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After Loud Bang, Captain Rejects Takeoff; DC-10 Runs Off End of Runway

The accident raised crew-training issues and renewed concern about rejected takeoffs when runways are wet or contaminated by slush or snow, the official Canadian accident report said.

FSF Editorial Staff

The Canadian Airlines International (CAI) McDonnell Douglas DC-10-30ER was well into its takeoff roll at Vancouver International Airport, British Columbia, Canada, when the flight crew heard a loud bang followed by airframe vibrations. The captain called for a rejected takeoff (RTO) and retarded the power levers, but the aircraft ran off the end of the runway. The nose-wheel gear collapsed in the soft ground and the aircraft came to rest in a nose-down attitude about 78 meters (255 feet) beyond the paved end of the runway in the Oct. 19, 1995, accident, which occurred at 1332 hours local time during visual meteorological conditions.

Six passengers were injured slightly in the subsequent evacuation and the aircraft received substantial damage in the area of the nose-wheel collapse, according to the Canadian Transportation Safety Board (TSB) accident report. CAI Flight 17 was scheduled to depart Vancouver for Taipei, Taiwan, with 243 passengers, two interpreters, eight cabin crew members and four flight crew members on board.

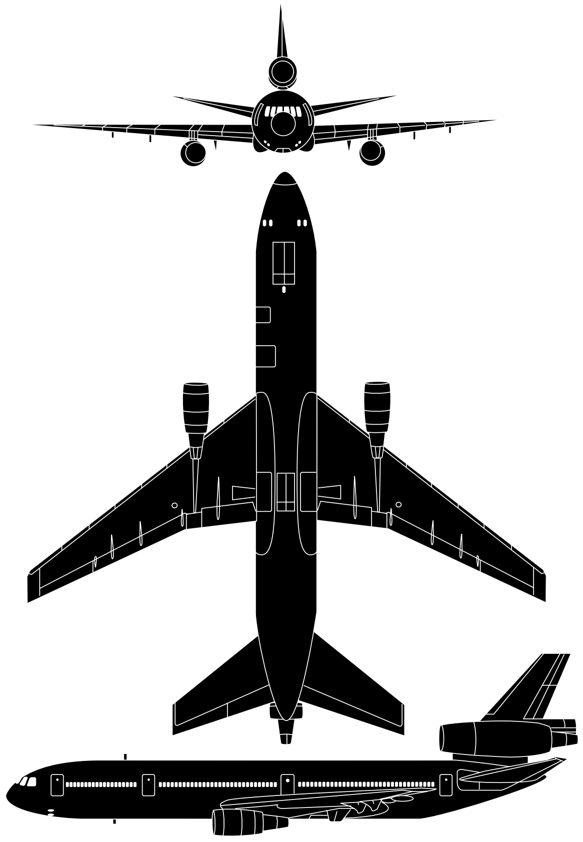
The TSB said the cause of the accident was the loss of power in the No. 1 (left) engine "at a critical point in the takeoff and the [RTO] was initiated at a point and speed where there was insufficient runway remaining to stop the aircraft on the runway. Contributing to this occurrence were the [crew's] misidentification of the cause of the loud bang and the [crew's] lack of knowledge regarding the characteristics of engine-compressor stalls. Contributing to the engine-power loss was a delay between the collection and analysis of the engine-monitoring data."

The TSB report said that the flight had been delayed for about 75 minutes because of a mechanical problem in the No. 2 engine's thrust reverser. The problem could not be corrected, and the aircraft was dispatched with that thrust reverser disabled. The report noted that had the No. 2 engine thrust reverser been operational, it would have further reduced the stopping distance by 41 meters (134 feet).

"The captain did a rolling takeoff," the TSB said. "The aircraft was aligned with the runway centerline, and the power levers were positioned to the takeoff power range by 80 knots (148 kilometers per hour); 'thrust set' was called by the second officer as the aircraft accelerated to 95 knots [176 kilometers per hour] [Figure 1, page 3]. The first officer called V_1 (critical engine-failure recognition speed) at 164 knots [303 kilometers per hour], and approximately two seconds later, there was a loud and startling bang, followed by an airframe shudder and considerable vibration." The captain called for the RTO 1.3 seconds after the bang at 171 knots (316 kilometers per hour) and retarded the throttles 0.8 seconds later, or 4.3 seconds after the V_1 call at 172 knots (318 kilometers per hour), the report said.

After the captain called for the RTO and retarded the throttles, the first officer advised the tower of the decision and the second officer manually deployed the spoilers, "which activated the wheel autobrakes as the aircraft reached a peak speed of 175 knots [324 kilometers per hour]."

