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

AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A19W0015

Loss of control and collision with terrain

Air Tindi Ltd.
Beechcraft King Air 200, C-GTUC
Whatì Airport, Northwest Territories, 21 NM ESE
30 January 2019

Canada

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Citation

Transportation Safety Board of Canada, *Air Transportation Safety Investigation Report* A19W0015 (released 27 April 2020).

Transportation Safety Board of Canada
200 Promenade du Portage, 4th floor
Gatineau QC K1A 1K8
819-994-3741; 1-800-387-3557
www.tsb.gc.ca
communications@tsb.gc.ca

Air transportation safety investigation report A19W0015

Cat. No. TU3-10/19-0015E-PDF
ISBN: 978-0-660-34577-2

This report is available on the website of the Transportation Safety Board of Canada at www.tsb.gc.ca

Le présent rapport est également disponible en français.

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AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A19W0015

LOSS OF CONTROL AND COLLISION WITH TERRAIN

Air Tindi Ltd.
Beechcraft King Air 200, C-GTUC
Whatì Airport, Northwest Territories, 21 NM ESE
30 January 2019

Summary

At 0851 Mountain Standard Time on 30 January 2019, the Air Tindi Ltd. Beechcraft King Air 200 aircraft (registration C-GTUC, serial number BB-268) departed Yellowknife Airport (CYZF), Northwest Territories, as flight TIN503, on an instrument flight rules flight itinerary to Whatì Airport (CEM3), Northwest Territories, with 2 crew members on board. At 0912, as the aircraft began the approach to CEM3, it departed controlled flight during its initial descent from 12 000 feet above sea level, and impacted terrain approximately 21 nautical miles east-southeast of CEM3, at an elevation of 544 feet above sea level. The Canadian Mission Control Centre received a signal from the aircraft's 406 MHz emergency locator transmitter and notified the Joint Rescue Coordination Centre in Trenton, Ontario. Search and rescue technicians arrived on site approximately 6 hours after the accident. The 2 flight crew members received fatal injuries on impact. The aircraft was destroyed.

1.0 FACTUAL INFORMATION

1.1 History of the flight

The International Civil Aviation Organization's (ICAO's) Annex 13 requires states conducting accident investigations to protect cockpit voice recordings.[1] Canada complies with this requirement by making all on-board recordings privileged in the *Canadian Transportation Accident Investigation and Safety Board Act*. While the TSB may make use of any on-board recording in the interests of transportation safety, it is not permitted to knowingly communicate any portion of an on-board recording that is unrelated to the causes or contributing factors of an accident or to the identification of safety deficiencies.

The reason for protecting on-board recordings lies in the premise that these protections help ensure that pilots will continue to express themselves freely and that this essential material is available for the benefit of safety investigations. The TSB has always taken its obligations in this area very seriously and has vigorously restricted the use of on-board recording data in its reports. Unless the on-board recording is required to both support a finding and identify a substantive safety deficiency, it will not be included in the TSB's report.

To validate the safety issues raised in this investigation, the TSB has made use of the available on-board recording in its report. In each instance, the material has been carefully examined in order to ensure that it is required to advance transportation safety.

On 30 January 2019 at 0830,[2] the Air Tindi Ltd. (Air Tindi) Beechcraft King Air 200 aircraft (registration C-GTUC, serial number BB-268) was scheduled to depart Yellowknife Airport (CYZF), Northwest Territories, to conduct flight TIN503, which consisted of 6 legs:

- The 1st leg was from CYZF to Whatì Airport (CEM3), Northwest Territories.
- The 2nd leg was from CEM3 to Wekweètì Airport (CYWE), Northwest Territories.
- The 3rd leg was from CYWE to Ekati Aerodrome (CYOA), Northwest Territories.
- The aircraft would then follow the reverse route back to CYZF (Figure 1).

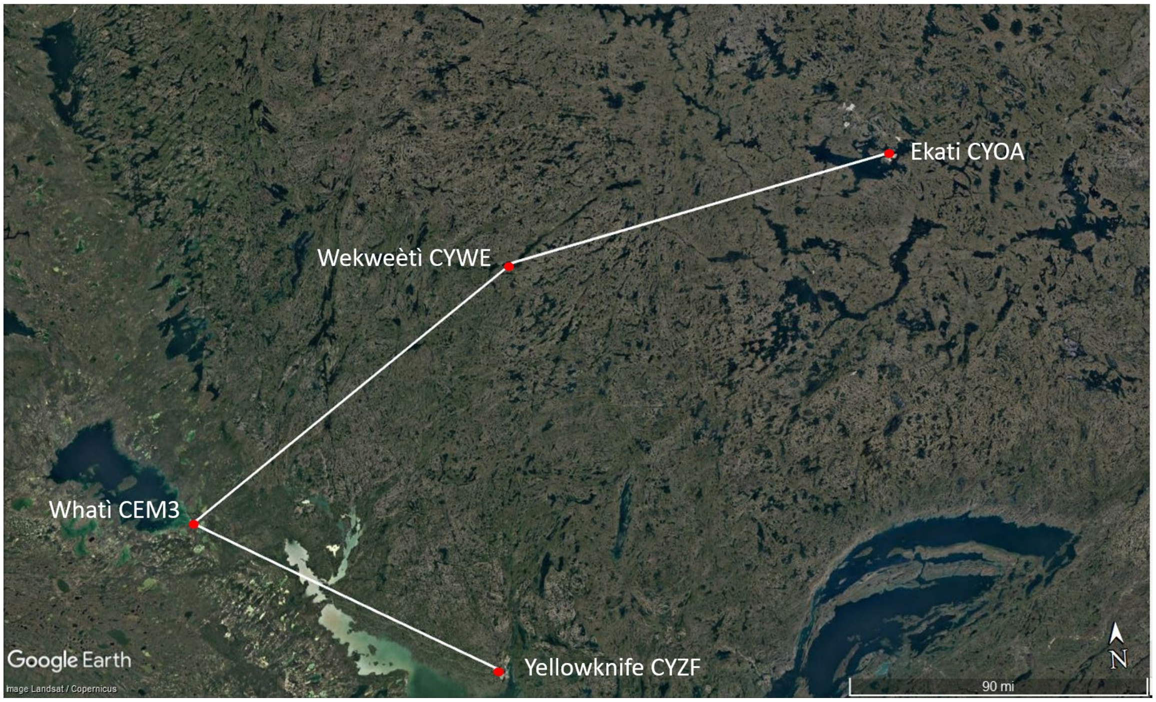
The captain met the first officer (FO) at the airport at approximately 0730 and they divided up the pre-flight duties between them.

At approximately 0745, the aircraft was pulled out of the hangar and was fuelled in preparation for the flight. A total of 3200 pounds of fuel was on board the aircraft when it departed on the 1st leg of the flight.

1 International Civil Aviation Organization, Annex 13 to the Convention on International Civil Aviation, *Aircraft Accident and Incident Investigation*, Eleventh Edition (July 2016), paragraph 5.12.

2 All times are Mountain Standard Time (Universal Coordinated Time minus 7 hours).

Figure 1. Map showing the planned flight route (Source: Google Earth, with TSB annotations)



The flight crew boarded the aircraft in preparation for the planned 36-minute 1st leg flight. The after-start checklist was commenced at 0842:31. While completing the checklist, the FO noted that the right-side vacuum-driven attitude indicator was not erect.[3] The captain assured the FO that the instrument would start to operate.

At 0844:15, the after-start checklist was confirmed complete and again the captain assured the FO that the right-side attitude indicator would start to work.

At 0845:00, the occurrence aircraft began to taxi for departure from Runway 10; the captain called for the taxi checks, and he and the FO proceeded to complete the checklist. During the taxi checks, the FO observed that the vacuum indication was sufficient and the pneumatic pressure was checked.

At 0847:46, the captain provided the take-off briefing, which highlighted the following 2 threats to the safety of the flight:

- moderate icing reported above 4000 feet above sea level (ASL); and
- snowy conditions and accumulation of snow on the ground.

Because of the snowy conditions, the captain indicated that the landing gear would be left extended for 5 seconds after rotation to allow any snow or slush accumulation to blow off the landing gear before retraction.

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3 An erect attitude indicator is one that has obtained its normal operating position in relation to aircraft position.

At 0848:10, the captain asked the FO if he had any questions; the FO replied he had none.

At 0848:15, the FO called for the run-up checks.[4] The captain indicated that it was complete; however, the investigation determined that the run-up checklist had not actually been completed.

At 0849:36, the captain called for the line-up checks and he and the FO proceeded to work through the line-up checklist,[5] which was completed at 0850:30.

AT 0850:50, air traffic control cleared the occurrence aircraft for takeoff and the aircraft proceeded onto the threshold of Runway 10.

At 0851:29, take-off power was applied and the take-off roll was commenced. During the initial segment of the take-off roll, the captain asked the FO if the right-side attitude indicator was still not working. The FO confirmed that it was not. The aircraft departed CYZF at 0851:50.

At 0853:30, the flight crew started the after-takeoff checklist, which the FO confirmed complete at 0853:39.

At 0854:06, the captain suggested to the FO that he should tap the attitude indicator to see if it was stuck or frozen. The FO replied that the attitude indicator was still not erect.

At 0855:53, the captain and the FO mentioned the inoperable right-side attitude indicator again.

At 0856:29, the flight crew commenced the 10 000 feet checklist, which was completed by 0857:07.

At 0858:29, the aircraft reached the planned cruising altitude of 12 000 feet ASL and the captain called for the cruise checks, which he completed with the FO.

At 0901:01, the captain engaged the autopilot. The captain (who was the pilot flying at the time) did not make the “AUTOPILOT ON” call as required by company standard operating procedures (SOPs)[6] and the FO (who was the pilot monitoring at the time) did not acknowledge autopilot engagement as required by company SOPs.

At 0902:23, the flight crew attempted to troubleshoot the right-side attitude indicator.

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4 The run-up checklist consists of the following items: pressurization, primary and overspeed propeller governors, rudder boost, autofeather, vacuum and pneumatic pressures, engine anti-ice, and ice protection equipment. The run-up check is required for the first flight of the day only. (Source: Air Tindi Ltd., BE 200 C-GTUC Cockpit Checklist, Edition 3, Version 2 [01 April 2018].)

5 The line-up checklist is completed while the aircraft is taxiing to position on the runway for takeoff.

6 Air Tindi Ltd., *Beechcraft 200/250 Standard Operating Procedures*, Edition 3, Version 1 (01 December 2017), Chapter 5: Enroute, Section 5.2: Use of Autopilot.

At 0905:40, the captain commenced the descent checklist, which included the approach briefing. The plan was to conduct the RNAV (GNSS)[7] approach to Runway 28 via the OVDOM waypoint, and then circling for Runway 10.

