FLIGHT SAFETY FOUNDATION
Accident Prevention
Vol. 55 No. 2 *For Everyone Concerned with the Safety of Flight* February 1998

Boeing 767 Descends Below Glide Path, Strikes Tail on Landing

The flight crew responded to a visual illusion with an unwarranted power reduction, said the official accident investigation report. Just before landing, the aircraft's pitch attitude increased; the tail skid struck the runway surface as the aircraft landed.

FSF Editorial Staff

The tail skid and aft fuselage of a Canadian Airlines International (CAI) Boeing 767-375 were substantially damaged during landing at Halifax, Nova Scotia, Canada, on March 8, 1996; none of the nine crew members and 91 passengers aboard CAI Flight 48 were injured.

"The tail strike occurred because the crew responded to a visual illusion with an unwarranted power reduction between the minimum descent altitude [MDA] and touchdown," said the Transportation Safety Board of Canada (TSB) accident report. "The upslope illusion led both crew members to believe [that] the aircraft was higher than it actually was, and the crew did not respond to the visual cues from the precision approach path indicator [PAPI], which showed the aircraft to be too low.

"Contributing to the accident were the captain's preoccupation with stopping on the slippery runway, and some loss of aircraft performance below [122 meters] 400 feet AGL [above ground level]. Also contributing were the lateral navigation/vertical navigation [LNAV/VNAV] procedures in use, and a higher than normal aircraft body angle, which was induced by a lower than normal approach speed and the aircraft's forward center of gravity."

Flight 48 usually was flown direct from Toronto to Rome, Italy. On the day of the accident, the flight was scheduled to stop at Halifax International Airport, where a special-charter group of 192 people would board the flight. The aircraft took departed Toronto at 1755 en route to Halifax.

The TSB said, "The captain had been watching the weather patterns for the east coast of Canada for several days prior to the [accident] flight. On the day of the [accident], he was concerned about the weather and reported for duty an hour earlier than usual. He told CAI personnel that he was concerned about operating through Halifax with the slippery runway conditions, and he recommended to CAI Operations that the passengers be flown from Halifax to Toronto."

The aircraft, with the captain as the pilot flying (PF), was cleared for a nonprecision back-course approach to Runway 06 at Halifax International Airport. Forecasted weather included light freezing drizzle, light snow and fog.

During descent, the pilots observed that the left engine bleed-air light was flickering, and they discussed the consequences of a loss of bleed air.

The aircraft, operating as CAI Flight 48, landed on Runway 06 at 1941 local time, which was about three hours after sunset. After crossing the runway threshold at an altitude of (6.1 meters) 20 feet AGL, the aircraft touched down about (61 meters) 200 feet past the runway threshold, at a vertical acceleration of 2.2 Gs.

During the rollout, the first officer observed that the tail-skid light was illuminated. Two flight attendants situated in the aft cabin later reported that they heard a loud noise and that the

Boeing 767

The Boeing 767-200 series is a medium- to long-range twin-turbofan airliner operated by a flight crew of two that carries 216 passengers in a typical two-class configuration. The stretched 767-300 series version is capable of carrying 269 passengers. Extended-range (ER) versions of both models exist and there is a B-767-300 freighter.

All models of the B-767 are powered by high-bypass turbofans. Available engines include the GE CF6-80A and CF680A2; the Pratt & Whitney JT9D-7R4D, JT9D-7R4E, JT9D-7R4E4 and PW4050; and the Rolls-Royce RB211-524G.

The basic B-767-200 fitted with Pratt & Whitney JT9D-7R4D engines has a design range of (5,852 kilometers) 3,636 miles. B-767-300ER versions have design ranges of as much as (11,223 kilometers) 6,974 miles.

The aircraft has a maximum takeoff weight ranging from (136,080 kilograms to 181,435 kilograms) 300,000 pounds to 400,000 pounds, depending on the model and the engines fitted. Normal cruising speed for all versions is Mach 0.80, with initial cruising altitudes ranging from (10,400 meters to 12,100 meters) 34,100 feet to 39,700 feet depending on the model and the engines fitted.

The aircraft first flew in September 1981 and was first delivered for airline use in October 1982.

