviation Week*, "Wires aren't consistently visible all of the time. Changing sunlight patterns can obscure them. [...] A wire that is perfectly visible from one direction may be completely invisible from the opposite."[39]

Many factors can increase the difficulty of seeing wires in a low-level environment:

> A pilot's ability to see and avoid collision with wires is complicated by the flood of visual cues seen from a different perspective as low-level work is carried out; by vegetation, shadows and landforms blocking the pilot's view of wires and wire support structures; by cockpit ergonomics; and by seemingly minor things like smudged handprints on the windscreen and insect [*sic*] that speckle the windscreen.[40]

The railway track curved slightly to the right just before the point of impact with the wires (3 seconds of flight time).

At the precise location of the impact with the wires, at the time of the accident,[41] the solar azimuth was 261.41°T, and the sun was at an altitude of 24.41° above the horizon. At the time of impact, the aircraft was following the railway tracks on a heading of 146°T.[42] The sun was therefore 115° to the right of the trajectory, i.e. behind and to the right of the aircraft.

To determine whether there were shadows in the valley, the angle between the railway tracks and the summit of the hills to the west (elevation 80 feet, distance 587 feet) was calculated to be approximately 8°. With an azimuth of 24°, the sun was about 16° above the hills.

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

39 P. Veillette, "How to Avoid Helicopter Wire Strikes," Aviation Week Network (07 October 2015), at http://aviationweek.com/business-aviation/how-avoid-helicopter-wire-strikes (last accessed on 18 June 2018).

40 R. L. Cassidy, "One Strike and You're Out," *Flight Safety Australia*, November–December 2005.

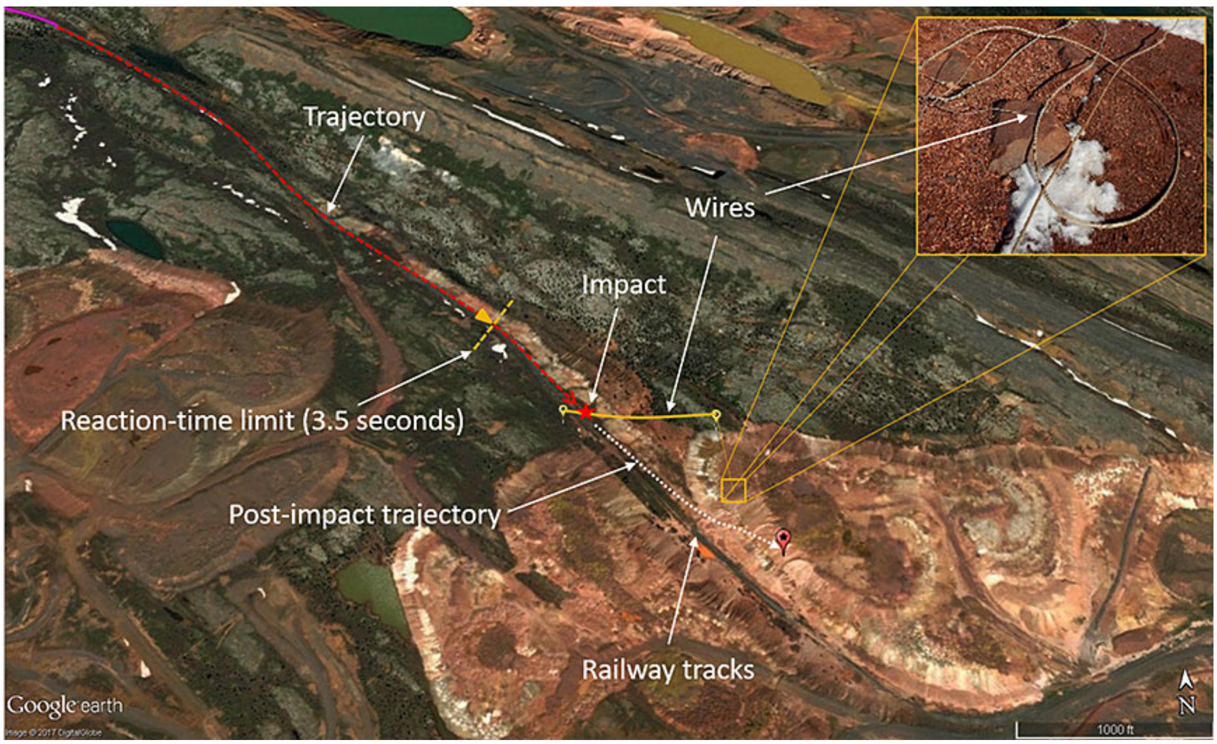
41 Coordinates 54°49'12.309" N, 066°54'28.297" W; 30 April 2017, at 1754.

