FLIGHT SAFETY FOUNDATION

Accident Prevention

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Airplane's Low-energy Condition and Degraded Wing Performance Cited in Unsuccessful Go-around Attempt

The Canadair Regional Jet's airspeed was decreasing, and its engines were producing idle thrust when the crew rejected the landing 33 feet (10 meters) above the runway. The Transportation Safety Board of Canada said that there was insufficient time for the engines to spool up to go-around thrust, and that a thin accumulation of ice was a major factor in causing the airplane to stall at a lower-than-normal stall angle-of-attack. The crew lost control of the airplane, and the airplane struck the runway and terrain.

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FSF Editorial Staff

On the night of Dec. 16, 1997, the crew of Air Canada Flight 646 (ACA 646), a Canadair Regional Jet, conducted a Category I instrument landing system (ILS) approach to Runway 15 at the airport in Fredericton, New Brunswick, Canada. The ceiling and visibility were below the minimums published for the instrument approach. Nevertheless, the runway visual range (RVR) on Runway 15 was 1,200 feet, and the crew was authorized by Canadian regulations to conduct the approach under these conditions.

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The captain saw the runway approach lights when the aircraft was 100 feet above decision height (DH). The first officer, the pilot flying (PF), disconnected the autopilot about 165 feet above ground level (AGL), and the aircraft began to drift above the glideslope and left of the runway centerline. The first officer reduced thrust to idle in an attempt to recapture the glideslope.

The captain believed that the aircraft was not in position to make a safe landing and commanded a go-around. The aircraft stalled during the go-around, struck the runway and then veered off the right side of the runway. The aircraft then struck a ditch, a hill and some trees, and came to rest approximately 1,130 feet (345 meters) from the runway. The captain and eight passengers were seriously injured; the first officer, the flight attendant and the remaining 31 passengers sustained minor injuries or no injuries.

The Transportation Safety Board of Canada (TSB), in its final report on the accident, said that the aircraft stalled at an angle-of-attack approximately 4.5 degrees lower than normal, and that the premature stall was caused primarily by a thin accumulation of ice on the wing leading edges.

"Many [other] factors were involved in this accident: the weather, darkness, flight-crew training and aircraft knowledge,

Canadair Regional Jet

Canadair, a subsidiary of Bombardier, began to design the Regional Jet — a stretched, commuter version of the 14-seat to 18-seat Challenger 601 business jet — in 1987. The engineering designation of the new airplane was CL-600-2B19. The fuselage forward of the Challenger's wings was extended 10.7 feet (3.3 meters) to increase cabin size to accommodate up to 50 passenger seats arranged four abreast. The Regional Jet first flew in 1991, and deliveries began in 1992.

The airplane is powered by two General Electric CF34-3A1 turbofan engines, each rated at 9,220 pounds thrust (41 kilonewtons) with automatic power reserve (APR), or 8,729 pounds thrust (39 kilonewtons) without APR. Fuel capacity is 1,400 gallons (5,300 liters). Fuel is carried in integral wing tanks.

Maximum takeoff weight is 47,450 pounds (21,523 kilograms). Maximum landing weight is 44,700 pounds (20,275 kilograms). Maximum rate of climb at sea level is 3,900 feet per minute (1,190 meters per minute).

Maximum operating altitude is 41,000 feet. Maximum operating speed is Mach 0.85, or 335 knots (621 kilometers per hour [kph]). Maximum cruising speed at 36,000 feet is Mach 0.8, or 459 knots (851 kph). Long-range cruising speed at 36,000 feet is Mach 0.74, or 424 knots (786 kph).

Range with maximum payload at long-range cruising speed is 845 nautical miles (1,566 kilometers) with U.S. Federal Aviation Regulations Part 121 reserves. Stall speed in landing configuration is 100 knots (185 kph).

Source: *Jane's All the World's Aircraft*

aircraft handling, aircraft operating procedures, aircraft performance and limitations, Canadian Aviation Regulations, runway lighting, dissemination of information, aircraft design and certification, and overview of operations," the report said. "The weather, with a low ceiling and low visibility in fog, was the one factor that led to the interaction of all the other factors and, finally, to the accident."

A warm front moved across New Brunswick on the evening of the accident, and a trailing, weak cold front remained west of the region. The Fredericton forecast, which was included in the flight crew's preflight briefing package, was for six statute miles (10 kilometers) visibility, scattered clouds and occasionally a broken ceiling at 400 feet, and a broken ceiling, occasionally overcast, at 2,500 feet.

Weather conditions forecast for the alternate airport — Saint John, New Brunswick, approximately 85 nautical miles (157 kilometers) southeast of Fredericton — were eight miles (13 kilometers) visibility, a few clouds at 300 feet and a broken ceiling at 1,400 feet.

Air Canada Flight 646 was a scheduled flight from Toronto, Ontario, to Fredericton, which is approximately 567 nautical miles (1,050 kilometers) east-northeast of Toronto.

The captain, 34, had an airline transport pilot (ATP) certificate and 11,020 flight hours, including 1,770 flight hours in type. He joined Air Canada as a Regional Jet (CL-65) first officer in June 1995 and was promoted to CL-65 captain in October 1996.

"Of his 1,770 hours on the aircraft type, just over 975 [hours] were as captain," said the report.

The first officer, 26, had an ATP certificate and 3,225 flight hours, including 60 flight hours accumulated in type during the 90 days preceding the accident. He joined Air Canada as a CL-65 first officer in September 1997.

"Based on the 72-hour history of the pilots and the circumstances of the accident, no medical, physical or psychological factors were identified that negatively affected either pilot's performance during this occurrence," said the report. [TSB uses the term *occurrence* to describe an aircraft accident or an aircraft incident.]

