AVIATION INVESTIGATION REPORT
A98Q0029

MID-AIR COLLISION

BETWEEN

TRANSPORT AIR

CESSNA 172 C-GXSD

AND

AÉROTAXI

DIAMOND DA 20-A1 KATANA C-GADA

ST-HUBERT AIRPORT, QUEBEC

26 FEBRUARY 1998

Aviation Investigation Report

Mid-Air Collision

between
Transport Air
Cessna 172 C-GXSD
and
Aérotaxi
Diamond DA 20-A1 Katana C-GADA
St-Hubert Airport, Quebec
26 February 1998

Report Number A98Q0029

Summary

While in cruising flight at night, the Cessna 172, C-GXSD, serial No. 17261853, experienced a complete loss of electrical power just south of Montreal, Quebec. The pilot decided to terminate the flight and land at the St-Hubert Airport, Quebec, on runway 24L. While the Cessna 172 was landing, the Katana, C-GADA, serial No. 10281, with an instructor and a student on board, was cleared to take off on St-Hubert Airport runway 06R. The two aircraft collided just west of taxiway Foxtrot. Both aircraft were extensively damaged. The three occupants sustained minor injuries.

Ce rapport est également disponible en français.

Other Factual Information

The pilot of the Cessna 172, the only occupant on board, was on a training flight. All current maps and publications necessary for the flight were carried on board the aircraft. The aircraft took off in daylight from Québec Airport under visual flight rules (VFR) and the pilot was planning to return there that same night. Stops were planned at the airports at Saint-Jean, Quebec, and then Winchester, Ontario. At 1847 eastern standard time (EST)[1], the pilot reported to the Montreal area control centre (ACC) that he was just west of the terminal control area at 3 000 feet altitude. The satellite terminal controller asked him to select transponder code 5200 and provided him with the altimeter setting. After the pilot acknowledged, the controller asked him to avoid the terminal control area by bypassing it to the south, passing over Valleyfield, Quebec, and flying over the Saint-Jean very high frequency (VHF) omnidirectional range (VOR) before continuing his flight to Québec. At 1904, the pilot informed the ACC that he wanted to avoid the Saint-Jean control zone and would pass over Beloeil, Quebec. This was the last communication received from the pilot. No irregularity was reported during these communications. However, during the flight, the pilot observed that the ammeter was showing a continuous rate of discharge, indicating low voltage in the electrical system.

The radar picked up the aircraft's signals at 3 000 feet above sea level (asl) while it was continuing its flight in Class E controlled airspace on the agreed track. In Class E controlled airspace, air traffic control (ATC) separation is provided only to aircraft operating in instrument flight rules (IFR). There are no special requirements for VFR.

At 1907, at the end of twilight, about 13 nautical miles (nm) west of the Saint-Jean VOR, the transponder began to transmit intermittently until ceasing to reply less than one minute later. Thereafter, no further secondary radar returns were recorded. At about the same time, the aircraft's radios began to crackle. The pilot tried unsuccessfully to communicate with the ACC. Recognizing that two-way communication was broken, he adjusted his transponder on code 7600 to alert ATC to the situation as per regulations. The emergency code, however, was not picked up by the air traffic services (ATS) radar. Shortly thereafter, the lighting in the cabin dimmed until the lights went out. The aircraft experienced a complete loss of electrical power 24 nm from the St-Hubert Airport and 14 nm from the Saint-Jean Airport.

When the pilot realized that the electrical system had failed, he decided to land on runway 24L at St-Hubert Airport, although Saint-Jean Airport was 10 nm closer to his position. His decision was based on his uncertainty about the hours of operation of the Saint-Jean tower, which in fact closed at 2100, and on his belief that the ATS radar would continue to track the flight. The radar did continue to pick up the aircraft's target, but in primary mode only. The aircraft remained on course between the St-Hubert and the Saint-Jean control zones and appeared to be heading towards Beloeil as planned. The emergency procedure to be followed by a pilot to alert radar stations when in distress and unable to establish radio contact is to fly a left-hand triangular pattern twice with two-minute legs, resume course and repeat the procedure at 20-minute intervals.