At 0907:23, the captain called for the descent and approach checks. The flight crew proceeded to work through both checklists.

At 0908:10, during the completion of the descent checklist, the crew received a radio call from another company aircraft that had landed at CEM3. During this communication, the flight crew of the occurrence aircraft received weather observations and a runway condition report for CEM3. The crew advised the other company aircraft of their intention to land on Runway 10.

The descent checklist was completed at 0910:08. At 0910:12, the crew commenced the initial descent to CEM3. The approach checklist was completed at 0910:26.

At 0910:42, the FO made a radio position call on the CEM3 traffic frequency. At the time, the aircraft was 26 nautical miles (NM) east of CEM3 and descending through 10 800 feet.

At 0911:01, the captain's attitude indicator on the left-side instrument panel displayed a red "GYRO" flag and the autopilot disconnected. At this time the captain began to manually fly the aircraft with partial flight instruments. The aircraft continued to descend, and the captain attempted to initiate a climb. The aircraft climbed briefly before beginning to descend again.

At 0911:12, the aircraft entered a right turn to a heading of 340° magnetic (M). Then, 38 seconds later, the aircraft entered a gradual left turn that progressed into a steep descending left turn (spiral)[8] from which the aircraft never recovered.

At 0912:14, the terrain awareness and warning system (TAWS) issued its first aural warning: "CAUTION, TERRAIN."

At 0912:16, the TAWS issued a "TERRAIN, TERRAIN" aural warning, followed 2 seconds later by a "PULL UP, PULL UP" aural warning.

At 0912:21, the TAWS issued the last [whoop whoop] "PULL UP" aural warning.

At 0912:24, the aircraft impacted terrain.

The aircraft's 406 MHz emergency locator transmitter (ELT) activated and the signal was received by search-and-rescue satellite (SARSAT) at 1003. An initial position was determined by SARSAT at 1111.

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7 RNAV refers to area navigation. An RNAV (GNSS) approach indicates a procedure requiring GNSS (global navigation satellite system).

8 Transport Canada's *Flight Training Manual – Aeroplane* defines a spiral as "a steep descending turn in which airspeed, rate of descent and wing loading increase rapidly". (Source: Transport Canada, TP 1102, 4th Edition (1994), p. 85.)

The Canadian Mission Control Centre received the ELT signal and informed the Joint Rescue Coordination Centre (JRCC) Trenton. JRCC then dispatched a search-and-rescue CC-130HE Hercules aircraft that departed Winnipeg, Manitoba, at 1105.

At 1455, the Hercules arrived in the area and, 50 minutes later, the occurrence aircraft was found. Two search and rescue technicians were deployed and arrived on the scene at 1631. Both flight crew members were fatally injured. The aircraft was destroyed.

1.2 Injuries to persons

Table 1. Injuries to persons

Injuries	Crew	Passengers	Total in aircraft	Others
Fatal	2	–	2	–
Serious	0	–	0	–
Minor	0	–	0	–
None	0	–	0	–
TOTAL	2	–	2	–

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

Approximately 3000 pounds of jet fuel contaminated the wreckage and soil at the site. Environmental damage was confined to the main impact site. There was no other property damage.

1.5 Personnel information

1.5.1 General

Records indicate that both the captain and FO were certified and qualified for the flight in accordance with existing regulations. Based on a review of the captain’s and FO’s work and rest schedules, fatigue was not considered to be a factor in the occurrence. In the 12 months before the occurrence, the captain and FO had been paired together on 9 occasions, during which they accrued a total of 27 hours of flight time as a crew. A review of Air Tindi's pilot training program revealed that all regulatory requirements were being met or exceeded.

Table 2. Personnel information

	Captain	First Officer
Pilot licence	Commercial pilot licence (CPL)	Commercial pilot licence (CPL)
Medical expiry date	01 September 2019	01 September 2019
Total flying hours*	2762	566
Flight hours on type*	1712	330
Flight hours in the last 7 days*	5.1	0
Flight hours in the last 30 days*	19.7	24.4
Flight hours in the last 90 days*	118.1	86.5
Flight hours on type in the last 90 days*	118.1	86.5
Hours on duty before the occurrence**	1.6	1.6
Hours off duty before the work period	24	48

* The flight crew members' logbooks were not found; all times are based on Air Tindi's air crew duty time software.

** Based on the flight crew's arrival at the airport 1 hour before the scheduled departure of 0830.

1.5.2 Captain

The captain obtained a commercial pilot licence on 26 April 2006, and held type ratings on the de Havilland DHC-7 (DH7) and the Beechcraft King Air 200 (BE20). His licence was endorsed with a Group 1 instrument rating. The captain began his employment with Air Tindi on 17 June 2011.

In January 2017, the captain completed his flight simulator training for the captain upgrade. The training met the Transport Canada (TC)–approved company training requirements and included unusual attitude recoveries, steep turns, crew resource management (CRM), traffic alert and collision avoidance system (TCAS) and ground proximity warning system (GPWS) operations. Following the simulator training, line indoctrination training was completed in March 2017. This included a total of 58.7 flight hours on 45 flight legs.

The captain had successfully completed his last line check ride on 30 July 2018 and his most recent flight simulator training session had been completed on 27 January 2019. Following the simulator training, a recommendation was made to conduct his pilot proficiency check (PPC) ride.

In the 12 months before the occurrence, the captain had accumulated 460.3 hours flying the various King Air 200 series aircraft of which 31.0 hours were on the occurrence aircraft.

The captain had last received threat and error management (TEM) training from the company as part of his CRM training. The computer-based academic portion of this training was completed on 15 December 2018 and was subsequently followed by the classroom practical portion, which was completed on 21 December 2018.

The captain had successfully completed the King Air 200 series differences training on 13 January 2017, and successfully completed the minimum equipment list (MEL) recurrent training course on 24 January 2019.

According to Air Tindi's training program in place at the time of the occurrence, the captain was not required to take the electronic flight bag (EFB) training set out in the company's approved Training Programs Manual. However, the captain had completed recurrent EFB training on 19 August 2016.

1.5.3 First officer

The FO obtained a commercial pilot licence on 05 November 2015 and held a type rating on the Beechcraft King Air 200 (BE20). His licence was endorsed with a Group 1 instrument rating. The FO began his employment with Air Tindi on 04 April 2016.

The FO completed his initial King Air 200 flight simulator training in April 2018. During this initial training, he received unusual attitude recovery training. His initial company line indoctrination training was then completed between 26 April and 24 May 2018. The FO's last line check was successfully completed 02 November 2018.

In the 12 months before the occurrence, the FO had accumulated 339.1 hours flying the various King Air 200 series aircraft. Of those hours, 20.9 were in the occurrence aircraft.

The FO had last received TEM training from the company as part of his CRM training. The computer-based academic portion of this training was completed on 14 December 2018. At the time of the occurrence, he had not completed the practical classroom portion of the CRM training as a flight crew member.[9]

The FO successfully completed the King Air 200 series differences training on 27 April 2018, and had completed the MEL recurrent training course on 22 January 2019.

Similar to the captain, the FO was not required to take the EFB training but had completed recurrent EFB training on 10 January 2018.

1.6 Aircraft information

1.6.1 General

The King Air 200 is a pressurized twin turboprop aircraft that is certified to carry up to 13 passengers and has a retractable landing gear. The occurrence aircraft was configured for 9 passengers. The aircraft is approved for operation by a single pilot or by 2 pilots. Air Tindi, in its Flight Operations Manual,[10] specified 2 pilots were required for all multi-engine aircraft, which included the King Air 200.

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9 The first officer had completed an "ACCESS CRM" classroom course while working as a dispatcher for Air Tindi in March 2018.

10 Air Tindi Ltd., *Flight Operations Manual*, Edition 4, Version 1 (01 January 2018), Section 7.4: Minimum Flight Crew, p. 7-3.

Table 3. Aircraft information

Manufacturer	Textron Aviation Inc.
Type, model and registration	Beechcraft King Air 200, C-GTUC
Year of manufacture	1977
Serial number	BB-268
Certificate of airworthiness issue date	22 May 1985
Total airframe time / Number of airframe cycles	20 890.8 hours / 18 863 cycles
Engine type (number of engines)	Pratt & Whitney Canada, PT6A-42 (2)
Maximum allowable takeoff weight	12 500 pounds
Recommended fuel type(s)	Jet A, Jet A-1, Jet B
Fuel type used	Jet A-1

The occurrence aircraft was registered to Air Tindi on 20 February 2002.

The aircraft's maximum operating speed is 259 knots indicated airspeed[11] and its flaps-up maximum flight load factor is 3.17 positive *g*.[12,13]

The weight and centre of gravity were calculated to be within the prescribed limits for all portions of the occurrence flight.

1.6.2 Right-side attitude indicator

A SIGMA-TEK 5000B series attitude indicator was installed in the right side of the instrument panel (Figure 2). This is a pneumatically operated (vacuum-driven) unit that provides both pitch and roll information to the co-pilot. The unit is not equipped with a caging knob,[14] or a warning flag. There is no maintenance schedule for this equipment.

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11 Raytheon Aircraft Company, *Beech Super King Air 200 & 200C Pilot's Operating Handbook and FAA Approved Airplane Flight Manual*, Revision A13 (January 2002), Section II, p. 2-3.

12 *g* is a unit of measurement of the force resulting from vertical acceleration due to gravity. An acceleration of 1*g* is 9.8 m/s^2.

13 Raytheon Aircraft Company, *Beech Super King Air 200 & 200C Pilot's Operating Handbook and FAA Approved Airplane Flight Manual*, Revision A13 (January 2002), Section II, p. 2-11.

14 When pulled, the caging knob will lock the attitude indicator in its erect position.

The attitude indicator was recovered from the wreckage in 3 separate pieces: the mounting bezel and front face, the rear instrument housing, and the rotor assembly. The rotor assembly and rear housing were sent to the TSB Engineering Laboratory in Ottawa, Ontario, for analysis to determine why the instrument was not functioning correctly.

Figure 2. Right-side attitude indicator with no vacuum applied (Source: Air Tindi Ltd.)

The TSB Engineering Laboratory completed a detailed examination of the attitude indicator and found no signs that the gyro rotor was rotating at the time of impact. The rotor bearings were examined and no anomalies were found. Due to the extent of damage to the aircraft and its systems, the investigation was unable to determine why the attitude indicator was not operating correctly.

The maintenance history for this model of attitude indicator installed in King Air 200 aircraft operated by Air Tindi was reviewed. Since 2015, this attitude indicator model had been removed for unscheduled repairs 15 times from various aircraft in the Air Tindi fleet. Of those, the cause of the reported fault was not determined in 5 cases.[15] The instrument repair facility confirmed the causes of the faults in the remaining 10 cases and repaired the attitude indicators. The time in service for the 10 confirmed cases ranged from a low of 2.9 hours to a high of 766.2 hours. At the time of the occurrence, the attitude indicator installed in the occurrence aircraft had 636.4 hours in service.