The flight attendant, whose age was not included in the report, had 28 years of experience with Air Canada, including two years in type.

"Coincidentally, an Air Canada CL-65 flight attendant was traveling as a passenger," the report said. "She had been with Air Canada for one and a half years and was qualified on all aircraft flown by Air Canada."

Forty-six minutes after takeoff from Toronto (at 2310 Fredericton local time), the crew received an amended forecast for Fredericton that called for a quarter-mile (0.4-kilometer) visibility in fog and a vertical visibility of 100 feet, with the conditions temporarily improving to four miles (6.4 kilometers) visibility and broken clouds at 1,500 feet.

As the aircraft neared Fredericton, the crew briefed themselves on the ILS approach to Runway 15 and the missed-approach procedures (see Figure 1). The published minimums for the approach were 2,600 feet (793 meters) RVR or one-half mile visibility. The DH was 264 feet (200 feet above the touchdown zone elevation).

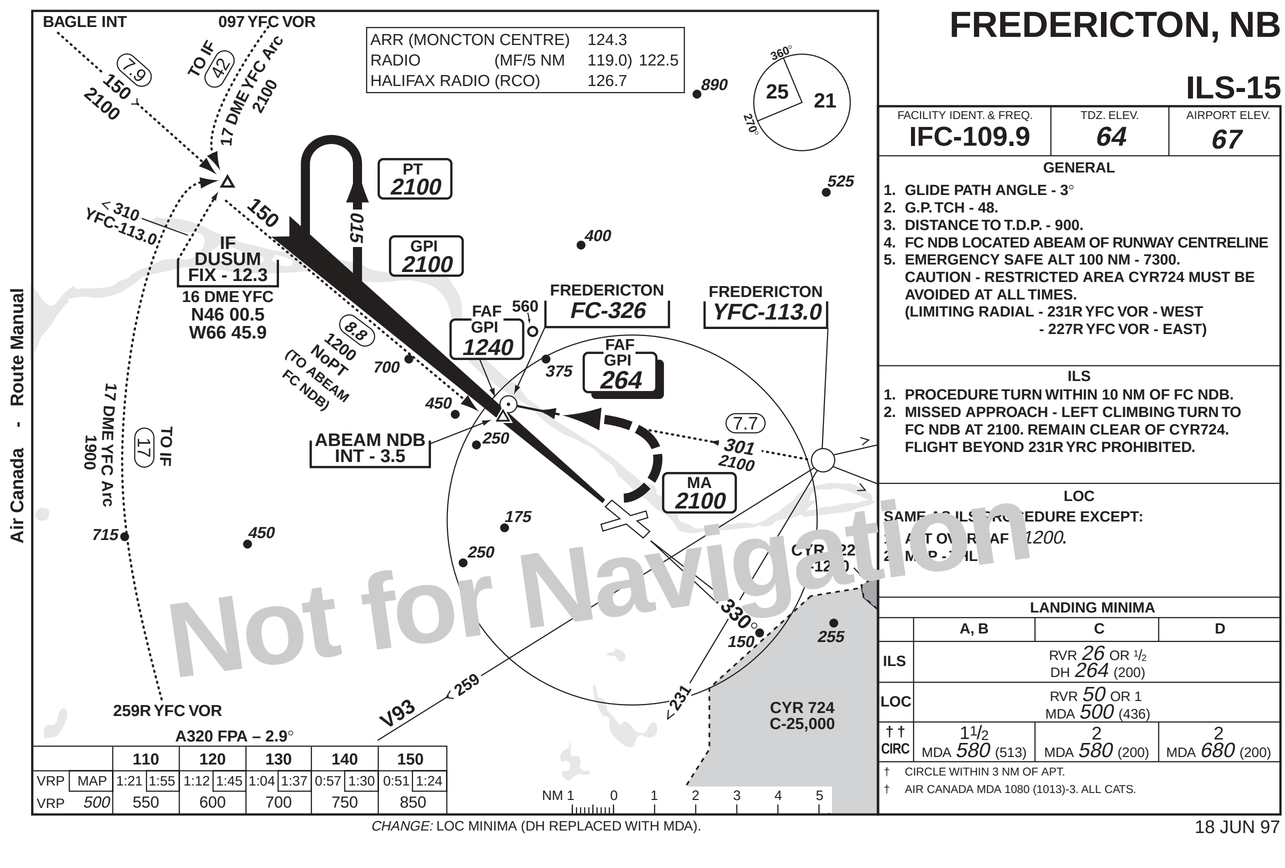
"Their intent was to conduct up to two approaches to Fredericton and then, if weather at Fredericton precluded landing, proceed to Saint John as the alternate," said the report.

The crew received vectors to the ILS final-approach course from Moncton Area Control Center (ACC). When the aircraft was established on final approach 18 nautical miles (33 kilometers) northwest of the airport, Moncton ACC told the crew to contact the Fredericton Flight Service Station (FSS), which provides advisory services at the uncontrolled airport.

At 2328 local time, an FSS specialist told the crew that the Fredericton airport had one-eighth mile (0.2 kilometer) visibility, 1,400 feet RVR in fog on Runway 15, 100 feet vertical visibility, and surface temperature and dew point both minus 8 degrees Celsius (18 degrees Fahrenheit). The specialist later told the crew that Runway 15 RVR was 1,200 feet and that the approach lights and runway lights were at "light setting 5," the brightest setting.

Although the reported RVR was below the minimum RVR published for the approach, the flight crew was authorized by Canadian Aviation Regulations (CARs) and Air Canada standard operating procedures (SOPs) to conduct the approach.