The captain steered the aircraft to the right to avoid hitting runway approach lights when it became clear that the DC-10 would not stop on the runway, the report said. "The aircraft



McDonnell Douglas DC-10

The McDonnell Douglas DC-10 first flew in 1970. It was designed as an all-purpose commercial transport able to carry 270 mixed-class passengers and 380 passengers in an all-economy configuration. The DC-10-30 series has a maximum takeoff weight of 263,085 kilograms (580,000 pounds), a maximum cruising speed of 490 knots (908 kilometers per hour) and a service ceiling of 10,180 meters (33,400 feet). The DC-10-30 has a range of 4,000 nautical miles (7,413 kilometers) with maximum payload at maximum zero-fuel weight.

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

was traveling approximately 40 knots [74 kilometers per hour] as it went off the end of the runway."

After the aircraft came to a stop, the lead flight attendant entered the cockpit and asked for instructions. "The augmenting first officer [an additional flight crew member assigned because Flight 17 was a long-haul operation] told him that there would probably be an evacuation, but to give them a minute," the report said. "The captain then directed the cockpit crew to initiate the evacuation checklist, and he ordered the evacuation over the public address system."

Some delay was caused because the flight crew operating manual and training manual did not note that when the aircraft emergency power switch is "on," the copilot's audio panel is not operative.

The report said that airport fire fighters heard a loud bang as the aircraft was taking off. They were en route to the aircraft before the dispatch order was given, and three foam trucks and a utility vehicle arrived at the aircraft within one minute of dispatch. Small grease fires ignited around the hot wheels, and they were extinguished. There were no other fires.

The aircraft, which had been built in 1980 and had accumulated a total airframe time of 61,289 hours, was equipped with three General Electric CF6-50C2B engines. Flight data recorder (FDR) information indicated that the No. 1 engine operated normally during the initial part of the takeoff roll.

"As the aircraft reached 129 knots [239 kilometers per hour], there was a slight increase in vibration level for about 12 seconds," the report said. "At approximately 170 knots [315 kilometers per hour], there was a spike in the vibration data coincident with the start of a rapid decrease in engine speed from 112 percent engine fan speed (N_1) to below 40 percent N_1. The FDR also indicated that about 2.0 seconds before this power loss, the exhaust gas temperature (EGT) on [the No. 1] engine started increasing. At the time of the power loss, the EGT reached about 960 degrees [C (1,760 degrees F)], subsequently peaking at 1,064 degrees [C (1,947 degrees F)] five seconds later, just after the power levers were retarded."

The report said, "The [FDR] indicated that the wheel brakes were applied by the autobrake system (ABS) [1.8 seconds after the captain pulled the power levers back to idle], which activated when the spoilers were selected by the second officer. FDR data further indicated that full brake pressure was maintained by the ABS until the aircraft came to a stop." The report said that the wheels did not lock and that the crew did not use the brake pedals during the RTO.

If the crew had relied on ABS activation by thrust reverser selection, "which occurred approximately 3.5 seconds after the power levers were retarded, the aircraft would have run off the end of the runway at a speed in excess of 80 knots instead of ... 40 knots. The captain allowed the ABS to bring the aircraft to a stop with maximum braking being applied and maintained throughout the [RTO]. The TSB noted that the second officer's early action to manually activate the spoilers "greatly reduced the amount of overrun."

The manufacturer's recommendation appeared to be in conflict with CAI's procedure to use ABS during an RTO rather than manual braking, per the U.S. Federal Aviation Administration (FAA)-approved Flight Crew Operating Manual. Nevertheless, the report said, "Although a manual braking procedure could have resulted in braking being applied quicker, evidence from previous [RTOs] indicate that it is unlikely that maximum, continuous brake pressure would have been maintained until the aircraft stopped.

"The FDR data indicate that crew reaction for this occurrence was somewhat better [faster] than the theoretical 3.1-second, 900-foot plateau."