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

landing had seemed very rough. After the aircraft had been parked at the boarding gate, the captain discovered the damage to the aircraft, which was removed from service.

The report said, "As the aircraft turned onto final for Runway 06, descent was initiated from [671 meters] 2,200 feet ASL [above sea level] and the aircraft was slowed to approximately [329 kilometers per hour (kph)] 178 knots indicated airspeed. The autopilot pitch and roll modes were selected to VNAV and LNAV, respectively, with the autothrottles selected to the speed mode.

"Just after the crew reported by the GOLF NDB [nondirectional beacon] inbound, the aircraft's landing gear was extended and the flaps were set first to 20 degrees, then 30 degrees. Airspeed decreased to the approximate 'flaps 30' reference speed plus five knots (V_{REF30} + 5) of [257 kph] 139 knots indicated airspeed as the flaps were fully extended.

"The descent rate averaged about [171 meters per minute] 560 feet per minute [FPM] on a glide path of 2.3 degrees, and engine power averaged about 67 percent N_1. [N_1 is the rated maximum revolutions per minute (RPM) of the fan in a turbofan engine.] Aircraft body attitude [the angle between the aircraft's longitudinal axis and the horizontal] averaged about four degrees.

"The crew indicated that they saw the runway environment at [MDA] ([232 meters] 760 feet ASL)," the report said. "At about [223 meters] 730 feet ASL, the autopilot pitch mode changed to altitude capture, and, approaching [214 meters] 700 feet, the aircraft began to level off. Aircraft body attitude increased from 4.5 degrees to 6.3 degrees and engine power increased to 80 percent N_1. The autopilot was disengaged … . Four seconds after autopilot disengagement, the autothrottles were disengaged.

"After autothrottle disengagement, the aircraft's nose lowered to 5.3 degrees, the engine power was reduced to 70 percent N_1, then further reduced to 50 percent N_1 at about [46 meters] 150 feet AGL. The descent rate, which had been steady at about [168 meters per minute] 550 FPM, increased to approximately [259 meters per minute] 850 FPM.

"LNAV had been in use, placing the aircraft slightly right of the actual localizer center line, and, simultaneously with the reducing pitch, a slight turn to the left was initiated, followed by a small turn to the right.

"During the approach, the captain was advised by ATC [air traffic control] that braking action 'looks like it's not good' and that an Airbus was having difficulty exiting the runway at Taxiway Delta. The captain of [the accident aircraft] did not ask for a current braking-action report from the Airbus … ."

The digital flight data recorder (DFDR) provided a detailed account of the aircraft's landing.

The report said, "The aircraft crossed the runway threshold at approximately [6.1 meters] AGL, the engine power was increasing through 58 percent N_1 (to 72 percent N_1 at touchdown), body attitude was increasing through 5.8 degrees and the aircraft was descending at [244 meters per minute] 800 FPM.

"In the last 10 seconds before touchdown, the N_1 averaged about 8 percent lower than the previous steady value during the approach, which equates to about 20 percent less thrust. Airspeed had decreased to [248 kph] 134 knots indicated

airspeed (V_{REF30}). The aircraft touched down, without slowing its descent, at about [61 meters] beyond the threshold, [12 meters] 40 feet left of the centerline, with a peak vertical acceleration of 2.2 Gs … a peak pitch attitude of 8.1 degrees."

After the airplane was parked, power was left on to the cockpit voice recorder (CVR), and the recording of the approach and landing was overwritten.

The tail skid on the B-767 oscillates with the landing gear. The tail skid is up when the gear is up, and vice versa. If the positions of the gear and the skid disagree (one up, the other down), the tail-skid warning light illuminates.

According to the Boeing flight crew training manual, the aircraft's normal body attitude during approach is three degrees when the aircraft's speed is (V_{REF30} + 5). The body attitude at the same speed during landing flare is given in the manual as five degrees to six degrees. Decreasing the approach speed by (9.3 kph) five knots increases the body attitude by one degree.

The report said, "The aircraft's tail skid will contact the runway when the aircraft has a 10-degree body attitude with the main landing-gear oleos [hydraulic struts] extended. Tail-skid contact will occur at a body attitude of eight degrees if the main landing-gear oleos are depressed."