---

[1] All times are EST (Coordinated Universal Time (UTC) minus five hours) unless otherwise stated.

When the aircraft was in Class E airspace, the terminal controller tried five times between 1913:34 and 1915:57 to contact the Cessna 172, but without any reply. There are no specific instructions to be followed by a controller when a VFR aircraft operating in Class E airspace no longer replies to the transponder signal and stops communicating on the ATC frequency. In Class E airspace, the pilot could leave the frequency and turn off his transponder without advising the controller; however, in VFR, it is customary to adjust the transponder to reply to code 1200.

At about 1918, the Cessna 172 entered St-Hubert Class D airspace, extending from 2 000 feet to 6 000 feet asl. Class D airspace is a controlled airspace within which both IFR and VFR flights are permitted, but VFR flights must establish two-way communication with the appropriate ATC agency before entering the airspace. Furthermore, in the St-Hubert Class D airspace, the aircraft's transponder had to be on. ATC separation is provided only to IFR aircraft, but other aircraft will be provided with traffic information.

At 1923:03, the controller tried once again unsuccessfully to contact the Cessna 172, which was still in Class D airspace and flying less than 4 nm from the St-Hubert control zone. This was the last attempt at communication with the Cessna 172 made by the controller. According to the ATS Manual of Operations (MANOPS), if a controller has reason to believe that an aircraft has experienced a radio failure, he must inform the appropriate radar units of the circumstances and request them to watch for the appearance of a special secondary surveillance radar (SSR) code or a triangular distress pattern.

The radar recording indicates that the pilot made a 90-degree left turn at 1924 over Saint-Mathias Airport and then entered the St-Hubert control zone at 1927:12. There were two aircraft in the control zone: one had just taken off from runway 06R, and the other was turning on the right-hand base leg for runway 06R. Two minutes later, at 1929:23, the Cessna 172 reached the final leg of runway 24L 2 nm from the threshold at a speed of 70 knots and then vanished from the ATS radar screen. The aircraft landed midway on the runway at about 1931. A limited quantity of radar returns of the Cessna 172 was recorded intermittently in the control zone. The radar detected the Cessna 172 at seven intervals; the primary target appeared for between 5 and 14 seconds, then disappeared for between 4 and 23 seconds. More than half of the returns were of poor quality and appeared as a point. The radar floor was about 900 feet asl in this area.

After ensuring that runway 06R and the runway centre line were clear, the airport controller cleared the Katana's pilot to take off. The Katana was on taxiway Tango at the time and clear of runway 06R. The student pilot began his take-off run for a night VFR training flight. The landing light, navigation lights and strobe light were lit. During the take-off roll at about 55 knots, the Katana's instructor saw the Cessna 172 rolling in the opposite direction a few metres ahead of him; to avoid collision, he pulled on the stick to pass over the Cessna. The Katana struck the roof of the Cessna 172 with its landing gear and then crashed on the runway, coming to a stop on its belly on taxiway Foxtrot. The collision occurred 950 feet from the runway threshold, 45 seconds after the Katana received clearance to take off. The weather conditions were suitable for visual flight, the wind was calm, and there was no visibility restriction.

St-Hubert Airport is certified and equipped with a control tower, which was in operation with the required personnel at the time of the occurrence. A controller and a supervisor were on duty. The tower was equipped with a radar screen. Airport controllers do not use radar data to provide aircraft separation, but do use them to

locate the position of aircraft. Runway 06R/24L is 3 920 feet long and 100 feet wide; it was not equipped with approach lights, which would have helped to determine the runway in use.