Various Air Tindi flight crews did experience, on occasion, slow erection of the vacuum powered attitude indicator when the aircraft cabin had cooled to cold ambient temperatures. The attitude indicator would begin to function normally after the cabin/cockpit area warmed up.

A review of TC's service difficulty reporting system for the period of April 2014 to April 2019 revealed 3 reported instances[16] of the SIGMA-TEK Model 5000B attitude indicator exhibiting indication issues requiring instrument replacement (Appendix A). A corresponding search of the U.S. Federal Aviation Administration's (FAA's) service difficulty reporting system for the same period revealed 1 reported incident[17] of a SIGMA-TEK Model 5000B attitude indicator installed in the right side of the instrument panel of a King Air C90A that tumbled 5 minutes into the flight. The pilot returned to the maintenance base and, during the return, the attitude indicator began to operate normally again. The attitude indicator was replaced as a precautionary measure.

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15 The instrument was returned from the repair facility with a "No fault found" condition.

16 Service difficulty report numbers 20160706012, 20170112006, and 20170424014.

17 Federal Aviation Administration service difficulty report unique control number 2015FA0000258.

1.6.3 Left-side attitude indicator

Figure 3. Left-side attitude indicator with power applied (Source: Air Tindi Ltd.)

The aircraft was equipped with a Collins FD-109Z integrated flight guidance system, which is a combination of guidance, displays, and sensors. As part of that system, the left side of the instrument panel was equipped with a Rockwell Collins model 329B-8Y flight director indicator. This instrument presents a 3-dimensional display of the aircraft's attitude, and displays pitch and bank commands. It also has a rate-of-turn indicator, glideslope deviation pointer, slip and skid indicator, and a decision height annunciator (Figure 3). The unit is powered by 26 V alternating current (AC) power supplied by the instrument inverter system. Pitch and roll data is supplied to the indicator from a Rockwell Collins model 332D-11A vertical reference gyroscope remotely mounted in the forward avionics compartment of the aircraft. The investigation determined that the instrument AC power supply was satisfactory at the time of the occurrence.

According to the instrument's Overhaul Manual, the red "GYRO" flag is in view when any of the following 5 conditions exist:

a. Loss of primary power.

b. Failure of internal power supply.

c. Absence of 3-wire inputs to pitch or roll servo.

d. Presence of a persistent, excessive error at null in pitch or roll servo.

e. Absence of ATTITUDE VALID (+28 Vdc [volts direct current]) signal.[18]

When the vertical reference gyroscope was recovered from the accident site, it was found to have separated from its mounting tray and showed visible signs of damage as a result of the impact with terrain. The unit was subsequently sent to the TSB Engineering Laboratory for analysis in an attempt to determine the condition that resulted in the red "GYRO" flag being displayed to the captain 84 seconds before impact with terrain. The investigation determined that the gyroscope displayed signs of rotation at the time of impact. However, the damage to the vertical gyroscope during the accident sequence was extensive; therefore, the reason the gyro flag was displayed could not be determined.

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18 Rockwell, *Overhaul Manual with IPL - COLLINS 329B-8Y - PART NO 792-6357-001* (01 January 1983), Equipment Specifications Figure 4 (Sheet 3), p. 5.

The vertical reference gyroscope was last repaired and recertified by an approved avionics repair facility in March 2016. It was then returned to Air Tindi, and installed on the occurrence aircraft. At the time of the occurrence, the vertical reference gyroscope had accumulated approximately 390 flight hours since the repair.

A review of TC's and the FAA's respective service difficulty reporting systems for the period of April 2014 to April 2019 did not reveal any reported issues with the Collins 332D-11A vertical reference gyroscope. There is no maintenance schedule for this equipment.

1.6.4 Maintenance

Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

The maintenance of the aircraft was primarily completed by the company's internal maintenance department. The maintenance department is certified by TC as an approved maintenance organization.

The entries made in the journey log for the 30 days before the occurrence were reviewed. No technical defects related to either the left- or right-side attitude indicators were recorded during that time. The last scheduled airframe and engine inspection was carried out on the aircraft on 10 September 2018. At that time, the airframe total time since new was 20 702.9 hours. Maintenance personnel performed the last daily inspection on 29 January 2019 at 20 890.8 hours total time airframe.

1.7 Meteorological information

1.7.1 Weather received by pilots before departure

Before departing CYZF, the captain contacted the flight information centre in Edmonton, Alberta, to file an instrument flight rules (IFR) flight itinerary and received a weather briefing for the intended route of flight from the flight service specialist.

According to the graphic area forecast (GFA) chart issued on 30 January 2019 at 0431 and valid at the time of the occurrence, the weather conditions for the proposed route of flight were forecast to be:

- cloud bases at 2000 feet ASL and tops 22 000 feet ASL
- visibilities 1 to 5 statute miles (SM) in light snow
- extensive ceilings at 600 to 1200 feet above ground level
- occasional altocumulus castellanus clouds with tops at 24 000 feet ASL
- visibility ½ SM in snow showers

The aerodrome forecast (TAF)[19] for CYZF issued on 30 January 2019 at 0849, and valid for the 24-hour period from 0800 on 30 January until 0500 on 31 January indicated the following:

- winds 100° true (T) at 15 knots gusting to 25 knots
- visibility ¾ SM in light snow
- overcast ceiling at 1200 feet AGL
- temporarily between 0800 and 1100: visibility 3 SM in light snow, and overcast ceiling at 2000 feet AGL

There are no weather reports available for CEM3. The closest location with an aviation weather report is Gamètì/Rae Lakes Airport (CYRA), Northwest Territories, which is approximately 60 NM north of CEM3. At 0900, 12 minutes before the accident, CYRA was reporting the following weather:

- wind 100°T at 9 knots
- visibility 2 SM in light snow showers
- vertical visibility 1800 feet AGL
- temperature −22 °C, dew point −25 °C
- altimeter setting 29.78 inches of mercury

1.7.2 Turbulence and icing

The associated icing, turbulence and freezing level chart issued at 0432 on 30 January 2019 and valid at the time of the occurrence, forecast the following conditions for the proposed route of flight:

- moderate mixed icing in cloud between 2000 and 12 000 feet ASL
- patchy moderate turbulence between the surface and 3000 feet AGL for areas southeast of CYZF

The flight crew had received information from air traffic services before departure that other aircraft had encountered moderate icing above 4000 feet ASL, and light icing below 4000 feet ASL on approach to CYZF. During the flight, just before starting the cruise checks, the flight crew checked for signs of ice collecting on the wings and had seen none.

1.8 Aids to navigation

1.8.1 Terrain awareness and warning system

The aircraft was equipped with a TAWS. TAWS is a self-contained instrument installed directly below the airspeed indicator and to the left of the flight director and horizontal situation indicator on the captain’s instrument panel. The unit provides full-time terrain display and combines terrain and traffic alerting information with mapping and navigation

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19 An aerodrome forecast (TAF) is valid for an area with a radius of 5 NM centred on the airport.

functions. The unit also provides aural warnings to the flight crew when the aircraft is too close to terrain. The model of TAWS installed on the occurrence aircraft provided the aural warnings as designed and can record up to 10 hours of TAWS flight data, including recording of alert data.

The TAWS was recovered and sent to the TSB Engineering Laboratory for data recovery and analysis. The recovery of this data allowed to create a visual depiction of the entire occurrence flight path (Appendix B) and analyze the rates of climb and descent and estimated airspeeds reached in the later portion of the flight. During the descent, the aircraft was calculated to have reached a maximum airspeed of over 400 knots calibrated airspeed (KCAS) just before impact, which exceeds the maximum operating speed of the aircraft by approximately 141 knots. The aircraft also achieved a maximum descent rate of 35 637 fpm. The calculated g loading during this attempted recovery is estimated to have reached a peak of 3 to 4 times the force of gravity.

Table 4. Terrain awareness and warning system alert data summary

Time to impact (seconds)	Aural alert	GPS altitude (feet ASL)	Radar altitude (feet AGL)	Vertical speed (fpm)	Estimated airspeed (KCAS)
10	CAUTION, TERRAIN	5584	3088	-25 940	299
9		5067	3085	-28 526	306
8	TERRAIN, TERRAIN	4544	3081	-31 011	313
7		3991	3085	-33 149	323
6	PULL UP	3399	3080	-34 932	340
5	PULL UP	2808	3081	-35 637	360
4		2226	1837	-34 901	376
3	[WHOOP, WHOOP] PULL UP	1692	989	-32 235	388
2		1244	538	-27 393	398
1		912	224	-20 452	404

1.8.2 Electronic flight bag

In accordance with Air Tindi's *Flight Operations Manual*,[20] both the captain and the FO had an EFB in the form of an iPad mini. These devices are equipped with the ForeFlight Mobile application (ForeFlight), which includes maps, charts, weather information, manuals and checklists required for planning and carrying out a flight. This application, in conjunction with the Garmin Flight Stream 210 device installed in the aircraft, provided GPS (global positioning system) navigation functions and had the capability to provide a backup attitude indication and synthetic vision view to both pilots on their respective iPad minis, if selected. Selection of this view is made by tapping the appropriate icon in a tool bar at the top of the display. This tool bar is visible at all times when using the application.

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20 Air Tindi Ltd., *Flight Operations Manual*, Edition 4, Version 2 (01 April 2018), Section 13.19: Electronic Flight Bag (EFB) Operations, p. 13-19.

The synthetic vision mode displays an image (Appendix C) of an artificially generated view of the terrain outside the aircraft. Overlaid on that image is an attitude indicator providing both pitch and roll information. To the leftside of the attitude indicator is a GPS-derived ground speed tape and to the right of the attitude indicator is a GPS-derived altitude tape and rate of climb tape. In the lower centre of the screen is a horizontal situation indicator, which provides the aircraft's current heading and track information.

Air Tindi did not have a formal or documented training program in place for using the attitude and heading reference system (AHRS) feature of ForeFlight. A documented and formal training program on using this feature was not required because AHRS is a backup feature of ForeFlight and, therefore, not required by or approved according to regulations. However, the investigation determined that both the captain and FO had been exposed to this feature of ForeFlight through video-based training about the application.

1.9 Communications

No difficulties with the quality of radio communications were noted throughout the flight.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

1.11.1 Flight data recorder

The occurrence aircraft was not equipped with a flight data recorder (FDR), nor was it required by regulation.