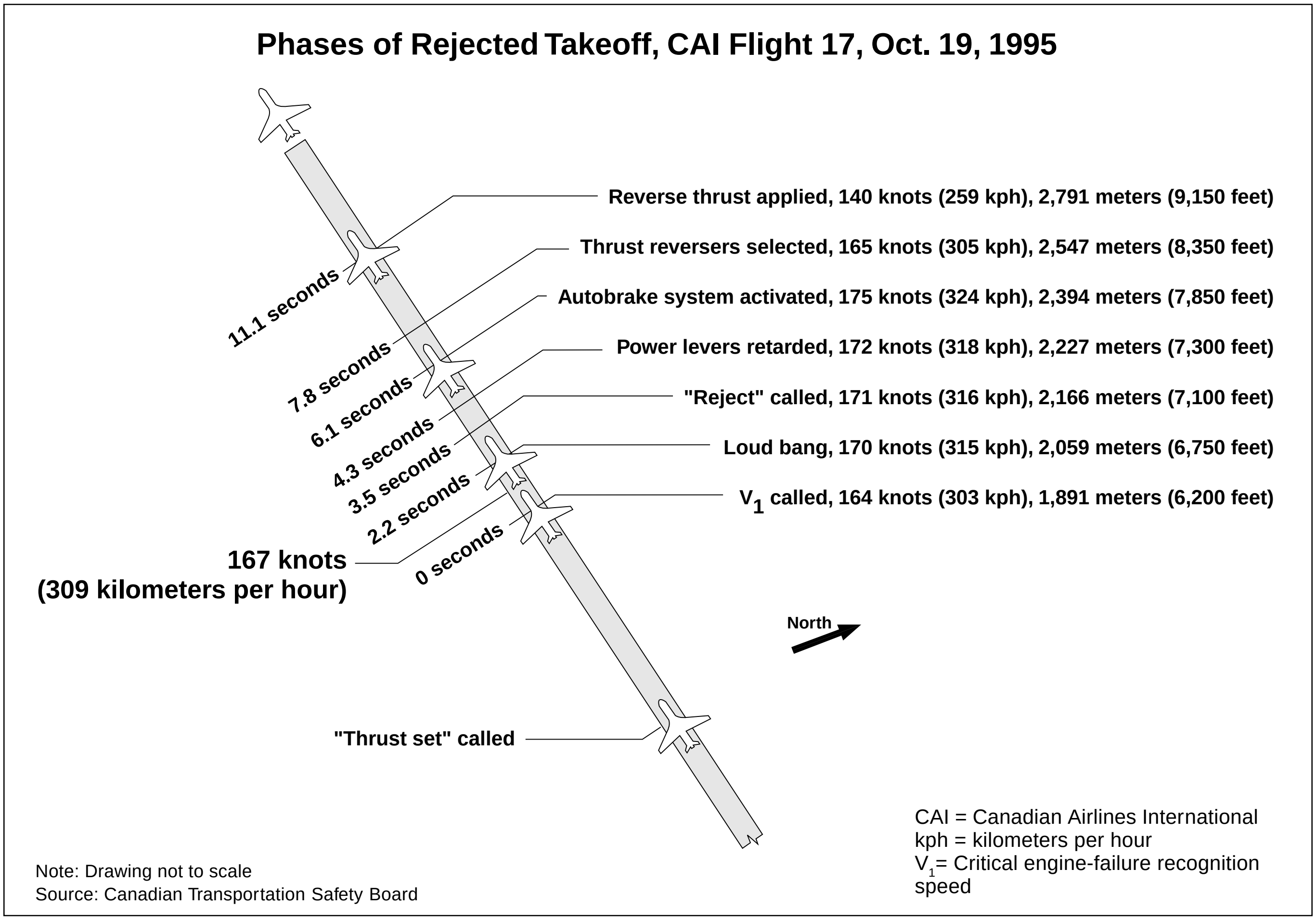
The report said that an external visual inspection of the No. 1 engine was conducted after the accident, but no anomalies were discovered. A borescopic inspection of the engine "revealed significant damage to the high-pressure compressor section of the engine," and the engine was removed from the aircraft to be disassembled in a detailed examination.

"The first notable blade damage was in stage 3 blades, mostly on the trailing edges," the report said (Figure 2, page 4). "Stage 4 contained one blade that separated about 30 percent from the tip. The remaining stages of the compressor rotor showed nicks, tears and tip damage caused by hard-body impacts. The degree of damage diminished toward the aft stages of the high-pressure compressor, and final stages 12 through 14 showed light-to-moderate leading-edge and trailing-edge blade damage in the forms of nicks, tears and missing fragments caused by hard-body impacts."

A detailed metallurgical examination of the high-pressure compressor blades "determined that there was fatigue damage to high-pressure compressor blades from stage 3 on," the report said. But it added that a laboratory examination of the physical evidence "did not yield sufficient information to pinpoint the cause of the fatigue cracking [or] to estimate the crack-propagation rates."

The TSB concluded that the power loss in the No. 1 engine was "sudden and occurred without being recognized by the flight crew. The rising internal engine temperature and uncommanded decrease in N_1 speed, accompanied by the loud bang and the number of thuds, are indicative of a series of engine stalls. The inability of the No. 1 engine to increase in speed in response to the selection of reverse thrust indicates that the stall never cleared itself, or that damage to the compressor was such that proper airflow through the engine could not be re-established."