Instrument Landing System Approach to Runway 15, Fredericton, New Brunswick, Canada, Air Canada Flight 646, Dec. 16, 1997



Source: Transportation Safety Board of Canada

Figure 1

"In Canada, pilots are banned from continuing an approach past the final approach fix to a runway which is equipped with RVR equipment and where the reported RVR is less than 1,200 feet," the report said. "In all other cases, there are no weather-related rules governing where an approach can or cannot be made."

The crew discussed the first officer's experience in conducting approaches with RVR at 1,200 feet. The first officer had flown such approaches in other aircraft, but not in the CL-65.

"Even though a Category I approach may be conducted in weather conditions lower than the [minimums] specified for the approach, there is no special training required by Transport Canada for any flight crewmember, nor is there a requirement that flight crew be tested on their ability to fly in such conditions," said the report.

Air Canada's flight operations manual recommended that the captain fly the approach when RVR is less than the published landing visibility, unless the runway has high-intensity approach lights, touchdown-zone lights and centerline lights. Runway 15 at Fredericton did not have touchdown-zone lights or centerline lights.

"Following the discussion, the captain decided to continue with the existing allotment of flying duties, with the first officer flying the approach," the report said. "The crew had flown together on this date only and had completed two legs. On these two legs and during the Toronto–Fredericton leg, the captain had found the first officer to be a competent pilot."

The report said that the ice-detection system inhibits illumination of the ice light when the aircraft is below 400 feet with the landing gear extended.

Both pilots were qualified to conduct Category II approaches, which normally have a published minimum RVR of 1,200 feet. Nevertheless, Air Canada SOPs for Category II approaches required that the captain serve as PF, that the autopilot remain coupled to at least DH (normally 100 feet) but no lower than 80 feet if the aircraft did not have autoland equipment, and that the runway have centerline lights and touchdown zone lights.

"The ILS approach to Runway 15 at Fredericton was a Category I approach; however, the weather conditions were those normally associated with Category II approaches, and some aids and defenses identified as needed for Category II approaches were not available or not used," said the report.

Although the first officer was qualified to conduct Category II approaches as the pilot not flying (PNF), he had received no training and had no experience as a CL-65 PF in weather conditions normally associated with Category II approaches. "Neither crewmember had specific training in flying Category I approaches to a landing in the same weather conditions," said the report.

The crew said that the flight was conducted in visual meteorological conditions until the aircraft entered clouds between 1,000 feet AGL and 500 feet AGL. They said that there were no indications of icing during the approach.

"In the two hours before the occurrence, two flights had landed at Fredericton in similar weather conditions," the report said. "The crew of one flight indicated that on final approach, after entering clouds, there was some light icing and [that] after landing, there was some light rime icing on the leading edge of the wing. The crew of the other flight did not see ice during the approach or on the wings after landing. A person driving from Edmundston to Fredericton on the evening of the accident reported encountering freezing fog north of Fredericton."

The accident aircraft was equipped with an ice-detection system that causes an amber "ice" light to illuminate on the engine indicating and crew alerting system display when ice builds to a thickness of 0.02 inch (0.5 millimeter) on either of the two ice-detection probes. The normal crew response to an ice light is to activate the anti-ice systems for the wings and engine cowls. The report said, however, that the ice-detection system inhibits illumination of the ice light when the aircraft is below 400 feet with the landing gear extended.

The crew determined that the aircraft's landing weight would be 44,530 pounds (20,200 kilograms) and calculated the following reference airspeeds: V_{FTO} (single-engine climb speed), 173 knots; V_2 (takeoff safety speed), 145 knots; and V_{REF} (reference speed for final approach), 139 knots. Following Air Canada SOPs, the crew used a reference speed of V_{REF} plus five knots on final approach.

"The aircraft arrived at [DH] in the landing configuration (landing gear down, flaps 45), three knots below the target airspeed of 144 knots (V_{REF} plus five knots), on glide path and tracking slightly right of the localizer," the report said. "The captain called the lights in sight. [See Table 1]. The first officer looked up and saw approach and runway-end lights, and … made the decision to land.

"Air Canada procedures for Category I approaches stipulate that once a decision to land is made, the PF will continue using outside references to maintain the aircraft on the slope and runway [centerline] and complete the landing. The PNF is expected to monitor the outside visual cues and the instrument indications in the cockpit, and notify the PF of significant deviations from the intended flight path.

Table 1
Data Derived from Flight Recorders, Air Canada Flight 646, Fredericton, New Brunswick, Canada, Dec. 16, 1997

Local Time	Event	ALT	VS	IAS	ASΔ	N_1%	P
2347:11.4	Captain calls minimums and lights	201	–700	141	0.0	68	–2.0
2347:14.8	First officer calls landing	166	–800	143	1.4	68.3	–2.2
2347:15	Autopilot disconnected	165	–800	143	1.2	68.3	–2.2
2347:19.4	Captain prompts first officer to keep it down	132	–500	145	0.3	68.5	–0.9
2347:22.5	Pitch adjusted (2347:21–2347:23)	96	–450	145	0.3	68.4	–1.1
2347:24	Engine N_1 starts to decrease to idle	79	–400	145	–0.7	64.7	–0.6
2347:25.1	Runway threshold crossing	72	–400	144	–1.0	58.8	-0.5
2347:25.9	Captain prompts first officer to keep it down	68	–300	143	–1.4	53.6	–0.1
2347:29.2	RADALT — “Fifty” feet	49	–500	138	–1.9	36.4	–1.5
2347:30.9	Captain commands the go-around	33	–600	135	–2.0	29.4	–1.0
2347:31.5	RADALT — “Thirty” feet	27	–600	134	–2.3	27.8	0.5
2347:31.9	First officer acknowledges go-around	23	–600	133	–2.5	26.9	1.3
2347:33.1	Stick shaker activates	14	–350	129	–2.9	27.0	4.0
2347:34.1	RADALT — “Ten” feet	11	–100	126	–3.5	30.5	7.8
2347:34.7	Stall onset/right roll starts	14	300	124	–3.9	34.7	9.6
2347:34.8	Captain calls flaps/warbler tone activates	13	400	124	–3.6	35.4	9.7
2347:36.3	Peak altitude	32	0	121	–2.8	59.0	3.2