42 The magnetic variation at CYKL is 22° W.

Wires can be extremely difficult to see, especially across valleys and in varying light conditions. For this reason, TC advises pilots to always cross power transmission lines at their towers, and to follow ridgelines and avoid flying in the centre of valleys.[43]

The mines operated in the area where the accident occurred were iron mines, and the mine tailings deposits there gave the terrain a reddish tint typical of iron oxide. In addition, the conductor cables were dusted with the same colour, reducing their contrast with the surrounding terrain (Figure 7). There was also very little contrast between the wooden pylons and the terrain. At the time and place of the occurrence, the top of the mine tailings deposit was about 75% covered in snow, but the sides exposed to the sun and the runoff water were free of snow.

Figure 7. Occurrence aircraft path immediately prior to impact (Source: Google Earth, with TSB annotations)



1.18.3.1 *Reaction time to avoid wires*

In the context of a collision between 2 aircraft in flight, the average time required to detect the potential collision, make a decision, and take evasive action is 12.5 seconds.[44] However, in the context of a pilot who has decided to fly at very low altitude (less than 100 feet AGL), situational awareness means certain elements are removed from this reaction time. In this particular context, the time to become aware of the trajectory (5 seconds) and the time to

43 Transport Canada, TP 9982E, *Helicopter Flight Training Manual* (June 2006), pp. 67, 91, 92.

44 U.S. Federal Aviation Administration, Advisory Circular No. AC90-48D, *Pilots' Role in Collision Avoidance*, Change 1, 28 June 2016.

decide to deviate to the left or to the right (4 seconds) do not need to be included when the pilot is very close to the ground.

Therefore, when the pilot, already at very low altitude, sees and recognizes the wires, the 12.5-second reaction time needed to avoid a collision between 2 aircraft can be reduced by 9 seconds. Consequently, in the very-low-altitude occurrence flight, the reaction time to avoid the wires was estimated at 3.5 seconds (Figure 7).

1.18.3.2 Marking of obstacles to air navigation

The conductor cables were not marked, and were not required by regulation to be marked.

CARs section 601.23 states that

> any building, structure or object, including any addition to it, constitutes an obstacle to air navigation if [...] in the case of any catenary[45] wires crossing over a river, any portion of the wires or supporting structures is higher than 90 m [about 300 feet] AGL.[46]

In addition, subsection 601.25(1) of the CARs states,

> If the Minister determines that a building, structure or object, other than a building, structure or object described in section 601.23, is hazardous to air navigation because of its height or location, the Minister shall require the person who has responsibility for or control over the building, structure or object to mark and light it in accordance with the requirements of Standard 621.[47,48]

According to the TC AIM,

> Because of the nature of obstructions, it is not possible to fully define all situations and circumstances. Thus, in certain cases, a Transport Canada aeronautical evaluation will be required to determine whether an obstruction to air navigation is a likely hazard to aviation safety or to specify alternative methods of complying with the obstacle marking and lighting standards while ensuring that the visibility requirement is met.[49]

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45 Standard 621 of the *Canadian Aviation Regulations* defines a catenary as "the curved span of overhead wires hung freely between two supporting structures, normally with regard to exceptionally long elevated spans over canyons, rivers and deep valleys."

46 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, subsection 601.23(1).

47 Ibid., subsection 601.25(1).

48 TC has stated that, in some instances, it may identify objects with a lower height than that specified in CARs section 601.23 as obstacles requiring lighting or marking, based on safety factors such as exposure to a known air traffic route or aviation activities.

49 Transport Canada, TP 14371E (2016-1, 31 March 2016), *Transport Canada Aeronautical Information Manual*, AGA – Aerodromes, section 6.3, p. 61. Note: This was the edition of the manual in effect at the time of the occurrence.

Power transmission lines are very common in Canada, and TC has determined that it would not be reasonable to require lighting or marking for all of them.

1.18.3.3 Identification of power transmission lines

Before conducting low-level navigation, a pilot should consult a current VNC to identify the location of obstacles along the planned route of flight.

If operations near obstacles such as power transmission lines are required, a reconnaissance flight conducted at a higher altitude is the first step in positively identifying their location.[50]

1.18.4 Flight following

Although Exact Air Inc. management uses a flight-monitoring system that records the aircraft's position every 2 minutes, the system did not allow flights to be followed in real time, and there was no process for evaluating the way in which a flight had been conducted. Current regulations do not require this level of flight following. However, the company's flight operations manual (FOM) reminds pilots that they assume full responsibility for conducting flights and that they must ensure that flights are conducted in accordance with existing regulations and the procedures set out in the manual.

On several occasions, TSB accident investigations involving various organizations have found that management was not aware that an employee or instructor was deviating from existing regulations or company policies. For example:

- TSB Aviation Investigation Report A09Q0065 found that, without management's knowledge, the instructor had been flying much lower than authorized by company policy.
- TSB Aviation Investigation Report A12W0031 found that the pilot was flying close to steep, rugged terrain. The company was not aware that the pilot had made any route changes on tour flights.
- TSB Aviation Investigation Report A15Q0120 found that the company was not aware that the pilot had regularly been making steep turns at low altitude on tour flights.