According to the airport operations manual, the City of St-Hubert fire department serves as the first respondent in airport emergencies. As the airport does not handle any scheduled flight, the response-time standards do not apply. The emergency vehicles of the engine manufacturer Pratt & Whitney, which is located on the airport, arrived at the accident site at 1941, followed one minute later by those of the City of St-Hubert.

The insufficient rate of charge shown on the ammeter warned the pilot that the alternator was no longer supplying power, and that only the battery was suppling the aircraft's electrical circuits. The procedure to follow, published in section III of the Cessna 172's aircraft operating manual (AOM), was first to turn off the alternator to reduce energy expenditure due to its excitation field circuit. The AOM then recommends to decrease consumption by cutting power to non-essential equipment and land as soon as practical. According to the aircraft manufacturer, the battery can normally supply power to essential equipment for about two hours.

As the pilot did not know that a low-voltage indication meant an electrical power failure in the direct current system, he did not follow the aircraft manufacturer's recommended procedure. He thought that the red over-voltage warning light illuminated in the event of an alternator malfunction. In fact, the over-voltage light illuminates only after the over-voltage sensor has detected an over-voltage and shut down the alternator. The pilot did not consult a checklist or the AOM on the flight.

Although the communication failure occurred within Class E airspace outside the St-Hubert control zone, the pilot could enter the zone without clearance and continue VFR flight. However, when landing at St-Hubert Airport, he had to follow the arrival procedures for no-radio (NORDO) aircraft. The pilot had to fly over the airport at an altitude at least 500 feet above the circuit height, then descend to circuit height in the upwind area of the active runway. He then had to join the crosswind leg abeam a point approximately midway between each end of the runway and enter the circuit on the downwind leg. He had to constantly be alert for visible signals to obtain clearance to land. The pilot was not very familiar with this procedure.

The pilots of the Cessna 172 and the Katana were certified and qualified for the flights in accordance with existing regulations. The pilot of the Cessna 172 held a private pilot licence and had a total of 120 hours' flight time; he was in the process of obtaining a commercial pilot licence. He had obtained his night rating on 27 January 1998. The Katana's pilot had obtained his commercial pilot licence on 10 January 1997 and his flight instructor rating on 11 April 1997.

The Katana was certified, equipped and maintained in accordance with existing regulations and approved procedures.

Transport Air bought the Cessna 172 in November 1997. The aircraft had a total of 2 083 hours' flight time. Before returning the aircraft to service at the flying school, the operator modified the avionic system. The operator installed new radios, a VOR/ILS indicator and a transponder. It also changed the alternator belt. The alternator field cable connector was also replaced on 17 December 1997. The aircraft was returned to service on 20 December 1997. After the return to service of the Cessna 172, three periodic inspections were carried out.

On 22 January 1998, in a 50-hour overhaul, the battery was recharged. On 07 February 1998, the Cessna 172 underwent a 100-hour overhaul, and on 22 February, a 50-hour inspection was carried out. In these three inspections, the electrical wiring was checked, and no irregularity was found. At the time of the accident, the aircraft had accumulated about six hours' flight time since the last 50-hour inspection. The aircraft was certified and equipped in accordance with existing regulations.

Examination of the wreckage revealed that the alternator positive-terminal cable was heavily damaged. Only 7 of the 133 strands of the cable were supplying power to the aircraft's electrical system at the time of the accident. The TSB Engineering Laboratory determined that, in all likelihood, fatigue loads due to reverse bending of the cable caused gradual wear and the failure of some hundred strands near the terminal. The remaining strands then fused when the electrical load exceeded their capacity. Federal Aviation Administration Advisory Circular AC43-13-1A, Section 7, Chapter 515, sets out the installation standards for electrical cables. To reduce fatigue loads, the bending radius of a cable near a connector may not be less than three times its outer diameter. In this instance, as the cable had a diameter of 0.25 inch, the bending radius had to be at least 0.75 inch.