1.11.2 Cockpit voice recorder

Although not required by regulations,[21] the aircraft was equipped with a cockpit voice recorder (CVR). The aircraft's CVR was recovered and sent to the TSB Engineering Laboratory for data recovery and analysis. The CVR captured audio from the following sources and was considered of good quality:

- captain's audio
- FO's audio
- cockpit area microphone
- the aircraft's radio communications system

1.12 Wreckage and impact information

The wreckage was located in trees, on a bearing of 089°T, 21 NM from the intended destination. The aircraft had initially impacted tree tops in a shallow nose low pitch attitude

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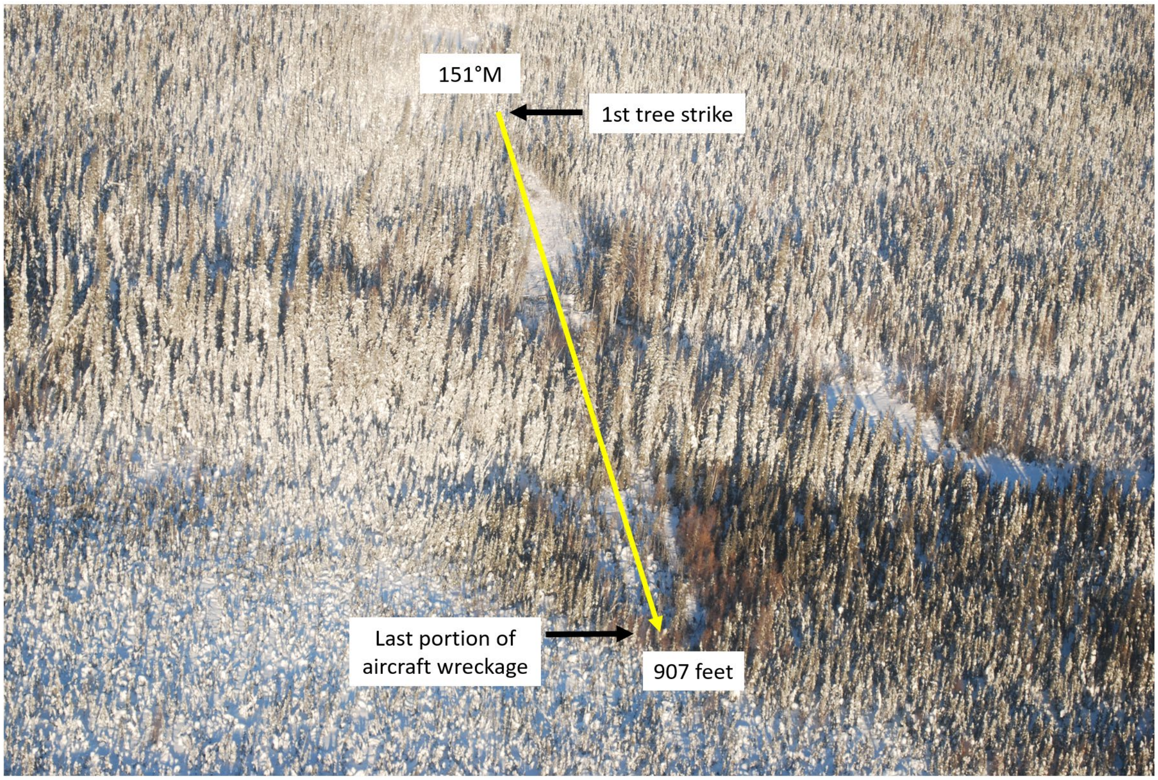
[21] Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, Subsection 605.34(1).

and at high speed, causing the aircraft to break up into a large number of pieces. The wreckage trail was approximately 900 feet long, oriented on a heading of 151°M (Figure 4).

Figure 4. Occurrence site, with yellow line depicting the beginning and end of the wreckage trail (Source: TSB)



All major aircraft structural components were accounted for in the on-site examination of the wreckage; therefore, the investigation determined that the aircraft did not break up while in flight. Both engines had separated from the aircraft structure during the impact sequence. Both propellers had broken free from their respective engines. All propeller blades were still attached to their respective propeller hub. Because the aircraft was destroyed, continuity of primary flight controls could not be established.

1.13 Medical and pathological information

The investigation determined that there was nothing to indicate that the captain's or FO's performance was degraded by physiological factors.

1.14 Fire

There was no fire.

1.15 Survival aspects

The accident was not survivable owing to the impact forces.

1.16 Tests and research

1.16.1 TSB laboratory reports

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

- LP032/2019 – Aircraft Performance Analysis
- LP050/2019 – Attitude Indicator Examination

1.17 Organizational and management information

1.17.1 Air Tindi Ltd.

Headquartered in Yellowknife, Northwest Territories, Air Tindi started as a private company in 1988 and was sold to Discovery Air in 2006. The company provides scheduled cargo and charter flights, as well as emergency medical evacuation flights.

Air Tindi is authorized to conduct commercial aircraft operations under subparts 702 (Aerial Work), 703 (Air Taxi), 704 (Commuter) and 705 (Airline) of the *Canadian Aviation Regulations* (CARs). It is certified to operate the King Air 200 under Subpart 703 of the CARs in day and night visual flight rules (VFR) and IFR conditions. This operations specification also provides for the carriage of persons and cargo.

At the time of occurrence, Air Tindi operated 5 King Air 200 series aircraft, including the occurrence aircraft and 4 more. Three of the remaining 4 were King Air B200GT models, manufactured in 2014. These 3 aircraft are equipped with a Garmin G1000 avionics suite, which is a digital electronic flight instrument system (EFIS). This system consists of 2 primary flight displays—1 for each pilot—and a multifunction display placed in the centre instrument panel. These aircraft are also equipped with a standby attitude indicator, placed in the centre instrument panel.

The 4th remaining aircraft was a King Air 200 manufactured in 1978 and had an instrumentation package that contained 2 electrically powered attitude indicators with an additional stand by attitude indicator. The occurrence aircraft was the only King Air 200 series aircraft in the fleet that was not equipped with a standby (3rd) attitude indicator, nor was it required to be by regulation.[22]

Air Tindi's training program includes a course that highlighted the differences between King Air 200 models[23] operated by the company. Air Tindi's company operations manual[24] is

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22 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, Subsection 605.41(3).

23 Air Tindi Ltd., *Training Programs Manual*, Edition 4, Version 1 (01 January 2018), Section 5.30: King Air Differences Training, p. 5-16.

24 Air Tindi Ltd., *Flight Operations Manual*, Edition 4, Version 2 (01 April 2018).

established and maintained in accordance with Subsection 703.104(4) of the CARs. The manual

> […] has been compiled for the use and guidance of flight operations personnel in the execution of their duties. It provides management and operations personnel with instructions and guidance for the conduct of a safe and efficient air service.[25]

Chapter 14 of the manual "addresses aircraft requirements and aircraft performance. These requirements apply to aeroplanes operated under [subparts] 703, 704 and 705 [of the CARs] […]."[26] Section 14.7 covers maintenance discrepancy reporting and Subsection 14.7.7 deals specifically with maintenance technical dispatch procedures and states the following:

> To assure the aircraft is airworthy (CARS Reference 706.06) prior to each departure, the Captain will ensure that:
>
> - all defects in the journey log have been addressed as being either rectified or deferred; the intended flight will not exceed any inspection due time listed on the status report which can be found on the last page of the Journey Log Book; and,
> - all equipment necessary for the intended flight is functioning normally.[27]

1.17.2 Minimum equipment list

An MEL is a document generated by an air operator and approved by TC that authorizes the operator to dispatch an aircraft with unserviceable equipment installed in accordance with specific conditions. Air Tindi's MEL for the King Air 200 is based on a combination of the FAA's master minimum equipment list (MMEL), a TC MMEL supplement, and the operator's particular aircraft equipment configuration. The document is designed to assist the pilot-in-command to determine whether a flight can be commenced or continued if a system or piece of equipment becomes unserviceable during the course of operation.

Item 34-3 on Air Tindi's MEL for the King Air 200 addresses gyroscopic pitch and bank indicator systems.[28] The item indicates that normally 2 instruments are installed and for the aircraft to be dispatched, 1 must be serviceable. The item also states the following exceptions:

> May be inoperative on right side provided:
>
> (a) A second in command is not required for the flight.

25 Ibid., p. 1-2.

26 Ibid., p. 14-3.

27 Ibid., p. 14-16.

28 Air Tindi Ltd., *Beechcraft King Air 200 (BE20) Minimum Equipment List (MEL) (19 July 2013)*, Item 34-3: Gyroscopic Pitch and Bank Indicator Systems (Mechanical Attitude Indicators Only), p. 34-03-1.

> (b) Aircraft is not equipped with EFIS or Servoed Electric Gyroscopic Pitch and Bank Indicator.
>
> NOTE: Where a servoed electric altimeter is installed, a functioning pneumatic indicator is required.[29]

In this occurrence, the left-side attitude indicator was an electric servoed gyroscopic pitch and bank indicator; therefore, the aircraft did not meet the MEL's requirements for dispatch.

The captain and the FO had both received Air Tindi's initial and recurrent MEL training.[30] According to Air Tindi's *Training Programs Manual*, "Recurrent [MEL] training shall be conducted, (annually [for personnel on] 703 [operations]), or when required to ensure Company personnel are aware of any changes to the MEL or MEL procedures."[31]

Topics covered in the training syllabus include:

> […]
>
> - specific use of the MEL;
>
> […]
>
> - practical demonstration of MEL use versus hypothetical situations at and away from a maintenance base; and,
> - supervised 'hands on' use of a MEL, until familiar with the location, contents and procedures, including those at or away from a maintenance base.[32]

1.18 Additional information

1.18.1 Limited or partial panel flying

TC's *Flight Test Guide – Commercial Pilot Licence – Aeroplane* contains the exercises that a candidate must successfully complete to obtain a commercial pilot licence rating.

Item B of Exercise 24, Instrument Flying and Use of Radio Navigation Aids, is described as follows:

> **B. Limited Panel**
>
> *Aim*
>
> To safely control the aeroplane in straight and level flight and while turning by reference to flight instruments, but without reference to the attitude indicator and the heading indicator, in the case of a traditional instrument panel; or, without reference to a primary flight display and multi-function display (**standby**

29 Ibid.

30 Air Tindi Ltd., *Training Programs Manual*, Edition 4, Version 1 (01 January 2018), Section 5.40: Minimum Equipment List Training, p. 5-21.