Given the combined accident statistics for operations under CARs subparts 702, 703, and 704, there is a compelling case for industry and the regulator to proactively identify hazards and manage the risks inherent in these operations. To manage risk effectively, they need to know why incidents happen and what the contributing safety deficiencies may be.

Moreover, routine monitoring of normal operations can help these operators both improve the efficiency of their operations and identify safety deficiencies before they result in an accident.

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50 Transport Canada, TP 9928E, *Helicopter Flight Training Manual*, 2nd edition (June 2006), p. 103.

1.18.4.1 Lightweight flight data recording and flight data monitoring systems

The development of lightweight flight data recording systems presents an opportunity to extend flight following to smaller operators. This technology as well as flight data monitoring (FDM) allows these operators to monitor activities such as compliance with SOPs, pilot decision making, and adherence to operational limitations. FDM also allows operators to identify problems in their operations and take corrective actions before an accident occurs. There is no CARs requirement for lightweight flight data recording systems to be installed on aircraft.

In the event of an accident, recordings from lightweight flight data recording systems would provide useful information that would better facilitate the identification of safety deficiencies in the investigation.

The Board acknowledges that issues remain to be resolved to facilitate the effective use of recordings from lightweight flight data recording systems, including questions about the integration of this equipment in an aircraft, human resource management, and legal issues such as the restriction on the use of cockpit voice and video recordings. Nevertheless, given the potential of this technology combined with FDM to significantly improve safety, the Board believes that no effort should be spared to overcome these obstacles.

In its investigation into the March 2011 loss of control and in-flight breakup of an aircraft near Mayo, Yukon,[51] the Board recommended that

> the Department of Transport work with industry to remove obstacles to and develop recommended practices for the implementation of flight data monitoring and the installation of lightweight flight recording systems by commercial operators not currently required to carry these systems.
>
> **TSB Recommendation A13-01**

TC has undertaken the following activities to address the safety deficiency identified in Recommendation A13-01, regarding the installation of lightweight flight recording systems by commercial operators not currently required to carry these systems:

- In 2013, after conducting a risk assessment to evaluate alternate approaches to FDM, TC informed the TSB that it supported Recommendation A13-01. In 2015, TC informed the TSB that it intended to revisit this risk assessment.
- In 2013, TC informed the TSB that it would develop an Advisory Circular outlining recommended practices for FDM programs.
- In 2013, TC informed the TSB that it would incorporate its analysis and review of Recommendation A13-01 into its planned assessment for cockpit voice and flight data recorders, which was scheduled to begin in 2014–15.
- In 2014, TC informed the TSB that it would consider adding FDM principles in future regulatory initiatives and amendments.

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51 TSB Aviation Investigation Report A11W0148.

- In 2015, TC informed the TSB that it would prepare an issue paper on the use of FDM, providing factual information on FDM, including its benefits, costs and challenges.

However, due to other commitments, TC did not initiate its work for any of these undertakings.

In February 2018, TC conducted a focus group with the industry to assess the challenges and benefits associated with the installation of lightweight flight recording systems on aircraft, which are not currently required to carry these systems.

However, until the focus group reaches conclusions as to the challenges and benefits associated with the installation of lightweight flight recorders in aircraft not currently required to carry them, and TC provides the TSB with its plan of action moving forward following those conclusions, it is unclear when or how the safety deficiency identified in Recommendation A13-01 will be addressed. The Board is concerned that few concrete actions have been taken to address Recommendation A13-01 and that this will result in protracted delays as observed on numerous other recommendations.

Therefore, the Board is **unable to assess** the response to the recommendation.

The TSB conducted an investigation[52] into a recent occurrence involving a Mitsubishi MU-2B-60 that struck terrain on final approach to Îles-de-la-Madeleine Airport (Quebec). All 7 occupants were fatally injured. Although regulations did not require it, the aircraft had a lightweight flight data recorder on board. Investigators recovered the recorder and extracted its data for analysis. This allowed them to better understand the sequence of events leading to the aircraft's loss of control. With no on-board recording system, investigators would not have obtained this information, which was vital to the understanding of the circumstances and facts that led to the occurrence.

In another recent occurrence[53] investigated by the TSB, investigators did not have any of the information normally contained in lightweight flight data recorders. As a result, it was not possible to determine the reasons for the aircraft's loss of control that led to the collision with the ground and killed all 4 occupants.

Although Recommendation A13-01 targeted commercial operators, these 2 recent occurrences highlight the value of an on-board lightweight flight data recording system by demonstrating the importance of the availability of these data. It is also important to note that these systems allow regular surveillance of normal flight activities, which helps operators improve operational efficiency and detect safety issues before they cause an accident. In this occurrence, investigators were able to obtain specialized GPS data used for magnetometric surveys. However, these data were not accessible to Exact Air for flight-monitoring purposes.