Investigators were not able to determine which compressor blade broke first, the report said. "It was also not possible to determine whether the compressor stall initiated the compressor-blade failures, or whether a blade failure initiated the events leading to the stall. Nevertheless, the gradual increase in EGT and fuel flow on [the No. 1] engine since Oct. 14, 1995 [as indicated in engine trend-monitoring data], and the stained and tarnished appearance of some fatigue-fracture surfaces of the compressor blades indicate that the damage to the compressor had built up gradually, and that, on the day of the occurrence, the combination of the compressor condition and the demand for power during takeoff created conditions that resulted in a compressor stall."

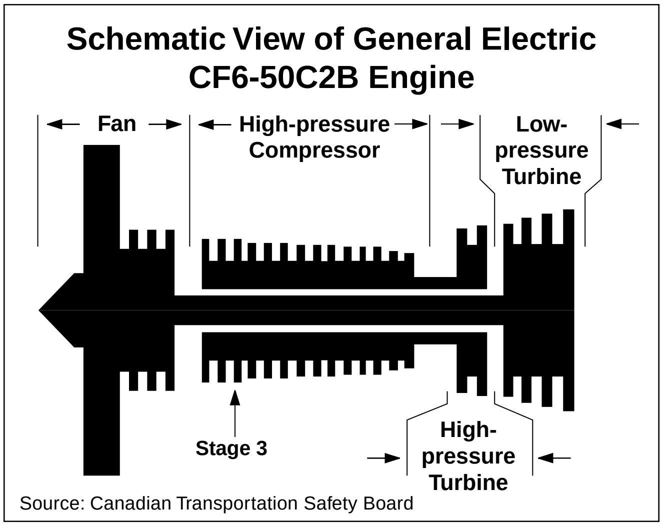


Phases of Rejected Takeoff, CAI Flight 17, Oct. 19, 1995

CAI = Canadian Airlines International
kph = kilometers per hour
V_1= Critical engine-failure recognition speed

Note: Drawing not to scale
Source: Canadian Transportation Safety Board

Figure 1


Schematic View of General Electric CF6-50C2B Engine

Source: Canadian Transportation Safety Board

Figure 2

The report said there was no evidence of foreign-object damage (FOD) to the stage 1 and stage 2 high-pressure compressor fan blades.

The captain, 55, held an airline transport pilot (ATP) certificate and had logged 16,631 total flying hours, of which 3,969 were in type. He had logged about 3,816 hours as captain on the DC-10. The captain held a valid first-class medical certificate and had flown a variety of aircraft, including the Boeing 727, Douglas DC-3, DC-8 and Boeing 747. He successfully completed a line check on Feb. 19, 1995, and his last recurrent training was on Sept. 15, 1995. "Both these flights were assessed as being very well flown and managed," the report said.

The first officer, 49, held an ATP certificate and had logged a total of 9,013 flying hours, of which 5,784 were on type. The first officer was hired by Canadian Pacific Airlines in 1973 and served as first officer on DC-3 and DC-8 aircraft. He then transferred to CAI, where he logged 1,668 hours as second officer and 4,118 hours as first officer on the DC-10. He successfully completed a line check on Feb. 25, 1995, and a combined proficiency check and instrument-rating renewal in June 1995. "Both these flights were assessed as being 'well flown,'" the report said.

The second officer, 44, held a commercial pilot certificate and had logged 6,964 total flying hours, of which 5,430 were in type. In September 1994, the second officer successfully completed an upgrade to first officer status on the DC-10 but was assigned second officer duties because of scheduling demands. The second officer completed recurrent training in May 1995 and was "assessed as having done 'excellent work' and as performing to 'high standard,'" the report said.

On long-haul flights, CAI assigned an augmenting first officer "to meet the regulatory requirement for exceptions to extend the maximum flight duty time beyond 15 hours. The airline's contract with its pilots require[d] that an augmenting first officer be assigned when flight-duty time [would] be over 14 hours." The report said that the first officer was responsible for preparing the takeoff data card and performing other duties as directed by the captain. The augmenting first officer held an ATP certificate and had logged a total of 11,736 flying hours, of which 5,774 were in type.

All eight flight attendants had successfully completed recurrent training within the previous 12 months, the report said. In addition to one Chinese-language-qualified flight attendant, CAI provided the services of two interpreters to translate cabin crew announcements into Chinese.

The captain's decision to reject the takeoff was examined in detail by the TSB.