31 Ibid., p. 5-21.

32 Ibid., p. 5-22.

> **instruments and magnetic compass only**), in the case of a technically-advanced aeroplane. The turn will not be less than 90° or more than 180°.
>
> *Description*
>
> Using limited panel, the candidate will:
>
> (a) maintain straight and level flight; and, when requested by the examiner
>
> (b) execute a continuous, coordinated turn, in the shortest direction, to a heading specified by the examiner.
>
> **Note**: One (1) heading correction is acceptable to more precisely achieve the specified heading.
>
> *Performance Criteria*
>
> Assessment will be based on the candidate's proficiency to control and manoeuvre the aeroplane using correct instrument scanning and interpretation, within:
>
> (a) ±15° of specified heading;
>
> (b) ±100 feet of assigned altitude;
>
> (c) ±10 knots of assigned airspeed.[33]

TC's *Flight Test Guide – Instrument Rating Groups 1, 2 and 3 – Aeroplane* provides guidance for conducting the flight test required for an instrument rating.

Items B, C, and D of Exercise 11 state the following:

> **11. B. C. D. System Malfunctions and Emergency Procedures**
>
> *Aim*
>
> To determine the candidate's competency to complete recommended checks and procedures in the event of system malfunctions or emergency situations related to IFR flight.
>
> *Description*
>
> The candidate will complete the recommended checks and procedures based on simulated malfunctions or emergency scenarios impacting the continuation of safe flight in IMC [instrument meteorological conditions] that are presented by the examiner.
>
> These situations will be applicable to the aeroplane being used for the test. These items may be tested on the ground or in flight, however at least one item should be tested in flight. Nevertheless, the examiner will determine if aeroplane performance, weather conditions and other factors permit their safe conduct in flight.
>
> The following lists some of the system malfunctions that may be assessed:
>
> (a) radio and navigation equipment;
>
> (b) electrical system;

[33] Transport Canada, TP13462, *Flight Test Guide – Commercial Pilot Licence – Aeroplane*, Fourth Edition (April 2016), p. 29.

> (c) vacuum system;
>
> (d) anti-ice and de-icing systems;
>
> (e) any other installed system required for IFR flight.[34]

The *Flight Test Guide – Instrument Rating Groups 1, 2 and 3 – Aeroplane* does not specify which system malfunction should be simulated during the instrument proficiency check (IPC).

TC's Advisory Circular (AC) No. 401-004, *Conduct of Instrument Proficiency Checks*, suggests that, depending on their level of instrument flight experience and recency, pilots may wish to obtain "recurrent training […] to achieve proficiency prior to attempting an IPC."[35] This includes a review of "basic attitude instrument and partial panel flying […] in an FSTD [flight simulation training device] or with a view-limiting device for IFR manoeuvres in VFR conditions."[36] This would imply that the operator would be required to meet this intent.

Examiners choose which aircraft system malfunctions are simulated during the IPC; therefore, after obtaining a commercial pilot licence, there is no guarantee that a pilot will have to demonstrate partial panel proficiency again.

The investigation reviewed the captain's and FO's records and did not find any documented partial panel exercises or evaluations since their respective commercial pilot flight tests, with the exception of unusual attitude recovery training.

TSB Aviation Investigation Report A08W0068 discussed a loss of control and in-flight breakup of a Piper PA-46-350P in Wainwright, Alberta, which was initiated by the failure of the pilot's attitude indicator and an attempt to fly the aircraft with a partial panel. The report included a safety concern which stated in part:

> This pilot had not practiced partial panel flying for a number of years and was not required to do so for his IFR renewal. Indeed, it is likely that he had not been required to demonstrate partial or limited panel skills since either his original commercial pilot test or his initial instrument training. Such skills deteriorate over time if not exercised.

1.18.2 Recovery from unusual attitude

1.18.2.1 Transport Canada requirements

Item C of Exercise 24, Instrument Flying and Use of Radio Navigation Aids, in TC's *Flight Test Guide – Commercial Pilot Licence – Aeroplane* is described as follows:

> **C. Recovery from Unusual Attitude**
>
> *Aim*

---

[34] Transport Canada, TP9939, *Flight Test Guide – Instrument Rating Groups 1, 2 and 3 – Aeroplane*, Tenth Edition (February 2017), p. 24.

[35] Transport Canada, Advisory Circular (AC) No. 401-004, *Conduct of Instrument Proficiency Checks*, Issue 02 (01 November 2015), Section 5.0: Training to Proficiency Prior to the Instrument Proficiency Check, p. 6.

[36] Ibid.

> To safely and promptly recover from an unusual attitude by reference to flight instruments, but without reference to the attitude indicator and the heading indicator in the case of a traditional instrument panel or; without reference to a primary flight display and multi-function display (**standby instruments only**) in the case of a technically-advanced aeroplane.
>
> *Description*
>
> The examiner will take control and fly the aeroplane into an unusual attitude, either nose-up or nose-down, then transfer control to the candidate and call for recovery. Using limited panel or standby instruments only, the candidate will promptly recover with minimum loss of altitude from one unusual attitude.
>
> *Performance Criteria*
>
> Assessment will be based on the candidate's proficiency to:
>
> (a) on command, recognize the unusual flight attitude by reference to available flight instruments;
>
> (b) apply smooth, coordinated control application in the correct sequence;
>
> (c) promptly recover to stabilized level flight using correct instrument cross-check and interpretation.[37]

TC's AC No. 401-004, *Conduct of Instrument Proficiency Checks*, provides guidance "to help the examiner determine that a pilot seeking an IPC recency endorsement has both the knowledge and skills for safe flight in all aspects of instrument flying."[38] The issue of TC's AC in effect at the time of the occurrence (Issue 02) did not include any guidance on recovery from an unusual attitude using all available flight instruments or recovery from an unusual attitude using a partial panel. In February 2019, TC published Issue 03 of the AC.[39] Among the changes to the document, 2 appendices were added providing guidance on recovery from an unusual attitude using all available flight instruments and using a partial panel. The version in effect at the time of drafting this report (Issue 04)[40] also contains these appendices.

1.18.2.2 Air Tindi unusual attitude recovery training

The Air Tindi Beechcraft King Air 200 (BE20) training syllabus[41] includes unusual attitude recovery in both initial training and recurrent training.

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37 Transport Canada, TP13462, *Flight Test Guide – Commercial Pilot Licence – Aeroplane*, Fourth Edition (April 2016), p. 29.

38 Transport Canada, Advisory Circular (AC) No. 401-004, *Conduct of Instrument Proficiency Checks*, Issue 02 (01 November 2015), Section 1.1: Purpose, p. 2.

39 Ibid., Issue 03 (15 February 2019).

40 Ibid., Issue 04 (15 March 2019).

41 Air Tindi Ltd., *Training Programs Manual*, Edition 4, Version 1 (01 January 2018), Appendix B – Flight Crew Training – BE20.

Unusual attitude recovery is included in the following sessions of initial training:

- *Aircraft-Only Training Program*, session 2:[42] by the end of the session, the candidate will be able to demonstrate unusual attitude recovery.
- *Simulator Training – Level C Program*, sessions 2 A/B[43] and 5 A/B:[44] by the end of the sessions, the candidate will be able to perform unusual attitude recovery.
- *Simulator Training – Level D Program*, sessions 2 A/B[45] and 6 A/B:[46] by the end of the sessions, the candidate will be able to perform unusual attitude recovery.

Unusual attitude recovery is included in the following sessions of recurrent training:

- *Aircraft-Only Training Program*, session 1:[47] by the end of the session, the candidate will be able to demonstrate unusual attitude recovery.
- *Simulator Training - Level C or D Program*, session 1 A/B:[48] by the end of the session, the candidate will be able to perform unusual attitude recovery.

Both the captain and FO had successfully completed unusual attitude recovery exercises as part of their training.

1.18.2.3 Recovery performance

1.18.2.3.1 Skill acquisition and performance reliability

Pilots acquire and develop their skills by physically performing the actions required to complete a task, such as handling an aircraft in instrument meteorological conditions (IMC). It is important for pilots to acquire these skills so that they can perform in stressful situations, such as in an emergency. Pilots who have developed the necessary skills are more likely to be able to perform a task rapidly, accurately and without much thought.

1.18.2.3.2 Situation awareness and autopilot disengagement

Situation awareness is the product of the continuous extraction of environmental information, integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing further perception and anticipating future events.[49]

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[42] Ibid., Section 2.4: Initial Training Course – Aircraft-Only Training Program, p. B-19.

[43] Ibid., Section 2.5: Initial Training Course – Simulator Training – Level C Program, p. B-26.

[44] Ibid., Section 2.5: Initial Training Course – Simulator Training – Level C Program, p. B-35.

[45] Ibid., Section 2.6: Initial Training Course – Simulator Training – Level D Program, p. B-41.

[46] Ibid., Section 2.6: Initial Training Course – Simulator Training – Level D Program, p. B-53.

[47] Ibid., Section 3.4: Recurrent Training Course – Aircraft-Only Training Program, p. B-65.

[48] Ibid., Section 3.5: Recurrent Training Course – Simulator Training – Level C or D Program, p. B-67.

[49] C. Dominguez, "Can SA be defined?," in: M. Vidulich, E. Vogel, et al., AL/CF-TR-1994-0085, *Situation awareness: Papers and annotated bibliography* (Armstrong Laboratory, 1994), Section I.

The processing of information by pilots at each of these 3 stages—perception, comprehension, and projection—must be unerring if accurate situation awareness is to be achieved and maintained. During an approach and landing, for example, a flight crew must perceive the visual references relevant to the approach, must understand what those references mean in the context of conducting an approach, and must predict the effect that information will have on the approach profile. If there is an error in the initial perception of critical elements in the environment, pilots may misunderstand the context and any associated hazards.

When the autopilot is engaged, pilots are no longer manually flying the aircraft, but they do retain a mental model of what course and height the aircraft was programmed to fly and they monitor the aircraft's performance. Before disengaging the autopilot and taking aircraft control, pilots can use external cues and instruments to maintain situation awareness. If the autopilot disengages unexpectedly, pilots may not have time to re-establish their awareness of the flight profile and therefore they may not be able to regain control of the aircraft.

Pilot training includes how to re-establish situation awareness (getting back in the loop) if the autopilot is disengaged or disengages unexpectedly, and how to re-establish and maintain situation awareness by using the aircraft's instruments when flying in IMC. If the autopilot disengages unexpectedly while the aircraft is in IMC, this results in a high workload for the pilots. In this situation, not only do pilots have to assume control of the aircraft before having the chance to re-establish their awareness of the flight profile, but the process of re-establishing situation awareness is also significantly more difficult without external visual cues.

1.18.2.3.3 Recovering with partial instruments

Pilot training also includes how to re-establish situation awareness with only partial instruments (partial panel flying). However, if the autopilot disengages unexpectedly while the aircraft is in IMC and one or more instruments fail, this results in a very high workload for the pilots. In this scenario, not only is the process of re-establishing situation awareness significantly more difficult without external visual cues, but it also becomes even more difficult without sufficient internal cues.