ALT = Radio altimeter altitude   VS = Derived vertical speed (feet per minute)   IAS = Indicated airspeed (knots)
ASΔ = Airspeed change per second N_1% = Left engine low-pressure compressor speed   P = Pitch attitude (degrees)
RADALT = Radio altimeter call-out

Source: Transportation Safety Board of Canada

“Air Canada recommends that the autopilot be used when conducting approaches in low-visibility conditions; however, there is no guidance as to when the autopilot might be disconnected during the approach. The [*Canadair Regional Jet Airplane Flight Manual*] states that the minimum altitude for disconnecting the autopilot is 80 feet.”

The first officer disconnected the autopilot at approximately 165 feet AGL. The aircraft began to drift above the glideslope, and the captain told the first officer to “keep it down.” The first officer lowered the airplane’s nose and began to reduce thrust. He also rolled the airplane into a five-degree left bank; as he did so, he raised the airplane’s nose. The airplane then began to drift left of the localizer and above the glideslope.

“Many CL-65 pilots stated that on final approach, the CL-65 is in a nose-low attitude because of its fairly high approach speed,” said the report. “The combination of low pitch attitude, high approach speed, darkness and low visibility may result in a sensation that the aircraft is approaching the ground too fast, which would result in a tendency to raise the nose to round out the aircraft earlier than required. … In addition, because the engines are above the [airplane’s center of gravity], there is a tendency for the CL-65 to pitch up when thrust is reduced.”

The captain again told the first officer to “keep it down.” The radio altimeter then called out “50,” indicating that the airplane was at 50 feet AGL. Neither pilot later remembered hearing the call-out.

“Moments later, the captain, aware that the aircraft was left of the [runway centerline] but not knowing the distance traveled down the runway and not sure that a safe landing could be made, ordered a go-around, which the first officer acknowledged,” said the report.

By this time, the first officer had reduced thrust to idle; engine low-pressure compressor speed (N_1) was 29 percent. Airspeed was 133 knots, six knots below V_{REF}, and continued to decrease at a rate of approximately three knots per second.

The report said that a go-around from a rejected landing typically is begun with the engines producing adequate thrust for a stabilized approach. In the CL-65, the engines would be at approximately 65 percent to 68 percent N_1.

“However, there will be times when a go-around is required, or deemed to be required, after the power has been reduced to idle for landing,” the report said. “This is the area of the approach to land where the crew … found themselves. There are no Canadian or American certification requirements related to a rejected landing with the power at idle, Transport Canada does not require manufacturers or operators to discuss the subject in applicable manuals, and pilots are not required to train for such a maneuver. …

"A go-around or balked landing outside the demonstrated flight envelope is a high-risk maneuver. If a go-around is attempted from a low-energy state, such as after the thrust levers are reduced for landing, ground contact is likely, and any attempt to commence a climb before the engines have achieved go-around thrust could result in a stall. This is primarily because of the time required for the engines to spool up to go-around thrust — about eight seconds."

The aircraft was 50 feet (15 meters) left of the runway centerline and 1,300 feet (397 meters) from the threshold of the 6,000-foot (1,830-meter) runway when the crew began the go-around. The crew did not conduct the go-around according to procedures in the Air Canada *CL-65 Airplane Operating Manual* (AOM).

The AOM said that, for a two-engine go-around, "PF calls 'go-around, flaps' while simultaneously applying go-around thrust [86 percent N_1], pressing the go-around button on the thrust lever and smoothly rotating toward the flight director target attitude [10 degrees] to achieve a speed not less than V_2 + 10 [knots]. The PNF selects flaps to the gate position (i.e., flap 8 [the go-around flap setting]) and confirms [that] thrust is correctly set."

In this go-around, the first officer began to advance the thrust levers but took his hand off the thrust levers when he felt the captain advancing them. The first officer selected the flight director go-around mode and began to increase pitch to the target attitude shown on the flight director.

"About one second after the first officer acknowledged the go-around, the stick shaker (stall warning) activated," said the report.

The first officer stopped pulling the control column back and then eased it forward slightly. The report said that this was consistent with the first officer's stall-recovery training.

"During practice landing-configuration stalls, smooth, continually increasing back pressure is applied to the point of the stall, and only a slight decrease in back pressure and almost no control column movement are required to maintain the pitch attitude," the report said. "For the occurrence flight, a significant change in control-column position would have been required to … stop the nose from rising.

"The training scenarios and profiles did not emulate the circumstances and control-input requirements for the occurrence stall. The first officer's reaction to the stick shaker was in keeping with the type of response practiced during stall training."

When the stick shaker activated, the aircraft was at 14 feet AGL. Airspeed was 129 knots. Pitch attitude was four degrees and continued to increase.

"As the aircraft reached 10 degrees nose up, about one and one-half seconds after the stick shaker activated, the captain called flaps and selected them to the go-around setting [eight degrees], the warbler tone associated with the stall-protection system (SPS) sounded, and the aircraft stalled aerodynamically," said the report.

The SPS stick pusher did not activate before the stall occurred because only one of the two angle-of-attack vanes (the right vane) had reached the stick-pusher trip point; both vanes must reach the trip point to activate the stick pusher. The report said the airplane stalled just before the left angle-of-attack vane reached the stick-pusher trip point.