When the tail skid struck the runway on landing, the force sheared the hydraulic-actuator attachment pin and drove the actuator upward. The actuator hit the stabilizer ball assembly, which caused the tail-skid light to illuminate. Failure of the tail skid allowed the tail section to contact the runway, causing many scrapes and buckles to the fuselage skin and minor damage to the stabilizer position switches and their associated mounting brackets.

Repairs required replacement of the actuator, the left and right tail-skid housings and all hydraulic lines and hoses common to the actuator. In addition, the skin in this area, along with five frames and numerous stringers and stiffeners, was replaced before the aircraft was put back in service.

The captain, 52, had a total of 17,300 hours of flight time, 2,215 hours of which were in type. He held an airline transport pilot (ATP) license and a valid first-class medical certificate with the restriction that eyeglasses be available.

The report said, "He was described by some as being a nervous individual and a heavy smoker. The captain had not had crew resource management (CRM) training.

"A review of the captain's company training file revealed that he had displayed satisfactory performance. However, the captain had experienced difficulties with back-course approaches on two successive pilot proficiency checks (PPCs), performed by company check pilots, three years before this [accident]. These were assessed as minor difficulties that were corrected by the simulator instructor. The captain had not been retested on localizer back-course approaches during subsequent PPCs, but he had been required to demonstrate other nonprecision approaches, which he did successfully."

Almost all of the captain's recent flying experience involved making instrument landing system (ILS) approaches to large airports with runways generally longer than Runway 06 at Halifax. It had been several years since he last flew a localizer back-course approach. His most recent localizer back-course approach was into Montreal, Quebec, Canada, at night in a winter snowstorm, and had been made using the aircraft's autoflight capability.

The report said, "The captain was uncomfortable with the [Montreal] approach in that, when visual reference with the runway was established, the aircraft was lower than he had anticipated, and he had to maneuver the aircraft to land on the runway."

The first officer, 49, held an ATP license and had 14,100 total hours of flight time, with 1,846 hours in type. He had been a first officer with CAI for more than 20 years in the Boeing 737, B-767 and McDonnell Douglas DC-10. His current first-class medical certificate contained the restriction that eyeglasses or contact lenses must be worn.

Both pilots had been off duty for 72 hours prior to starting the duty period that included the accident.

The report said, "It had been many years since either crew member had flown to Halifax, and neither one could recall ever having flown the back-course approach for Runway 06."

When the aircraft took off from Toronto, its center of gravity (CG) was in the forward part of the allowable range. As fuel was burned during the two-hour flight, the CG moved farther forward, but was within limits on landing. Landing weight was also within limits.

Freight in the forward hold and a light passenger load accounted for the CG being forward of usual values; this, in turn, caused the aircraft's body attitude to increase slightly.

The report said, "The increase in aircraft body attitude between a midrange CG and a forward CG is about three-quarters of a degree.

"When the aircraft's CG is near the forward limit, as opposed to being aft, approximately three degrees of additional elevator deflection is required to compensate for ground effect and flare. The additional elevator deflection and associated increase in control-column force are small and not readily apparent to the pilot."

The aircraft had an automatic braking system. The system had five settings, 1 through 4 and MAX AUTO. The higher the number, the more positive the braking action and the greater the rate of deceleration. MAX AUTO provides for the shortest stopping distance on a dry runway. According to the report, the normal setting for a wet runway would be 3 or 4. When the automatic braking system is used, the pilot does not touch the brake pedals on rollout; stopping is done automatically, according to the level of braking action that was preselected.

The report said, "On this flight, the captain instructed the first officer to select MAX AUTO for landing, a selection almost never considered necessary by pilots who fly the Boeing 767, apparently because of passenger comfort considerations. There is no specific guidance in the aircraft manuals as to the brake settings when operating on icy runways."

According to the U.S. Federal Aviation Administration (FAA)-approved flight manual, the landing distance for a B-767-300 on a wet runway, after crossing the runway threshold at an altitude of (15 meters) 50 feet, is (1,647 meters) 5,400 feet. Runway 06 at Halifax is (2,708 meters) 8,880 feet long.