Pilots who are experiencing high cognitive workload conditions will be vulnerable to perceptual bias (selectively focusing attention on specific cues at the sacrifice of the wider scenario) and narrowing of attention through stress (reducing their ability to scan and process information), and will be dependent on the remaining cockpit displays, communication with other flight crew members, and their own perceptions of motion and orientation to be able to continue the flight safely.

1.18.2.3.4 Susceptibility to spatial disorientation

Spatial disorientation can be described as "the inability of a pilot to correctly interpret aircraft attitude, altitude or airspeed in relation to the Earth or other points of reference."[50]

In addition to being vulnerable to perceptual bias and narrowing of attention, pilots who are experiencing high cognitive workload conditions—having to unexpectedly re-establish situation awareness without reference to external visual cues and with insufficient internal cues—are at an increased risk of experiencing spatial disorientation if they rely too heavily on their perceptions of motion and orientation.

Through training, pilots learn how to individually manage the environmental, aircraft, pilot and manoeuvring factors that are often present when spatial disorientation occurs. However, if more than one of these factors are combined during an in-flight emergency, the risk of disorientation increases.

When pilots do not have reliable external or internal cues to alert them to the aircraft's orientation, they can become susceptible to vestibular illusions. One such illusion can cause pilots to sense that the aircraft is level even though it is in a bank or pitched up or down. This illusion may continue unrecognized until the aircraft impacts terrain.

1.18.3 Crew resource management

The objective of CRM is to reduce human error in aviation. CRM is widely accepted as the use of all human, hardware, and information resources available to the flight crew to ensure safe and efficient flight operations.

As described in the FAA's Advisory Circular No. 120-51E,

> […] measurements of the impact of CRM training show that after initial indoctrination, significant improvement in attitudes occurs regarding crew coordination and flight deck management. In programs that also provide recurrent training and practice in CRM concepts, significant changes have been recorded in flightcrew performance during line-oriented flight training (LOFT) and during actual flight. CRM-trained crews operate more effectively as teams and cope better with non-routine situations.
>
> Research also shows that when there is no reinforcement of CRM concepts by way of recurrent training, improvement in attitudes observed after initial indoctrination tends to disappear, and individuals' attitudes tend to revert to former levels.[51]

Researchers have recommended that future CRM training should be based on the underlying premise that human error is inevitable and cannot be entirely eliminated, and see CRM "as a set of error countermeasures with three lines of defense."[52] The 1st defence is

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50 SKYbrary, "Spatial Disorientation," at https://www.skybrary.aero/index.php/Spatial_Disorientation (last accessed on 19 March 2020).

51 Federal Aviation Administration, Advisory Circular No. 120-51E, *Crew Resource Management Training* (22 January 2004).

52 R.L. Helmreich et al., *The Evolution of Crew Resource Management Training in Commercial Aviation*, 1999, University of Texas at Austin Human Factors Research Project 235.

the avoidance of error, the 2nd defence is trapping errors before they occur, and the 3rd defence is mitigation of the consequences of errors that occurred but were not trapped.

In Canada, Subsection 725.124(39) of the *Commercial Air Service Standards* (CASS) requires airline operators under Subpart 705 of the CARs to provide all flight crew members with initial and annual recurrent CRM training. This requirement did not extend to operators under subparts 704 (Commuter) and 703 (Air Taxi) at the time of the occurrence; however, Air Tindi provided training that met these standards to all its flight crew members. Subsection 725.124(39) of the CASS requires that, for operations under Subpart 705 of the CARs, all crew members must receive initial CRM training covering subject categories that include TEM, communications, situation awareness, pressures and stress, fatigue, workload management, decision making, leadership and team building, automation and technology management, and a relevant case study.

The human behaviour categories listed above have been described in detail in CRM research papers. One example regarding teamwork states that "good communications within the group, a high degree of situation awareness, and a comprehensive understanding of the decision-making process by all members of the group are all prerequisites for the creation of synergy and the effective performance of the team as a whole."[53]

1.18.3.1 Threat and error management

A key component of effective CRM is TEM. The TEM model is a conceptual framework that

- is employed to describe how flight crews manage the situations they encounter that increase the risks associated with flight;
- is used as a tool to analyze the development of situations that culminated in an occurrence;
- examines the key elements of threats, errors, and undesired aircraft states; and
- outlines countermeasures that have been shown to be effective in managing those elements.

The key principles of TEM are anticipation of, recognition of, and recovery from threats and errors. It advocates carefully analyzing potential hazards and taking appropriate steps to avoid, trap, or mitigate threats and errors before they lead to an undesired aircraft state. Flight crews may trap an error by identifying and correcting it, exacerbate an error by making a subsequent error, or make no response because they ignore or do not detect the error.[54]

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53 Royal Aeronautical Society, *Crew Resource Management: A Paper by the CRM Standing Group of the Royal Aeronautical Society* (1999).

54 International Civil Aviation Organization (ICAO), *Line Operation Safety Audit (LOSA)*, First Edition (2002), pp. 2-4.

The TEM model identifies 5 types of errors:

- intentional non-compliance errors (violations of SOPs)
- procedural errors (slips and lapses in the application of procedures)
- communication errors (information is incorrectly transmitted or interpreted)
- proficiency errors (skill or knowledge is lacking to manage the aircraft)
- operational decision errors (where a decision is taken that increases the risk of the flight)[55]

The most common crew behaviours that manage errors effectively include vigilance and crew member advocacy and inquiry. Although threats and errors are present in the majority of flight segments, they rarely carry significant consequences because they are effectively managed by the crew. The effective management of risks on the flight deck is inextricably linked to effective CRM. When managing errors,

> [r]egardless of the type of error, an error's effect on safety depends on whether the flight crew detects and responds to the error before it leads to an undesired aircraft state and to a potential unsafe outcome. This is why one of the objectives of TEM is to understand error management (i.e., detection and response), rather than solely focusing on error causality (i.e., causation and commission). From the safety perspective, operational errors that are timely detected and promptly responded to (i.e., properly managed), errors that do not lead to undesired aircraft states, do not reduce margins of safety in flight operations, and thus become operationally inconsequential. In addition to its safety value, proper error management represents an example of successful human performance, presenting both learning and training value.[56]

1.18.3.1.1 Use of knowledge and rules

Knowledge-based performance is largely conscious, occurring as the pilot learns new situations and outcomes. As training progresses, rules will be learned to produce more regulated if-then performance.[57] With experience, performance will become more automatic, where the pilot responds appropriately upon perceiving relevant cues, for example, when A happens, the individual will perform B. In turn, if A doesn't happen, B will not occur.

1.18.3.1.2 Unserviceable equipment

According to Air Tindi's King Air Threat Reference Chart (Figure 5), an unserviceable piece of equipment, such as an attitude indicator, is deemed to be a yellow threat. This means that pilots would need to initiate the appropriate TEM strategies to ensure that the unserviceable equipment would not lead to unsafe flight conditions. These strategies may include referring to company procedures, applicable regulations, and the King Air 200 MEL.

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55 Ibid., pp. 2 and 3.

56 Captain D. Maurino, Threat and Error Management (TEM), Canadian Aviation Safety Seminar, Vancouver, April 2005.

57 J. Reason, *The Human Contribution: Unsafe acts, accidents and heroic recoveries* (2008), pp. 13 and 38.

Figure 5. Air Tindi's King Air threat reference chart (January 2018, version 1) (Source: Air Tindi Ltd.)

FATIGUE	WEATHER	RUNWAY LENGTH	COLD WEATHER OPS
RUNWAY CONDITION	CURRENCY	UNSERVICEABLE EQUIP.	CYZF: TOWER OR FSS?
APPROACHING LIGHTING	AUTOMATION	HIGH/LOW TIME CREW	CARS AVAILABILITY
FUEL AVAILABILITY	MEL'S	BLACK HOLE APPROACH	RVOP
NOTAMS	APPROACH BAN	TRAFFIC CONGESTION	CONTROLLED AIRSPACE
COMPLACENCY	NIGHT CIRCLING	IFR/VFR DEPARTURE	OCC COMM
OTHER?			

In this occurrence, both flight crew members considered that the right-side attitude indicator had delayed initiation rather than that it was unserviceable; therefore, Air Tindi's threat reference chart and MEL were not consulted.

1.18.3.1.3 Cognitive bias and decision making

Pilots operate in a complex environment where there are multiple sources and types of information to monitor. Organizing and simplifying information lessens the burden on information processing capacity. Although such information management can facilitate effective performance in some conditions, it can sometimes result in strong performance biases that lead to unsafe decisions and a reduced probability of recognizing such decisions.

Two examples of decision making biases are the representativeness heuristic and the availability heuristic.[58] The representativeness heuristic is where an individual may assume a diagnosis of a situation by probability matching the cues, symptoms or evidence to that stored in their long-term memory (derived from experience, or training or reading of the situation). If the situation is considered to have a good probability match, the state or diagnosis is assumed, sometimes at the expense of a balanced review of another possible diagnosis. The availability heuristic is similar in its bias, but focuses on the timing of the experience, "in that more recent events or conditions in the world generally are recalled more easily," i.e., the pilot may make a diagnosis based on a recent diagnosis of that equipment.

Even if one makes an initial assumption during a decision, there is always scope to double check the available information to ensure all facts have been considered. Typically, the more uncertain the individual is, the more information is likely to be sought. However, "[i]f one is

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58 C. D. Wickens and J. G. Hollands, *Engineering Psychology and Human Performance*, Third Edition (1999), Chapter 8: Decision Making, pp. 308–309.

more confident than is warranted in the correctness of one's hypothesis, then one will not be likely to seek additional information."[59] This is known as overconfidence bias.

Once a decision has been made, an individual may then bias all subsequent beliefs in favour of that initial decision (anchoring heuristic) and actively seek information and cues that confirm the decision, while also discounting those that support an opposite conclusion (confirmation bias).[60] As a result, "[t]he false hypothesis can be extremely resistant to correction,"[61] especially when expectancy is high and when attention is diverted elsewhere in the flight, e.g., to other flight condition threats.

Once a pilot has reached a hypothesis about a certain situation, this will form the basis of their mental model of that situation as they proceed with the flight. Once the decision to proceed with the flight has been made, a crew may then be at risk of plan continuation bias. Plan continuation bias, a form of confirmation bias, is a "deep-rooted tendency of individuals to continue their original plan of action even when changing circumstances require a new plan."[62] Resistance to changing the plan may be affected by factors such as the perceived loss or gain from changing the plan. Research[63] shows that, in real world flight environments, the framing of a decision in terms of loss or gain of potential outcomes may be affected by the proximity of a pilot's goals, such as the destination airport. As goal achievement gets closer, there may be a natural shift to the "loss frame," i.e., changing the plan becomes more negative, resulting in an increased motivation to continue with the original plan.