52 TSB Aviation Investigation Report A16A0032.

53 TSB Aviation Investigation Report A16P0186.

On 26 April 2018, the Board issued Recommendation A18-01, calling for TC to require the mandatory installation of lightweight flight recording systems by commercial operators and private operators not currently required to carry these systems. This new recommendation replaces Recommendation A13-01. The Board is calling for TC to use the work done for Recommendation A13-01 to accelerate the adoption of safety measures in response to Recommendation A18-01.

1.18.4.2 TSB Watchlist

The TSB Watchlist identifies the key safety issues that need to be addressed to make Canada's transportation system even safer.

Safety management and oversight is a Watchlist 2016 issue.

This Watchlist issue was raised in the TSB investigation report on an accident that occurred in May 2013.[54] Although 95% of air transport users fly with operators that have an SMS in place, the report noted that approximately 90% of all Canadian aviation certificate holders are still not required by existing regulations to have an SMS, and that TC does not have assurance that these operators are able to manage safety effectively. The report highlighted the need for TC to adapt its approach to regulatory oversight to the competence of the operator.

Safety management and oversight will remain on the TSB Watchlist until

- Transport Canada implements regulations requiring all commercial operators in the air and marine industries to have formal safety management processes and effectively oversees these processes;
- transportation companies that do have SMS demonstrate that it is working—that hazards are being identified and effective risk-mitigation measures are being implemented; and
- Transport Canada not only intervenes when companies are unable to manage safety effectively, but does so in a way that succeeds in changing unsafe operating practices.

In 2016, TC published a guide[55] on the development of SMSs for smaller aviation organizations, but operators under subparts 406, 702, 703, and 704 are not currently required to implement SMSs.

In this occurrence, Exact Air Inc. had voluntarily implemented an SMS. However, TC did not have assurance of the company's ability to manage safety effectively, since it does not conduct assessments of voluntary SMSs.

TSB Aviation Investigation Report A13H0001 highlighted the need for TC to adapt its approach to regulatory oversight to the competence of the operator.

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54 TSB Aviation Investigation Report A13H0001.

55 Transport Canada, Advisory Circular No. 107-002, Safety Management System Development Guide for Smaller Aviation Organizations, Issue No. 2 (02 September 2016), at http://www.tc.gc.ca/en/services/aviation/documents/AC_107-002_ISSUE_2.pdf (last accessed 18 June 2018).

Consequently, in the conclusion of Aviation Investigation Report A13H0001, this Watchlist issue was formalized in the following recommendations to the Department of Transport:

> the Department of Transport require all commercial aviation operators in Canada to implement a formal safety management system.
>
> **TSB Recommendation A16-12**
>
> the Department of Transport conduct regular SMS assessments to evaluate the capability of operators to effectively manage safety.
>
> **TSB Recommendation A16-13**
>
> the Department of Transport enhance its oversight policies, procedures and training to ensure the frequency and focus of surveillance, as well as post- surveillance oversight activities, including enforcement, are commensurate with the capability of the operator to effectively manage risk.
>
> **TSB Recommendation A16-14**

1.19 Useful or effective investigation techniques

Not applicable.

2.0 Analysis

On the return flight from the magnetometric survey work area, the aircraft descended, and maintained an altitude of less than 100 feet above ground level (AGL) until it collided with the wires.

There is no indication of airframe or engine failure or system malfunction during the occurrence flight, and the aircraft's performance was not a factor in the occurrence. The pilots were qualified to conduct the flight in accordance with existing regulations and had received the training required by Transport Canada (TC). The autopsies of the pilots, as well as an examination of the pilots' medical records, did not reveal any medical factor that could have affected their performance. Weather conditions were favourable for visual flight rules flight.

Therefore, this analysis will focus on the crew's actions on the return flight after the magnetometric survey work, the risks associated with very-low-altitude flying, the collision with the wires, flight following and monitoring, and post-impact occupant survivability.

2.1 Return from survey area

2.1.1 Very-low-altitude flying

In this occurrence, very-low-altitude (less than 100 feet AGL) round-trip flights between the airport and the survey area differ from the low-altitude magnetometric survey flights (300 feet AGL) in that they are not subject to oversight.

2.1.1.1 Risk taking

2.1.1.1.1 Sensation seeking

The crew had just completed a 2nd magnetometric survey flight of approximately 5 hours at an altitude of 300 feet AGL. According to Zuckerman (see Section 1.18.2.2 of this report), sensation seeking is a tendency to seek novel, varied, complex, and intense sensations and experiences, and is more prevalent in young men. Given the pilots' age and sex, it is conceivable that, for sensation-seeking purposes, they wanted to fly even lower.

2.1.1.1.2 Sustained attention and mental fatigue

Mental fatigue is a psychological state that results from spending extended or intense periods of time on a task. Mental fatigue can cause lowered vigilance and situational awareness, reduced attention span, and an increased tendency to take risks.