The aircraft rolled right. When the bank angle reached approximately 55 degrees, the right wing tip struck the runway approximately 2,700 feet (824 meters) from the threshold and 45 feet (14 meters) left of the centerline (Figure 2).

The aircraft then rolled left and was in a 20-degree right-wing-down and 12-degree nose-down attitude when it struck the runway again. The nose wheel separated, the right winglet separated, and all electrical power, except electrical power for the emergency lighting, was lost.

"The crew was not able to control the aircraft because of the darkness inside and outside the aircraft, aircraft damage, disorientation and the roughness of the ride," said the report.

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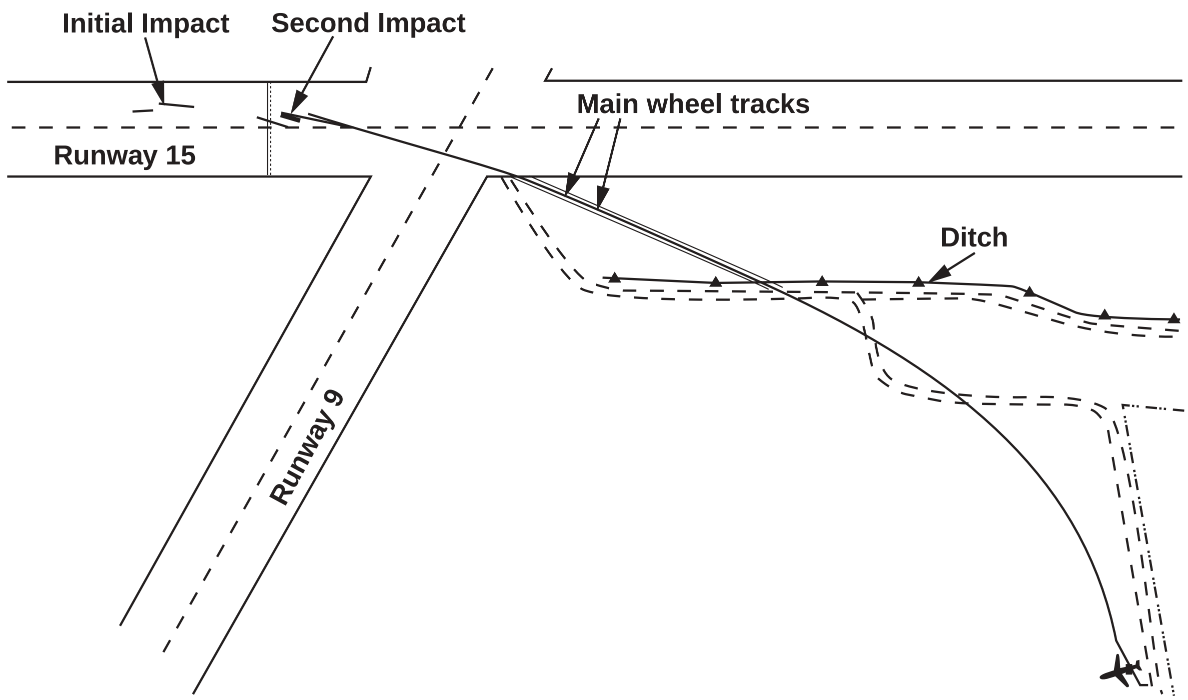
The aircraft departed the right side of the runway, just past the intersection of Runway 9/27, with the engines at full power.

"The aircraft plowed through the snow, on its main wheels, until it struck a ditch parallel to and about 200 feet [61 meters] from the runway," the report said. "The tracks in the snow past the ditch were much lighter than the tracks left by the main wheels. These marks were made by the flap fairings and aircraft equipment dangling on wiring still attached to the aircraft. The marks show that the aircraft became airborne after striking the ditch … and flew in an arc to next strike a sand hill about 1,000 feet [305 meters] right of the runway."

Impact Points and Ground Track, Air Canada Flight 646, Fredericton, New Brunswick, Canada, Dec. 16, 1997



Source: Transportation Safety Board of Canada

Figure 2

The aircraft slewed right at the top of the hill, struck trees and came to rest approximately 2,100 feet (641 meters) from where it first struck the runway. One tree, approximately 22 inches (56 centimeters) in diameter, penetrated the passenger door, which is in the forward, left section of the cabin.

"As the aircraft moved forward, the tree cut through the aircraft cabin to a point about nine feet [three meters] aft of the door, just left of the [centerline] of the aircraft," said the report. "Apart from damage where the tree had torn through the aircraft, the rest of the cabin floor, seat rails, seats and overhead bins showed no sign of deformation or damage."

There was no postaccident fire. Both engines continued to operate at full power after the aircraft came to rest. The crew tried to shut down the engines with the fire switches, but the fire switches were inoperable because of the electrical failure.

"The captain attempted to shut down the engines by moving the thrust levers to the shut-off position," the report said. "The right engine shut down at the same time that the right thrust lever was retarded; however, as the right-engine fuel line was found broken, the engine could have stopped either because of the fuel being shut off or because of fuel starvation.

"The left thrust lever could not be pulled back. The captain got out of his seat, braced his foot on the instrument panel and succeeded in pulling the thrust lever aft, and the engine stopped. It was found that the left-engine cable had been stretched taught and damaged as the tree entered the aircraft, making it difficult to move the left thrust lever."

The cabin door and the galley door were jammed. Seven passengers were trapped in the aircraft. The remaining passengers were evacuated through both overwing exits. The flight-deck escape hatch was not used. (Investigators found that Air Canada did not require flight crews to receive hands-on training on the operation of emergency exits and did not require flight attendants to receive hands-on training on the operation of the flight-deck escape hatch.)