1.18.3.1.4 Changes to mental models, cognitive load and perceptual bias

Although mental models and assumptions about the environment can be useful to help a person filter, organize and act on large amounts of information quickly and error-free, there can be discordance when a mental model and situation do not match, i.e., when individuals receive information contrary to their expectations, their performance tends to be slow or inappropriate.[64] Depending on the type of scenario and the timing of the contrary

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59 C. D. Wickens and J. G. Hollands, *Engineering Psychology and Human Performance*, Third Edition (1999), Chapter 8: Decision Making, p. 310.

60 Ibid., p. 312.

61 R. D. Campbell and M. Bagshaw, *Human Performance and Limitations in Aviation*, Third Edition (2002). Chapter 6: Human error and reliability, p. 118.

62 Benjamin A. Berman and R. Key Dismukes, "Pressing the Approach," in Flight Safety Foundation, *Aviation Safety World* (December 2006).

63 D. O'Hare and T. Smitheram, "'Pressing On' Into Deteriorating Weather Conditions: An Application of Behavioral Decision Theory to Pilot Decision Making," in *International Journal of Aviation Psychology*, Vol. 5, Issue 4 (1995), pp. 351–370.

64 K. Smith and P. A. Hancock, "Situation Awareness Is Adaptive, Externally Directed Consciousness," in *Human Factors*, Vol. 37, Issue 1 (1995), pp. 137–148.

information, the workload or effort involved in managing the change in information, along with the time available versus the potential severity of the consequence, this discordance may also induce an acute stress reaction.[65] For the flight crew, this is in part because the crew have not prepared, planned or briefed for this change of information or condition, or the implications it may have on their current flight plan.

When focusing on a particular task, individuals generally seek the most meaningful information needed at that time, fixating on the cues important to a scenario often at the sacrifice of other available cues. This is a phenomenon known as perceptual bias.[66] As workload and stress increase, narrowing of visual and auditory attention may also occur,[67] exacerbating any perceptual bias. Ultimately, this may result in a breakdown of the pilot's instrument scan and crew communication, and cause a drop-off of secondary tasks, such as air traffic communications.

1.18.4 Crew resource management training

Air Tindi's CRM training program is a combination of computer-based training and practical classroom presentations and exercises. Section 5.15 of Air Tindi's *Training Programs Manual* describes the topics covered in initial ground training as follows:

- attitudes and behaviours;
- communication skills;
- problem solving;
- human factors;
- conflict resolution;
- decision making;
- team building and maintenance; and
- workload management.[68]

The practical classroom presentation and exercise portion of the program is designed to engage the participants in scenario-based events and provide the opportunity to put into practice the theoretical skills gained during the computer-based portion of the training program. Topics covered during the classroom portion include communication, safety culture, and TEM.

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65 P.A. Hancock and J. L. Szalma, *Performance Under Stress* (2008), Chapter 1: Stress and Performance, p. 5.

66 Ibid.

67 C. D. Wickens and J. G. Hollands, *Engineering Psychology and Human Performance*, Third Edition (1999), Chapter 12: Stress and human error, pp. 483–484.

68 Air Tindi Ltd., *Training Programs Manual*, Edition 4, Version 1 (01 January 2018), pp. 5–11.

1.19 Useful or effective investigation techniques

1.19.1 Automatic dependent surveillance – broadcast data

Automatic dependent surveillance – broadcast (ADS-B) is an air traffic surveillance monitoring technology which NAV CANADA utilizes in providing air traffic services in Canada. In recent years, Aireon, an international consortium of air navigation service providers, including NAV CANADA, has developed space-based ADS-B technology to monitor both private and commercial air traffic around the world.

NAV CANADA describes the system as follows:

> The Iridium NEXT constellation consists of 66 Low Earth Orbit (LEO) satellites carrying the Aireon ADS-B receiver payloads. […]
>
> Each payload receives ADS-B messages from aircraft containing data sets that include position, speed and heading. These position reports are delivered to NAV CANADA within one second of their broadcast by the aircraft transponder.
>
> Each satellite orbits the earth once every 100 minutes, at about 780 kilometers above earth's surface. They are linked to their closest neighbors in the constellation, creating a dynamic surveillance network. […]
>
> Aireon's global coverage will […] allow rescue coordination centers to obtain GPS location and tracking data for ADS-B equipped aircraft in an alert, distress phase or emergency situation.[69]

The occurrence aircraft was equipped with ADS-B. NAV CANADA supplied the ADS-B data early in the investigation, and that information proved valuable in providing an initial flight path analysis for the occurrence. The data was also compared against the flight path data that was subsequently recovered from the Sandel ST3400 TAWS unit to generate a graphic illustration of the flight (Appendix B). If the data from the TAWS unit had not been recovered, the ADS-B data would have been the only information available to determine the flight path of the aircraft during the occurrence flight.

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69 NAV CANADA, Space-based Automatic Dependent Surveillance-Broadcast (ADS-B), available at http://www.navcanada.ca/EN/products-and-services/Pages/Space-based-ADS-B.aspx (last accessed on 19 March 2020).

2.0 ANALYSIS

2.1 Introduction

The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. With the exception of the attitude indicators, no mechanical discrepancies had been reported or were found during the wreckage examination that would have prevented normal operation of the aircraft.

The high-energy impact with terrain destroyed the aircraft. However, the investigation determined that the flight control system did not exhibit any conditions that would have resulted in a loss of control or would have prevented a successful recovery following a loss of control.

Turbulence and icing were not considered factors in this occurrence.

The analysis will focus on the right- and left-side attitude indicators, decision making, partial panel flying, unusual attitude recovery and spatial disorientation, and the electronic flight bag (EFB).

2.2 Right-side attitude indicator

The right-side attitude indicator was not erect when the crew carried out the after-start checklist. Even though the vacuum system was operating within acceptable parameters, the right-side attitude indicator never erected during the course of the occurrence flight. The investigation determined that the gyro rotor was not rotating at the time of impact; however, the reason the gyro rotor was not rotating could not be determined.

2.3 Left-side attitude indicator

For undetermined reasons, the left-side attitude indicator failed in flight. The captain then attempted to use partial panel flying techniques to maintain control of the aircraft because the aircraft was in instrument meteorological conditions (IMC).

2.4 Decision making

While completing the after-start checklist, the first officer (FO) noted that the right-side attitude indicator was not erect. However, the captain expressed that he believed the condition of the attitude indicator was only temporary. While the captain did express that he had not experienced this anomaly in C-GTUC in the past, it is likely that at some time in his flying career, he had experienced a situation when there was the delayed initiation of a pneumatically operated attitude indicator. It is therefore likely that this past experience influenced the belief that the current condition of the instrument was only temporary, and the decision to depart CYZF was made.

There were several opportunities for the flight crew to identify the hazard or threat that the non-functioning right-side attitude indicator represented. This section will discuss the possible reasons why the decision was made to depart with this instrument not working and the defences that were available but were ineffective in ensuring a successful outcome. The defenses included the minimum equipment list (MEL), threat and error management (TEM) and crew resource management (CRM).

2.4.1 Minimum equipment list

Air Tindi uses a Transport Canada (TC)–approved MEL. The MEL serves as an administrative defence for flight crews by providing guidance on the safe operation of an aircraft that has unserviceable equipment on board.

In this occurrence, the flight crew did not consider the right-side attitude indicator to be unserviceable or inoperative; they considered it to have a delayed initiation, which they believed would resolve itself before, or at least during flight. As a result, the crew did not reference the Air Tindi MEL and the process normally used to manage an unserviceable piece of equipment before flight was not followed.

Although just before take off the crew acknowledged that the right-side attitude indicator was not operative, they expected it to become operative at some point in the flight. As a result, they did not refer to the MEL, and departed into instrument meteorological conditions with an inoperative attitude indicator.

If flight crews do not use the guidance material provided in the MEL when aircraft systems are unserviceable, there is a risk that the aircraft will be operated without systems that are critical to safe aircraft operation.

2.4.2 Threat and error management

Before departure, the flight crew did not reference Air Tindi's King Air threat reference chart.

Once the assumption had been made that the condition of the right-side attitude indicator was only temporary, expectancy that the attitude indicator would erect would have been high. As result, the crew did not consider alternate actions.

The crew's TEM was not effective in mitigating the risk associated with the unserviceable right-side attitude indicator.

Once the decision had been made to proceed with the flight, it is likely that all subsequent decisions regarding the progress of the flight would be made based on the initial decision to take off, possibly at the expense of considering other courses of action, such as returning to base.

The flight crew continued with the plan to land at their destination without discussing a return to Yellowknife Airport (CYZF). Instead, the flight crew's TEM focused on the weather conditions and potential icing and snowy conditions at the destination. The combination of the flight crew's attention to the weather and the flight duration of only 36 minutes increased the risk that decision biases would be maintained.

2.4.3 Crew resource management

The flight crew received training on several key components of CRM; however, the FO had not yet received the practical portion of the training as a flight crew member. In particular, communication skills, problem solving and decision making skills are integral to being an effective team. With effective team work, the following can be realized:

- a high degree of situation awareness;
- an understanding of the decision-making process; and
- effective communications.

Several safety significant events occurred during the flight where teamwork was not effective, resulting in an undesired outcome.

- The captain did not include the FO in the discussion of the problem (right-side attitude indicator fault), or ask for his input on actions to be taken. Additionally, the FO did not express any concern to the captain about commencing or continuing the flight with the unserviceable right-side attitude indicator.
- The significantly increased workload experienced during the additional failure of the left-side attitude indicator was not distributed between both flight crew, likely as a result of the cognitive overload the pilot flying was experiencing.
- The inability of either flight crew to recognize and effectively communicate to the other that the aircraft was in an unusual attitude.

The crew's CRM was not effective, resulting in a breakdown in verbal communication, a loss of situation awareness, and the aircraft entering an unsafe condition.

2.5 Partial panel flying

After the left-side attitude indicator failed, partial panel flying techniques were required to maintain control of the aircraft. There was no requirement by TC or Air Tindi for partial panel exercises beyond unusual attitude recoveries during the captain's recurring proficiency flight tests or his transition training for the King Air 200.

The captain had not practiced partial panel flying for a number of years and was not required to do so for his instrument proficiency check (IPC). It is likely that he had not been required to demonstrate partial or limited panel skills since either his original commercial pilot licence test in 2006 or his initial instrument training. Such skills deteriorate over time, if not practised. As a result, it is likely that the captain was not proficient in partial panel flight. The combined malfunction of the left and right attitude indicators likely exceeded the captain's ability to control the aircraft in IMC.

The captain did not have recent experience in flying partial panel. As a result, the remaining instruments were not used effectively and the aircraft departed controlled flight and entered a spiral dive.