Analysis

The Cessna 172 experienced a complete loss of electrical power due to the failure of the alternator positive-terminal cable. To generate the reverse-bending fatigue loads that caused the degradation of the cable, its bending radius had to be less than the recommended standard. The investigation was unable to establish the decay time of the cable; however, it is unlikely that its deterioration began after the 22 February inspection; i.e., less than six hours before it broke. It is likely that the cable was bent beyond the established standard when the alternator was manipulated during maintenance work. The alternator and its wiring should have been examined on five occasions: during replacement of the alternator field cable and of the belt and during the last three periodic inspections. The investigation was unable to determine why the operator did not detect the wear and improper installation of the cable. It is possible that the staff who performed the periodic inspections and the work on the alternator were not aware of either the bending standards for electrical wires or the consequences of improper installation or both.

The low-voltage indication of the electrical system made it possible to anticipate a loss of electrical power at least within the hour. The description of the aircraft's electrical system and the consequences of a low-voltage indication, as set out in the AOM, would have allowed the pilot to realize that the alternator was not meeting the electrical demand necessary for flight. Therefore, it can be concluded that the pilot was not familiar enough with the aircraft electrical system , as described in the AOM. If the pilot had recognized the nature of the problem, he would have been able to report it to the controller over the radio and then land in daylight before the failure.

The terminal controller probably stopped monitoring the aircraft because he did not realize what was happening. Yet, there were clues that the aircraft's communication system had failed. Specifically, the pilot's last communication suggested that further communications were possible, because the intended track shortly brought the aircraft, flying at 3 000 feet asl, into St-Hubert Class D airspace. Accordingly, the controller had no reason to believe that the pilot had shut down the transponder and changed the radio frequency before entering Class D airspace, where two-way communication with the ACC and activation of the transponder were

mandatory. If the Cessna 172 had descended below 2 000 feet asl to pass under the Class D airspace, the controller could at least have expected the pilot to select code 1200 for VFR flight. The aircraft, which was still visible on the radar screen, had been in St-Hubert Class D airspace for 4 minutes and 30 seconds when the terminal controller tried to reach it for the last time. As the pilot did not acknowledge and the transponder did not reply, the controller could have inferred that the aircraft had experienced a complete communication failure. The terminal controller should have informed St-Hubert tower of the situation, especially because the break in communications occurred at night when the Cessna 172 was flying less than 4 nm from the St-Hubert control zone within airspace where use of the two transceivers was mandatory. The tower controller might then have been advised of the presence of the Cessna 172.

The following factors probably influenced the terminal controller's decision to treat the break in communications and the loss of transponder information as a normal situation: the loss of electrical power occurred in Class E airspace; the Cessna 172's primary target held steady on the intended track; and no manoeuvre was performed by the pilot to alert the radar system. If the pilot, who knew he was being tracked by radar, had flown a left-hand triangular pattern twice, the controller would have been advised of the situation and would have informed the appropriate control units of the circumstances. Given the sporadic nature of the primary radar returns and the absence of related data blocks on the radar screen that might have signalled an emergency situation, the airport controller would find it hard to detect the Cessna 172 on the radar screen and infer that the aircraft would land on the runway opposite to the active one. The airport controller could also expect the NORDO aircraft to perform the corresponding arrival procedure and obtain clearance before touching down. The airport controller visually scanned the runway and the runway centre line before clearing the Katana's take-off. The contrast between the lightless Cessna 172 and the nighttime background made the aircraft virtually indiscernible to the controller and the Katana's crew. It may be concluded that the airport controller accomplished his duties in accordance with established procedures and his assigned responsibilities.

Because he thought that the radar was tracking the flight, the pilot of the Cessna 172 wrongly assumed that the St-Hubert airport controller knew of his presence and was providing aircraft separation and the availability of runway 24L, although he had not received any visible signal from the tower clearing him to join the final leg and land. The pilot had to ensure that his intentions were known, especially as it was night at the time and only visual acquisition made a safe landing possible.