"The captain's decision to reject was based on the fact that he did not recognize the initial sound and subsequent thumping noises and that, because he thought the bang could have been a bomb, he had concerns about the integrity of the aircraft and its ability to fly," the report said. "Also, the captain stated that, based on the [RTO] provisions in the DC-10 flight manual and on a fatal DC-8 accident that he had witnessed, he had developed a mental rule to not take an aircraft into the air if he suspected that there was aircraft structural failure."

The TSB said that when the captain decided to reject the takeoff, the EGT was above 950 degrees C (1,742 degrees F) in the No. 1 engine and that the N_1 speed had dropped to below 85 percent. According to FDR indications, "none of the crew members noticed anything unusual about the engine operation during the takeoff roll, including the second officer, whose prime duty is to watch the engine instruments. The crew reported being extremely startled by the suddenness and intensity of the loud bang, and none of the crew members recognized the sound or its origin. Because the No. 1 engine was still operating in the idle range when the aircraft came to a stop, the crew [was] not aware that there had been a power loss on that engine until this fact was discovered on the FDR data."

The report added: "FDR data indicate that, on the takeoff roll, at the time that the No. 1 engine speed decayed more than 11 percent below the speed of the other engines, there was an abrupt, backwards movement of the control column, and a momentary, nose-up pitch of 1.4 degrees. At this time, the ground-sensing [relay] system [on the nose gear] changed to the air mode for about two seconds, which would have de-armed the engine-fail light system. Then engine-fail lights may have illuminated for up to approximately one second. ... During simulator flights conducted by TSB investigators ... it was noted that the engine-fail light was not very compelling."

The report said that because the situation "did not match any of the captain's previous training or actual flying experience, he was required to respond instantly to the situation by drawing on whatever knowledge or other experience he had." The report added: "The only procedural guidance available for this circumstance was that [an RTO] after V_1 [can] be initiated when the captain believes that the aircraft has suffered catastrophic failure and will not fly."

None of the flight crew members had ever experienced such a compressor stall "and there is no information in [the CAI] operational and training manuals or in other guidance material [including the aircraft manufacturer's and engine manufacturer's manuals] on the symptoms of large-fan engine stalls [or surges]."

RTO scenarios are part of CAI's annual recurrent simulator training, the report said. But the report added that "training scenarios ensure that there are adequate cues to clearly portray the nature of the emergency. ... Compressor stalls are simulated by a series of muffled thumps."

CAI uses the SABRE flight-support computer system of the AMR Corp. (parent company of American Airlines) to support its flight operations, the report said. That system includes the takeoff performance system (TPS), which is used to calculate takeoff performance (including engine power and flap settings, V_1 and rotation speed, V_R) based on such factors as runway conditions, aircraft loading and weather.

According to the report, TPS calculates DC-10 engine power settings in three categories: STANDARD power, MAX (C2) power and BLACK (C2B) power. "The TPS always uses the lowest power possible for any given takeoff," the report said. "The TPS will not provide C2B power setting figures if it calculates that a lower power setting is sufficient for a particular takeoff."

TPS determined that the C2 power setting was required for takeoff, the report said. It calculated the operational parameters as follows: engine speed 110.4 N1; flaps 16 degrees; V_1 of 164 knots (303 kilometers per hour); V_R of 175 knots (324 kilometers per hour); V_2 (takeoff safety speed) of 187 knots (346 kilometers per hour); flap retraction at 203 knots (376 kilometers per hour) and slat retraction at 255 knots (472 kilometers per hour). "This information was entered on the takeoff data card, and the speeds were set on the airspeed bugs."

The report added: "The captain, knowing that one of the thrust reversers was not available and assessing that a takeoff using C2B power would provide additional runway for stopping the aircraft in the event of [an RTO], requested CAI's flight operations to provide him with the operational parameters for a C2B-power takeoff. However, because the TPS had calculated that the lower C2 power setting was sufficient for the takeoff conditions, the TPS program could not provide the C2B power parameters."

The crew then calculated C2B power using data from the aircraft's performance manual, the report said. The flight crew determined that the parameters were the same for each setting with the exception of V_1, which was calculated as 167 knots (309 kilometers per hour) compared with the 164 knots calculated for C2 power. "The takeoff data card was amended to show the C2B power setting of 112 percent; however, the C2B-power V_1 of 167 knots was not set on the airspeed indicator bugs or the takeoff data card," the report said.

The TSB concluded: "When the captain decided to reject the takeoff, it was his correct belief that because they were using C2B power figures, the aircraft would have reached the 164-knot V_1 earlier and that there would be additional runway available for the reject. Based on this fact and his visual impression of the runway available, he was confident that the aircraft would be able to stop on the runway."