Aircraft rescue and fire fighting (ARFF) personnel had been alerted by the FSS specialist after he received no calls from the flight crew at the aircraft's expected time of arrival. ARFF personnel searched the runway for the aircraft and for tracks from the aircraft. They had to drive slowly because of the dense fog, and they found no sign of the aircraft.

The aircraft was not equipped with an emergency locator transmitter (ELT).

"Under CARs 605.38, multi-engine, turbojet airplanes of more than 5,700 kilograms [12,500 pounds] maximum certified takeoff weight, such as the CL-65, are not required to be equipped with an [ELT] when operating in [instrument flight rules (IFR)] flight within controlled airspace over land and south of latitude 66 degrees 30 minutes north," said the report.

The flight attendant saw lights on the ARFF vehicles and heard sirens. He used his flashlight to signal the ARFF personnel, but received no response. He asked a passenger to continue signaling with the flashlight, and he then re-entered the aircraft.

"The three crewmembers and some passengers who had re-entered the aircraft worked together to extricate the trapped passengers, but were not successful," the report said. "At one point, the flight crew used the handle of the crash axe in an unsuccessful attempt to pry free a passenger's hand trapped between the fuselage and a seat; the axe handle bent. Neither flight crewmember was aware that a pry bar was standard equipment on the aircraft."

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The flight attendant who was traveling as a passenger assumed responsibility for the passengers who had evacuated the aircraft. She kept the passengers together, counted them periodically to ensure that nobody had wandered away, warned them not to smoke or light matches and retrieved coats from the aircraft for passengers who had none.

The flight attendant assigned to the flight later told some passengers to take the flashlight and walk to the runway.

"Most passengers made their way in small groups, some passengers without winter clothing or footwear," the report said. "They shouted for help as they went, but rescue personnel could neither see nor hear them."

Approximately 14 minutes after the accident occurred, the driver of an ARFF vehicle saw the passengers walking toward the runway. The passengers were taken to the airport terminal, and ARFF personnel then plowed a path to the aircraft. The last trapped passenger was removed from the aircraft at 0234 — two hours and 46 minutes after the accident occurred.

"Of the 42 persons on board, 35 were sent to hospital; eight passengers and the captain were admitted," the report said. "Some minor injuries were incurred when passengers evacuating via the overwing exits slipped and fell on the slippery wing surface.

"All the passengers who incurred serious injury were located in the first four rows of the passenger cabin, seven passengers on the left side of the aircraft, at or just aft of the point where the tree broke through the fuselage at impact, and one on the right."

The report said that the investigation produced the following findings regarding the causes of the accident and factors that contributed to the accident:

- "Although for the time of the approach the weather reported for Fredericton — ceiling 100 feet and visibility 1/8 mile — was below the 200-foot [DH] and the charted 1/2-mile (RVR 2,600) visibility for the landing, the approach was permitted because the reported RVR of 1,200 feet was at the minimum RVR specified in CARs 602.129;

- "Based on the weather and visibility, runway length, approach and runway lighting, runway condition and the first officer's flying experience, allowing the first officer to fly the approach is questionable;

- "The first officer allowed the aircraft to deviate from the flight path to the extent that a go-around was required, which is an indication of his ability to transition to landing in the existing environmental conditions;

- "Disengagement of the autopilot at 165 feet, rather than at the 80-foot minimum autopilot altitude, resulted in an increased workload for the PF, allowed deviations from the glide path and deprived the pilots of better visual cues for landing;

- "The lack of runway [centerline lighting] and touchdown-zone lighting probably contributed to the first officer not being able to see the runway environment clearly enough to enable him to maintain the aircraft on the visual glide path and runway [centerline];

- "The first officer's inexperience and lack of training in flying the CL-65 in low-visibility conditions contributed to his inability to successfully complete the landing;

- "The situation of a captain being the PNF when ordering a go-around probably played a part in the uncertainty regarding the thrust lever advance and the raising of the flaps because there was no documented procedure covering their duties;

- "The go-around was attempted from a low-energy situation outside of the flight boundaries certified for the published go-around procedures; the aircraft's low energy was primarily the result of the power being at idle;

- "The sequential nature of steps within the go-around procedures, in particular, in directing the pitch adjustment prior to noting the airspeed, the compelling nature of the command bars and the high level of concentration required when initiating the go-around contributed to the first officer's inadequate monitoring of the airspeed during the go-around attempt;

- "Following the command bars in go-around mode does not ensure that a safe flying speed is maintained, because the positioning of the command bars does not take into consideration the airspeed, flap configuration and the rate of change of the angle-of-attack, considerations required to compute stall margin;

- "The conditions under which the go-arounds are demonstrated for aircraft certification do not form part of the documentation that leads to aircraft limitations or boundaries for the go-around procedure; this contributed to these factors not being taken into account when the go-around procedures were incorporated in aircraft [manuals] and training manuals;

- "The published go-around procedure does not adequately reflect that once power is reduced to idle for landing, a go-around will probably not be completed without the aircraft contacting the runway (primarily because of the time required for the engines to spool up to go-around thrust);

- "The Air Canada stall-recovery training, as approved by Transport Canada, did not prepare the crew for the conditions in which the occurrence aircraft stick shaker activated and the aircraft stalled;

- "The limitations of the ice-detection and annunciation systems, and the procedures on the use of wing anti-ice did not ensure that the wing would remain ice-free during flight;

- "Ice-accretion studies indicate that the aircraft was in an icing environment for at least 60 seconds prior to the stall and that, during this period, a thin layer of mixed ice with some degree of roughness probably accumulated on the leading edges of the wings. Any ice on the wings would have reduced the safety margins of the [SPS];