The report said, "There were no charts available to the crew to correct the landing distance for James Brake Index (JBI) values. In the past, charts existed to calculate the effect of JBI on landing operations, but these were no longer in use. Other Boeing 767-300 pilots with the airline indicated that, for the reported JBI of 0.36, and based on their experience, there should have been adequate stopping margin." [The JBI is an index of runway friction to determine how much greater the landing distance would be on a contaminated runway than for the same aircraft on a dry runway.]

The report said, "The … flight crew indicated that the aircraft decelerated well; the aircraft turned off the runway at Taxiway 'D,' which is about [1,982 meters] 6,500 feet from the runway threshold."

The report said, "The … special weather observation for Halifax, four minutes after the [accident], was as follows: clouds [92 meters] 300 feet overcast, visibility [2.4 kilometers] in light freezing drizzle and fog, temperature -3.9 degrees C [25 degrees F], dew point -4.4 degrees C [24 degrees F] and wind 090 degrees true at [11 kph] six knots.

The field elevation at Halifax is (145 meters) 477 feet ASL. Runway 06 is 2,708 meters long and 61 meters wide. The first one-fourth of the runway has an upward slope of 0.77 percent, which is within 0.03 percent of the maximum upslope allowed by Standard 3.1.2.3 in TP 312, *Aerodrome Standards and Recommended Practices.* The runway then slopes downward 0.5 percent to about the halfway point, and the rest of the runway is level.

The report said, "The slope of a runway is published by the *Canada Air Pilot* (*CAP*) when the average slope is 0.3 percent or greater. … Jeppesen approach charts were used by CAI, and those charts do not provide runway slope information. … Occasionally the Jeppesen charts do provide narrative information regarding unusual conditions such as visual illusions. No such narrative was provided on the Jeppesen charts for Halifax."

The report said, "If adequate visual reference were established, a pilot would continue the approach and use the PAPI … for glide path guidance. This method [Figure 1], although more difficult than using a constant-rate descent provided by a glide path, has been used safely for many years. … The Boeing flight crew training manual, in describing PAPI, states that 'PAPI may be safely used with respect to threshold height, but may result in landing [farther] down the runway.'"

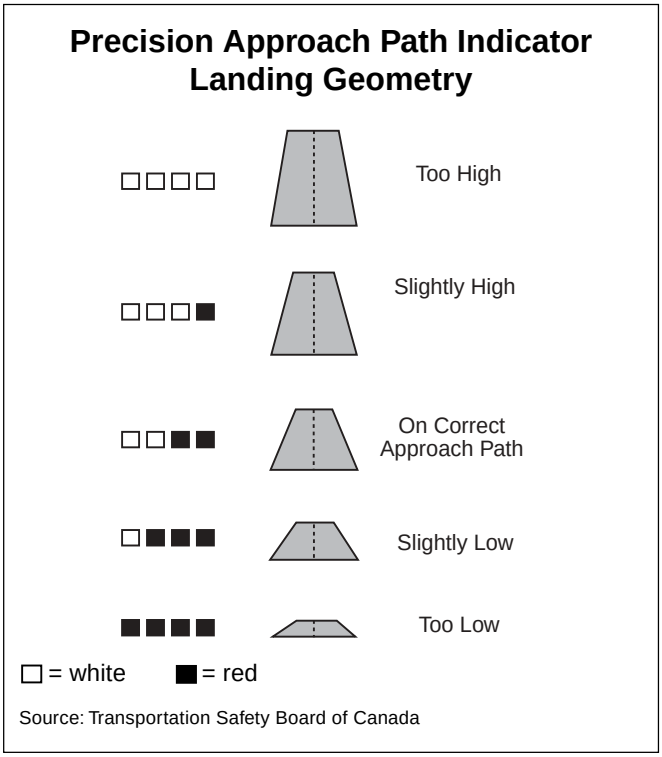

Figure 1

The PAPI at Halifax International Airport is a type 3, which is suitable for aircraft the size of a Boeing 747 and smaller, with an eye-to-wheel height of up to (14 meters) 45 feet. The PAPI comprises four light units; it is located on the left side of the runway, (399 meters) 1,307 feet from the runway threshold, and provides pilots with a visual glideslope of about three degrees.