Runway 26 at Vancouver International Airport's declared distance for takeoff-run available (TORA) and the accelerate stop distance available (ASDA) is 3,355 meters (11,000 feet). The takeoff-distance available (TODA), which includes a clearway, is 3,660 meters (12,000 feet). The runway was dry at the time of the accident, the report said.

The report said that the first officer called V_1 as the DC-10 accelerated through 164 knots and that the captain "believed that he would have some time after the 164-knot V_1 call to make a reject decision."

The TSB noted that CAI's DC-10 flight crew operating manual stated that "a 'further three seconds is allowed until full braking with spoiler actuation is attained,' [which] may be ambiguous in that it implies that some time beyond V_1 is available for the pilot reaction. The limited published information regarding the inevitability of an overrun when takeoff is rejected beyond the V_1 speed could also lead to this adverse consequence not being considered in the decision to reject."

The captain also stated that the delay (3.5 seconds) in selecting reverse thrust after the throttles were retarded was "in part due to an expletive expressed by another crew member, which interrupted his thought process."

The TSB noted that an FAA and industry team was formed in 1989 in response to a number of accidents that were caused by improper RTOs and procedures. The team studied about 3,000 RTOs that had occurred between 1959 and 1990. The team's findings are contained in the FAA's *Takeoff Safety Training Aid*, published in 1993 and in a training video, *Rejected Takeoff and the Go/No Go Decision.*

The report said that in 1993 CAI's director of flight training development provided all company pilots with a copy of a company publication on takeoff safety that included a chapter from the FAA training aid. The video was also shown during recurrent training sessions.

"These training aids emphasize the need to adhere to the V_1 decision-making concept and highlight the inevitably of an overrun if [an RTO] is initiated after V_1," the report said. "In its discussion of [RTO] situations, the *Takeoff Safety Training*

Aid states that a takeoff should not be rejected [after] the aircraft has passed V_1 unless the pilot has reason to conclude that the airplane is unsafe to fly. The study concluded that in most overrun accidents the pilot, using visual cues, did not accurately asses the amount of runway remaining or the aircraft's ability to stop."

The report added: "The FAA/industry analysis of the 74 rejected [takeoffs] that resulted in overruns indicate[d] that a number of these RTOs involved crew uncertainty about the ability of the airplane to fly, as well as unidentifiable loud bangs, vibrations and other characteristics that later were assessed to be indications of engine stall or engine failure."

The TSB also referred to a study conducted by the Boeing Commercial Airplane Group of "occurrences involving benign engine malfunctions and inappropriate crew responses [that concluded that] the majority of these engine-plus-crew-error events involved engine malfunctions that generated loud noise." In the Boeing events studied, 70 percent occurred near the ground or in high–engine power phases such as takeoffs, climbs or go-arounds, the report said.

The Boeing study concluded that "the time needed to process and integrate the auditory, tactile and visual symptoms of engine malfunctions in a time-constrained environment may be so difficult that it leads to inappropriate flight crew response," the TSB report said. "Another factor cited was [that] because of the high reliability of today's turbine engines, many [flight crew members] will complete their whole career[s] without experiencing an engine failure; consequently, training programs and simulators must provide flight crews with the knowledge to positively recognize an engine-failure condition. The Boeing study conclude[d] that lack of positive recognition of the engine event appeared to be the most significant factor contributing to inappropriate crew actions."

An analysis of FDR and cockpit voice recorder (CVR) data indicated that engine-power loss occurred at 170 knots (315 kilometers per hour) when the aircraft was 2,059 meters (6,750 feet) from the beginning of the runway and 1,296 meters (4,250 feet) from the end of Runway 26 (or about [168 meters (550 feet) beyond the V_1 call).

"When engine No. 1 lost power, engines [No.] 2 and [No.] 3 were still producing takeoff thrust," the TSB said. "Because there were no other factors that would have adversely affected the aircraft's performance, the DC-10-30ER certification data indicate that, at the time of the engine failure, the aircraft would have been able to continue the takeoff and get airborne safely with only two engines operating."

The report said that CAI used General Electric's early fault-detection engine monitoring program and "integrated it into the operation of the DC-10 fleet by monitoring cruise data. Generally, readings are taken and entered on an 'instrument readings DC-10' form by the flight crews every three hours, or once per flight for shorter flights.

"When the aircraft lands at a base that has access to the CAI/AMR mainframe computer in Tulsa, Oklahoma [U.S.], the data from the completed forms are entered into the computer. Once every 24 hours, the mainframe computer processes the data using the General Electric aircraft data engine-performance trending (ADEPT) computer program. The output from ADEPT is then sent to CAI's computers in Vancouver, where it is analyzed by the power plant maintenance group. At CAI, it takes somewhere between two and a half to four days from the time the readings are taken in the aircraft until the results are analyzed and can be acted upon."