The aircraft's loss of electrical power led to multiple failures: all electrically powered systems, gauges and flight/engine instruments were rendered inoperative. The communication system, the interior and exterior lighting system and the navigation system stopped working. The fact that the loss of electrical power occurred at night made the emergency more complicated than a similar failure in daylight. The pilot, alone on board, had to control his aircraft, navigate, watch the available instruments and use a flashlight to consult the AOM, the navigation charts and the relevant checklists. The pilot's workload and stress level had to have been high and had to have affected his decision making.

The pilot had to have a good knowledge of the following aircraft systems and procedures to continue the flight safely: aircraft electrical system, appropriate emergency procedures published in the AOM, ATS system, manoeuvres to alert radar stations, complete communication failure procedures, NORDO aircraft arrival procedures, NORDO aircraft landing procedures and the meaning of the authorized visual signals used by the

tower. Although understanding these systems and procedures is mandatory to obtain a private pilot licence, the pilot's inexperience probably led him not to realize the imminence of the loss of electrical power and to overestimate the assistance of ATS.

As the Cessna 172 landed midway on the runway, almost two minutes had to have elapsed between the aircraft's last recorded position 2 nm on the final leg and landing. It may be concluded that runway 24L was clear when the Cessna 172 was on the final leg, and that the Cessna 172 landed shortly after the Katana's pilot entered the runway and began his take-off run. Because the collision occurred less than 1 000 feet from the threshold of runway 06R and 42 seconds after the Katana's pilot acknowledged the take-off clearance, the length of the head-on collision course is likely to have left the pilot of the Cessna 172 little time to see the other aircraft, realize the imminence of the danger and try evasive action.

If the pilot had followed the NORDO aircraft arrival procedure, he would have been able to see the traffic and identify the runway in use. It is also possible that the controller would have noticed the aircraft on the radar, reported its presence to other pilots and cleared the landing using visual signals.

Findings

1. The Cessna 172 experienced a complete loss of electrical power at night while in Class E airspace.

2. The loss of power was caused by the failure of the alternator positive-terminal cable.

3. The installation of the cable was not in compliance with the recommended standard and caused reverse-bending fatigue loads causing degradation.

4. The operator did not detect the wear and improper installation of the cable in the last periodic inspection, six hours before the flight.

5. The pilot of the Cessna 172 had observed a low-voltage indication before the failure.

6. The pilot of the Cessna 172 was not very familiar with the consequences of low voltage.

7. The pilot of the Cessna 172 did not follow the aircraft manufacturer's recommended procedure for low voltage.

8. The Montreal terminal controller and the St-Hubert airport controller did not know that the Cessna 172 had experienced a complete loss of electrical power, and that the pilot would touch down on runway 24L.

9. The terminal controller should have informed the St-Hubert tower of the presence of the Cessna 172 which was 4 nm from the St-Hubert control zone after he tried unsuccessfully to communicate with the aircraft in Class D airspace.

10. The airport controller accomplished his duties in accordance with established procedures and his assigned responsibilities.

11. The contrast between the lightless Cessna 172 and the nighttime background did not allow the airport controller and the Katana's crew to see the Cessna 172 on approach and on the runway.

12. The pilot of the Cessna 172 did not follow the NORDO aircraft arrival procedure at St-Hubert Airport.

Causes and Contributing Factors

The pilot of the Cessna 172 did not follow the NORDO aircraft arrival procedure and did not make an adequate visual check before landing in the opposite direction on runway 06R just as the Katana was cleared to take off from runway 06R. The following factors contributed to the accident: the installation of the alternator positive-terminal cable was not in compliance with the recommended standard; the operator did not detect the wear and improper installation of the cable; the pilot of the Cessna 172 was not familiar with the consequences of a low-voltage indication; and the terminal controller's lack of vigilance.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 17 May 2000.