The report said, "[The captain] reported that, on final approach, he noticed that the PAPI indicated mostly red, but he believed that the landing could be continued safely. The captain also believed that, by following the approach-slope indications of the PAPI, the aircraft would touch down beyond the [305-meter] 1,000-foot runway marks, and it was his intention to touch down near the [305-meter] marks."

Assuming no landing flare, an aircraft following indications from PAPI would touch down about 214 meters from the runway threshold; with normal flare, touchdown would be expected about 305 meters from the runway threshold.

In discussing the approach procedures, the report said, "During the approach to Runway 06, the captain selected VNAV, but the system went to altitude hold because (702 meters) 2,300 feet was still set in the MCP [mode control panel]. The first officer (the PNF [pilot not flying]) reset the altitude to [214 meters] and then initiated the final descent on VNAV. … The

captain had briefed the use of the B/CRS [back course] and LOC [localizer] functions; however, LNAV was used.

"With [519 meters] 1,700 feet, the minimum height at the FAF [final approach fix], set on the MCP, the glide path was approximately 2.3 degrees from the FAF to the touchdown zone. Because of his concerns about going too low on approach, the captain instructed the first officer to add [three meters] 10 feet to the [15-meter] 48-foot TCH [threshold crossing height] given by the aircraft's database for the approach to Runway 06."

Other visual aids for landing on Runway 06 at Halifax included an omnidirectional approach lighting system (ODALS), a (458-meter-long) 1,500-foot-long row of bright, nonvariable sequenced strobe lights; green threshold lights; white runway-edge lights; and white centerline lights, all of which were variable in intensity.

The report said, "It could not be determined what setting the lights were on when [Flight 48] landed; however, the captain reported that all the other lights seemed dimmer than the threshold strobe lights. The captain did not recollect seeing the lead-in strobe lights. The area approaching Runway 06 is devoid of any ground lighting."

The report said that all visual approach aids were functioning normally at the time of the accident. Nevertheless, in 1994 several pilots had complained about poor vertical reference on Runway 06 at Halifax with the ODALS in operation. In response to complaints, TC conducted a number of night approaches to Runway 06 at Halifax in visual flight conditions; TC inspectors found that PAPI provided the desired glide paths.

Investigations into procedures and performance were conducted by both CAI and by the aircraft manufacturer. Boeing examined possible causes for the reduced aerodynamic performance just before landing. Simulator tests were conducted by CAI to study approach profiles, assess visual cues and evaluate aircraft handling techniques.

The following observations, among others, resulted from the tests:

- "Workload during a nonprecision approach was assessed as higher than that during precision approaches;
- "Simulator 'aircraft' body attitudes during the approach above MDA were consistent with those predicted by the manufacturer;
- "When an NDB crossing altitude of [625 meters] 2,050 feet ASL was used to produce a three-degree VNAV glide path, the transition to visual flight for the landing was easier and smoother than with the 2.3-degree glide path;
- "When the simulator was 'flown' at the 2.3-degree glide path (using an NDB crossing altitude of [519 meters] ASL), the PAPI at MDA showed a below-slope indication (four red lights). After raising the NDB crossing altitude to 625 meters ASL, the PAPI at MDA showed an on-slope indication (two red lights and two white lights); [and,]
- "With the MDA set on the MCP window and the autopilot engaged, the approach became unstable in pitch and thrust when the autopilot began to level the aircraft."

The report discussed the physiological effects of cigarette smoking. The report said, "Smoking can … directly interfere with some aspects of flying aircraft because of its visual and psychomotor effects. It is well known that night vision is degraded by [hypemic] hypoxia [degradation of the oxygen-transport mechanism].

"At least one study carried out in a vehicle simulator indicates that smokers and nonsmokers do not differ in terms of tracking and vigilance errors. However, deprived smokers made more tracking and vigilance errors. It was concluded that [nicotine] withdrawal constitutes a form of physiological stress. The captain indicated that he combated nicotine withdrawal while flying by using [nicotine] gum.

The effect of visual illusions was also discussed. The report said, "Given the correct set of circumstances, a pilot's perception of the aircraft's position relative to the proper glide path may be significantly impaired, regardless of the pilot's experience or visual ability.