In this accident, the task of maintaining an altitude of precisely 300 feet AGL required a significant degree of sustained attention. Although the pilots alternated this task regularly, the pilot not flying still had to conduct surveillance. On the day of the accident, the crew was conducting their 2nd magnetometric survey flight of nearly 5 hours. Thus, at the time of the accident, the crew were probably subject to the effects of mental fatigue, which may have increased their tendency to take risks and, consequently, influenced their decision to descend to a very low altitude.

2.1.1.2 *Risk perception*

Individuals who repeatedly perform a dangerous activity with no, or few, negative repercussions may become desensitized or habituated to the high level of risk. Problems can arise when perceived risks no longer match the actual risks and dangers associated with an activity. Without mitigations in place to recalibrate risk perception, the subjective evaluation of low personal risk may lead to increases in the performance of high-risk activities.

Since the start of the contract, the crew had conducted 21 magnetometric survey flights in 12 days, over the 19 days preceding the accident. Over these 12 days of survey work, the crew logged 7.8 flight hours per day, on average. The vast majority of these hours were flown at low altitude (300 feet AGL); however, this activity was subject to control measures to reduce the risks. The number of flying hours without incident led the crew to become accustomed and desensitized to the risks of low flying.

During this period, the crew had also flown 27 flight segments involving very-low-altitude flying (less than 100 feet AGL), also without incident. It is therefore possible that the flight crew had become accustomed and desensitized to very-low-altitude flying.

Because risk can increase based on the values of a group, and because the pilots had been working together since the start of the contract, it is possible that the very-low-altitude and therefore higher-risk occurrence flight had become normal and accepted. Therefore, it is likely that the risks perceived by the pilots did not match the actual risks and hazards of very-low-altitude flying.

It can therefore be concluded that sensation seeking, mental fatigue, and an altered risk perception very likely contributed to the fact that, immediately after completing the magnetometric survey work, the pilot flying descended to an altitude varying between 100 and 40 feet AGL and maintained this altitude until the aircraft collided with the wires.

2.1.2 *Power transmission line wires*

Power transmission line wires are known to be extremely difficult to see in flight. Although there are solutions to prevent aircraft from colliding with them—such as their depiction on visual flight rules navigation charts (VNCs), marking, and reconnaissance flights—these solutions are not infallible. Therefore, if pilots fly at low altitude, there is a risk that they will collide with wires, given that these are extremely difficult to see in flight.

2.1.2.1 *Visual flight rules air navigation charts, marking, and identification of power transmission line*

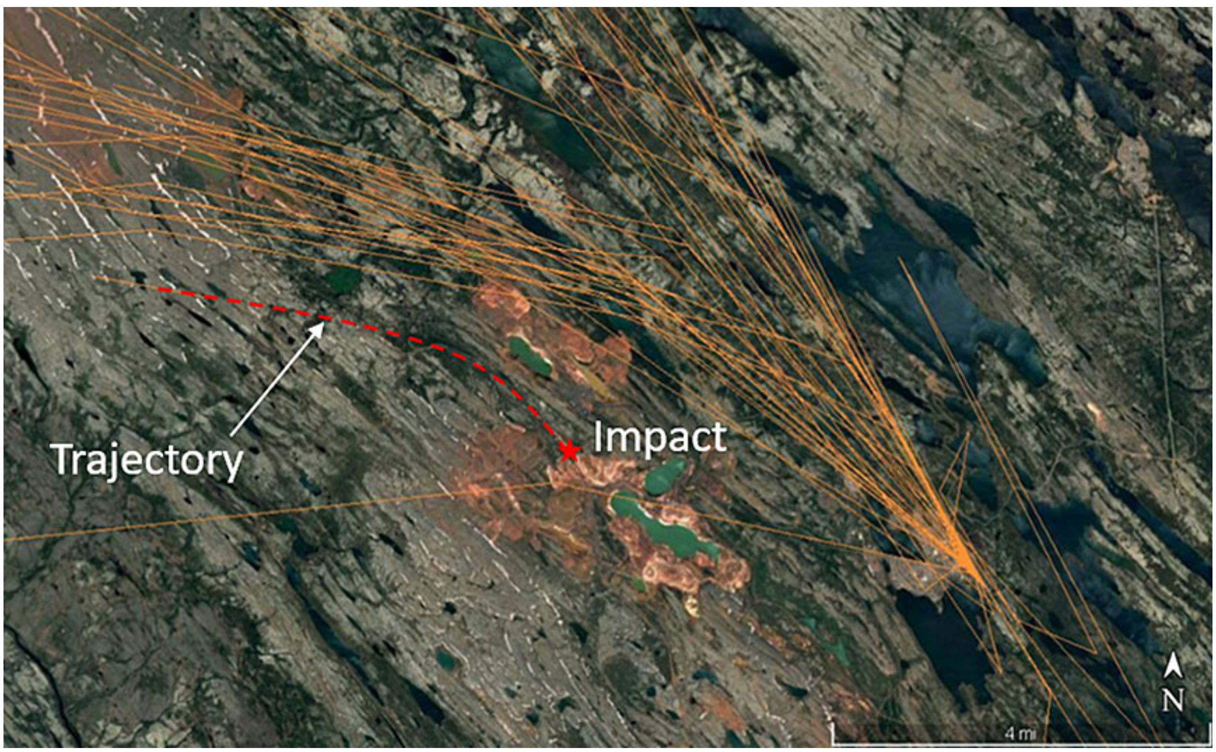
Power transmission lines are depicted on VNCs because they constitute cultural features that are useful for navigation; however, their representation depends on data availability.