Engine monitoring records from ADEPT on Oct. 19, the morning of the accident, were based on flight data up to Oct. 16, the report said. "This printout indicated that, starting on [Oct. 14], the No. 1 engine EGT had drifted upward by nine degrees [C (16 degrees F)] toward the baseline over the past three entries. Records indicate that a similar drift was experienced around [Sept. 25]; however, on that occasion, the EGT subsequently dropped back to normal. Consequently, the increase in EGT recorded in the [Oct. 19] printout was viewed at CAI as normal variation or scatter."

The data for the two days before the accident, analyzed after the accident, showed that the upward trend on the EGT had reached 27 degrees [C degrees (49 degrees F)] along with increases in engine core [high-pressure compressor] speed (N_2) and fuel flow, the report said. An EGT up-shift of more than 20 degrees [C (36 degrees F)] requires troubleshooting before the next flight, a requirement that is published by General Electric.

The report concluded: "For this magnitude of shift in engine parameters, General Electric recommends an immediate borescopic inspection of the high-pressure compressor and low-pressure turbine. In addition, CAI's *DC-10 Flyaway Manual* specifies a borescopic inspection of the high-pressure compressor in the event of abnormal EGT and engineering performance-trend increase."

The TSB said that the CAI monitoring program met General Electric's guidelines, which did not specify how much time the data analysis should take. But the report noted that CAI's procedures "were not fast enough to have information on the previous day's flight available for analysis by the power-plant engineering group before the occurrence aircraft took off.

"Had CAI's maintenance personnel known that the trend of the EGT of engine No. 1 had reached 27 degrees [C] and that there was a corresponding upward trend on the fuel flow and [N_2], a borescopic inspection of the engine probably would have been done. An inspection would most likely have discovered the damage to the high-pressure compressor section, so that appropriate maintenance could have been performed prior to the flight."

The TSB examined the history of the CF6-50 engine and reviewed occurrence data bases for accidents and incidents involving stalls, compressor failures, FOD and power loss. “General Electric records indicate that there are over 2,100 CF6-50 engines now in service installed on DC-10s, [Airbus] A300s and B-747s,” the report said. “Stall testing during the development of the CF6-50 engine has shown the engine to be stall-tolerant.”

The report added: “Between 1972 and 1995, there were approximately 300 takeoff-power events involving stalls or power loss. About 30 percent of the events were related to high-pressure compressor blade damage. ... About 10 percent if the events resulted in [RTOs]. The number of bird-ingestion events is in excess of 2,400 [and there were about 500 nonbird FOD events]. Records also indicate that there have been about 400 FOD events that resulted in only high-pressure compressor blade damage.”

According to the report, there were no records of the “fatigue failure characteristics and the midchord fatigue-origin location [found] on blade 31,” which was also found to be bent and “may explain the location of the fracture origin.”

> ***“Had the runway been wet, the runway overrun would have been significantly longer and the adverse consequences of the overrrun much greater.”***

The captain’s command to evacuate the aircraft came about one minute after the aircraft came to a stop and after the flight crew contacted the tower to find out if there was any indication of fire, the report said.

“The cabin crew reported that during the [RTO] procedure the passengers quietly remained in their seats, watching the flight attendants and waiting for instructions,” the report said. “Other than a ceiling panel over door 1L dropping down because of an unfastened connector and some spilled milk in a galley, the cabin area remained secure and intact.” The report said that many passengers attempted to take luggage with them during the evacuation and that “for the most part, the flight attendants removed luggage from exiting passengers; however, in order to not unnecessarily slow down the evacuation, some passengers were allowed to egress with small hand luggage. There were no indications that the carrying of luggage impeded the evacuation.” Six passengers were slightly injured during the evacuation.

The evacuation signal, a series of beeping sounds and a flashing evacuation light, was not recognized by some flight attendants, who said that the low volume of the sound made it difficult to hear, the report said. Flight attendants could have had difficulty recognizing the evacuation signal because the CAI DC-10 door trainer was not equipped with one and because the signal came (from the first officer) before the captain’s announcement over the public address system, which differed from their expectations, the report said.

The TSB also examined wet runway factors in the context of the accident, although the runway was dry and weather was not a factor in the overrun.

“Had the runway been wet, the runway overrun would have been significantly longer and the adverse consequences of the overrun much greater,” the report said. “Based on the McDonnell Douglas DC-10-30 [chart] *Wet Runway RTO Stopping Distance Increment* ... the aircraft would have required an additional [244 meters (800 feet)] to stop on a wet runway. Based on the actual distance used by the aircraft to accelerate to 164 knots (303 kilometers per hour) using C2B power, the theoretical crew-reaction and deceleration distance [1,266 meters (4,152 feet)], and the wet runway factor, the aircraft would not have been able to stop on a wet 11,000-foot runway, even if the [RTO] were to have been initiated at the 164-knot V_1 point.”