- "The implications of the ice buildup below the threshold of detection and the inhibiting of the ice advisory below 400 feet were not adequately considered when the stall margin was being determined during the 1996 certification of the ice-detection system and associated procedures;

- "The [SPS] operated as designed: that it did not prevent the stall is related to the degraded performance of the wings;

- "The Category I approach was without the extra aids and defenses required for Category II approaches;

- "Canadian regulations with respect to Category I approaches are more liberal than those of most countries and are not consistent with the [International Civil Aviation Organization] *International Standards and Recommended Practices* (Annex 14), which defines visibility limits; in Canada, the visibility values, other than RVR, are advisory only;

- "Even though a Category I approach may be conducted [in Canada] in weather conditions reported to be lower than the landing minimums specified for the approach, there is no special training required for a flight crewmember, and there is no requirement that flight crew be tested on their ability to fly in such conditions;

- "Air Canada's procedures required that the captain fly the aircraft when conducting a Category II approach, in all weather conditions; however, the decision as to who will fly low-visibility Category I approaches was left to the captain, who may not be in a position to adequately assess the first officer's ability to conduct the approach;

- "The aircraft stalled at an angle-of-attack approximately 4.5 degrees lower, and at a C_{Lmax} [coefficient of lift] 0.26 lower, than would be expected for the natural stall;

- "On final approach below 1,000 feet AGL, the wing performance on the accident flight was degraded over the wing performance at the same phase on the previous flight;

- "Engineering simulator comparison indicated two step reductions in aircraft performance, at 400 feet [AGL] and 150 feet AGL, as a result of local flow separation in the vicinity of wing station (WS) 247 and WS 253;

- "Pitting on the leading edges of the wings had a negligible effect on the performance of the aircraft;

- "The sealant on the leading edges of both wings was missing in some places and protruding from the surface two [millimeters] to three [millimeters; 0.07 inch to 0.12 inch] in [other places]. Test flights indicate that the effect of the protruding chordwise sealant on the aircraft performance could have accounted for a reduction of 1.7 [degrees] to 2.0 degrees in maximum fuselage angle-of-attack and [a reduction] of 0.03 to 0.05 in C_{Lmax};

- "The maximum reduction in angle-of-attack resulting from ground effect is considered to be in the order of 0.75 ± 0.5 degree: the aircraft angle-of-attack was influenced by ground effect during the go-around maneuver;

- "The performance loss caused by the protruding sealant and by ground effect was not great enough to account for the performance loss experienced; there is no apparent phenomenon other than ice accretion that could account for the remainder of the performance loss; [and,]

- "Neither Bombardier [the parent company of Canadair], nor Transport Canada, nor Air Canada ensured that the regulations, manuals and training programs prepared flight crews to successfully and consistently transition to visual flight for a landing or to go around in the conditions that existed during this flight, especially considering the energy state of the aircraft when the go-around was commenced."

The report said that the following were "other findings" produced by the investigation:

- "Both the captain and the first officer were licensed and qualified for the duties performed during the flight in accordance with regulations and Air Canada training and standards, except for minor training deficiencies with regard to emergency equipment;

- "The occurrence flight attendant was trained and qualified for the flight in accordance with existing requirements;

- "The aircraft was within its weight [limits] and center-of-gravity limits for the entire flight;

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

- "There was no indication found of a failure or malfunction of any aircraft component prior to or during the flight;

- "When the stick shaker activated, it is unlikely that the crew could have landed the aircraft safely or completed a go-around without ground contact;

- "When power was selected for the go-around, the engines accelerated at a rate that would have been expected had the thrust levers been slammed to the go-around power setting;

- "The aircraft was not equipped with an [ELT], nor was one required by regulation;

- "The lack of an [ELT] probably delayed locating the aircraft and its occupants;

- "Passengers and crew had no effective means of signaling emergency rescue services personnel;

- "The flight crew did not receive practical training on the operation of any emergency exits during their initial training program, even though this was required by regulation;

- "Air Canada's initial training program for flight crew did not include practical training in the operation of overwing exits or the flight-deck escape hatch;

- "Air Canada's annual emergency procedures training for flight crew regarding the operation and use of emergency exits did not include practical training every third year, as required. Annual emergency-exit training was done by demonstration only;

- "The flight crew were unaware that a pry bar was standard emergency equipment on the aircraft;

- "The four emergency flashlights carried on board were located in the same general area of the aircraft, increasing the possibility that all could be rendered inaccessible or unserviceable in an accident; [and,]

- "That there was a flight service station specialist, as opposed to a tower controller, at the Fredericton airport at the time of the arrival of ACA 646 was not material to this occurrence."

The report said that the following actions resulted from the accident investigation:

- Air Canada amended the CL-65 AOM to achieve the following:

  – Require that the anti-ice systems for the wings and the engine cowls be activated when the crew visually observes ice forming on the airplane's surfaces and when operating the airplane below 400 feet AGL in icing conditions;

  – Emphasize the importance of airspeed control during a go-around; and,

  – Note that the landing gear might contact the ground when a go-around is begun close to the ground;

- Air Canada changed its CL-65 wing-maintenance procedures to require the following:

– Washing and polishing the leading edge every 60 days;

– Replacing sealant on the leading edge with an improved sealant;

– Inspecting and restoring the leading-edge sealant every 400 hours; and,

– Repainting wing surfaces, as required, every 2,250 hours;

- Bombardier issued an all-operator message that said that ice-protection systems should be activated whenever the airplane is operated in icing conditions;

- Transport Canada's Civil Aviation Regulatory Committee initiated rule making to require that ELTs be installed in multi-engine turbojet aircraft that weigh more than 5,700 kilograms and are operated under IFR in controlled airspace;