Moreover, sections may be deleted or masked to ensure chart legibility. The power transmission line in this occurrence was not depicted on the VNC and there was no regulatory requirement for it to be portrayed.

Given the number of power transmission lines in Canada, TC has determined that it would not be reasonable to require the lighting or marking of all of them. In the area of the accident, the wires were not marked, and there was no regulatory requirement for them to be marked.

Because magnetometric survey flights are conducted at low altitude, the crew had conducted a reconnaissance flight over the survey area to identify potential hazards; however, reconnaissance was not required for the outbound and inbound segments, and the investigation determined that no flight over the accident site had been conducted (Figure 8).

Figure 8. Area of the occurrence aircraft's last very-low-altitude flight (Source: Google Earth, with TSB annotations)



The power transmission line was not depicted on the chart, the wires were not marked, and no reconnaissance flight had been conducted. As a result, it is highly likely that the pilots were unaware that there was a power transmission line in their path.

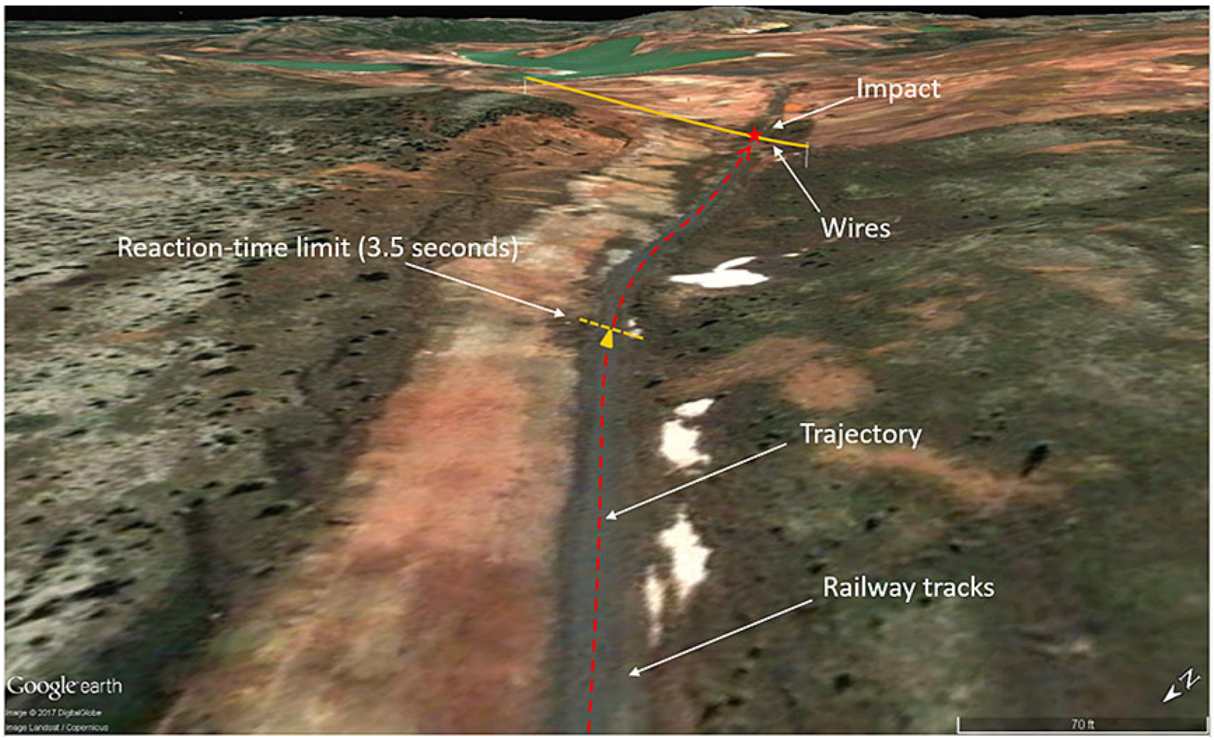
2.1.2.2 Collision with the wires

Based on the sun's position, the pilot would not have been blinded by the sun, and there were no shadows in the valley that could have hindered detection of the wires. However, the wires, pylons, and terrain were all a similar colour, and there was no contrast between them.