"According to material published by [TC], a normal approach to a runway that has even a small uphill slope will create an illusion that the aircraft is too high, causing pilots to descend to make the runway visual image compatible with the one [that] they are used to. … The illusion is usually increased as visibility decreases and fewer visual references are available to the pilot."

The report said that — although the prospects of a slippery runway, unfavorable en route weather and farther-than-normal alternate airports presented challenges to the flight crew — there does not appear to have been an operational reason to cancel the accident flight to Halifax International Airport.

CAI's procedures, like those of other airlines operating flight management system (FMS)–equipped aircraft, call for the use of VNAV to control the aircraft's vertical flight path in nonprecision approaches.

The report said, "The procedure is intended to place the aircraft below cloud in good position for a visual landing.

"The approach for Runway 06 was set up by the crew using a beacon-crossing altitude of [519 meters] ASL, in accordance with the company's procedures, which produced a virtual glide-path angle of about 2.3 degrees. The extra [three meters] added to the [TCA], by request of the captain, had a negligible effect on the glide-path angle.

"The approach, as programmed in the FMS, created the situation where the approach would become unstabilized at MDA, where the crew would transition to visual flight to make the landing using the three-degree PAPI glide path. There was no training provided to the crew indicating that there would

be a difference in flight paths when transitioning from VNAV to visual conditions for landing.

"The use of a beacon-crossing altitude that produces a shallower-than-normal (or optimal) three-degree glide-path angle can create problems for crews when transitioning to visual flight. However, during the accident approach, the autoflight selections led to the autopilot leveling the aircraft at about [214 meters] ASL, which caused the glide-path angle to change unexpectedly.

"Thus, the 2.3-degree virtual glideslope did not directly cause the approach of [Flight 48] to become unstabilized; nonetheless, the procedures regarding the use of VNAV were flawed, and led to unexpected changes in the flight path that initiated the perception by the captain that he may have been too high … or going too high."

The report said, "The crew did not always follow standard procedures in conducting the approach to Halifax [on the accident flight]." Procedural deviations included lowering the landing gear and selecting flaps 20 degrees later than normal, selecting flaps 30 degrees slightly below the normal altitude given in the CAI flight crew operations manual (FCOM) and using LNAV on the final approach.

But, the report said, "In some cases, it was difficult to determine exactly what procedure should have been followed. … There is a difference between the method taught by the airline to conduct localizer back-course approaches and that contained in the CAI FCOM, CAI SOP [standard operating procedures] and the Boeing flight crew training manual."

During the final approach, VNAV's attempt to level the airplane at the preselected altitude of 214 meters disturbed the stable descent; engine thrust increased above approach value, body attitude increased and the flight-path angle decreased.

The report said, "This would have given [the captain] the impression that the aircraft was going above the glide path that he wanted; he therefore reduced power and pitch angle. The power reduction to below the nominal approach value in the last 10 seconds of flight resulted in a higher-than-normal rate of descent. As a result, the aircraft deviated below the normal glide path, and the approach became unstable in pitch and power.

"The captain's decision to ignore the PAPI was not justified, and his allowing the aircraft to go below the glide path created the situation leading to the tail strike. By transitioning to and using the on-slope PAPI indications, a good thrust/lift relationship would have been maintained and the likelihood of a tail strike would have been reduced.

"At the last instant before landing, the captain pulled back on the control column, causing the aircraft body attitude to increase; the rate of descent, however, did not appear to decrease. … The aircraft landed hard, which compressed the oleos, with the body attitude increasing. The tail struck the ground at the peak body attitude of 8.1 degrees, close to the value for the tail-skid-contact angle of eight degrees, with oleos compressed, given in the [Boeing] flight crew training manual."

An engineering analysis revealed that, compared with theoretical data, a loss of lift and an increase in drag occurred in the last 122 meters of the landing approach. The captain's inability to slow the descent during the landing flare may have been caused, at least in part, by this loss of aerodynamic performance. Possible causes for the increase in drag and decrease in lift included inadvertent deployment of the speed brakes, wind shear and the accretion of airframe ice.