The report said that “takeoff-performance data charts for the DC-10 ... do not include provisions for the adverse effect of wet runways on the accelerate/stopping distances,” although there are provisions for takeoffs on runways contaminated with snow, ice and slush.

“Other certification agencies, such as the U.K. Civil Aviation Authority (CAA) require that aircraft manufacturers provide performance data for takeoffs on wet runways,” the report said. “The CAA also requires that operators certified in the United Kingdom take into account wet runways,” which led to development of the McDonnell Douglas wet-runway chart for the DC-10.

Neither FAA nor Transport Canada (TC) regulations “appropriate to the DC-10” require that wet runways be taken into account in calculating takeoffs, the report said. It added: “CAI, in common with most carriers in North America, does not have any procedures to compensate for the reduced braking action that would occur as a result of [an RTO] on a wet runway surface. To date, the aviation industry and regulatory authorities have not been able to resolve this issue for North American–certified aircraft.”

The report said that although the TSB was not making additional recommendations on wet runways, the TSB remained “concerned that fare-paying passengers continue to be placed at risk when field-length-limited takeoffs are conducted without taking into account reduced braking effectiveness on wet runways.”

The TSB also concluded that, based on discrepancies in the ramp fuel weight, taxi fuel burn and passenger baggage weight, the accident aircraft “could have been up to [431 kilograms (951 pounds)] over maximum ramp weight and [1,316 kilograms (2,901 pounds)] over the maximum design takeoff weight.”

Since the accident, several safety actions have been taken, the report said. CAI has since completed equipping all of its DC-10 aircraft with the aircraft communications and reporting system (ACARS), the report said. The system relays flight data to ground stations, and new procedures require flight crews to transmit engine readings when they are taken. "The new system will provide a near–real time acquisition, processing and evaluation of the engine trend-monitoring data."

Other actions include:

- "As a result of CAI's assessment of the potential delay resulting from relying on the selection of thrust reversers to deploy the spoilers to activate the autobrake system, CAI has drafted its DC-10 flight crew operating manual [RTO] checklist to indicate that the second officer 'deploys the spoilers without command.' CAI's DC-10 standard operating procedures on RTOs have also been amended to direct the second officer 'as soon as the throttles are closed to pull the spoiler handle full aft and up without command';
- "As a result of CAI's assessment of the potential adverse effect of a disabled thrust reverser on a high-weight [RTO], CAI redrafted its MEL [minimum equipment list]. ... TC has approved CAI's MEL amendment, which specifies that the dispatch of a DC-10-30 aircraft within [9,072 kilograms (20,000 pounds)] of its runway-limit weight or above [259,459 kilograms (572,000 pounds)] with a thrust reverser disabled will require the concurrence of the captain and chief pilot and their favorable assessment of the takeoff conditions and environment; [and,]
- "[AMR Corp.] has stated that software changes are being developed to correct the TPS program errors in calculating engine thrust when pressure altitudes are below sea level. AMR is also amending the TPS program to make it possible for crews to obtain performance data for power settings other than the TPS selected settings."

The report said that further action was required in engine-malfunction recognition by flight crews.

"If pilots do not consider a loud bang as a symptom of a possible compressor stall, they may assume that the noise was caused by a bomb (a much less likely event) and unnecessarily reject the takeoff," the report said. "In light of the risks associated with unnecessary RTOs, the [TSB] recommends that the [Canada] Department of Transport ensure that flight crews operating high–bypass ratio engines can correctly identify and respond to compressor stalls or surges."♦

Editorial note: This article was adapted from *Rejected Takeoff/Runway Overrun, Canadian Airlines International, McDonnell Douglas DC-10-30ER C-GCPF, Vancouver International Airport, British Columbia, 19 October 1995*, Report no. A95H0015, prepared by the Transportation Safety Board of Canada. The 64-page report contains figures and appendices.

Further Reading from FSF Publications

"Rejected Takeoff in Icy Conditions Results in Runway Overrun." *Accident Prevention* Volume 52 (May 1995).

King, J.L. "During Adverse Conditions, Decelerating to Stop Demands More from Crew and Aircraft." *Flight Safety Digest* Volume 12 (March 1993).

Chamberlin, Capt. R.W. "Rejected Takeoffs: Causes, Problems and Consequences." *Flight Safety Digest* Volume 12 (January 1993).

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