According to the global positioning system (GPS) data, the aircraft flew over the railway tracks at a ground speed of 169 knots, or 286 feet per second. The product of this speed multiplied by the estimated 3.5 seconds of reaction time necessary to avoid the wires is approximately 1000 feet. Therefore, the pilot would have to be in a position to see the wires 1000 feet ahead of them; otherwise, it would be impossible to avoid them.

As the aircraft was approaching this limit, the pilot had to turn right to remain above the railway tracks, creating a situation that was not conducive to a longer-distance visual scan to detect the wires. During the turn, the aircraft passed the point (Figure 9) at which there was insufficient reaction time to avoid the wires.

Figure 9. Trajectory prior to impact (Source: Google Earth, with TSB annotations)



Consequently, as the aircraft was flying at very low altitude above the railway tracks, the pilot flying did not detect the power transmission line in time to avoid it, and the aircraft collided with the wires, which were 70 feet above the ground.

2.2 *Flight following and monitoring*

In principle, operations managers must ensure the safety of operations. In practice, they may not necessarily have all the tools they need in order to do so. This is why the company's flight operations manual (FOM) reminds pilots that they assume full responsibility for conducting flights and that they must ensure that flights are conducted in accordance with existing regulations and the procedures set out in the manual.

2.2.1 *Monitoring of flight time, flight duty time, and rest periods*

According to the FOM, contracted pilots must log their flying hours in their own version of the time-monitoring application in order to avoid any deviation from the *Canadian Aviation Regulations* (CARs). This file is then sent, on the first day of the month following the flights, to the company for verification.

Because the director of operations was aware that the pilots at CYKL were conducting many flights during the week of 12 April, he intervened to verify and limit flights on 18 April in order to remain within the regulatory limit of 60 hours within 7 consecutive days.

Although company management did oversee the contracted pilots' flight time effectively, the company mainly relies on the pilots to monitor their flight time. The director of operations' situational awareness is an additional line of defence to prevent regulatory flight time limits from being exceeded.

2.2.2 *Flight data monitoring and lightweight flight data recording systems*

Despite the warning regarding low-altitude flying in the *Transport Canada Aeronautical Information Manual*, and in the absence of minimum-altitude restrictions imposed by the company, the pilot chose to descend to a very low altitude on the return flight; as a result, this flight segment carried an unacceptable level of risk.

Exact Air Inc., like most companies of its size, has no specific method of monitoring how flights are conducted. In this occurrence, although the client provided an online flight-monitoring system to the company, it was not used for flight monitoring, and there was no requirement to use it. As a result, the company was unaware that the occurrence pilots flew at very low altitude while transiting between survey areas and the airport. Moreover, no member of the company was aware that the pilots' flying habits carried a level of risk that was unnecessary for these return trips to the airport.

Given that the occurrence aircraft was not equipped with a lightweight flight data recorder,[56] company management did not have access to flight data that would show whether operating limits were being respected or that would detect risky manoeuvres.

For decades, heavy passenger-aircraft operators have been required to carry flight data recorders (FDRs). These operators can use FDR data for internal flight data monitoring (FDM) programs and air-operation quality assurance. These programs help operators to take a preventive approach to safety management.

The development of lightweight flight data recording systems makes it possible to broaden the level of surveillance through FDM, in particular to ensure compliance with company procedures and adherence to operational limits, as well as to monitor risky manoeuvres.

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56 This type of recorder was not required by regulation.

In addition, the presence of a lightweight flight data recording system on board can have a positive influence on pilot behaviour. Monitoring these data allows operators to identify operational discrepancies and take corrective measures before an accident occurs. If lightweight flight data recording systems are not used to closely monitor flight operations, there is a risk that pilots will deviate from established procedures and limits, thereby reducing safety margins.

The TSB has previously recognized that monitoring systems and FDM have the potential to help operators proactively identify safety deficiencies before they cause an accident. But although affordable devices are available, installing them in an aircraft requires special certification, which can make the implementation process costlier and more complex. For this reason, the Board made Recommendation A13-01, aimed at eliminating barriers to the implementation of FDM and the installation of lightweight flight data recording systems by commercial operators that are still not required to equip their aircraft with such systems.

TC supported this recommendation and held a meeting in February 2018 to examine policy questions, challenges, and benefits associated with the possible extension of FDR requirements to small Canadian aircraft, which are not currently required to be equipped with an FDR under the CARs. Although this meeting was a step in the right direction, the fact remains that, for the moment, no concrete measure has been taken to implement the TSB's recommendation. Consequently, it is not known when or how the safety deficiency raised in Recommendation A13-01 will be corrected. If TC does not take concrete measures to facilitate the use of lightweight flight data recording systems and FDM, there is a risk that operators will be unable to proactively identify safety deficiencies before they cause an accident.

Recommendation A13-01 was replaced by Recommendation A18-01, which calls for TC to require the mandatory installation of lightweight flight recording systems by commercial and private operators not currently required to carry these systems. The Board is calling for TC to use the work done for Recommendation A13-01 to accelerate the adoption of safety measures in response to Recommendation A18-01.