2.6 Unusual attitude recovery and spatial disorientation

When individuals receive information contrary to their expectations, their performance tends to be slow or inappropriate. For a critical flight environment, this discordance may result in perceptual bias, whereby the pilot selectively focuses only on the critical pieces of information relevant to the evolving scenario at the expense of the bigger picture. The discordance may also lead to an acute onset of high cognitive workload and stress, with narrowing of attention, whereby a pilot is now unable to process peripheral information.

It is likely that as a result of the cognitive biases involved in the initial diagnosis of the right-side attitude indicator, the captain and FO were not prepared for the consequences of a right- or left-side attitude indicator failure or a double indicator failure. After many discussions regarding the unserviceability of the right-side attitude indicator, it likely became apparent the right-side indicator was in fact unserviceable. The discordance of this information in relation to the captain’s expectancies likely impaired his information processing and distracted his cockpit scan.

When the left-side attitude indicator failed, and unexpectedly disconnected the autopilot while in IMC, the captain was suddenly required to assume control of the aircraft before having the chance to re-establish his awareness of the flight profile. Further, the process of re-establishing situation awareness was significantly hindered by the lack of external visual cues because the aircraft was in IMC and insufficient internal cues because of the partial panel.

For example, with a vestibular illusion, the aircraft can continue to feel level despite being banked. Without reference to reliable external or internal cues or rectifying information from the pilot not flying to alert the pilot flying to the aircraft’s orientation, the aircraft may continue in that attitude despite the pilot still feeling the aircraft is level.

When the autopilot disengaged, the aircraft entered a right bank before entering a very gentle but progressive left bank, which continued into a steep descending left turn. Neither crew spoke of the aircraft’s changing attitude. It is likely at this stage that the captain experienced unrecognized spatial disorientation. It is possible that when returning the aircraft to a straight and level position from the right bank, the captain actually levelled out with a slight left bank. In such situations, there is an increased risk pilots may become too reliant on their perceptions of motion and orientation, which makes them susceptible to disorientation.

Without reference to attitude information, the gentle left bank would have started to feel straight and level. The presence of cloud, the loss of an attitude indicator, a disengaged autopilot, a lack of practice in handling the aircraft with partial instruments and the onset of acute stress with narrowing of attention are all factors that increased the risk of spatial disorientation.

Pilots who do not have the skills necessary to fly safely using a partial instrument panel have limited chances of recovering from disorientation. Also, when pilots do not detect that they are experiencing spatial disorientation, the chances of adequately recovering from it are limited. The captain and FO likely experienced spatial disorientation.

Based on the weather reports for the day, it is likely that the aircraft exited cloud at an altitude of approximately 2000 feet above ground level, and it is likely at that point, that the captain regained an outside attitude reference. Both the automatic dependent surveillance – broadcast (ADS-B) and the terrain awareness and warning system (TAWS) data recovered indicate that a recovery attempt was made from the unusual attitude as there was a significant reduction in the vertical descent rate.

During the attempted recovery, the aircraft's vertical speed was partially converted into horizontal speed (see Table 4 in Section 1.8.1). The calculated *g* loading during this recovery is estimated to have reached a peak of 3 to 4 times the force of gravity, which likely exceeded the published maximum loading factor of 3.17*g* for the aircraft.

Once the aircraft emerged below the cloud layer at approximately 2000 feet above ground, the crew were unable to recover control of the aircraft in enough time and with enough altitude to avoid an impact with terrain.

2.7 Electronic flight bag

The iPad mini devices provided to the flight crew by Air Tindi, in combination with the ForeFlight Mobile EFB application and the Garmin Flight Stream 210 device installed in the aircraft, had the capability to provide both pilots with basic flight information regarding the following:

- Pitch and roll
- Ground speed derived from the GPS (global positioning system)
- GPS-derived altitude and vertical speed
- Horizontal situation indicator with current heading
- Synthetic view of surrounding terrain

Based on the information gathered during the investigation, neither flight crew made an attempt to select the synthetic vision with backup attitude and heading reference system (AHRS) option available to them through the ForeFlight application.

As shown in this occurrence, if flight crews do not use all available resources at their disposal, a loss in situation awareness can occur, which can increase the risk of an accident.

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. For undetermined reasons, the left-side attitude indicator failed in flight.

2. Although just before take off the crew acknowledged that the right-side attitude indicator was not operative, they expected it to become operative at some point in the flight. As a result, they did not refer to the minimum equipment list, and departed into instrument meteorological conditions with an inoperative attitude indicator.

3. The crew's threat and error management was not effective in mitigating the risk associated with the unserviceable right-side attitude indicator.

4. The crew's crew resource management was not effective, resulting in a breakdown in verbal communication, a loss of situation awareness, and the aircraft entering an unsafe condition.

5. The captain did not have recent experience in flying partial panel. As a result, the remaining instruments were not used effectively and the aircraft departed controlled flight and entered a spiral dive.

6. The captain and first officer likely experienced spatial disorientation.

7. Once the aircraft emerged below the cloud layer at approximately 2000 feet above ground, the crew were unable to recover control of the aircraft in enough time and with enough altitude to avoid an impact with terrain.

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 use the guidance material provided in the minimum equipment list when aircraft systems are unserviceable, there is a risk that the aircraft will be operated without systems that are critical to safe aircraft operation.

2. If flight crews do not use all available resources at their disposal, a loss in situation awareness can occur, which can increase the risk of an accident.

3.3 Other findings

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

1. A review of Air Tindi Ltd.'s pilot training program revealed that all regulatory requirements were being met or exceeded.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 Air Tindi Ltd.

Following the accident, Air Tindi Ltd. (Air Tindi) conducted its own internal safety investigation and identified several processes and procedures that could be improved. As a result, Air Tindi took the following actions:

- Met with employees to discuss
  - the significance of the threat and error management (TEM) briefing;
  - the importance of the conversation-building flow achieved when the pilot monitoring reviews threats, followed by the pilot flying; and
  - the significance of using all available tools to mitigate threats.
- Conducted a review of the minimum equipment lists (MELs) on company aircraft to
  - eliminate any phrases or wording that may hinder their use by the flight crew; and
  - create an individual summary document for each MEL to explain potentially unclear language.
- Created a new MEL template that includes a "Notes" section, which can be used to clarify specific terms, as well as a sample journey log entry for flight crew to use as an example.
- Amended the crew resource management training program and material.
- Amended the electronic flight bag training material to include the use of the synthetic vision feature.
- Standardized and labelled the power supply type for all attitude indicators in the company's King Air fleet.
- Installed a standby (3rd) attitude indicator in all aircraft that did not have one installed.
- Provided instrument suction covers in all aircraft to cover failed instruments and avoid distraction.
- Established life limits on all attitude indicators installed in company aircraft.
- Amended all aircraft simulator and flight training programs to include partial panel flying exercises.
- Relocated 6 standby attitude indicators in company aircraft that were not in the captain's primary field of view.
- Established TEM as a specific safety goal for the company.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 18 March 2020. It was officially released on 27 April 2020.

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

APPENDICES

Appendix A – Transport Canada service difficulty reports involving SIGMA-TEK Model 5000B attitude indicator

20160706012 — King Air B200

PILOT REPORTED A RH ARTIFICIAL HORIZON HAD FLAGGED. THE RH AI WAS REPLACED WITH A OVERHAULED UNIT AND FUNCTION CHECKED SERVICEABLE, AIRCRAFT WAS RELEASED FOR NORMAL OPERATIONS.

20170112006— Cessna U206F

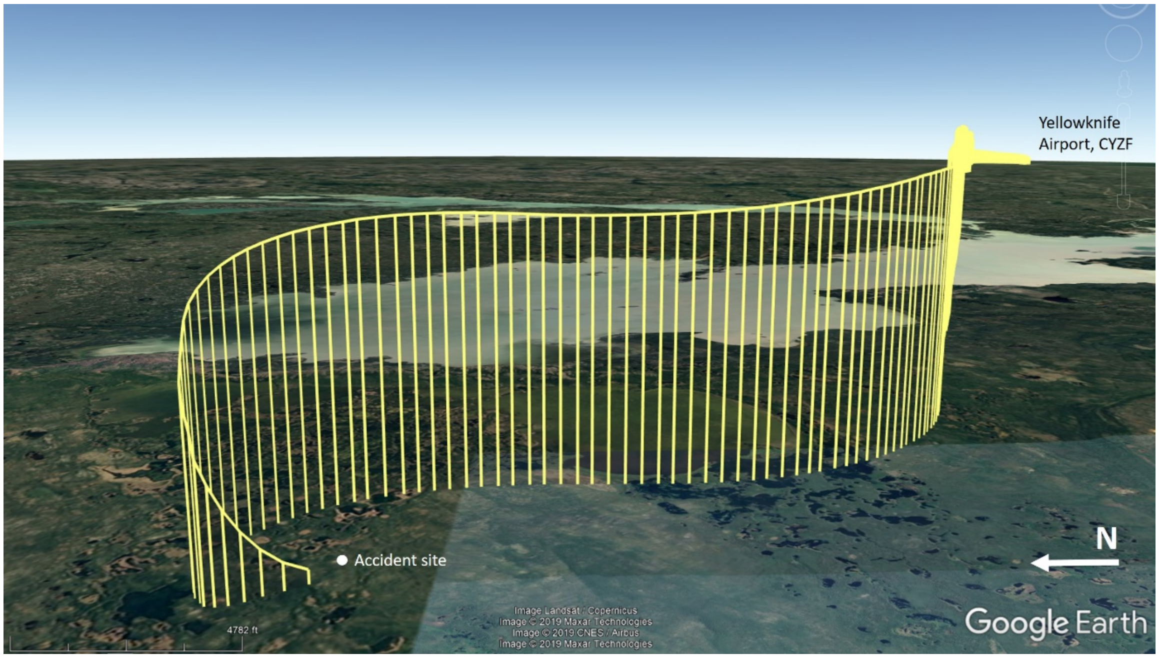
PILOT REPORTED THE ARTIFICIAL HORIZON WAS GIVING ERRONEOUS INDICATIONS. REPLACED WITH OH UNIT AND FUNCTION CHECKED SERVICEABLE.

20170424014— King Air B200

PILOT REPORTED THE CO-PILOT ARTIFICIAL HORIZON WAS U/S. MAINTENANCE REPLACED WITH AN OVERHAULED UNIT. FUNCTION CHECKED SERVICEABLE.

Appendix B – Flight profile

Figure B1. Flight path on the terrain awareness and warning system, looking east (Source: Google Earth, with TSB annotations)



Appendix C – ForeFlight sample synthetic vision screen

Figure C1. ForeFlight Mobile application screen. The light blue square icon at the top of the display is the selection to activate the synthetic vision screen. (Source: Air Tindi Ltd.)