None of these three possible causes were confirmed. The report said, "Performance tests and DFDR data indicate that speed brakes were not extended. … Pilot reports and the reported wind conditions do not indicate the presence of any wind shear.

"Wing anti-ice was not used, but the manufacturer indicated that such a performance loss could not be attributed to leading-edge ice accretion in the range of [angles-of-attack] recorded by the DFDR during the approach and landing. There is no direct evidence of ice being observed on the aircraft wings or tailplane after landing. The crew did not observe ice accretion near the cockpit windows during the approach."

Although the absence of a cockpit voice recorder (CVR) transcript made exact analysis impossible, the report discussed several difficulties that the flight crew encountered in flying to Halifax.

"Icing conditions were forecast [for Halifax] in cloud and freezing precipitation," said the report. "Alternate airports were [farther] than normal from Halifax, but sufficient fuel was on board to allow for a diversion if necessary."

The report said that the captain's concern with the weather and runway surface conditions at Halifax was demonstrated by his reporting an hour earlier than usual for the flight; and by his suggesting to CAI operations that the passengers in Halifax be flown to Toronto instead, to eliminate the Halifax stop. The captain's concern about the runway condition was also reflected in his selection of MAX AUTO for the automatic braking system on landing — a setting rarely considered necessary.

The captain had not often flown a localizer back-course approach in a B-767, either on line or in a simulator. He had demonstrated difficulty with these approaches during training, and was now faced with completing an actual localizer back-course approach in marginal weather. While on approach, the captain was distracted by a malfunction in the bleed air that threatened to affect the reverse-thrust capability.

The report said, "There are several indications that the captain was overly concerned about the runway condition, leading to a condition of channelized attention [the focusing of attention on one particular object or consideration to the exclusion of others] and a loss of situational awareness."

About the visual illusion on final approach, the report said, "The illusion created by the [runway] upslope is that the aircraft is higher than it should be, and a reaction to correct for this perceived problem causes the aircraft to deviate below the proper path.

"The visibility present during the landing would limit the amount of runway that could be seen, which would have made the first portion [of the runway] upslope more of a visual-illusion problem. It appears that both pilots were unaware of, and affected by, the visual illusions presented by the runway and approach lights, causing them to believe that the aircraft was higher than it actually was.

"This could explain why the power was reduced to 50 percent N_1 by the captain, leading to an unstabilized approach as the aircraft descended through [46 meters] AGL. A call of the [244 meters per minute to 275 meters per minute] 800 [FPM] to 900 FPM descent rate, even though it was not required by company SOPs, might have been helpful to the captain.

"The PAPI provided information that would have assisted the captain in maintaining the proper visual glide path to landing. However, he discounted these visual cues. Ignoring the PAPI is consistent with his preoccupation with the possibility of overrunning the runway, and contributed directly to the deviation below the desired glide path.

"At certain points in the approach, deviations from procedures led to increased crew workload. A serious problem appears to be the unexpected partial leveling of the aircraft near MDA because of the VNAV procedures used. … There is no doubt that the captain's capacity to deal with the increased workload was degraded by his concern about the possibility of being unable to stop on the runway."

Based on its investigation, the TSB developed the following findings:

- "The flight crew was certified and qualified in accordance with existing regulations;
- "The CVR recording of the accident was overwritten after the aircraft was parked because power to the CVR was not removed;
- "The aircraft was loaded within approved weight-and-balance limits but near the forward limit, and was flown at minimum airspeed, resulting in a higher-than-normal body attitude on approach;
- "The weather conditions at Halifax were conducive to ice accretion on aircraft during the approach;
- "Wing anti-ice was not used during the approach, nor was it required by SOPs;
- "The aircraft flew a 2.3-degree glide path on the approach to Runway 06 because of the NDB crossing altitude selected as per company SOPs;
- "After reaching MDA in visual conditions, the captain flew the aircraft below the visual glide-path angle indicated by the PAPI;
- "Theoretical flight simulations indicated that there was a loss in aircraft performance below [122 meters] AGL. The reasons for the performance loss could not be determined;
- "The captain used the aircraft's LNAV for lateral guidance during the approach instead of B/CRS and LOC;
- "In following LNAV, the aircraft was displaced slightly to the right of the runway centerline at MDA, which required last-minute corrective action by the captain;
- "The aircraft began leveling off unexpectedly at MDA because of VNAV procedures used by the crew;
- "Procedures used in the operator's training for LNAV/VNAV approaches differed from the operator's published procedures for flying the approach;
- "The captain had previously experienced difficulties performing localizer back-course approaches during his recurrent training;
- "The captain had not performed an actual localizer back-course approach for several years;
- "There was limited training regarding landing from nonprecision VNAV approaches and the change of VNAV flight path to visual flight path near MDA;
- "Neither the captain nor the first officer had received formal CRM training;
- "The first officer did not observe the PAPI or notice any unsafe condition during the approach;
- "The first officer did not call out the rate of descent during the approach, nor was he required to do so by company SOPs because the rate of descent was less than [305 meters] per minute;
- "The first quarter of Runway 06 at Halifax has a 0.77-percent upslope, which is not noted on the instrument approach charts;
- "Visual illusions during the approach caused both crew members to believe that the aircraft was higher than it actually was, leading to an unwarranted thrust reduction 10 seconds before touchdown; [and,]
- "There were no charts available to the crew to indicate the adequacy of the runway length for the runway surface conditions."

As a result of this investigation, safety actions were taken:

Procedures for nonprecision approaches using VNAV. The report said, "On May 14, 1996, CAI issued a flight operations bulletin (B767-10-96) entitled *3 Degree Glide Path Conversion Chart.* The stated purpose of the chart is 'to provide B-767 crews conducting nonprecision approaches with a smooth

transition at the [MDA] to the visual airport vertical guidance system.'

"Subsequently, the TSB forwarded an aviation safety advisory to TC on the use of ad hoc VNAV procedures for nonprecision approaches. The advisory suggested that TC consider publishing guidelines on the use of VNAV for nonprecision approaches, and consider amending nonprecision approach charts to facilitate the use of VNAV systems.

"It was further suggested that TC encourage operators which use VNAV for nonprecision approaches to establish applicable [SOPs] and associated training. In response, TC identified their intention to establish an internal working group to study the issue and recommend the publication of appropriate guidance material and the establishment of SOPs and associated training."

Preventing overwriting of the CVR recording. The report said, "CAI has taken steps to ensure that, when there is an occurrence during the final portions of the flight, crews pull the CVR circuit breakers immediately after the aircraft has parked at the gate or has come to a final stop, in order to preserve the CVR recording of the event."

Training in CRM. The report said, "The Canadian Air Regulations (CARs) which came into force on Oct. 10, 1996, require that airlines which operate large aircraft (generally 20 or more passengers) have an approved CRM training program."

Use of JBI charts. The report said, "The [TSB] determined that the accident occurred, in part, because of the crew's preoccupation with stopping on the slippery runway. Subsequent to the accident, CAI issued a flight operations information circular which allows B-767 crews to determine, for a specific runway and JBI, the maximum landing weight which will facilitate a safe stopping distance."

Providing information about runway slope. The report said, "In June 1997, the TSB forwarded another aviation safety advisory to TC concerning the availability of information on 'abnormal' slope conditions existing in runway approach environments. It was suggested that the provision of such information would allow pilots to better assess and adapt their final approaches to landing, thereby reducing the risk of flight-path errors caused by visual illusions.

"In the advisory, the TSB suggested that TC consider establishing criteria for the inclusion of information and/or cautionary statements concerning sloped runway environments in the *Canada Flight Supplement* and the *Canada Air Pilot,* and encourage the provision of such information in similar documents used by Canadian operators."

"In response, TC stated that this is the first observation regarding this matter and by itself does not document a threat to safety caused by the current method of providing runway slope information. TC further stated that Canada's methodology is consistent with the requirements agreed to through ICAO, and that they would reserve further analysis until the accident report was received."♦

Editorial note: This article was adapted from *Aviation Occurrence Report, Tail Strike on Landing, Canadian Airlines International, Boeing 767-375 C-FOCA, Halifax, Nova Scotia, 08 March 1996.* Report no. A96A0035. The 34-page report contains figures and appendices.

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