2.2.3 Safety management systems

Exact Air Inc. implemented a safety management system (SMS), even though an SMS is not required by regulation for operators under subparts 406, 702, and 703 of the CARs. However, implementing an SMS is a challenging process, requiring a company to transform its culture of compliance into one of safety hazard management. This transformation is all the more difficult for a company that has neither the personnel nor an organizational structure comparable to large air carriers.

TC does not evaluate or verify voluntarily implemented SMSs. As a result, Exact Air Inc.'s SMS was not evaluated or subject to surveillance by TC during the most recent program validation inspection (PVI) in 2016.

Investigations into this occurrence and other recent occurrences underscore that operators must effectively manage safety risks. Although many companies, including Exact Air Inc., have recognized the benefits of having an SMS and have voluntarily begun implementing them within their organizations, and 95% of air transport users fly with operators that have implemented an SMS, approximately 90% of all Canadian aviation certificate holders are still not required by regulation to have an SMS.[57] Over 10 years after the introduction of the first SMS regulations for CARs Subpart 705 air operators and aircraft maintenance companies working for these operators, SMS implementation for Subpart 406, 702, 703, and 704 operators seems to have stagnated. This is despite the fact that, in 2016, TC published a guide on the development of SMSs for smaller aviation organizations.

As a result, TC has no assurance that these operators are able to detect and mitigate risks. Accordingly, through the TSB Watchlist and recommendations,[58] the Board has emphasized the fact that if SMSs are not required, assessed, and monitored by TC in order to ensure continual improvement, there is an increased risk that companies will be unable to effectively identify and mitigate the hazards involved in their operations.

2.3 Post-impact survivability

2.3.1 Restraint device

The pilot seated in the right-hand seat was not wearing his safety belt and was ejected from the aircraft. However, the damage sustained by the aircraft and the impact forces in this occurrence were not survivable. Not wearing a safety belt increases the risk of injury or death in an accident.

2.3.2 Emergency locator transmitter

Following the impact, no emergency locator transmitter (ELT) signal was captured. Damage to the antenna coaxial cable likely led to the rapid discharge of the battery. However, the broken antenna and the fact that the wreckage was upside down would have made it impossible to detect the signal. Although the design specifications for impact resistance are stringent for the ELT itself, they do not cover other key elements of the system (namely, the wiring and the antenna). The current ELT system design standards do not include a requirement for a crashworthy antenna system. As a result, there is a risk that potentially life-saving search- and- rescue services will be delayed if an ELT antenna is damaged during an occurrence.

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57 TSB Aviation Investigation Report A13H0001.

58 TSB Aviation Investigation Report A13H0001 and TSB recommendations A16-12, A16-13, and A16-14.

3.0 Findings

3.1 Findings as to causes and contributing factors

1. Sensation seeking, mental fatigue, and an altered risk perception very likely contributed to the fact that, immediately after completing the magnetometric survey work, the pilot flying descended to an altitude varying between 100 and 40 feet above ground level and maintained this altitude until the aircraft collided with the wires.

2. It is highly likely that the pilots were unaware that there was a power transmission line in their path.

3. The pilot flying did not detect the power transmission line in time to avoid it, and the aircraft collided with the wires, which were 70 feet above the ground.

4. Despite the warning regarding low-altitude flying in the *Transport Canada Aeronautical Information Manual*, and in the absence of minimum-altitude restrictions imposed by the company, the pilot chose to descend to a very low altitude on the return flight; as a result, this flight segment carried an unacceptable level of risk.

3.2 Findings as to risk

1. If pilots fly at low altitude, there is a risk that they will collide with wires, given that these are extremely difficult to see in flight.

2. If lightweight flight data recording systems are not used to closely monitor flight operations, there is a risk that pilots will deviate from established procedures and limits, thereby reducing safety margins.

3. If Transport Canada does not take concrete measures to facilitate the use of lightweight flight data recording systems and flight data monitoring, there is a risk that operators will be unable to proactively identify safety deficiencies before they cause an accident.

4. If safety management systems are not required, assessed, and monitored by Transport Canada in order to ensure continual improvement, there is an increased risk that companies will be unable to effectively identify and mitigate the hazards involved in their operations.

5. Not wearing a safety belt increases the risk of injury or death in an accident.

6. The current emergency locator transmitter system design standards do not include a requirement for a crashworthy antenna system. As a result, there is a risk that potentially life-saving search- and- rescue services will be delayed if an emergency locator transmitter antenna is damaged during an occurrence.

4.0 Safety action

4.1 Safety action taken

4.1.1 Exact Air Inc.

Following the accident, Exact Air Inc. conducted an awareness campaign and held meetings with all company staff regarding the causes of the accident and the risks associated with low-altitude flying. They also held a meeting with the management of GDS (the client) to explain the situation and to emphasize the necessity of teamwork to prevent other dangerous behaviours.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 20 June 2018. It was officially released on 05 July 2018.

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