- Transport Canada issued an advisory circular on the potential hazards of go-around maneuvers. "The circular states that an aircraft is not certified to successfully complete a go-around without ground contact once it has entered the low-energy landing regime," the report said. "For the purpose of the circular, the low-energy landing regime is defined as follows:

– "Aircraft flaps and landing gear are in the landing configuration;

– "Aircraft is in descent;

– "Thrust has stabilized in the idle range;

– "Airspeed is decreasing; and,

– "Aircraft height is 50 feet or less above the runway elevation;

"The circular further stated that the decision to place an aircraft in the low-energy regime is a decision to land; if there is any doubt regarding the probability of a safe landing, a go-around must be initiated prior to entry into this regime";

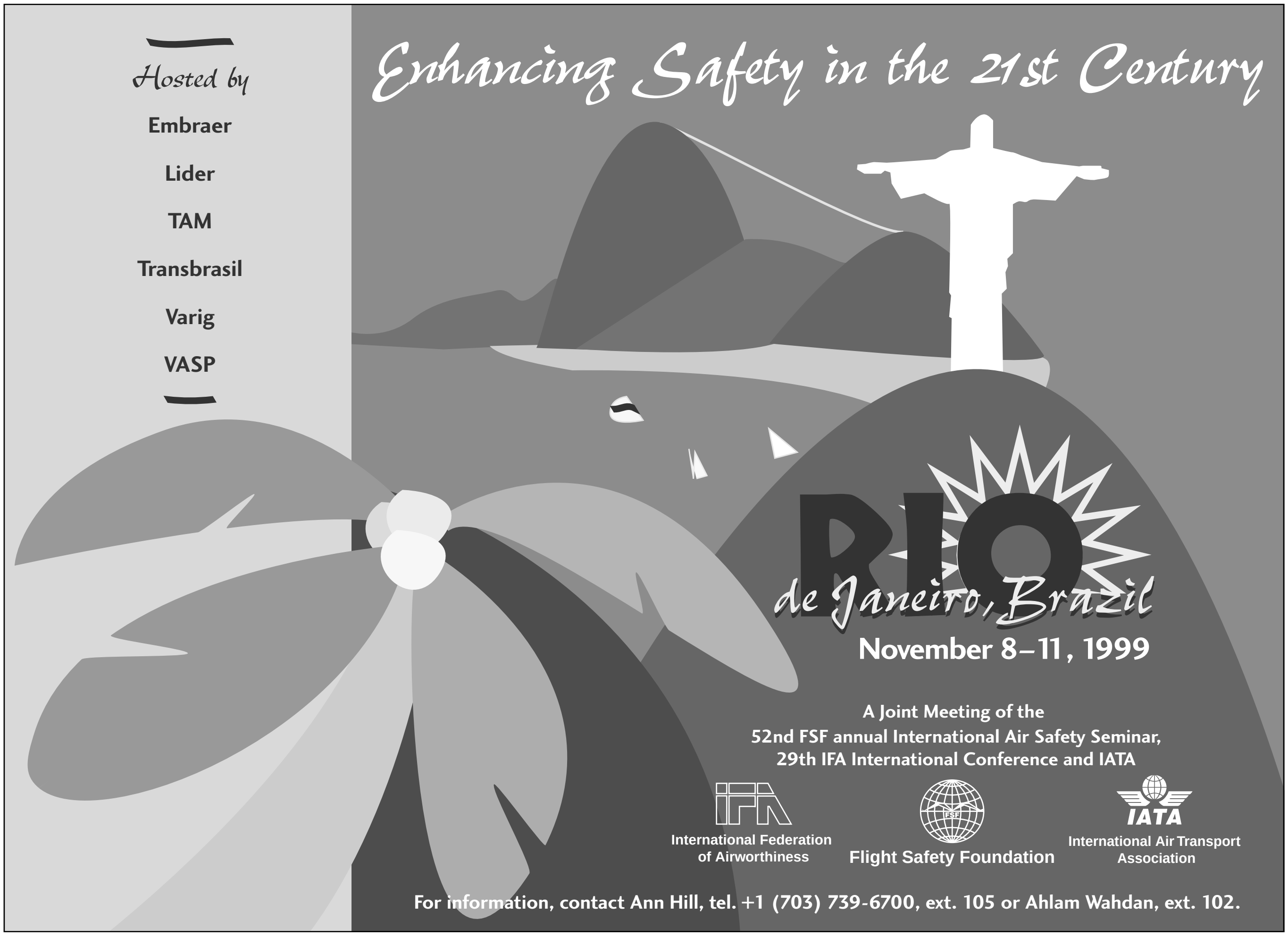
- Transport Canada said that it would develop advisory circulars regarding crew training on the use of emergency exits and emergency equipment, and would establish a working group to review survival-equipment regulations;

- TSB recommended that Transport Canada consider requiring that illumination of the [ice-protection system] amber "ice" light not be inhibited below 400 feet AGL;

- TSB recommended that Transport Canada "reassess Category I approach-and-landing criteria (realigning weather minimums with operating requirements) to ensure a level of safety consistent with Category II criteria"; and,

- TSB recommended that Transport Canada "ensure that pilots operating turbojet aircraft receive training in, and maintain their awareness of, the risks of low-energy conditions, particularly low-energy go-arounds."♦

[Editorial note: This article, except where specifically noted, is based entirely on Transportation Safety Board of Canada *Aviation Occurrence Report A97H0011: Loss of Control on Go-around (Rejected Landing); Air Canada Canadair CL-600-2B19, C-FSKI; Fredericton Airport, New Brunswick; 16 December 1997*. The 98-page report contains diagrams and appendixes.]



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